UNIVERSITY OF LJUBLJANA
FACULTY OF ECONOMICS

ANI GERBIN

KNOWLEDGE TRANSFER PROCESS IN LIFE SCIENCES

DOCTORAL DISSERTATION

Ljubljana, 2017

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The undersigned Ani Gerbin, a student at the University of Ljubljana, Faculty of Economics (hereafter: FELU), author of this doctoral dissertation with the title Knowledge transfer process in life sciences (Prenos znanja v vedah o življenju), prepared under supervision of Prof. Dr. Mateja Drnovšek

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KNOWLEDGE TRANSFER PROCESS IN LIFE SCIENCES

SUMMARY

This dissertation focuses on academic-industry knowledge and technology transfer in life sciences, the research area that has received much attention in the science policy, innovation and entrepreneurship literature over the past thirty years. In this research I define knowledge transfer as the application and sharing of scientific knowledge, new discoveries and innovations between scientists from academic and other research institutions and the commercial sector. Non-profit institutions involved in life science research include universities, government laboratories, research institutes and research hospitals (Ewing Marion Kauffman Foundation 2003).

The dissertation explores four main research problems. First, numerous studies investigating the benefits and challenges of academic-industry knowledge transfer process yield rich but often conflicting and fragmented findings, without clear policy implications and recommendations on how to facilitate this process. More precisely, there is no agreement among the authors of empirical studies regarding the particular academic-industry knowledge transfer drivers, both on the individual and the organizational level. Also, when conducting comparative analyses of academic institutions with respect to their knowledge and technology transfer performance, different authors focus on different measures and predictors of performance. Therefore, the general framework for evaluating the effectiveness of academic-industry knowledge transfer and its impact on public science has not been conceptualized yet. Second, despite the growing interest in the impact of academic-industry knowledge transfer on knowledge sharing restrictions among the members of the life science academic communities, the majority of studies have focused on patenting, leaving the effects of other forms of knowledge transfer largely underexplored. Also, in assessing this knowledge transfer-knowledge sharing relationship, many studies have failed to consider the potential heterogeneity of different forms of academic knowledge sharing. Furthermore, there is an overall lack of research in this area in institutional contexts other than the USA. Accordingly, the individual-level knowledge transfer-knowledge sharing model has not been conceptualized in a comprehensive manner yet. Third, drawing from the social capital theory, existing empirical studies mostly investigate only a narrow range of determinants of knowledge sharing restrictions in the life science academic community, which provides partial understanding of this research phenomenon. Thus, there is a need for identification and empirical assessment of a range of both personal and context-specific predictors of knowledge sharing restrictions, which contribute to existing theory and allow the generation of specific science policy recommendations. Fourth, little is known about how life science research funding and existing intellectual property rights system facilitate innovation performance of the international healthcare biotechnology business sector. The identification of key determinants that motivate the biotechnology innovation performance is of practical importance for the management of companies that compete in this sector.

The identified research problems are addressed in four chapters of the doctoral dissertation. The first chapter of the doctoral dissertation provides a systematic review of the accumulated body of knowledge on academic-industry knowledge transfer, with a particular emphasis on life sciences. Following the systematic analysis and synthesis of 135 articles published between 1980 and 2014, we discuss the most interesting findings for each of the six identified principal academic-industry research topics: involvement predictors and motivators, role of incentives, institutional performance determinants, knowledge transfer institutionalization, relationship with scientific output and impact on open science. Based on our findings, we propose a conceptual framework for studying academic-industry knowledge transfer and evaluating its effectiveness and impact on public science.

In the second chapter of the dissertation, we explore how different knowledge transfer processes between academia and industry impede formal and informal knowledge sharing in the field of life sciences. We perform an extensive review of the existing literature and collect qualitative data from 38 in-depth interviews with academics, industry professionals and technology transfer specialists from six countries. We develop a grounded theoretical framework for individual knowledge transfer-knowledge sharing interactions.

In the third chapter of the dissertation we empirically test the knowledge transfer-knowledge sharing conceptual model on a sample of 212 life scientists from Croatia. We hypothesize that the involvement in academic-industry knowledge transfer is positively associated with knowledge sharing restrictions, but the strength of the relationship varies depending on academic-industry knowledge transfer activity type and knowledge sharing form in question. Moreover, we include into our analysis a range of hypothesized personal and context-specific predictors of knowledge sharing restrictions.

The fourth chapter of the dissertation analyses determinants of innovation performance in the healthcare biotechnology industry to develop propositions for the future development of this sector. We use empirical data to point to specific differences in this domain between Europe and USA. We build from a body of literature investigating the historical development of the industry, its expansion to new entities and new scientific fields and the role of different sources of funding of biomedical commercialization process. We use the theory of innovative enterprise and the "maximizing shareholder value" concept to elucidate determinants of biotechnology innovation performance.

This study deepens our knowledge about academic-industry knowledge transfer interactions. We make several key contributions to the field of knowledge from the theoretical, methodological and practical perspective:

First, by performing a comprehensive and systematic review of empirical studies on main academic-industry knowledge transfer mechanisms we emphasize both the broad developments and exceptional findings in this research area, as well as outline those topics that have so far received limited empirical evidence, despite their salience. Second, the systematic review enables us to propose a new conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science, which should help direct the future empirical research in this area. Third, by analysing broader implications of knowledge transfer activities for academic settings, the study contributes to the ongoing debates on the relationship between commercial activities and open science at academic institutions. This is of great relevance for the national and institutional policy makers, who have been highly interested in both the drivers of academic-industry knowledge transfer and the consequences of these activities for public science. Fourth, this study is the first that conceptualizes and empirically tests academic-industry knowledge transfer-knowledge sharing relationship by considering the heterogeneity of different forms of academic knowledge transfer and knowledge sharing. Fifth, this is the first study that comprehensively explores the role of the institutional context in knowledge transfer-knowledge sharing interactions. Sixth, the study contributes to the body of knowledge on determinants of sharing restrictions among academic life scientists. The dissertation takes into account a broad range of individual and context-specific predictors of knowledge sharing restrictions, which enables the generation of specific science policy recommendations. Seventh, by using two divergent theories in assessment of how university-generated intellectual property rights, public investments into knowledge base and business funding mechanisms affect biotechnology innovation performance, the study contributes to our understanding of driving forces of innovation performance in healthcare biotechnology. Finally, from the methodological perspective, this study is the first to introduce the measures of the extent of both formal and informal knowledge sharing restrictions among the members of the life science community. In the dissertation we deploy a variety of qualitative and quantitative research methods, including in-depth literature review, systematic review, in-depth semi-structured interviews, univariate and bivariate statistics as well as multivariate analyses (regression analyses).

Key words: knowledge transfer, academia-industry, life sciences, determinants, implications, knowledge sharing restrictions, institutional context, innovation, biotechnology industry

PRENOS ZNANJA V VEDAH O ŽIVLJENJU

POVZETEK

V disertaciji se osredotočam na prenos znanja med akademskim svetom in gospodarstvom na področju ved o življenju. Temu raziskovalnemu področju je bilo v zadnjih tridesetih letih posvečene veliko pozornosti, tako s strani raziskovalcev kot tudi oblikovalcev vladnih politik. Prenos znanja opredelim kot uporabo in izmenjavo znanja med znanstveniki iz akademskih in drugih raziskovalnih zavodov in gospodarstva. Neprofitni zavodi ki so vključeni v raziskovanje ved o življenju vključujejo univerze, javno financirane laboratorije, raziskovalne inštitute in raziskovalne bolnišnice (Ewing Marion Kauffman Foundation 2003).

V disertaciji obravnavam štiri osnovne raziskovalne probleme. Prvič, številne študije, ki so do sedaj raziskovale priložnosti in izzive prenosa znanja in tehnologije med akademskim svetom in gospodarstvom, dajejo sicer zanimive uvide in rezultate, vendar brez jasnih priporočil oblikovalcem vladnih politik, kako olajšati sam proces prenosa. Med raziskovalci ni enotnega mnenja o tem, kateri dejavniki spodbujajo procesa prenosa znanja med akademskim svetom in gospodarstvom na individualni ravni kot tudi ravni organizacije. Primerjalne študije med raziskovalnimi inštituti, ki analizirajo uspešnost prenosa znanja in tehnologij, opozarjajo na sklop različnih dejavnikov, ki so povezani z uspešnim prenosom. Žal pa zaenkrat še ne poznamo celotnega modela spremenljivk, ki bi učinkovito napovedoval uspeh prenosa znanja med akademskim svetom in gospodarstvom, kot tudi ne vpliva, ki ga to ima na oblikovanje znanstveno raziskovalne politike. Drugič, kljub naraščajočemu zanimanju, kako prenos znanja med akademskim svetom in gospodarstvom vpliva na omejevanje izmenjave znanja med raziskovalci na področju ved o življenju, se je večina raziskav do sedaj osredotočala na vidik patentiranja, učinkom drugih oblik prenosa znanja do sedaj ni bilo posvečene večje pozornosti. V vrednotenju odnosa med prenosom in izmenjavo znanja dosedanje raziskave ne upoštevajo v zadostni meri heterogenost različnih oblik izmenjave akademskega znanja. Z izjemo v ZDA, raziskave na tem področju v drugih državah in institucionalnih okoljih primanjkuje. Tretjič, izhajajoč iz teorije socialnega kapitala, obstoječe empirične raziskave večinoma raziskujejo ozek nabor omejitvenih dejavnikov v izmenjavi znanja na področju ved o življenju, kar omejuje celostno razumevanje tega fenomena. Iz tega izhaja, da je treba identificirati in empirično ovrednotiti celoten nabor dejavnikov omejevanja prenosa znanja, tako na ravni individualnega raziskovalca kot tudi na organizacijski ravni, saj to vedenje prispeva k razvoju teorije in oblikovanju priporočil za vodenje politike na tem področju. Četrtič, na področju ved o življenju je manjko znanja o tem, kako financiranje temeljnega raziskovanja in pravice iz naslova intelektualne lastnine omogočajo podjetjem globalen inovacijski uspeh v dejavnosti biotehnologije zdravstvenega varstva. Identifikacija dejavnikov, ki spodbujajo inovacijski uspeh biotehnoloških podjetij ima pomembne implikacije za vodje podjetij, ki delujejo v tej panogi dejavnosti.

Doktorska disertacija je razdeljena na štiri poglavja. Prvo poglavje doktorske disertacije obsega sistematični pregled celotnega znanja o prenosu znanja in tehnologije med akademskim svetom in gospodarstvom s posebnim poudarkom na vedah o življenju. Na osnovi sistematične analize in sinteze 135 raziskovalnih člankov objavljenih med letoma 1980 in 2014, razpravljamo o najzanimivejših rezultatih za vsako od šestih raziskovalnih tem: vključenost napovedovalnih spremenljivk in spodbujevalcev, vloga iniciativ, pregled dejavnikov institucionalne uspešnosti, proces institucionalizacije prenosa znanja, odnos z znanstvenimi izhodnimi rezultati in vpliv na odprto znanost. Na podlagi naših spoznanj predlagamo konceptualni okvir za preučevanje prenosa znanja in tehnologije med akademskim svetom in gospodarstvom, vrednotenje njegove učinkovitosti in vpliva na javno znanost.

V drugem poglavju disertacije raziskujemo, kako različni prenosi znanja in tehnologije med akademskim svetom in gospodarstvom preprečujejo formalno in neformalno izmenjavo znanja na področju ved o življenju. Izdelamo obsežen pregled obstoječe literature in zberemo kvalitativne podatke iz pol strukturiranih intervjujev, ki smo jih opravili z 38 akademiki, gospodarstveniki in

specialisti v prenosu tehnologije iz šestih držav. Razvijemo celosten teoretični okvir interakcij, ki se dogajajo v prenosu znanja in tehnologije med akademskim svetom in gospodarstvom.

V tretjem poglavju disertacije empirično preizkusimo konceptualni model prenosa znanja–izmenjave znanja na primeru 212 biomedicinskih znanstvenikov na Hrvaškem. Hipoteza, ki jo testiramo pravi, da je vključenost v prenos znanja in tehnologije pozitivno povezana z omejitvami izmenjave znanja, vendar pa se moč te povezave spreminja z vrsto aktivnosti v prenosu znanja in tehnologije in predmetno obliko izmenjave znanja. V analizo vključimo vrsto napovedovalnih spremenljivk na individualni ravni raziskovalca kot tudi spremenljivk ki so specifične za kontekst izmenjave znanja.

Četrto poglavje disertacije analizira dejavnike inovacijskega uspeha v panogi biotehnologije zdravstvenega varstva, z namenom izdelave priporočil za prihodnji razvoj te panoge dejavnosti. Na osnovi analize empiričnih podatkov izpostavimo specifične razlike med Evropo in ZDA na tem področju. Izhajamo iz celostnega pregleda literature, upoštevajoč zgodovinski razvoj panoge, širitev znanstvenih področij, kakor tudi vlogo različnih virov financiranja procesa komercializacije biomedicine. Kot teoretično podlago uporabimo teorijo inovativnega podjetništva in koncept „povečanja vrednosti delničarjev", z namenom razlage dejavnike, ki prispevajo k inovacijskemu uspehu v biotehnologiji zdravsvenega varstva.

Doktorska disertacija prispeva k obstoječemu vedenju o odnosih in prepletu različnih dejavnikov na področju prenosa znanja in tehnologije med akademskim svetom in gospodarstvom. Podamo nekaj ključnih teoretičnih, metodoloških in praktičnih priporočil:

Prvič, ko smo izvedli obsežen in sistematičen pregled dosedanjih empiričnih raziskav o mehanizmih prenosa znanja med akademskim svetom in gospodarstvom, smo povzeli dosežke in izjemne rezultate na tem področju raziskovanja, ter izpostavili tiste teme, ki do sedaj niso bile empirično dovolj preverjene. Drugič, sistematični pregled literature nam je omogočil razvoj novega konceptnega okvirja za oceno učinkovitosti prenosa znanja in tehnologije med akademskim svetom in gospodarstvom ter njegov vpliv na javno znanost, ki pripomore k načrtovanju prihodnjega empiričnega raziskovanja na tem področju. Tretjič, z analizo širšega konteksta dejavnikov prenosa znanja, pomembnega za akademska okolja, raziskava prispeva k aktualnim razpravam o razmerju med komercialnimi aktivnostmi in novoustvarjenimi znanostmi v akademskih ustanovah. To je izjemnega pomena za oblikovalce politik na nacionalni in institucionalni ravni, ki zanimajo pobudnike prenosa znanja med akademskim svetom in gospodarstvom in za posledice teh aktivnosti na javno znanost. Četrtič, to je prva raziskava, ki konceptualizira in empirično raziskuje prenos znanja med akademskim svetom in gospodarstvom na način, da upošteva heterogenost različnih oblik akademskega prenosa znanja in izmenjave znanja. Petič, to je prva raziskava, ki sistematično ovrednoti institucionalni kontekst v interakcijah prenosa znanja-izmenjave znanja. Šestič, raziskava prispeva k celostnemu uvidu v omejitvene dejavnike izmenjave znanja med raziskovalci na področju ved o življenju. Disertacija upošteva široki razpon napovedovalnih spremenljivk na ravni posameznika, povezanih z osebnostnimi in organizacijskimi specifikami omejevanja izmenjave znanja. Na tej osnovi lahko oblikujemo priporočila za oblikovalce zakonodaje na področju znanosti. Sedmič, izhajajoč iz dveh različnih teorij, ki pojasnjujeta, na kakšen način je na univerzi nastala intelektualna pravica lastnine, javna vlaganja v bazo znanja in, kako finančni mehanizmi vplivajo na uspeh inovacij v biotehnologiji, raziskava prispeva k našem razumevanju dejavnikov inovacijskega uspeha v panogi biotehnologije zdravstvenega varstva. Metodološko gledano je to prva raziskava, ki uvaja ukrepe velikosti in omejitev formalne in neformalne izmenjave znanja med člani skupnosti ved o življenju. V disertaciji uporabljamo različne kvalitativne in kvantitativne raziskovalne metode, vključno s temeljitim pregledom literature, pol-strukturiranimi intervjuji, univariatno in bivariatno statistično analizo in drugimi tehnikami multivariatne analize.

Ključne besede: prenos znanja, akademski svet - gospodarstvo, vede o življenju, napovedovalne spremenljivke, implikacije, omejitve izmenjave znanja, institucionalni kontekst, inovacija, biotehnološka dejavnost.

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INTRODUCTION

"Science is about knowledge and in the ideal world, scientists should share everything; particularly when using public money, we should be quite open with what we have. But, the reality is much more complicated, because there are careers at stake, which are dependent on publication of that knowledge and in a sense ownership. If you are a scientist and made a discovery, it is most important that you are credited by being the first to discover…publication has extreme value. So now when you extend your thoughts to include business interests, it becomes even worse in a sense that if there is a commercial value to it, then the irony becomes that you might not even disclose it at all publication-wise, because you have this conflict that you want to patent it first to preserve its commercial value before you publicly disclose it in the paper for example. I think inherently all these issues can work against the scientific enterprise in a sense that knowledge is not freely available."

-- academic sector respondent, USA. Interview conducted by the author of the dissertation, April 2011

The research area focusing on academic-industry knowledge transfer in life sciences has received much attention in the science policy, innovation and entrepreneurship literature over the past thirty years. There is no universally accepted definition of academic-industry knowledge transfer. In fact, a more commonly used term in the literature is academic-industry *technology transfer*. For the purpose of this research, knowledge transfer is defined as the application and sharing of scientific knowledge, new discoveries and innovations between scientists from academic and other research institutions and the commercial sector. Non-profit institutions involved in life science research include universities, government laboratories, research institutes and research hospitals (Ewing Marion Kauffman Foundation 2003).

The Association of University Technology Managers (AUTM), a global network of 3,500 technology transfer professionals from more than 350 universities, research institutions, teaching hospitals, government agencies as well as the industry, defines *technology transfer* as the formal transfer of new discoveries and innovations resulting from scientific research conducted at universities and non-profit research institutions to the commercial sector for public benefit.

Therefore, knowledge (or technology) transfer processes occur between research institutions or individual researchers (who develop or discover new technologies) on one side, and the business sector (that commercializes university-based technologies) on the other. In practice, academic-industry knowledge transfer occurs through three basic mechanisms: 1) collaborative research projects, including consulting and sponsored research; 2) patenting and licensing inventions to existing companies, charging royalties for the use of the patent as well as splitting the realized income among the participants in the process (Henderson et al. 1998), and 3) establishing of new spin-off companies for commercialization of academic research results (see Bozeman 2000, Lockett et al. 2005). Each process can be facilitated by the third key stakeholder, technology transfer offices (TTOs) or administrators of the university's intellectual property (Siegel et al. 2004).

The global upsurge of knowledge transfer activities initiated in the USA through the adoption of The Patent and Trademark Amendments of 1980 (Public Law 96-517), also known as the Bayh-Dole Act. The Bayh-Dole Act gave universities (and other non-profit institutions, as well as small businesses) the right to retain the property rights to inventions deriving from publicly funded research. Since then universities have had very broad rights to exploit inventions derived from their research - from charging royalties for the use of the patent and assigning the patent to a third party, to specifying how any realized income is to be divided among the institution, the researcher, and research centres or departments (Henderson et al. 1998). The described change of legislation, first in the USA, and later in most European countries, as well as the increased reliance of business firms on university research and development (R&D), enabled the expansion of universities' traditional mission of teaching and research towards a "third academic mission", the transfer of university technology to industry (Kruecken 2003).

A recent report published by the European Commission (2013) reveals that the targets specified in its Recommendation on the management of intellectual property in knowledge transfer activities (2008) had been reached approximately by half by European countries in the period 2010-2012. Moreover, it reports that the revenue from academic-industry knowledge transfer is highly concentrated, with the top 10% of universities accounting for almost 90% of all revenue. Several studies show that an average US university outperforms its European counterpart in the number of inventions and patents, due to Europe's less systematic and professional management of knowledge and intellectual property (European Commission 2007).

Considering the high importance of the topic from policy perspective, a substantial body of studies has dealt with academic-industry knowledge transfer, varying greatly depending on perspective (industry, university, government), structure (formal, informal), level of analysis (market, organization, individual), and effect (economic, academic, scientific capacity, institutional, cultural, management) (Boardman and Ponomariov 2009). These studies investigate different benefits and challenges arising from involvement of academic researchers and institutions in knowledge transfer activities. On one hand, scholars have found evidence that tight links between academia and industry have many positive aspects for both the business partner involved as well as the academia, in terms of the realization of complementarities between applied and basic research (Azoulay et al. 2006), the generation of new research ideas (Rosenberg 1998) and the overcoming of the shortage of funding of basic research through the private sector (Agrawal and Henderson 2002, Czarnitzki et al. 2009). On the other hand, it has also been argued that engagement of researchers into knowledge transfer activities with industry could undermine their commitment to the norms of open science, in that way leading to secrecy and publication delays (Geuna and Nesta 2006). Dasgupta & David (1994), Henderson and colleagues (1998), Kenney & Patton (2009) and many others discuss the inefficiency of knowledge transfer, which partly stems from the constant friction between academic institutions that desire publication and the establishment of priority, and corporate research sponsors that wish to defer disclosure until the patents can be employed to protect the future economic returns of an innovation. Thus, the rules of market competition may not be compatible with the social norms of priority and free circulation of knowledge (considered as the most important values of their profession) within the scientific community (Calderini et al. 2007).

Research problem and purpose

The dissertation explores four main research problems. First, numerous studies investigating benefits and challenges of academic-industry knowledge transfer process yield rich but often conflicting and fragmented findings, without clear policy implications and recommendations. More precisely, there is no agreement among authors of empirical studies regarding what particular academic-industry knowledge transfer drivers are, both on the individual and the organizational level. Also, when conducting comparative analyses of academic institutions with respect to their knowledge and technology transfer performance, different authors focus on different measures and predictors of performance. Therefore, the general framework for evaluating the effectiveness of academic-industry knowledge transfer and its impact on public science has not been conceptualized yet.

Second, despite a growing interest in the impact of academic-industry knowledge transfer on knowledge sharing restrictions among the members of the life science academic communities, a majority of studies has focused on patenting, leaving the effects of other forms of knowledge transfer largely underexplored (Larsen 2011). Also, in assessing this knowledge transfer-knowledge sharing relationship, many studies have failed to consider a potential heterogeneity of different forms of academic knowledge sharing (Blumenthal et al. 1996, Louis et al. 2001, Campbell et al. 2002, Walsh et al. 2007). Furthermore, there is an overall lack of research in this area that considers a role of different institutional contexts (Haeussler 2011, Haeussler 2014, Walsh and Huang 2014). Accordingly, a model organizing individual-level knowledge transfer-knowledge sharing mechanisms has not been conceptualized in a comprehensive manner yet.

Third, drawing from the social capital theory, existing research mostly investigates a narrow range of determinants of knowledge sharing restrictions in life science academic community, which provides partial understanding of this important phenomenon. Thus, there is a need for identification and empirical assessment of a range of both personal and context-specific predictors of knowledge sharing restrictions, which contributes to existing theory and allows a generation of specific science policy recommendations.

Fourth, little is known about how life science research funding and existing intellectual property rights system facilitate innovation performance of the international healthcare biotechnology business sector. An identification of key determinants that motivate biotechnology innovation performance is of practical importance for the management of companies that compete in this sector.

The identified research problems are addressed in four chapters of the doctoral dissertation. The first chapter of the doctoral dissertation provides a systematic review of the accumulated body of knowledge on academic-industry knowledge transfer, with a particular emphasis on life sciences. Following a systematic analysis and synthesis of 135 articles published between 1980 and 2014, we discuss the most interesting findings for each of the six identified principal academic-industry research topics: involvement predictors and motivators, role of incentives, institutional performance determinants, knowledge transfer institutionalization, relationship with scientific output and impact on open science. Based on our findings, we develop a conceptual framework for studying academic-industry knowledge transfer and evaluating its effectiveness and impact on public science.

In the second chapter of the dissertation, we explore how different knowledge transfer processes between academia and industry impede formal and informal co-operation in the field of life sciences. We perform an extensive review of the existing literature and collect qualitative data from 38 in-depth interviews with academics, industry professionals and technology transfer specialists from six countries. We develop a grounded theoretical framework for individual knowledge transfer-knowledge sharing interactions.

In the third chapter of the dissertation we empirically test the knowledge transfer-knowledge sharing conceptual model on a sample of 212 life scientists from Croatia. We hypothesize that the involvement in academic-industry knowledge transfer is positively associated with knowledge sharing restrictions, but the strength of the relationship varies depending on academic-industry knowledge transfer activity type and knowledge sharing form in question. Moreover, we include into our analysis a range of hypothesized personal and context-specific predictors of knowledge sharing restrictions.

The fourth chapter of the dissertation analyses determinants of innovation performance in the healthcare biotechnology industry to develop propositions for the future development of this sector. We use empirical data to point to specific differences in this domain between Europe and USA. We build from a body of literature investigating the historical development of the industry, its expansion to new entities and new scientific fields and the role of different sources of funding of biomedical commercialization process. We use the theory of innovative enterprise and the "maximizing shareholder value" concept to elucidate determinants of biotechnology innovation performance.

The specific context of life sciences and biotechnology has been selected for this study considering that they represent the fields most widely studied when it comes to academic-industry knowledge transfer activities (Blumenthal et al. 1996, Powell and Owen.-Smith 1998, McMillan et al. 2000, Owen-Smith et al. 2002, Stuart and Ding 2006)

Research questions

The dissertation addresses several research questions. The first research question refers to the analysis of determinants and public policy implications of academic-industry knowledge transfer in life sciences, as follows:

Research question 1: Which factors do researchers and academic institutions need to consider when assessing the effectiveness of academic-industry knowledge transfer activities and their impact on public science?

The second group of research questions explores the heterogeneity of academic-industry knowledge transfer and knowledge sharing mechanisms in life sciences as well as the role of the institutional context in academic-industry knowledge transfer processes:

Research question 2: How do different academic-industry knowledge transfer activities affect knowledge sharing between the members of the life science academic communities?
Research question 3: Which factors in addition to academic-industry knowledge transfer activities influence knowledge sharing (restrictions) in the life science communities?
Research question 4: How does the institutional context influence academic-industry knowledge transfer-academic knowledge sharing interactions in the life science communities?

The third group of research questions seeks to provide better understanding of determinants of knowledge sharing restrictions in life sciences. The research questions are as follows:

Research question 5: How frequent is the phenomenon of knowledge sharing restrictions among members of the life science community?

Research question 6: Does the strength of relationship between particular knowledge transfer activities and knowledge sharing restrictions among life science researchers vary depending on the type of knowledge sharing in question?
Research question 7: Does the strength of association between particular knowledge transfer activities and knowledge sharing restrictions among researchers vary depending on demographic, professional and contextual characteristics of researchers involved in these activities?

The fourth group of the research questions is focused on determinants of innovation performance in the healthcare biotechnology industry:

Research question 8: How do university-derived intellectual property rights affect innovation performance of the healthcare biotechnology industry?
Research question 9: How do public investments into knowledge base at universities and other research institutions affect innovation performance of the healthcare biotechnology industry?
Research question 10: How do different commercialization funding mechanisms affect innovation performance of the healthcare biotechnology industry?

Research goals

The aim of the dissertation is to contribute to the better understanding of academic-industry knowledge transfer process in life sciences. The research goals are as follows:

Research goal 1: To provide a systematic review (identification, evaluation, extraction and summarizing) of the accumulated body of knowledge on academic-industry knowledge transfer in life sciences.
Research goal 2: To develop a general conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science.
Research goal 3: To explore the heterogeneity of academic-industry knowledge transfer and knowledge sharing mechanisms in academic life science communities.
Research goal 4: To explore the role of the institutional context in academic-industry knowledge transfer-knowledge sharing relationship.
Research goal 5: To develop the comprehensive individual-level knowledge transfer-knowledge sharing conceptual model.
Research goal 6: To determine the relationship between different forms of academic-industry knowledge transfer and different forms of knowledge sharing restrictions in life sciences.
Research goal 7: To provide evidence on the role of different individual and contextual predictors of knowledge sharing restrictions in life sciences.
Research goal 8: To describe the role of university-derived intellectual property rights and research and development funding mechanisms in innovation performance of the healthcare biotechnology industry.

Theoretical and practical contributions

This study contributes to a cumulative body of knowledge about academic-industry knowledge transfer interactions. We make several theoretical, methodological and practical contributions.

First, by performing a systematic review of empirical studies on main academic-industry knowledge transfer mechanisms we emphasize both the broad developments and exceptional findings in this research area, as well as outline those topics that have so far received limited empirical evidence, despite their salience. Specifically, whereas many studies reach consensus regarding the particular personal and contextual predictors of involvement of researchers in knowledge transfer, we also find substantial evidence that depending on empirical setting, variables such as scientific productivity and institutional technology transfer support policies and structures can act both as enablers and inhibitors in the process.

Second, our systematic review enables us to propose a new conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science. We thus produce more explicit research and provide a more comprehensive overview of academic-industry knowledge transfer, which can help direct future empirical research in this area.

Third, by analysing broader implications of knowledge transfer activities for academic settings, the study contributes to the ongoing debates on the interplay between commercial activities and open science at academic institutions (Calderini et al. 2007). This is of great relevance for the national and institutional policy makers, who have shown high interest in both, understanding the drivers of academic-industry knowledge transfer and the consequences of these activities for the functioning of public science.

Fourth, this study is one of the first to conceptualize and empirically test academic-industry knowledge transfer-knowledge sharing relationship by considering the heterogeneity of different forms of academic knowledge transfer and knowledge sharing. Despite the abundance of articles published in the field, only a limited number has dealt thoroughly with a complex problem of restrictions in informal and formal sharing of knowledge among the members of the scientific community, in relation to scientists' involvement in academic-industry knowledge transfer and commercialisation activities (Haeussler 2014). Also, most studies in this specific field have focused on the impact of knowledge transfer activities in general, without distinguishing between different mechanisms of academic-industry knowledge transfer (Abreu and Grinevich 2013). This is an important research problem because not all forms of academic-industry knowledge transfer are necessarily negatively related with knowledge sharing.

Fifth, this is one of the first studies that comprehensively explores an instrumental role of the institutional context in knowledge transfer-knowledge sharing interactions. This represents an important contribution because so far, the majority of the published articles in the field have focused only on one country, predominantly the USA (Baldini 2008).

Sixth, this study contributes to the body of knowledge on determinants of sharing restrictions among academic life scientists. The dissertation takes into account a broad range of individual and context-specific predictors of knowledge sharing restrictions. The results of the empirical research have important implications for not only life science researchers, but also for research organisations managers as well as policy makers, through obtaining insights into the knowledge sharing in the academic community and the norms of sharing practices. We also point to the possible causes of such behaviours and the impact of data and materials withholding on the progress of science. Based on our findings, we propose several recommendations for improvement of the practices in this area.

Seventh, by using two divergent theories as complementary views in assessing how university-generated intellectual property rights, public investments into knowledge base and business funding mechanisms affect biotechnology innovation performance, this study contributes to our understanding of driving forces of innovation performance in healthcare biotechnology.

Finally, from the methodological perspective, this study is the first to introduce several measures to capture the extent of both formal and informal knowledge sharing restrictions among the members of the life science community since existing studies have mostly measured only the existence (Blumenthal et al. 1997, Campbell et al. 2000) or frequency (Campbell et al. 2002, Walsh et al. 2007) of data and materials withholding, without trying to at the same time capture the effect of knowledge transfer activities on formal knowledge sharing among scientists. In the dissertation we deploy a variety of qualitative and quantitative research methods, including in-depth literature review, systematic review, in-depth semi-structured interviews, univariate statistics (frequencies, means and standard deviations), bivariate statistics (correlations) as well as multivariate analyses (regression analyses).

Structure of the dissertation

The doctoral dissertation is structured in the form of a collection of scientific papers and is divided into four main chapters and concluding remarks. After the introduction, Chapter 1 provides a systematic review of the accumulated body of knowledge on academic-industry knowledge transfer in life sciences, with the purpose of development of a conceptual framework for studying academic-industry knowledge transfer and evaluating its effectiveness and impact on public science. Chapter 2 explores to what extent and how different knowledge transfer processes between academia and industry impede formal and informal co-operation in life science academic communities and focuses on the development of a grounded theoretical framework for individual knowledge transfer-knowledge sharing interactions. Chapter 3 empirically examines the relationship between different forms of academic-industry knowledge transfer and knowledge sharing in the life sciences. Moreover, other personal and context-specific predictors of knowledge sharing restrictions are included in the analysis. Chapter 4 analyses determinants of innovation performance in the healthcare biotechnology industry. In the concluding chapter we overview main findings as well as implications and limitations of the dissertation. At the very end, after the references section and appendices, the extended summary of the dissertation in Slovene language is provided.

1 DETERMINANTS AND PUBLIC POLICY IMPLICATIONS OF ACADEMIC-INDUSTRY KNOWLEDGE TRANSFER IN LIFE SCIENCES: A REVIEW AND A CONCEPTUAL FRAMEWORK[1]

1.1 Introduction

There is no universally accepted definition of knowledge transfer. In the broadest sense, knowledge transfer can occur at various levels: between individuals, from individuals to explicit sources, from individuals to groups, between groups, across groups, and from the group to the organization (Alavi and Leidner 2001). This manuscript investigates specific aspects of knowledge transfer – we focus on academic-industry knowledge and technology transfer. Hereinafter we define it as the application and sharing of scientific knowledge, new discoveries and innovations between researchers from academic and other research institutions and the commercial sector. Research-oriented institutions include universities, government laboratories, research institutes or research hospitals (Ewing Marion Kauffman Foundation 2003).

The increased reliance of the business sector on academic research and development (R&D) and legislative changes adopted in 1980 in the US, and later in most countries in Europe, enabled non-profit research institutions to exercise very broad rights to inventions derived from publicly funded research. In practice, academic-industry knowledge transfer occurs through three basic mechanisms: 1) collaborative research projects, including consulting and sponsored research; 2) patenting and licensing inventions to existing companies, charging royalties for the use of the patent as well as splitting the realized income among the participants in the process (Henderson et al. 1998), and 3) establishing of new spin-off companies for commercialization of academic research results (see Bozeman 2000, Lockett et al. 2005). Each process can be facilitated by the third key stakeholder, technology transfer offices (TTOs) or administrators of the university's intellectual property (Siegel et al. 2004).

A recent report published by the European Commission (2013) reveals that the targets specified in its Recommendation on the management of intellectual property in knowledge transfer activities (2008) had been reached approximately by half by European countries in the period 2010-2012. Moreover, it reports that the revenue from academic-industry knowledge transfer is highly concentrated, with the top 10% of universities accounting for almost 90% of all revenue. Several studies show that the average US universities outperform European in the number of inventions and patents, due to Europe's less systematic and professional management of knowledge and intellectual property (European Commission 2007).

Given the prominence of the topic, a substantial body of studies has dealt with university-industry knowledge transfer during the past 30 years, varying greatly depending on perspective (industry, university, government), structure (formal, informal), level of analysis (market, organization, individual), and effect (economic, academic, scientific capacity, institutional, cultural, management) (Boardman and Ponomariov 2009). These studies investigate different benefits and challenges arising from involvement of academic researchers and institutions in

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[1] This chapter of the dissertation was presented as a working paper at the EBR 2014 conference in Ljubljana. The paper was published first online in 2015 in the Journal of Technology Transfer, international peer-reviewed journal, Web of Science-indexed (IF 2015 = 2,213, 5-year IF = 2,474, Q2), DOI 10.1007/s10961-015-9457-0. The final publication (41(5); 979-1076) is available at Springer via http://link.springer.com/article/10.1007/s10961-015-9457-0. The paper was written in co-autorship with Prof. Dr. Mateja Drnovšek.

knowledge transfer activities and yield rich but often conflicting and fragmented findings, without clear policy implications and recommendations. For example, there is no agreement among the authors of empirical studies regarding the particular academic-industry knowledge transfer drivers, both on the individual and the organizational level. Also, when conducting comparative analyses of academic institutions with respect to their knowledge and technology transfer performance, different authors focus on different measures and predictors of performance.

The purpose of this paper is to address above mentioned limitations in the literature by providing a systematic review of the accumulated body of knowledge on academic-industry knowledge transfer. The main question motivating our research is: Which factors do researchers and academic institutions need to consider when assessing the effectiveness of academic-industry knowledge transfer activities and their impact on public science? The practical relevance of this query resides in the fact that most of commercialization-oriented policies fail in their attempts to facilitate knowledge transfer to industry as well as in building sustainable technology transfer support systems.

We deployed a systematic review methodology, which enabled us to identify, evaluate, extract and summarize the existing ample empirical evidence. The body of articles for our study was identified using keyword search in Web of Science database and manual search of articles published in the top journals on academic-industry interactions and science policy. We then evaluated the content of each identified article and excluded from further analysis conceptual papers and those focusing only on the business sector. Next, we extracted the data on the study type, level of analysis, empirical setting and key findings from each paper. This enabled us to cluster the studies into several categories based on the emerging common themes. We content analyzed the papers within each cluster and compared them with reference to the obtained results and deployed research methods, variables and empirical settings in their focus. Finally, we summarized the findings and drew general conclusions for each of the clusters.

This study deepens our knowledge about academic-industry knowledge transfer interactions. By performing a comprehensive and systematic review and comparison of empirical studies on each of the above mentioned three main transfer mechanisms we emphasize both the broad developments and exceptional findings in this research area, as well as outline those topics that have so far received limited empirical evidence, despite their salience. Specifically, whereas many studies reach consensus regarding the particular personal and contextual predictors of involvement of researchers in knowledge transfer, we also find substantial evidence that depending on empirical setting, variables such as scientific productivity and institutional technology transfer support policies and structures can act both as enablers and inhibitors in the process. What is more, we observe that some predictors, such as researchers' age, business training or institutional policies, may or may not be of relevance depending on specific type of knowledge transfer activity in focus. We also find mixed findings concerning the role of variable financial incentives in stimulating knowledge transfer involvement and performance. When assessing institutional knowledge transfer performance predictors, we find no straightforward evidence regarding the role of the size, age and structure of technology transfer offices in the knowledge transfer performance of academic institutions. We also show that most studies agree that engagement in knowledge transfer activities does not negatively affect the researchers' scientific output. Yet, it is less clear to what extent university-industry interactions can be detrimental for the norms of open science specific for the scientific communities.

Second, the systematic review enabled us to propose a conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science, which should help direct the future empirical research in this area. Third, the study analyzed broader implications of knowledge transfer activities for academic settings. This is of great relevance for the national and institutional policy makers, who have been highly interested in both the factors driving academic-industry knowledge transfer and the consequences of these activities for public science.

1.2 Methodology

We deployed the systematic review methodology to direct us in our study of academic-industry knowledge transfer. The research steps that this method normally comprises are: definition of the research boundaries and identification of literature selection criteria, literature search, assessment of the quality of identified studies, extraction of relevant data and synthesis of empirical evidence in several categories or clusters comprising common emerging themes (adapted from Petticrew and Roberts 2006, see also Perkmann et al. 2013).

We first conducted extensive search of the published peer-reviewed articles in this area between 1980 and 2014 using the Web of Science bibliographical database and by combining the keywords “knowledge transfer”, “technology transfer”, “university-industry”, “academic-industry”, “academia”, “patenting”, “commercialization”, “academic entrepreneurship” and “life science”. We also systematically examined all issues of the journals Research Policy, Journal of Technology Transfer, Management Science and Scientometrics, which were shown to have the highest number of published articles on the topic in the period of observation. We analyzed the cited references in each of the articles found through bibliographic search and in that way accessed additional articles, not initially identified using keyword search. We inspected the content of each article and took into consideration the qualitative and the quantitative studies, as well as the studies focusing on all levels of analysis: individual, organizational and country-level, which provided insights into different stakeholders’ perspectives. We excluded from the analysis the articles focusing merely on the perspective of the business sector, as we put the emphasis of this study on public science. We also excluded conceptual papers. At the end of the content assessment procedure, we had in total 135 articles at disposal for further analysis. These articles were cited in total 10,276 times (in November 2014, when the analysis was done) and the average number of citations per article was 76.12. The breakdown of the articles according to the journal of publication is presented in Table 1. Apart from the journals explicitly listed in the table, analyzed articles categorized as *Other* were published in different management, economics, medical, sociological and education journals.

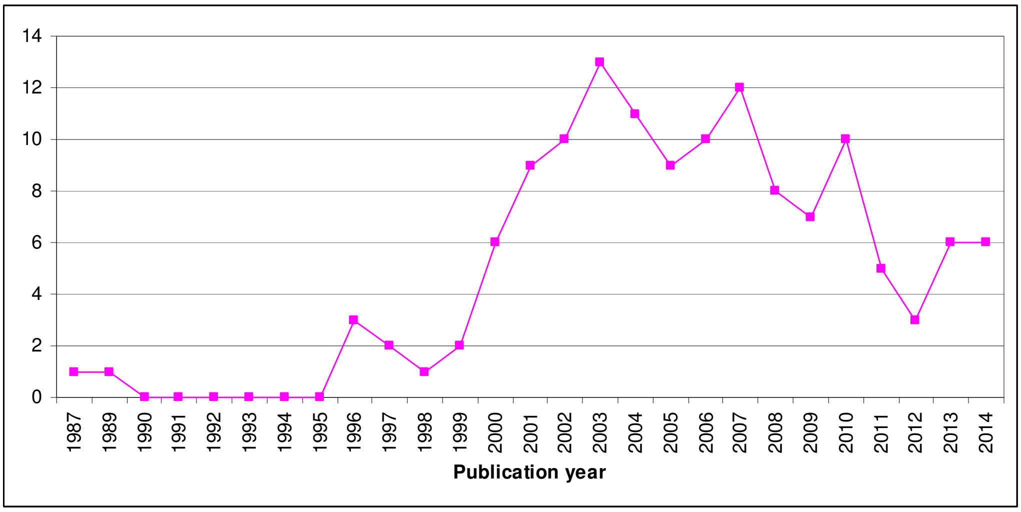
Table 1. Breakdown of analyzed articles on academic-industry knowledge transfer

Journal	**No. of articles**	**%**	**Total no. citations**	**Average no. citations**
Research Policy	54	40	3,703	68.57
Journal of Technology Transfer	16	12	93	5.81
Management Science	6	4	1,117	186.17
Scientometrics	4	3	91	22.75
Journal of the American Medical Association	3	2.2	1,249	416.33
Technovation	3	2.2	60	20.00
Journal of Business Venturing	3	2.2	214	71.33
Journal of Economic Behavior and Organization	3	2.2	242	80.67
International Journal of Industrial Organization	3	2.2	240	80.00
Other	40	30	3,267	81.68
Total	**135**	**100%**	**10,276**	**76.12**

Source: ISI Web of Knowledge

Most of the analyzed articles were published in the period between 2000 and 2010 (Figure 1).

Figure 1. Overview of the number of published articles subject to analysis per year



Source: ISI Web of Knowledge

The next step included a detailed review of the articles and extraction of the following data: study type (qualitative, quantitative), level of analysis (individual researchers, institutions, countries), empirical setting (country) and key findings. These data were organized in the tabular form. Based on the content analysis we extracted common themes and categorized the articles in six major areas, some of which were further divided into sub-areas. This procedure resulted in altogether 16 analytical clusters (see Appendices A-G). Of in total 135 articles analyzed, 98 were categorized into only one cluster, whereas 37 addressed two or more of the identified research areas and were therefore categorized into multiple clusters.

In the final step, we compared major findings across all articles within a cluster and did comparative analysis of research methods used, independent and dependent variables analyzed and empirical settings. Based on that, we outlined common findings and drew some general conclusions.

1.3 Findings

Our main finding concerns a systematic overview of knowledge transfer research areas. Figure 2 summarizes the results of the clustering process and indicates the number of articles that we content analyzed in each cluster.

While the first three major identified research areas (sections 3.1-3.3) refer to the drivers of knowledge transfer involvement and determinants of knowledge transfer performance of researchers and their institutions, the fourth research area (section 3.4) considers the historical perspective in assessing the development of university-industry interactions in different empirical settings. The final two identified main research areas (3.5 and 3.6) focus on the consequences of knowledge transfer involvement of academic researchers for their scientific productivity and knowledge sharing behavior.

Figure 2. Overview of knowledge transfer research areas and sub-areas, with the number of analyzed articles per cluster

A. Academic-industry knowledge transfer involvement predictors and motivations
- **1. Industry collaboration predictors and motivators (10)**
- **2. Patenting and licensing predictors and motivators (11)**
- **3. Academic entrepreneurship predictors and motivators (17)**
- **4. Composite knowledge transfer involvement predictors and motivators (13)**

B. 5. Knowledge transfer awarding mechanisms (12)

C. Performance level and success factors of academic-industry knowledge transfer
- **6. Performance in academic-industry knowledge transfer (8)**
- **7. Industry collaboration success factors (5)**
- **8. Intellectual property exploitation success factors (22)**
- **9. Academic entrepreneurship success factors (16)**
- **10. Predictors of composite academic-industry knowledge transfer performance indicators (6)**

D. 11. Institutionalization of academic-industry knowledge transfer (5)

E. Academic-industry knowledge transfer and scientific output
- **12. Knowledge transfer and research type (9)**
- **13. Patenting and scientific output (13)**
- **14. Knowledge transfer and scientific output (11)**

F. Academic-industry knowledge transfer and open science
- **15. Patenting and open science (10)**
- **16. Knowledge transfer and open science (23)**

1.3.1 Academic-industry knowledge transfer involvement predictors and motivations

Numerous studies have attempted to answer the basic questions of *who* and *why* in the assessment of academic-industry knowledge transfer interactions. In other words, these studies are interested in personal and contextual characteristics as well as motivations of researchers that engage in knowledge transfer activities. Whereas some studies focus only on particular types of knowledge transfer, such as patenting, university-industry collaboration or spin-off founding, others investigate simultaneously a wide range of knowledge transfer activities, including industry funding, consulting, patenting, licensing and spin-off entrepreneurship. Although most of the predictors are similar for all types of knowledge transfer activity, there seem to be some determinants specific for particular groups of activities. Therefore, we have separately presented these streams of research in a detailed overview of key studies and their comparison provided in Appendices A and B.

The systematic review reveals two principal groups of academic-industry knowledge transfer involvement predictors: internal (individual characteristics - human and social capital and psychological traits, as well as experiences and attitudes which enable the recognition of entrepreneurial opportunities), and external (contextual conditions, such as policy changes, e.g. reduced academic workload or part-time work, decreased public funding, institutional knowledge transfer experience and norms). Table 2 summarizes these findings.

Table 2. Internal and external predictors and motivators of involvement of researchers in academic-industry knowledge transfer, with indicated number of identified articles per each finding

Knowledge transfer activity / **Predictor - motivator**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
INTERNAL				
Scientific productivity and impact	**Positive** (5) **Not significant** (1)	**Positive** (5) **Mixed** (1) **Negative** (1)	**Positive** (2) **Negative** (1) **Not significant** (2)	**Positive** (2) **Not significant** (1) **Negative** (1)
Professional status				
Tenure, number of years since PhD	**Positive** (4) **Negative** (1) **Not significant** (1)	**Positive** (4) **Mixed** (1) **Negative** (1) **Not significant** (2)	**Positive** (4) **Not significant** (3) **Negative** (1)	**Positive** (6) **Not significant** (2)
Jobs in career			**Positive** (1)	
Management / business training	**Positive** (1) **Not significant** (1)	**Not significant** (1)	**Positive** (2)	**Positive** (1) **Not significant** (1)
Demographic characteristics				
Ethnicity (non-minority)			**Less likely** (1)	**More likely** (2)
Age - senior	**Positive** (3) **Not significant** (1) **Mixed** (1)	**Positive** (2) **Not significant** (1)	**Not significant** (5) **Negative** (1)	**Positive** (1) **Not significant** (2) **Negative** (2)
Gender – female	**Less likely** (2) **Not significant** (1)	**Less likely** (2)	**Less likely** (4) **Not significant** (2)	**More likely** (1) **Less likely** (3) **Not significant** (2)
Social capital				
Number of collaborators		**Positive** (2)	**Positive** (1)	**Positive** (2) **Not significant** (1)
Partnerships with users			**Negative** (1)	
Networks with industry			**Positive** (1)	
Attitudes				
Hybrid role identity				**Positive** (1)
Closely aligned with open science values	**Negative** (3) **Positive** (1)	**Negative** (2) **Not significant** (1)	**Negative** (3) **Not significant** (1)	**Negative** (3)
Entrepreneurial self-efficacy			**Positive** (1)	
Perceived role models			**Positive** (1)	
Motivations				
Reputation with scientific peers	**Positive** (1)	**Positive** (3)	**Positive** (1) **Not significant** (1)	**Positive** (1)
Valuation of scientific awards for reputation	**Not significant** (1)	**Not significant** (1)	**Positive** (1)	**Positive** (1)

(table continues)

(continued)

Knowledge transfer activity / Predictor - motivator	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Financial (funds for the laboratory)	**Positive** (2)	**Positive** (1)		
Financial (personal)		**Positive** (1)		
Curiosity to validate or find application for basic research	**Positive** (2)	**Positive** (2)		
Research type (applied)	**Positive** (2)	**Positive** (1) **Not significant** (1)	**Positive** (2)	**Positive** (2)
Research discipline (life sciences)		**More likely** (1) **More likely –** diversity (1)		**Less likely** (1)
Previous academic-industry knowledge transfer or business experience	**Positive** (4)	**Positive** (4)	**Positive** (5) **Not significant** (1)	**Positive** (3) **Not significant** (1)
Entrepreneurship in family	**Positive** (1)	**Positive** (1)	**Positive** (1)	**Positive** (1)

EXTERNAL				
Research resources				
Students and postdoctoral researchers		**Positive** (1)		**Positive** (1)
Team members in laboratory	**Positive** (1) **Mixed** (1)	**Positive** (1) **Mixed** (1)	**Positive** (1) **Not significant** (1)	**Mixed** (1) **Not significant** (1)
Scientific quality of department	**Not significant** (1) **Negative** (1)	**Positive** (1) **Not significant** (1)	**Positive** (1) **Not significant** (1)	**Positive** (1) **Not significant** (1)
Public R&D expenditure				**Not significant** (1)
Institutional norms and support structures				
Local norms, awareness, support, training, recognition in academic career	**Positive** (1) **Mixed** (1)	**Positive** (3)	**Positive** (3)	**Positive** (1)
TTO presence in the process		**Not significant** (1)	**Positive** (1) **Negative** (1)	**Positive** (1)
Patent stock of the institution	**Positive** (1)	**Positive** (1)		
Co-authors and colleagues with knowledge transfer involvement	**Positive** (1)	**Positive** (2)	**Positive** (1)	**Mixed** (1) **Not significant** (1)

(table continues)

(continued)

Knowledge transfer activity / Predictor - motivator	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Scientific productivity of colleagues with business work experience			**Positive** (1)	
Affiliation with university research centre		**Not significant** (1)	**Not significant** (1)	**Positive** (2)
Institutional and departmental policies, regulations and incentives	**Not significant** (1) **Not significant or weakly significant (positive)** (1)	**Positive** (2) **Not significant or weakly significant (positive)** (1)	**Positive** (2) **Not significant or weakly significant (positive)** (1)	**Positive** (3)
New funding programmes and opportunities				**Positive** (1)
Technology opportunities				
New technologies, invention value			**Positive** (1)	**Positive** (1)
Development of biotechnology industry				**Positive** (1)
Geographic proximity to firms			**Positive** (1)	

The studies included in our review generally agree that academic researchers that have the highest number of interactions with industry are usually scientifically the most productive in their areas, notwithstanding the type of knowledge transfer activity they engage in. Indeed, intellectual eminence, leaders or champions, sometimes even called "star scientists", have an important role in influencing the tendency towards spin-offs and serving as signals for investors (Zucker and Darby 1996, Di Gregorio and Shane 2003). However, concerning specifically the patenting predictors, as shown by Calderini and colleagues (2007) on a sample of Italian researchers, and in contrast to several other analyzed studies, for the most distinguished basic scientists, the probability to patent decreases with every increase in high-impact academic publishing. A recent study by Schuelke-Leech (2013) comprising a composite indicator of knowledge transfer involvement shows that academically productive scientists are less likely to be intensively involved in knowledge transfer with industry relative to less productive researchers. This is an interesting finding worth further investigation since most empirical studies on this topic refer only to a limited number of settings, predominantly the US. A question that can be evoked based on this finding is whether settings that do not have such a long tradition in academic-industry knowledge transfer activities could facilitate similar results.

The extent of involvement in knowledge transfer activity is in the majority of cases positively correlated with tenure positions, although we also find some evidence of more extensive engagement of younger researchers in different types of knowledge transfer activity compared to their senior colleagues (Bercovitz and Feldman 2008, Astebro et al. 2012, Tartari et al. 2014). It seems that age is the least decisive factor for engagement in academic entrepreneurship, with most studies showing its non-significance (Louis et al. 1989, Boardman and Ponomariov 2009, Aldridge and Audretsch 2010, Haeussler and Colyvas 2011, Abreu and Grinevich 2013). Female researchers and researchers who are closely aligned with open science values are less likely to involve in each of the types of knowledge transfer activity. Widespread networks of collaborators, applied research orientation, prior knowledge transfer experience and motivation to get additional funding for the laboratory are all positively related with involvement in different knowledge transfer activities.

Entrepreneurial self-efficacy and perceived role models are shown to be significantly related to the formation of academic-entrepreneurial intentions (Prodan and Drnovsek 2010). In order to promote academic entrepreneurship universities are increasingly introducing tailored courses in entrepreneurship, and adapting their general courses to include methodologies which develop entrepreneurial skills (del-Palacio et al. 2008). Interestingly, training in business skills is shown to be positively correlated with involvement in collaboration with industry and academic entrepreneurship, but not with invention disclosing, patenting and licensing (Haeussler and Colyvas 2011, Abreu and Grinevich 2013).

Contextual knowledge transfer involvement predictors include changes in the broader institutional framework, research funding pressures, institutional experience in knowledge transfer (e.g., patent stock), culture of the university/department - local group norms and peer influence - number of active colleagues in knowledge transfer (Louis et al. 1989, Stuart and Ding 2006) or the adoption of adequate policies (e.g. willingness to take an equity stake in exchange for paying patenting and licensing costs) (Di Gregorio and Shane 2003). When it comes to research resources, there is empirical evidence of both positive (Oliver 2004, Landry et al. 2007) and inverted U-shaped (Haeussler and Colyvas 2011) relationship between team size and knowledge transfer involvement. There is also no consensus in the literature concerning the relationship between scientific quality of the department and the extent of involvement of researchers in knowledge transfer.

The availability of institutional technology transfer support mechanisms is positively related with all forms of knowledge transfer. Yet, we also find evidence that substantial institutional support may be negatively related with industry collaboration, in the cases were researchers establish informal activities with industry (Abreu and Grinevich 2013). Moreover, the existence of institutional technology transfer policies could be correlated with involvement of researchers in patenting and spin-off founding, but not with industry collaboration. Finally, geographic proximity to firms was found to be relevant in the case of scientists taking active roles in spin-off companies (Audretsch and Stephan 1996).

The above analysis helped us identify the specific personal characteristics of academic researchers that engage in knowledge transfer with industry as well as the institutional context in which they operate. A vast number of studies agree that more productive scientists, male, with permanent positions, applied research orientation, extensive networks of collaborators, previous knowledge transfer experience and supportive institution are more likely to start involving in all types of academic-industry knowledge transfer. Yet, we also find substantial evidence that depending on empirical settings, the same variables can act both as enablers and inhibitors of knowledge transfer involvement. This, for example, refers to scientific productivity and institutional technology transfer support policies and structures. What is more, we observe that some predictors, such as researchers' age, business training or institutional policies, may or may not be of relevance depending on specific type of knowledge transfer activity in focus.

1.3.2 Awarding mechanisms and knowledge transfer involvement and performance

Another stream of studies on knowledge transfer motivations has in its focus the investigation of the role of faculty-awarding mechanisms or incentives for involvement in knowledge transfer, which has also attracted significant attention in the literature (refer to the overview of key findings in Appendix C). Numerous authors have criticized the "publish or perish" paradigm, characteristic not only for the settings in which the commercialization of research results generated by academia is a complete novelty, but also for the research organizations with developed policies and significant experience in this domain, particularly the US (Thursby and Thursby 2002, Link and Siegel 2005, Renault 2006). These authors showed that tenure and promotion policies widely fostered publishing and research activities, whereas university patenting and spin-off companies were at best tolerated, sometimes even penalized.

Empirical investigation about the technology transfer processes of eleven inventions from Columbia and Stanford University revealed that financial incentives played little or no role in motivating faculty to embark on invention-yielding research projects (Colyvas 2000). Instead, researchers' professional interests in the practical application of their inventions motivated them to engage in relationships with industry, often even prior to the involvement of technology transfer offices in the process.

Another reason for the inefficiency of financial incentives as a mechanism to boost the involvement of researchers in knowledge transfer might be the "delay-of publication" clauses in licensing contracts. Specifically, the perceived risk to delay a publication, the unwillingness of faculty members engaged in basic research to devote time to the applied research as well as their unwillingness to cooperate in further development, prevents inventions from being disclosed to TTOs. The generally accepted observation is that, until patents and spin-off companies are recognized as evidence of scholarly contributions, and used and not just tolerated in the tenure and promotion process, the willingness of the faculty to spend their time on such activities will be considerably reduced (see Renault 2006). Therefore, patent-related indicators such as patent counts, co-patenting as well as citations as adequate non-financial incentives and methods to examine entrepreneurial activities at knowledge generating institutions, were recommended (Van Looy et al. 2003).

Scholars propose different measures to encourage faculty involvement in commercialization of their research results: financial rewards that provide performance-based payment structure, such as licensing royalties or equity compensation are sometimes suggested as being most effective. On the other hand incentives that are not tied to the outcome of the venture, such as wage, provide the weakest motivation for the academic to foster the commercialization of the invention. In agreement with this, based on the survey of 62 US universities Jensen and Thursby (2001) perform game theoretical modeling and find that lump-sum payments alone, such as fixed fees or funds for sponsored research or grants, although often viewed as positive since they allow researchers to continue their research in a laboratory, do not provide an incentive for the inventors to continue putting efforts into the development of the embryonic invention after the licensing agreements are signed.

Thus, methods that link commercial success to the inventor's development effort are necessary. This is confirmed by Link and Siegel (2005). Interestingly, Di Gregorio and Shane (2003) show that on the opposite, a high inventor share of (licensing) royalties appears to be a disincentive to potential inventor-entrepreneurs. Moreover, Markman and colleagues (2004) provide evidence that while monetary rewards to TTO staff are significantly and positively related to equity licensing and to firm creation, royalty payments to scientists and their departments are negatively related to university-based technology transfer. We explain these divergent findings with differences in samples, deployed research methods and analyzed knowledge transfer performance indicators. A recent report published by the European Commission (2013) also shows that the percentage given to inventors is not related to knowledge transfer performance. This is explained with a heterogeneous IP ownership situation for university researchers in Europe and a lower degree of IPR law enforcement than in the US.

In addition to the financial incentives, policies to keep or attract scientists are recommended to be adopted, such as liberal leave of absence and consulting privileges that generally allow the academic to pursue commercial opportunities, while maintaining employment at the faculty (Goldfarb and

Henrekson 2003). A summary of findings on knowledge transfer involvement incentives is provided in Table 3.

Table 3. Overview of findings on knowledge transfer involvement incentives

Incentives	**Strong motivator (concerned knowledge transfer mechanism identified in the bracket)**	**Weak motivator or disincentive**
Financial: performance-based (royalties, equity)	Lach and Schankerman 2004 (licensing) Markman et al. 2004 (if for TTO personnel) (equity licensing and start-up founding) Link and Siegel 2005 (licensing) Renault 2006 (patenting, spin-off founding)	Di Gregorio and Shane 2003 (start-up founding) Colyvas et al. 2002 (licensing) Markman et al. 2004 (if for researchers and departments - equity licensing and start-up founding) Baldini 2007 (patenting) Arundel - European Commission 2013 (IP exploitation)
Financial: non-performance based (grants, wages)		Jensen and Thursby 2001 (licensing) Link and Siegel 2005 (licensing)
Non-financial: promotion, academic / institutional reputation / perceived benefits for end user	Van Looy et al. 2011 (patenting) Large et al. 2000 (knowledge transfer)	Arundel - European Commission 2013 (IP exploitation)
Non-financial: policies (sabbatical, consulting privileges)	Goldfarb and Henrekson 2003 (knowledge transfer)	Louis et al. 1989 (knowledge transfer)

In an earlier study Louis and colleagues (1989) analyze the propensity of life-science researchers to engage in various aspects of technology transfer, including commercialization. By focusing on scientists at 50 research universities that received the most funding from the National Institutes of Health they find that the most important motivator of involvement in technology commercialization was local group norms, while university policies and structures had little effect on this activity. In contrast to other areas of academic research, the motivations for involvement into entrepreneurial activities in the life sciences are not driven by a lack of resources, but rather by the opportunity to expand the pool of available research funds and the chance to develop a new line of research more rapidly (also discussed by Colyvas et al. (2002)). Thus, knowledge transfer incentivizing policies of academic institutions active in life science research and teaching should certainly develop in this direction. The same applies to the future research efforts, which should pay more attention to the diversity of available knowledge transfer awarding mechanisms, both financial and non-financial.

1.3.3 Performance and success factors of academic-industry knowledge transfer

While the studies discussed above attempt to identify the factors that motivate researchers to engage in knowledge transfer, they mostly do not explain their performance or performance of their institutions in such activities. Several important observations can be yielded following the review of articles dealing with performance of academic institutions in knowledge transfer to the business sector (Appendices D and E).

First, as it is the case with other sub-areas reviewed in this paper, most studies on this topic focus on US universities, which leaves us with limited findings for other settings. Second, most of the analyzed studies focus only on the top universities or best practice examples, which give rather skewed insights. Third, there is no consensus among different authors regarding knowledge transfer performance measurement criteria. In the majority of cases, knowledge transfer performance of academic institutions is measured by intellectual property exploitation-based indicators, such as the number of invention disclosures, patent applications, granted patents, licenses and revenue from licensing (see for example Mowery and Ziedonis 2002, Geuna and Nesta 2006, Leydesdorff and Meyer 2010, Geuna and Rossi 2011). Some studies focused on patent relevance (measured by citations) and scope

(Mowery and Ziedonis 2002, Geuna and Rossi 2011). We observed a limited number of studies that also measured the intensity of industry collaboration (Campbell et al. 2004) or academic entrepreneurship-related indicators of performance, including a number of generated spin-off companies and their market success (Carlsson and Fridh 2002, Arundel et al. 2013, Jacobsson et al. 2013). Some respondents interviewed at academic institutions propose alternative performance measures, such as informal transfer of know-how (Siegel et al. 2003), satisfaction of researchers that engage in technology transfer (Carlsson and Fridh 2002) or perceptions of institutional managers on technology transfer effectiveness, but there is a limited empirical evidence with respect to such indicators as it is more difficult to collect the data. In addition, the validity of such findings is questionable, due to the possible interest in sending the positive image (Rogers et al. 2000).

By focusing solely on financial performance indicators we observe that most universities in the USA and Europe are actually not successful in knowledge transfer, since the costs related to such activities significantly exceed the obtained revenues (Arundel et al. 2013). Also, the distribution of income from commercialization is highly skewed (Carlsson and Fridh 2002, Campbell et al. 2004, Geuna and Nesta 2006). Interestingly, several studies point to the trend of a general decline in university patenting over the past 10 years, both in Europe and in the USA, and argue that this is due to the lack of institutional incentives or changes of policies towards university ownership of patents (Leydesdorff and Meyer 2010, Geuna and Rossi 2011). In any case, a recent study reveals that the USA still outperforms Europe when it comes to most knowledge transfer efficiency indicators, except for the number of founded spin-offs and number of executed licenses (Arundel et al. 2013).

While some of the studies we analyzed seek to identify wide-ranging knowledge transfer success factors, others consider specific determinants, such as the role of university technology transfer offices or the importance of scientific networks. We identify six principal groups of success factors: characteristics and quality of researchers-inventors, characteristics and quality of technologies subject to knowledge transfer, institutional capabilities and resources, policies, prior knowledge transfer experience and geographic proximity to supporting infrastructures and industry. The key success factors are summarized in Table 4, with reference to industry collaboration, intellectual property exploitation, academic entrepreneurship and composite indicators of knowledge transfer performance.

Table 4. Overview of knowledge transfer success factors, with indicated number of articles identified per each finding

Knowledge transfer performance output / **Performance predictor**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	**Composite** (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
Characteristics and quality of inventors and teams				
Scientific productivity and impact	**Positive** (1) **Negative** (1)	**Positive** (6) **Not significant** (1)	**Positive** (4)	**Positive** (1) **Negative** (1)
Faculty size, team size	**Positive** (1)	**Positive** (2) **Not significant** (1)	**Positive** (1) **Not significant** (3)	
Involvement in the process		**Positive** (1)	**Positive** (2)	
Characteristics and quality of inventions and technologies				
Novelty, technological radicalness, market attractiveness			**Positive** (1)	
Patent complexity		**Positive** (1) **Not significant** (1)	**Positive** (1) **Not significant** (1)	
Stage of development (later)	**Negative** (1)	**Positive** (1) **Negative** (1)		
Effectiveness of protected invention		**Positive** (1)	**Positive** (1)	
Cooperation with industry in R&D		**Negative** (1) **Not significant** (1)	**Not significant** (1)	
Institutional capabilities and resources				
Support structures, skills and incentives of “intermediary” human resources, top management and public-private team	**Positive** (1)	**Positive** (4)	**Positive** (4)	**Positive** (1)
Entrepreneurial culture		**Positive** (1)		**Positive** (1)
TTO age		**Positive** (4) **Negative** (3) **Not significant** (3)	**Positive** (2) **Negative** (1) **Not significant** (2)	
TTO size	**Not significant** (1)	**Positive** (9) **Negative** (1) **Not significant** (3)	**Positive** (5) **Not significant** (1)	**Positive** (1) **Negative** (1)

(table continues)

(continued)

Knowledge transfer performance output / **Performance predictor**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	**Composite** (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
TTO salary			**Positive** (1) **Not significant** (1)	
TTO organisational forms (information processing and coordination capability)	**Positive** (1)	**Positive** (1)		
Traditional TTO organizational structure		**Negative** (1)	**Negative** (1)	
TTO evaluation of KT activity significance	**Positive** (1)	**Not significant** (1)		
Institutional / government R&D funding / expenditure		**Positive** (6) **Not significant** (3)	**Positive** (4) **Not significant** (2)	**Positive** (2) **Not significant** (1)
IPR expenditures of TTO		**Positive** (2) **Negative** (2) **Not significant** (1)	**Positive** (1)	
Industry funding private gifts, grants and contracts		**Positive** (3) **Not significant** (1)	**Positive** (3)	**Positive** (2)
Quality of an institution's patent portfolio			**Not significant** (1)	
Prior knowledge transfer experience	**Positive** (1)	**Not significant** (1)	**Positive** (3)	
Network ties to industry and investors		**Positive** (1)	**Positive** (1)	**Positive** (3)
Geographic proximity to supporting infrastructure and industry				
Access to science incubators / parks			**Not significant** (2)	**Positive** (1)
Access to venture capital / seed capital		**Positive** (1) **Not significant** (1)	**Positive** (2) **Negative** (1) **Not significant** (1)	**Positive** (1)
Business reliance on external R&D		**Positive** (1)		
R&D intensity of the local setting	**Not significant** (1)	**Positive** (3) **Not significant** (2) **Negative** (1)	**Positive** (1) **Not significant** (1)	
Broader institutional setting (education, social and religious differences, national language and industrial distance, political distance)		**Mixed** (1)		

Concerning the characteristics of researchers and their teams, the great majority of analyzed studies report the positive relationship between high quality research base and all forms of knowledge transfer. However, in a study in which Thursby and Kemp (2002) rely on the data envelopment analysis to measure the relative efficiency of universities with regard to sponsored research in licenses, invention disclosures, patenting and royalties, institutions of higher research quality were evaluated as less efficient in knowledge transfer. These authors attribute the results to the predominant basic research orientation of such institutions. Next, the faculty size is shown to be positively related to industry-sponsored research, patenting and licensing (Powers 2004, Van Looy et al. 2011), but not with the number of established spin-off companies (O'Shea et al. 2005, Powers and McDougall 2005, Van Looy et al. 2011).

Thursby and Thursby (2002, p. 92) suggest that "increased licensing is due primarily to an increased willingness of faculty and administrators to license and increased business reliance on external R&D rather than a shift in faculty research". Indeed, scientist's involvement in further development is evaluated as essential for commercial success of the licensed inventions (Jensen and Thursby 2001, Agrawal and Henderson 2002, Thursby and Thursby 2002, Jensen et al. 2003, Thursby and Thursby 2003) and start-up ventures (Nerkar and Shane 2003, Ensley and Hmieleski 2005).

When it comes to the characteristics of inventions that are subject to knowledge transfer, novelty, technological radicalness, market attractiveness, patent complexity and effectiveness are shown to be most relevant for survival of spin-offs (Nerkar and Shane 2003). The latter two are also positively associated with patenting and licensing (Shane 2002, Crespi et al. 2010).

The support of institutional and departmental management and capabilities of technology transfer specialists in evaluating the technology transfer projects and providing incentives for commercialization have been evaluated as critical both for patent-related knowledge transfer activities and for academic entrepreneurship. Large and colleagues (2000) focus on the importance of team building process, and particularly on "linchpins", or individuals in managing positions of the public labs who control the flow of money and/or possess expert knowledge, usually the lead scientist, the lab director, R&D manager or the marketing manager. The empirical evidence shows that successful projects (measured by profit indicators) assemble more linchpins than unsuccessful projects. Moreover, the need for dedicated champions, both managerial and technical, with top qualifications, assembled in cross-functional teams, is empirically affirmed.

The role of the size, age, structure and capabilities of technology transfer offices in the success of knowledge transfer process has received particular attention in the literature. Due to their demanding role of "dual agents" or "boundary spanners" between the academic inventors and the industry, attracting and retaining good TTO personnel is extremely important and at the same time very challenging, because "their work is routinely at the fuzzy front end of innovation, where market, legal, technology and competitive uncertainties coalesce" (Markman et al. 2004, p. 356). A university that offers higher pay to its TTO staff is likely to attract and retain highly qualified and talented recruits that can work with both faculty and industry representatives (Rogers et al. 2000, Siegel et al. 2003). According to Carlsson and Fridh (2002), the extent to which a university is active in finding potential licensees depends largely on the number and capabilities of the staff within the TTO and more importantly, on the inventors themselves, since they are likely to be familiar with the enterprises within the sector related to their inventions. Heslop, McGregor and Griffith (2001) survey technology transfer professionals at universities or federal research laboratories in Canada and the US and interestingly, report that many of these rely heavily on their "gut feelings" when assessing the commercial potential of new technologies.

The majority of empirical studies that we analyzed find the positive relationship between the size of TTO and the number of disclosed inventions, patents, licenses, spin-offs and licensing revenue, whereas the relationship with industry-sponsored research is not supported (Van Looy et al. 2011). However, we also find evidence that rapid expansion of TTOs can negatively affect their licensing productivity (Thursby and Thursby 2002). When we add the role of the TTO age into analysis, the empirical evidence is even less conclusive. In contrast to the report on EU universities published by the European Commission (2013), Chapple and colleagues (2005) use the example of UK universities to show that larger and at the same time older TTOs appear to be less efficient than younger and smaller TTOs in terms of the number of concluded licensing agreements. Next, Lach and Schankerman (2004) find no evidence of relationship between the size of a TTO and the success of a TTO (measured by licensing revenue) and evidence of a positive relationship between the age of a TTO and its performance. Moreover, the broader the research scope of a university is, the less successful a TTO is likely to be. Since a broad-based nature of research requires large commercialization services for a wide range of industries, TTOs of large universities are assumed to suffer from being generalists (Chapple et al. 2005). TTOs therefore may be differentiated by establishing divisions focusing on particular sectors. To sum up, we find no straightforward evidence regarding the role of the size, age and organizational structure of the TTO in the knowledge transfer performance of academic institutions.

Institutional R&D expenditure is one of the most important determinants of knowledge transfer performance. Institutional expenditure on intellectual property protection has been shown to positively correlate with spin-off founding (Lockett and Wright 2005), whereas there is mixed evidence in relation to licensing agreements and revenue from licensing (Siegel et al. 2003, Chapple et al. 2005).

Another important determinant of knowledge transfer performance is the level of industry funding. Equally important are network relationships with industry and investors (Harmon et al. 1997, Colyvas et al. 2002, Shane and Stuart 2002, Owen-Smith and Powell 2003, Palmintera 2005). Following the examination of eleven technology transfer cases in two US universities, Colyvas and colleagues (2002) observe that the active role of TTOs in the knowledge transfer process is often limited to solving complicated legal issues with licensing agreements or marketing inventions in areas with weak links between academia and industry. In many cases the industry initiates the knowledge transfer process by directly contacting the researchers in their networks. The findings from Siegel, Waldmann and Link (2003) and especially Harmon et al. (1997) support this claim by showing that in most instances the academic inventor had either prior work experience with the company (formal relationship), was close friends with the companies' staff (informal relationships) or established contact with companies representatives in a professional setting such as a conference, notwithstanding the type of technology transferred. In contrast, the empirical evidence from the study by Crespi and colleagues (2010) does not reveal the positive influence of cooperation with industry during the research and development stage on patent use, licensing and spin-off founding. Using the results of the survey conducted at MIT, Shane and Stuart (2002) explain how spin-offs with social relations to venture capitalists are "most likely to receive venture funding and are less likely to fail". This is definitely in accordance with the claim that whatever the route of technology transfer is, central to its success will be the role played by the creator of the intellectual property, the individual scientist.

The studies focusing specifically on academic entrepreneurship often draw their theoretical basis from the entrepreneurship and business literature and in this regard concentrate on the factors influencing the entrepreneurial intentions and decision-making of academic researchers compared to other entrepreneurs (individual level), as well as on the business success or failure determinants of academic spin-offs, in comparison to non-academic start-ups (organizational level).

When discussing the choice between academic and surrogate (external) entrepreneurs, Franklin, Wright and Lockett (2001) show that universities with most experience in successfully spinning-off technologies had more favorable attitudes towards surrogate entrepreneurs than those with little experience in this respect; nevertheless, they advocate the balanced approach as the most beneficial.

Mustar, Wright and Clarysse (2008) show that research-based spin-off firms are, in contrast to what is proposed in the established policies of EU countries, not a source of wealth for universities and other public research organizations (see also Lerner 2004). Many studies of the financial returns from investments in innovating activities show that a small number of projects generate the major part of the returns, and if they do, then mostly in the USA and extremely rarely in Europe. The authors suggest that this is due to the policy approach that ignores the diversity of university spin-offs, i.e. assumes their homogeneity across different sectors. This is in line with the finding by Ensley and Hmieleski (2005), according to which university start-ups have less developed dynamic and lower financial performance than independent start-ups. Therefore, while some authors advocate the presence of scientists-inventors as an essential component for the successful growth of academic spin-offs, others emphasize the benefits of engagement of experienced, external experts to support the commercialization process in spin-offs. These findings call for further research on the role of team structure in the success of academic spin-offs.

In summary, we identified a broad range of possible knowledge transfer performance predictors. In order to be successful in knowledge transfer, academic institutions should focus on the individual researchers and their inventions, and their own knowledge transfer capabilities, resources, experience and strategies.

1.3.4 Institutionalization of academic-industry knowledge transfer

How academic-industry knowledge transfer activities gained importance over the years and across different empirical settings represents an interesting research topic, again, mostly investigated in the USA. The reviewed studies in this area mostly deploy qualitative research techniques, such as archival data reviews, interviews and case studies.

Colyvas (2007) sets her study at Stanford University, USA, and concludes that life science technology transfer institutionalization at that institution resulted from a combination of several divergent approaches, or models, which were based on the attitudes of involved researchers towards commercial science from their, academic science point of view. These approaches differed in the following ways: definition of patenting scope; defining inventor; determining the allocation of credits and revenues from commercialization; agreeing on boundaries between university and industry. The identified key factors that influenced the standardization (institutionalization) were: faculty advocacy and authority, the career structure of science, technological change, and resources. The institutionalization marked technology transfer as acceptable for integrating the norms of academic science with commercial gains. Such model was later widely emulated in other US universities.

Building on that study, Jong (2008) compares the institutional adaptations at Stanford University and University of Berkeley at California and shows that following the rise of biotechnology industry, researchers involved in technology transfer reshaped the local social order (norms) and organization of life sciences within their universities: their own operations within the scientific communities and relationships with other departments in order to gain legitimacy of technology transfer activities and new modes of knowledge generation.

Focusing more narrowly on the changes in the patenting regime following the Bayh-Dole Act in the USA, which enabled the expansion of patent protection to biomedical research tools, and to new actors, public research institutions, Jonjic (2010) identifies a variety of public scientists' responses to the new situation and their operation in a hybrid institutional system: from categorical opposition to patents, pre-emptive publication and informal adaptation to hybrid responses, such as open-source biology and publicly minded patenting, to complete market acceptance (see also Owen-Smith and Powell 2001).

Broadening the analysis to universities located in settings other than the USA, in Europe and Latin America, Etzkowitz (2003) finds that commercialization of research has gradually become accepted as a legitimate administrative function of research universities in addition to research and teaching, particularly because of pressures on the universities to contribute to economic development and opportunities to gain personal wealth. University-based innovation has occurred both endogenously (internal development) and exogenously (external research funding for new therapeutics and chemicals). According to this scholar, the transition to entrepreneurial university grew from the internal organization of research laboratories as “quasi-firms”, to the translation of the results of research into economic goods, to economics of science, with an emphasis on intellectual property. Kruecken (2003) analyses German universities and finds that the institutionalization of technology transfer was a long and complex process, and a result of a top-down approach, with a more important role of informal connections with industry than formal structures, such as technology transfer offices, for stimulating the involvement of researchers in such activities.

Despite the valuable findings of the above elaborated studies, a limited number of articles in the area of knowledge transfer institutionalization imply the need for further empirical investigation, particularly for the heterogeneous European settings. In some countries in Europe the academic-industry knowledge transfer practice is still in its early phase, which is why it may be beneficial to analyze its evolution in comparison to more advanced settings.

1.3.5 Academic-industry knowledge transfer and researchers’ scientific output

The final two identified groups of studies investigate the implications of academic-industry knowledge transfer. Links between academia and industry are shown to enable the realization of complementarities between applied and basic research (Azoulay et al. 2006), the generation of new research ideas (Rosenberg 1998) and the overcoming of the shortage of funding of basic research through the private sector (Agrawal and Henderson, 2002 in Czarnitzki and Glanzel (2009)). At the same time, academic-industry interactions may result in numerous challenges for public science. In his analysis of 82 scientific papers, Baldini (2008) identifies the following threats arising from involvement of academic researchers into knowledge transfer activities: threat to scientific progress due to increasing disclosure restrictions; declining patents’ and publications’ quality, biasing research efforts toward commercial priorities, crowding-out between patents and publications and reducing the relevance and quality of teaching activity in academia.

Regarding the impact of knowledge transfer activities on scientific output (summary of key findings provided in Appendix F), a vast number of studies relies on scientometrics. There is a long tradition in scientometrics of exploiting information on co-authorship of scientific papers (Balconi et al. 2004, Breschi and Catalini 2010) and patent-paper pairs (Murray 2002) to analyze knowledge exchange among researchers and between researchers and industry.

Van Looy et al. (2004) find, for the science-, medicine- and applied engineering-related disciplines at the University of Leuven in Belgium, that engagement in contract research for industry coincides with an increased level of publication, without affecting the nature of the publications involved. Lowe and Gonzalez-Brambila (2007) also find that faculty entrepreneurs who start businesses are among the most productive and best-cited in their respective fields. However, they do note differences across disciplines, i.e. a more positive effect and spin-off founding earlier in the career in engineering than in biomedicine. In sharp contrast with this finding, Buenstorf (2009) (based on his study of Max Planck directors from 1985-2004) reports positive effects of inventing commercially useful technologies, but negative effects of spin-off founding, on publication quantity and quality. In fact, he finds positive relationship only when licensed inventions are considered. He attempts to justify this with the explanation that spin-offs are often found in the later stage of the scientist's career, when his publication track record is usually the declining phase. He also finds no evidence that the flow from income drawn from licensing and commercialization of invention is positively associated with the number and quality of publications.

Even though no consensus has been reached with respect to this sub-topic, there is no apparent trade-off between patenting or knowledge transfer in general and either quantity or quality of research output (Agrawal and Henderson 2002, Van Looy et al. 2006, Fabrizio and DiMinin 2008): scientists with better patenting performance tend to exhibit superior publication scores with no decrease in the quality of output and exactly the most productive scientists are those most likely to become inventors (Caulfield and Ogbogu 2008, Breschi and Catalini 2010).

Although it is not possible to determine a causal relationship between industry funding and increased productivity, potential explanations for this relationship include the assumption that industry funds scientists who are already more productive, or that industry funding provides additional resources to faculty, which in turn increases their productivity (Campbell et al. 2004).

1.3.6 Impact of academic-industry knowledge transfer on the norms of open science

As to the stream of research investigating the impact of knowledge transfer activities on knowledge diffusion among members of the scientific community, scholars have mostly discussed how engagement of individual researchers into knowledge transfer activities could undermine their commitment to the norms of open science, in that way leading to secrecy and publication delays (Dasgupta and David 1994, Geuna and Nesta 2006). Dasgupta and David (1994), Henderson and colleagues (1998), Jensen, Thursby and Thursby (2003) and Kenney and Patton (2009) discuss the inefficiency of knowledge transfer, which partly stems from the constant friction between academic institutions that desire publication and the establishment of priority, and corporate research sponsors that wish to defer disclosure until the patents can be employed to protect the future economic returns of an innovation. The rules of market competition may not be compatible with the social norms of priority and free circulation of knowledge (considered as the most important values of their profession) within the scientific community (Calderini et al. 2007).

In this respect, a significant fraction of the articles focuses on the impact of patenting, as one form of knowledge transfer, on knowledge diffusion among researchers. In life sciences, patenting is viewed as a means of providing investment incentives, essentially due to long product development time horizons and high associated risks (Kneller 2001). On the other hand, the expansion of proprietary interests to life sciences is assumed to have the strongest influence on endangering free knowledge flows among academic researchers. In particular, the facilitation of patenting of life forms represented a big challenge for the conventions of sharing of biological tools among scientists (Colyvas 2007). It seems that patenting and exclusive licensing of fundamental technologies or upstream discoveries with broad application in the life sciences could in fact restrict future innovation, by increasing costs and hindering the access to technologies and the free flow of scientific knowledge needed for subsequent research and even redirecting the research (Rai and Eisenberg 2003, Campbell et al. 2004). This concern has been captured in the phrase "*the tragedy of the anti-commons*", which has been used extensively to point to the problem of existence of multiple holders of rights to separately patentable inputs which combined from one product or resource (Heller and Eisenberg 1998, Mazzoleni and Nelson 1998, Walsh et al. 2003).

In a qualitative study of the impact of patenting of research tools in biomedicine on innovation, Walsh and colleagues (2003) find that university research has not been substantially impeded by an increase in patenting; with an exception of patented genetic diagnostics. Relying on the analysis of citation rates of scientific publications before and after the grant of associated patents, Murray and Stern (2007) test the anti-commons hypothesis and find a modest evidence of the restrictive impact of patents on knowledge diffusion. Walsh and colleagues (2007) conduct the survey of US biomedical researchers in genomics and proteomics and report that patents do not usually prevent them from gaining access to knowledge required for their research. However, they differ between accessing knowledge inputs and accessing other researchers' tangible inputs, such as cell lines, reagents, or unpublished information, and find that the withholding is more common for the latter. Furthermore, based on a survey of Canadian stem cell researchers, Caulfield and colleagues (2008) show that even though about one half of researchers view patents negatively in terms of their impact on research environment by increasing secrecy, there is little evidence that patenting in reality interferes with the research process through increased withholding of protected materials. More than a half of the respondents report that they have been denied the request for research materials; however, academic competitiveness, and not patents, is viewed as a principal reason for the denials. Davis and colleagues (2011) on a sample of Danish researchers confirm the skepticism of life scientists, particularly of those with industry work experience and industry grants, regarding the impact of university patenting on academic research and the norms of open science.

Overall, those studies point to data and materials withholding among researchers. Moreover, they show evidence of negative attitudes of researchers toward the impact of patenting on knowledge sharing. However, it is also observable that patenting alone may not be sufficient to explain the limitations in knowledge diffusion among researchers in the life science field.

While considering the impact of other forms of knowledge transfer in addition to patenting on knowledge sharing between researchers, the empirical studies have investigated the restrictions in knowledge diffusion from both the demand and the supply side. Focusing on the demand side, Campbell and colleagues (2000) investigate the incidence of being denied access to other academics' research results based on a survey of US medical school researchers. They show evidence that 12.5% of researchers had data withheld from them, with the researchers involved in commercializing their research being more likely to be denied access to other investigators' research results.

In a later study Campbell and colleagues (2002) find that almost half of genetics researchers had been turned down when approaching colleagues with requests for information, data, or materials regarding published research. From the supply side, on the other hand, twelve percent had denied another researcher's request for data concerning published results. As in their previous study, involvement in commercialization of university-based research is shown to be significantly associated with increased likelihood of data withholding (also confirmed by Blumenthal et al. 1996, Louis et al. 2001, Walsh et al. 2007). Yet, the most frequently reported reasons for the lack of openness to co-operation include too much effort, cost and time to produce the materials or information, protecting the ability of the faculty member to publish, and protecting their own ability to publish (see also Blumenthal et al., 1997; Louis, Jones and Campbell, 2002; Walsh et al., 2007). Reasons related to commercial value protection are again ranked low by the respondents.

Only a limited number of studies have considered the heterogeneity in university-industry interactions when assessing their relationship with knowledge diffusion. In a study aimed to reveal the reasons behind two forms of data withholding, publication delays and refusals to share biomaterials and data, Blumenthal and colleagues (1997) find that involvement in academic-industry research relationship and engagement in the commercialization of university research are both associated with publication delays, whereas only the latter is associated with refusal to share research results upon request. A more recent study of geneticists and other life scientists (Blumenthal et al., 2006) shows that not only industry research support and commercialization endeavors, but also other industry involvements, such as consulting or equity, have an adverse effect on verbal or publishing data sharing in life sciences. Going in the same direction but in the context of scientific norms (for practical contribution and for open science), Shibayama (2012) on a sample of Japanese natural scientists finds that not all entrepreneurial activities discourage cooperative relationships between scientists: while commercial activity facilitates secretive publications and non-compliant behaviors in material transfer, no significant effects are shown for collaboration with industry and funding from industry. These findings are particularly interesting because they point to the need for distinguishing between particular forms of knowledge transfer in investigating their impact on open science in the life science communities.

In conclusion to this section, we notice that the existing findings are disparate: on one hand, some authors report modest or no evidence of increasing restrictions in knowledge diffusion due to involvement of researchers in knowledge transfer activities. Instead, they attribute the limitations in knowledge sharing to reasons such as academic competition or logistical difficulties. On the other hand, others point to significant limitations in the dissemination of research materials and information resulting from knowledge transfer, particularly within the life science areas that are more commercially attractive. Next, the published articles largely focus on the impact of patenting on limiting the access to scientific knowledge, without or only to a certain extent taking into account other forms of knowledge transfer. This has been confirmed also by Abreu and Grinevich (2013), who argue that the current focus of the academic entrepreneurship literature, which is mostly on patent-based activities such as spin-offs and licensing, should be widened to also include other informal commercial and non-commercial activities that are entrepreneurial in nature.

Moreover, only certain forms of knowledge flows, such as sharing of materials and data or sharing via publications, are in the focus of attention of such studies; the empirical findings with reference to the other forms of knowledge sharing (e.g., in collaborative grants, at scientific conferences, via material transfer agreements or among doctoral students) have been poorly represented in the literature (Rodriguez et al. 2007, Haeussler et al. 2014). An outline of all analyzed studies is provided in Appendix G.

1.3.7 Conceptual framework for investigating academic-industry knowledge transfer

Our systematic review provides grounds to identify the gaps in the existing literature and to propose some interesting avenues for further research. Our main output is the identification of emerging themes, which target both the determinants and consequences of academic-industry knowledge transfer interactions for public science institutions.

The investigation of knowledge transfer predictors and motivations of individual life scientists revealed that in most cases, researchers with higher professional status, established collaborative networks, applied research orientation, willingness to obtain more funding for laboratory research and previous industry involvement experience are also more active in knowledge transfer. However, the situation is not so straightforward with scientific productivity, measured by the number of publications and their impact, which was shown to be both, the positive and the negative predictor of knowledge transfer involvement, depending on the empirical context, knowledge transfer mechanisms in the focus of analysis and publication output level in question. In this regard, high-impact academic publishing has been negatively correlated with patenting as one form of knowledge transfer. We explain this with the basic research orientation of most productive scientists and their complete focus on publishing priority. Yet, additional research is needed to elucidate this relationship, particularly in empirical settings other than the USA. This might bring us novel insights into knowledge transfer predictors with reference to the role of institutional context.

Apart from these internal motivators, we also identified knowledge transfer involvement predictors from the organizational and institutional environment of academic researchers, such as availability of institutional financial and human resources, including technology transfer support personnel; peer influence, technology opportunities, location, and commercialization-oriented policies. The latter have particularly attracted our attention considering that previous studies yielded disparate findings as to the effectiveness of different financial and non-financial incentives in motivating researchers to embark on knowledge transfer activities. Future research efforts should thus pay more attention to the heterogeneity of available knowledge transfer awarding mechanisms when assessing their impact of knowledge transfer involvement and performance of researchers and their institutions.

While most of the above identified studies identify the factors that motivate researchers to engage in knowledge transfer, they often do not explain the level of performance of individuals and their institutions in such activities. We were therefore interested to find out why some researchers and academic institutions are more successful than others in knowledge transfer with the business sector. At this point, an important role lies with institutional capabilities and resources, primarily with technology transfer officers, who are responsible for the evaluation of university-generated research results with commercial potential, selection of commercialization mechanism and attraction of external funding or networking with industry representatives. Previous empirical studies resulted in ambiguous findings concerning the relationship between the specific characteristics of technology transfer offices and knowledge transfer performance, which indicates the need for further studies in this area. Future research efforts should also consider the fact that in many cases, technology transfer occurs outside the formal institutional structures, via direct, informal communication between researchers and industry. Moreover, formal and informal knowledge transfer activities can take place as parallel or complementary processes. When measuring knowledge transfer performance, scholars should therefore try to include into analysis these informal knowledge transfer channels by surveying not only institutional support offices, but also individual researchers.

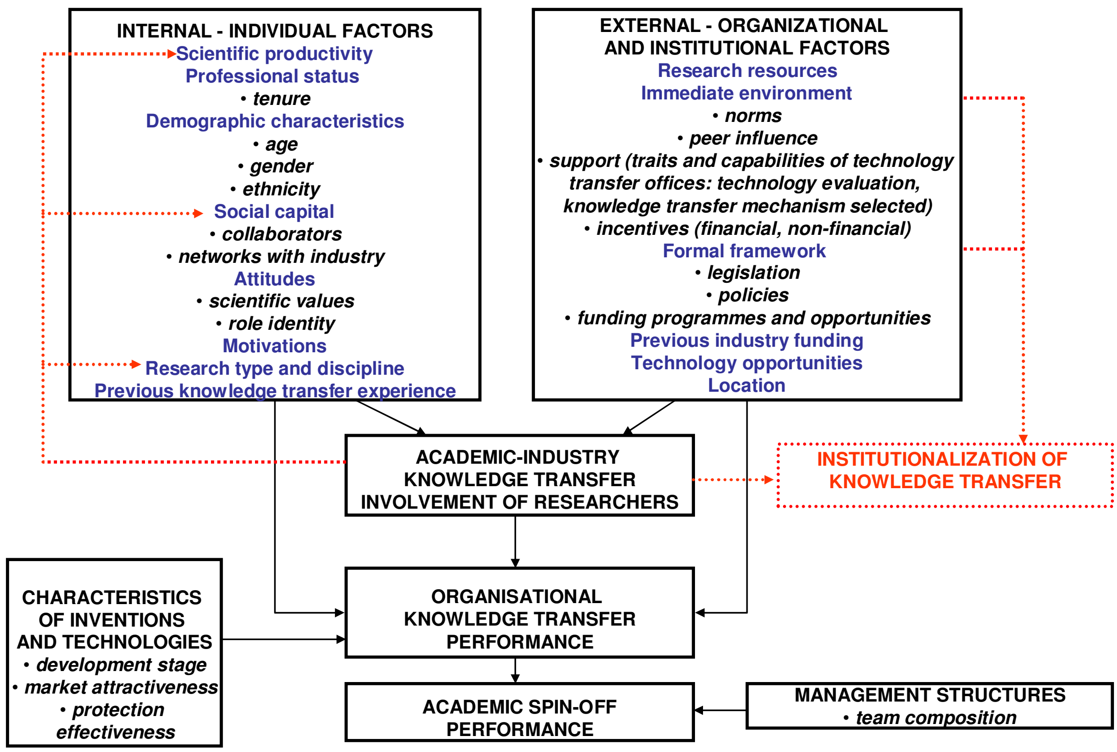
When it comes to the success factors of academic spin-off entrepreneurship as a specific form of knowledge transfer, one of the key issues concerns the role of the scientist-inventor in the technology commercialization and company growth, as opposed to the engagement of external, non-academic managers and entrepreneurs by academic institutions. In a broader sense, we are interested in the identification of factors contributing to market success or failure of biotechnology-related university spin-off companies. The knowledge in this area is still quite limited, but can be expanded, particularly in the European settings, considering that the number of established academic spin-offs there even exceeds the one in the USA.

Furthermore, we identified a stream of articles that took a historical perspective in investigating academic-industry knowledge transfer in different countries and studied the evolution of the process over the years. These studies enabled us to make a comparison across several empirical settings, where we identified approaches ranging from top-down and external, to bottom-up and informal, of how knowledge transfer activities gained importance and legitimacy. Again, the existing studies tell us little or nothing about the institutionalization of knowledge transfer in transitional economies, especially former socialist countries, where intellectual property assessment at academic institutions is still a relatively new phenomenon.

Finally, we analyzed the studies focused on the implications of academic-industry knowledge transfer for scientists and academic institutions. The correlation between knowledge transfer activity and scientific productivity of researchers was shown to be positive in most observations, although with some exceptions, particularly with regard to the publication impact, measured by citations. The situation is more complicated with the implication of knowledge transfer activities for open science, characterized by free exchange of knowledge among the members of the scientific communities. Most studies pointed to many barriers to knowledge sharing; however, only in some cases can these unquestionably be attributed to knowledge transfer activities, but rather to the factors such as scientific competition or resource constraints. It should also be borne in mind that most of the observed studies do not determine a causal relationship between knowledge transfer and various forms of knowledge diffusion. Moreover, empirical studies have for the great part dealt with the impact of patenting on the open science environment, often without paying specific attention to other knowledge transfer activities (Heller and Eisenberg 1998, Murray and Stern 2007). Next, the studies that did consider the impact of different forms of knowledge transfer on knowledge flows among researchers have mostly examined only one aspect of knowledge diffusion - informal cooperation between researchers (Blumenthal et al. 1997, Campbell et al. 2000, Walsh et al. 2007). The empirical findings with reference to formal knowledge sharing have typically been restricted to investigations of the relationship between knowledge transfer and quantity and quality of the researchers' scientific output (Agrawal and Henderson 2002, Van Looy et al. 2006, Fabrizio and DiMinin 2008). Thus, only few studies attempted so far to consider the determinants of other forms of formal collaboration among researchers, such as collaborative research projects or personnel exchange between laboratories. Finally, most articles contain empirical findings relating to only one country, predominantly the USA (Baldini 2008). Future studies should also potentially investigate how commercialization activities affect the size and structure of the life science and biotechnology scientific networks.

The above discussed findings enable us to develop a conceptual framework for studying academic-industry knowledge transfer and evaluating its effectiveness and impact on public science (Figure 3). This framework can be a useful guide for researchers, policy makers and managers of public research institutions. The latter are particularly interested in maximizing the knowledge transfer performance in relation to invested resources.

Figure 3. Conceptual framework for evaluating the effectiveness of academic-industry knowledge transfer and its impact on public science



1.4 Conclusions and policy implications

In this paper we conducted a systematic review of substantial literature focusing on knowledge transfer from academic institutions to the business sector, with the particular emphasis on life sciences. This enabled us to indicate the trends in this research area, as well as identify the topics that require additional investigation.

The systematic review also enabled us to develop a new conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science. This should help direct the future empirical research in this area and serve as a useful tool for practitioners involved in knowledge transfer activities at academic institutions, who have been highly interested in the factors driving academic-industry knowledge transfer and the consequences of these activities for the public science following the intensive research and innovation policy changes over the recent years.

In particular, there are several policy implications on both the individual and the organizational level, which can be drawn from the presented analysis. First, concerning knowledge transfer motivators, policy makers should try to develop mechanisms to stimulate the involvement of non-tenured researchers in knowledge transfer activities, as our literature review indicated that in most cases, their participation had so far been less pronounced compared to more senior researchers, with stable positions. It is understandable that organizational hierarchies and academic advancement policies may act as barriers for younger, non-tenured researchers to engage in independent projects. However, specifically-tailored training and funding programs can be developed with the view to increase the business and managerial skills of these personnel and therefore create favourable conditions for their future involvement in commercialization projects. The same refers to female researchers, who are shown to be less likely to engage in different forms of knowledge transfer than their male colleagues.

Next, several studies from our review show that academically most productive researchers are less likely to be intensively involved in knowledge transfer with industry than less productive researchers. These studies suggest that this could be due to the researchers' fear of losing priority in publishing and lack of time to devote to knowledge transfer activity. As a consequence, the authors discuss the lack of inventions of sufficient quality for further commercial exploitation. On the other hand, empirical studies in several settings reveal that less scientifically productive researchers can also positively contribute to the level of patenting at academic institutions. In our opinion, these findings need to be considered with caution, as institutions should give advantage to quality, rather than quantity, in assessing knowledge transfer performance. This recommendation also applies to national and EU policy makers, who should expand the existing list of knowledge transfer performance indicators by including also those that promote quality and not merely the number of outputs, such as new patents, licensing agreements and generated spin-offs.

When defining the incentives for researchers to engage in knowledge transfer, academic institutions should bear in mind that financial incentives are not the only available mechanism, since life science researchers sometimes more highly value the opportunity to receive industry funds to expand the research activities of their laboratory than only receiving the financial compensation from royalties. Furthermore, institutional managers should not neglect the fact that knowledge transfer also occurs outside the formal institutional structures, such as technology transfer offices. Instead, they should investigate to what extent and why their faculty sustains from establishing contacts with the technology transfer administrators, regardless of the existence of regulations and other formal documents which insist on this knowledge transfer process route. By understanding and acknowledging that formal and informal activities are both important for the successful realization of knowledge transfer, institutions could improve communication between researchers and technology transfer intermediaries.

In addition, institutional policies promote the establishment of academic spin-off companies partly or fully in their ownership, but often fail to consider their management and team structures and market attractiveness of spin-off technologies. As shown in the paper, the consequence is a high failure rate of academic spin-offs. In line with this finding, technology managers at academic institutions should carefully assess the readiness of university inventions for commercialization via establishment of new ventures. In addition, future empirical studies should pay more attention to the composition of spin-off management teams, or role of the scientist-inventor and external, non-academic managers and entrepreneurs in the technology commercialization and company growth.

Finally, we showed that knowledge transfer activities do not necessarily yield only positive results, such as increased revenues for academic institutions and better exploitation of university-generated research results. In fact, this is the case for only a minor part of the institutions, especially in Europe. Policies at academic institutions must therefore not promote unconditional commercialization; exactly the opposite, they should carefully consider the scientific interests of academic researchers and characteristics of inventions before proceeding to the contractual relationships with the business sector. In this regard, it would also be interesting to compare the performance of systems that rely on the institutional management of academic-industry knowledge transfer activities (dominant) with those that favor the exploitation by individual researchers (professor's privilege).

2 EXPLORING KNOWLEDGE TRANSFER-KNOWLEDGE SHARING RESTRICTIONS RELATIONSHIP IN A CROSS-CULTURAL CONTEXT: THE CASE OF LIFE SCIENCE COMMUNITIES[2]

2.1 Introduction

The increased reliance of the business sector on academic research and development as well as legislative changes adopted in 1980 in the US and later in most countries in Europe, enabled the expansion of universities' traditional mission of teaching and research towards the "third academic mission" - transferring university knowledge and technologies to industry use (Kruecken 2003).

On the positive side, interactions between academia and industry can facilitate an increase of basic research funding sources and help remove the borderline between basic and applied research, thus leading to faster development of innovations (Czarnitzki et al. 2009). On the negative side, engagement of researchers in business activities could potentially undermine their commitment to the traditional norms of open science, characterized by free sharing of research resources, and result in commercially-biased, lower quality research, increased secrecy about research findings and purposefully delaying publications to protect commercial interests (Dasgupta and David 1994, Geuna and Nesta 2006, Baldini 2008). Considering the crucial importance of knowledge sharing for scientific progress and future innovation, the described conflict between commercialization and open science in academic settings requires further research attention.

Past literature on academic-industry knowledge transfer-knowledge sharing relationship mostly discusses in what way commercial activities at academic institutions have changed the adherence of research community to the norms of open science, traditionally considered to be the most important norms of the scientists' profession (Merton 1973). Merton and others (Dasgupta and David 1994) argued for the strict demarcation between the knowledge sharing behavior of academic researchers and industrial researchers, the latter being guided primarily by the necessity to protect the commercial value of information. However, more recent studies pointed to the dual use of scientific information (scientific dissemination and commercial exploitation) in the current science systems (Shibayama 2012), and consequently, to the need for recognizing the trade-off between the incentives for these two modes of application (Stokes 1997, Murray 2002, Murray and Stern 2007, Mukherjee and Stern 2009, Murray 2010).

This study is motivated by the fact that most studies published in the field do not distinguish between different forms of academic-industry knowledge transfer when assessing their impact on academic knowledge sharing. A large stream of studies has focused only on the impact of patenting on knowledge sharing among researchers (Larsen 2011). Patenting is viewed as the most important source of financing in the life sciences' research, and is vital due to long time to the market and associated risks (Kneller 2001). Yet, patent protection and exclusive licensing of upstream, basic discoveries can endanger free knowledge flows among academic researchers (Heller and Eisenberg 1998, Rai and Eisenberg 2003). For example, relying on the analysis of citation rates of scientific publications before and after the grant of associated patents, Murray and Stern (2007) find modest evidence of the restrictive impact of patents on knowledge diffusion. Davis and colleagues (2011) and Caulfield and colleagues (2008) confirm the skepticism of Danish and Canadian life scientists regarding the impact of university patenting on academic research and the norms of open science. In

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[2] This chapter of the dissertation was presented as a working paper at the 2nd and 3rd Conference of the Central and South-East European PhD Network in 2010 and 2011 in Ljubljana, EBR 2011 conference in Ljubljana, IAMOT 2011 conference in Miami Beach, ICSB 2011 conference in Stockholm and DRUID 2015 conference in Rome.
The paper will be submitted to an international peer-reviewed journal.
The paper was written in co-autorship with Prof. Dr. Mateja Drnovšek.

other studies, evidence of negative effects of patenting on university research is found only in specific scientific areas, such as genetic diagnostics (Walsh et al. 2003) or for certain types of research resources, such as cell lines or reagents (Walsh et al. 2007). Existing research therefore points to distrustful attitudes of researchers toward extensive patenting in life sciences, but at the same time generally modest evidence of actual interference of patents with academic research.

The second stream of studies has considered other forms of university-industry interactions in addition to patenting when assessing their relationship with academic knowledge sharing, however, mostly by aggregating different knowledge transfer and knowledge sharing forms into a single indicator (Haeussler 2014). In these studies, connections with industry and commercialization of university-based research, measured by the level of industry research funding, patenting, licensing, spinning-off and/or new product development, are shown to be overall significantly associated with increased likelihood of data withholding (Campbell et al. 2002, Blumenthal et al. 2006).

The existing body of knowledge thus tells us little about specific implications of particular types of academic-industry knowledge transfer for knowledge sharing in academic science. Academic researchers can collaborate with industry informally, through occasional consulting or presentations, or formally, through sponsored research projects or exchange of research personnel. Researchers can be engaged in the activities related to intellectual property protection and exploitation, such as patenting or licensing. They can also become actively engaged in business activities, through founding and managing spin-off companies or selling their goods and services on the market. All these activities are specific in nature and can thus produce very different effects for the academic knowledge sharing. As recently argued by Abreu and Grinevich (2013), the current focus of the academic entrepreneurship literature, which is mostly on patent-based activities such as spin-offs and licensing, should be widened to informal commercial and non-commercial activities that are entrepreneurial in nature to fully capture the characteristics of academic-industry interactions.

Furthermore, most studies in the field do not pay specific attention to different types of academic knowledge sharing. Researchers can share knowledge in many different ways: from exchange of team members, materials, data and information, to joint participation in projects, publishing or public presentations. In the majority of previous studies, the authors investigate how university-industry interactions are related only with informal, direct exchange of materials and information among researchers (Vogeli et al. 2006, Walsh et al. 2007) and/or with publishing delays. For example, Blumenthal and colleagues (1997) and Shibayama and colleagues (2012) find that not all entrepreneurial activities discourage cooperative relationships between academic researchers: while commercial activity facilitates secretive or delayed publications and non-compliant behaviors in material and data transfer, no significant effects or weaker effects are shown for collaboration with industry and funding from industry. These results are of relevance for further research as they indicate that the universal view on academic-industry knowledge transfer and partial view on academic knowledge sharing ignores the specificities of their interaction and potentially hinders the generation of accurate conclusions regarding the actual impact of commercial activities in academia on the norms of open science.

The first aim of our study is to explore how different types of academic-industry knowledge transfer activities affect different forms of knowledge sharing restrictions between the members of the life science academic communities. We focus on sharing restrictions to account for a variety of situations that can occur in the process of exchange of knowledge between academic researchers. They can, for example, intentionally and explicitly refuse to share knowledge directly with other researchers or publicly, ignore or forget other researcher's request, only partially comply with it or delay a response or a publication. There are also other approaches in the literature on knowledge sharing predictors: whereas some authors focus on the likelihood for knowledge sharing (Chiu et al. 2006, Amayah 2013), knowledge sharing intentions (Bock et al. 2005, Fullwood et al. 2013) or collaboration

(Gulbrandsen and Smeby 2005), others concentrate on the action or process of exchange of knowledge (Bouty 2000). Some studies measure the lack of knowledge sharing or knowledge withholding (Blumenthal et al. 2006). Finally, recent studies in the management area (Connelly et al. 2012, Cerne et al. 2014) put forward knowledge hiding as a distinct construct from knowledge sharing or knowledge hoarding (accumulation), by arguing that it comprises purposeful concealing or withholding upon request. In our study, we refrain from the narrow definition and instead use the term knowledge sharing restrictions.

Furthermore, we argue that it is essential to consider the institutional regime (norms, policies, regulations) in which the researchers operate when assessing their knowledge sharing decisions (Blume 1974). Overall, there have been a limited number of studies empirically investigating relationship between academic-industry interactions and knowledge sharing restrictions in more than one geographical setting. Only recently (Haeussler 2011, Haeussler 2014) compare information sharing in the UK and Germany academic settings and find that British academic researchers are more likely to share than their German counterparts. Walsh and Huang (2014) compare how commercialization of academic science (industry funding and patenting) affects publication secrecy of research results (partial publication and publication delay) in the USA and Japan and find the negative relationship between patenting and openness in both countries, but with lower impact on academic secrecy in Japan. The second aim of our study is thus to explore to what extent the institutional context influences academic-industry knowledge transfer-academic knowledge sharing interactions in the life science communities. This question is of particular importance for understanding the implications of our study for science policy. In developing our research propositions we rely on the multiple case-studies design and include respondents from six different cultural settings.

The analysis of our research findings enables us to develop a conceptual model of the effects of involvement of researchers in different forms of knowledge transfer with the industry on particular forms of knowledge sharing restrictions among researchers. We argue that we need to consider a diversity of knowledge transfer activities when drawing general conclusions regarding the real scope of impact of academic-industry knowledge transfer on academic knowledge sharing.

2.2 Data and methodology

2.2.1 Research methodology

We used the grounded theory building approach by Glaser and Strauss (1967) as well as the multiple case-studies research design (Yin 2014). This approach enabled us to explore the patterns of relationships among constructs within and across multiple individual cases relying on the replication of emerging findings, and subsequently develop the research propositions and associated theoretical model (Eisenhardt and Graebner 2007).

We collected the data on 38 cases using primarily in-depth semi-structured interviews. According to Neergaard (2005), the advantage of the semi-structured approach is that it allows the interviewer to pursue unexpected paths introduced by the interviewee and encourage discussion by probing. At the same time, the structure allows the comparison of themes across interviews.

The three thematic sections of the interview guide were based on the literature review. Open-ended questions of the interview were complemented by a questionnaire comprising 22 open-ended and multiple-choice questions, aimed to collect information about socio-demographic background and professional experiences of respondents. These included the quantitative information on the extent of involvement in different forms of knowledge transfer, type of research conducted, amount and sources of funding, research productivity and impact, intensity of collaboration with other colleagues and intensity of scientific competition in their work.

The validity of the study was ensured through triangulation (Yin 2014). Wherever possible, the data collected directly from respondents were complemented by written documents, including information from their institutional websites and Web of Science.

2.2.2 Sample selection

The sample selection method applied was reference-based, using key informants (Patton 1990) who had the specialized knowledge that we required or who were able to identify respondents within their organization or life science association with the required knowledge (Tremblay 1957). We combined this method with the snowball or chain sampling. Random sampling was not considered as an appropriate method having in mind that the aim of the study was not to generalize from a sample to population, but to obtain extensive information about the research problem (Neergaard and Ulhøi 2006) and understand the respondents' perceptions related to academic-industry knowledge transfer-knowledge sharing interactions. As suggested by Patton (1990), relevance rather than representativeness should be the criterion for case selection in such studies. The profiles of interviewed respondents are shown in Table 5.

We conducted interviews with three groups of respondents: academic researchers (29), industry researchers / entrepreneurs / managers (6) and technology transfer specialists (3). The reason for interviewing industry researchers and technology transfer intermediaries was to resolve bias challenge (Eisenhardt and Graebner 2007) since they could provide alternative insights into the research problem to those offered by academic researchers. The academic researchers respondent group reported affiliations to pre-clinical (17) and clinical (5) university departments, public research institutes (6) and government laboratories (1).

Having in mind the exploratory nature of this study and global nature of life science knowledge transfer (Zucker and Darby 2007), the respondents were selected from six countries: Croatia (9), Slovenia (7), Germany (7), the USA (6), Italy (5) and Israel (4), to account for cultural variability and comparability (Rowley 2002, Ireland and Hine 2007). Most of the respondents had between 11-20 and 21-30 years of professional experience, and most frequently reported full and associate professorship as their current academic ranks. The respondents came from various life science fields and the majority declared their interest in more than one field, in most cases molecular biology, biotechnology, immunology and genetics. Table 6 summarizes information on respondents and provides descriptive statistics.

Table 5. Profiles of interviewed respondents

Case number	Country	Gender	Years of professional experience	Primary affiliation	Professional position	Respondent status
1	Croatia	M	31-40	Higher education institution – pre-clinical department	Full professor	Key informant (national science foundation board and academy of sciences member, European Research Council (ERC) grantee)
2	Croatia	M	21-30	Higher education institution – pre-clinical department	Full professor	Suggested by key informant
3	Croatia	M	31-40	Higher education institution – pre-clinical department	Full professor	Key informant (president of a European scientific association)
4	Croatia	M	11-20	Public research institute	Research associate	Suggested by key informant
5	Croatia	M	11-20	Higher education institution – pre-clinical department	Associate professor	Suggested by key informant
6	Croatia	F	31-40	Biotechnology company	Head of R&D, Full professor	Key informant (manager of one of the first biotechnology firms)
7	Croatia	F	31-40	Higher education institution – clinical department	Full professor	Suggested by key informant
8	Croatia	M	11-20	Biotechnology company	Product expert	Suggested by key informant
9	Croatia	M	11-20	Higher education institution – pre-clinical department	Postdoctoral fellow	Suggested by key informant
10	Slovenia	F	21-30	Higher education institution – pre-clinical department	Full professor	Key informant (prominent scientist-inventor)
11	Slovenia	M	21-30	Biotechnology company	Founder, top manager, Assistant professor	Key informant (manager of one of the first biotechnology firms)
12	Slovenia	M	11-20	Public research institute	Associate professor	Suggested by key informant
13	Slovenia	F	21-30	Public health institute	Full professor	Suggested by key informant
14	Slovenia	M	21-30	Public research institute	Full professor	Key informant (head of a national institute department)
15	Slovenia	M	11-20	Private research institute	Top manager, technology transfer specialist	Key informant (manager of a national centre of excellence)
16	Slovenia	F	21-30	Higher education institution – pre-clinical department	Full professor	Suggested by key informant
17	Germany	M	11-20	Higher education institution – pre-clinical department	Full professor	Suggested by key informant
18	Germany	F	> 40	Higher education institution – pre-clinical department	Full professor	Suggested by key informant
19	Germany	M	31-40	Government laboratory	Deputy Head of the Institute	Suggested by key informant

(table continues)

(continued)

Case number	Country	Gender	Years of professional experience	Primary affiliation	Professional position	Respondent status
20	Germany	M	11-20	Public research institute	Associate professor	Key informant (ERC grantee)
21	Germany	M	11-20	Biotechnology company	Middle manager	Suggested by key informant
22	Germany	M	21-30	Higher education institution – pre-clinical department	Full professor	Suggested by key informant
23	Germany	F	21-30	Private technology transfer company	Senior technology manager, department head, technology transfer specialist	Suggested by key informant
24	USA	F	11-20	Higher education institution – clinical department	Assistant professor	Suggested by key informant
25	USA	M	11-20	Higher education institution – pre-clinical department	Postdoctoral fellow	Suggested by key informant
26	USA	M	31-40	Higher education institution – clinical department	Full professor	Key informant (member of the academy of sciences)
27	USA	M	21-30	Biotechnology company	Founder, top manager, Adjunct professor	Key informant (prominent scientist-entrepreneur)
28	USA	M	6-10	Higher education institution – clinical department	Assistant professor	Suggested by key informant
29	USA	M	> 40	Higher education institution – pre-clinical department	Full professor	Key informant (researcher from a prominent clinic)
30	Italy	M	21-30	Higher education institution – pre-clinical department	Associate professor	Key informant (one of the most highly cited scientists in country)
31	Italy	F	11-20	Higher education institution – pre-clinical department	Assistant professor	Key informant (one of the 100 top national scientists, ERC grantee)
32	Italy	M	11-20	Consultancy company	Top manager, technology transfer specialist	Key informant (technology transfer specialist)
33	Italy	F	21-30	Higher education institution – pre-clinical department	Associate professor	Suggested by key informant
34	Italy	M	21-30	Biotechnology company	Top manager	Suggested by key informant
35	Israel	M	11-20	Higher education institution – pre-clinical department	Full professor	Key informant (one of the 100 top national scientists, ERC grantee)
36	Israel	M	21-30	Higher education institution – pre-clinical department	Associate professor	Suggested by key informant
37	Israel	F	21-30	Higher education institution – clinical department	Associate professor	Suggested by key informant
38	Israel	F	31-40	Public research institute	Associate professor	Key informant (president of a national scientific society)

Table 6. Descriptive statistics – interviewees

Type of research conducted (% of weekly time for research) (N=35)	**Average %**	**Min**	**Max**	**Median**
Pure basic research	39.88%	0	100	40
Basic research with potential real utility	37.26%	0	100	30
Pure applied research	22.86%	0	100	5
Research funding sources (% of current funding) (N=36)	**Average %**	**Min**	**Max**	**Median**
Government or state budget	33.86	0	100	25
National and international project granting programs, agencies and foundations	43.83	0	100	47.5
Industry	6.47	0	100	0
Own revenues (sales, royalties, etc.)	9.17	0	95	0
Other (private donors, service contracts, small grants from societies, VAT refund)	6.67	0	75	0
Research funding last fiscal year - EUR (N=30)	386,310	0	3,000,000	175,000
Research productivity - papers published or accepted in international peer-review journals in the past 3 years (N=38)	12.61	0	35	9
Research impact - total number of citations of articles published in international peer-reviewed journals in career (N=38)	1,906.89	0	11,229	776.5
Number of collaborators of academic researchers in industry (N=28)	1.57	0	7	0.5
Number of collaborators of academic researchers in academia (N=28)	8.68	1	30	7
Number of research team members of academic researchers (N=28)	10.46	1	35	9.5
Number of persons which academic researchers directly supervise (N=28)	19.29	0	250	9
% of research papers published in the last 3 years in co-authorship with partner laboratories from academia (N=28)	62.64	0	100	60
Number of collaborative research grants with academic groups in the past 3 years (N=28)	4.68	0	20	4
Number of laboratory team members trained in partners' academic labs or vice versa in the last 3 years (N=27)	3.96	0	24	2
Number of conferences at which academic researchers presented their research results during the past three years (N=28)	11.70	2	31	9
Number of research groups that are direct competitors to academic researchers' research team (N=22)	7.33	0	31	5

When asked about their academic-industry knowledge transfer experience, most of the academic respondents reported industry-sponsored research, invention disclosures, university-industry joint research grants and consulting of the industry, whereas founding of spin-off companies and products under regulatory review were rather rare. On average, the academic respondents were engaged in less than eight academic-industry knowledge transfer activities in the past three years. With industry respondents, the average number of academic-industry knowledge transfer activities in the past three years was 16, and with technology transfer specialists 74 (see Appendix H for a more detailed overview).

2.2.3 Data collection and analysis

54 potential respondents were initially contacted and 38 participated in the study (70.37% response rate). We ended the process of respondent identification and data collection when interviews did

no longer provide any new insight (Glaser and Strauss 1967). All interviewees had been contacted by e-mail and informed about the aims of the study and background of its authors prior to the interview beginning. As suggested by Yin (2014), all interviewees signed the Consent form, which provided information about the interview structure and confidentiality provisions. The total length of all conducted interviews was 31 hours and the average interview duration was 49 minutes.

Table 7. Overview of quotes and codes per code family, with frequency counts

Code family (main analytical category)	**N codes**	**N quotes**
A. General knowledge transfer experience and attitudes:		
Academic-industry knowledge transfer involvement motivations	30	85
Academic-industry knowledge transfer attitude	65	111
Academic-industry knowledge transfer experiences	40	110
Academic-industry knowledge transfer involvement extent self-evaluation	9	21
Academic-industry knowledge transfer scientific areas	52	64
Perceived benefits of involvement in academic-industry knowledge transfer	23	47
Perceived challenges of involvement in academic-industry knowledge transfer	70	123
Importance of intellectual property protection in commercialization of academic research	22	55
Academic-industry knowledge transfer recommendations	11	17
Role of the institutional environment (institutional / government policies and regulations)	154	250
B. Specific knowledge transfer-sharing experience and attitudes:		
Knowledge sharing experiences (sub-categories):		
Knowledge sharing prerequisites	4	12
Formal general and specific knowledge sharing types	6	12
Informal specific knowledge sharing types	27	55
Frequency of informal knowledge sharing	6	24
Knowledge sharing restrictions experiences	27	80
Knowledge sharing restrictions reasons	59	122
Knowledge sharing restrictions consequences	2	7
Impact of competition on knowledge sharing - conferences	7	24
Impact of academic-industry knowledge transfer on knowledge sharing (emerging sub-categories):		
Impact of knowledge transfer on knowledge sharing in general, including specific exchange – experience	22	46
Impact of knowledge transfer on knowledge sharing – attitude	8	8
Impact of knowledge transfer on general knowledge sharing – presentations at conferences	10	22
Impact of knowledge transfer on formal knowledge sharing – collaborative projects	7	20
Impact of knowledge transfer on formal knowledge sharing – MTAs	11	28
Impact of knowledge transfer on formal knowledge sharing – personnel exchange	6	16
Impact of knowledge transfer on formal knowledge sharing – publishing – PhD students	9	14
Impact of knowledge transfer on formal knowledge sharing – publishing timing	10	41
Impact of knowledge transfer on formal knowledge sharing – publishing contents	6	10
C. Other emerging categories		
Scientific values (norms)	25	66
TOTAL ALL	**728**	**1490**

In order to avoid or reduce bias in responses and encourage open discussion with the interviewer on a sensitive topic, we first asked the respondents several general questions related to their experiences and attitudes toward academic-industry knowledge transfer activities (results not presented in this paper). After that, we posed more specific questions about knowledge transfer-knowledge sharing interactions and knowledge sharing restrictions.

We voice recorded all interviews and transcribed them post hoc using a verbatim transcription method. We analyzed the transcribed data following the three steps described by Miles and Huberman (1994): data reduction, data display, and conclusion drawing/verification. First, we identified the main analytical categories on the basis of the main research questions and interview questions, followed by coding, using pre-developed coding scheme, and categorization. Then we identified more specific emerging themes within categories and categorized quotes into appropriate themes. Atlas.ti software (version 6.2) facilitated data organization and coding for content analysis as well as data comparison and interpretation across the three categories of respondents and six different settings. The results of analysis are summarized in Table 7.

2.3 Findings

2.3.1 Characteristics of knowledge sharing in life science communities

We first asked the respondents about knowledge sharing experiences in general. The collaboration that is not based on contracts or other formal "hurdles" and that is based on friendship and trust was considered by the interviewees as having the highest quality. In frame of such informal collaboration, our respondents exchange practically everything: information, results, protocols, people and materials (reagents, cells, samples). Most respondents are engaged in daily or regular informal knowledge sharing, and in only few of them experienced lack of sharing.

Collaboration projects are often motivated by friendship relations that began during scientific conferences. However, even in the case of friendly context of exchange of information or materials, "paperwork-free" cooperation is not always possible. In fact, material transfer agreements (MTAs) have become common in all types of research institutions and usually require that the materials that are subject to transfer are not used for commercial purposes. Other forms of reported formal knowledge sharing include collaborative grants and exchange of personnel.

We also asked our respondents how they experienced sharing restrictions. The most frequent statement was that when results are published, researchers are obliged to provide the interested parties with nuanced information on protocols and/or reagents used. However, this fear was rarely the case in reality, both with published and unpublished research results. The great majority of our respondents experienced non-compliance with their direct requests for materials or information, ranging from frequent to occasional. The consequences for the inquiring researchers include refocusing research in another area or losing time to produce the needed materials on their own. When asked about their personal attitudes and behavior in sharing, most respondents claimed that they had never rejected any request. However, several respondents restricted their sharing only to the closest group of long-term collaborators.

Although academic-industry knowledge transfer activities have been emphasized as the strongest reason for knowledge sharing restrictions, several other factors were also mentioned. Other reasons for sharing restrictions included the following categories: a) human and social capital-related, and b) context-related (detailed overview shown in Appendix I).

2.3.2 Academic-industry knowledge transfer as a determinant of sharing restrictions

Several challenges associated with knowledge sharing were emphasized (see Table 8). Responses from industry respondents are excluded from this part of our analysis since their sharing is related to motives different than those among public sector researchers (Haeussler 2011, Haeussler 2014). Below we report the most important findings for each of the identified forms of knowledge sharing.

Table 8. Impact of academic-industry knowledge transfer (KT) on academic knowledge sharing

Impact (summary of codes)	All	Cro	Slo	Ger	USA	Ita	Isr
Impact of KT on knowledge sharing in general and specific sharing							
KT is less relevant than competition	**2**	1		1			
Difficult to estimate to what extent KT is the reason for sharing restrictions	**1**				1		
Trying to formalize all informal collaborations due to potentially patent issues in the future	**1**					1	
KT can restrict knowledge sharing	**11**	1	4	2	2	1	1
KT can have a worse impact on sharing restrictions than competition due to commercial interests	**1**				1		
Extent of impact depends on KT type	**1**	1					
Industry-sponsored research did not require any restrictions	**1**		1				
It is logical that KT can restrict knowledge sharing as industry wants exclusive rights to product to get returns	**3**	1		1		1	
Did not accept industry sponsored research contract due to too many restrictions with disclosures and substantial publishing delays	**1**			1			
Industry-sponsored research prevents sharing due to industry ownership of results	**2**					1	1
Industry-sponsored research completely restricted information disclosing	**3**	1			1		1
Restrictions based on project type - if basic and commercial project separated, no problems	**1**			1			
No negative impact of patenting	**1**			1			
Patent protection can limit sharing	**4**	2	1		1		
Provide licensed reagents for free for research purposes	**1**		1				
Negative impact possible if KT is privatized (as in spin-offs)	**3**	2	1				
With spin-off exclusively licensed to, reagents are still available, but just charged	**2**			1			1
No experience	**6**		2	2	2		
TOTAL	**45**	**9**	**10**	**10**	**8**	**4**	**4**
Impact of KT on general knowledge sharing at conferences							
Commercially interesting results could never be publicly disclosed	**1**	1					
Never present research done in collaboration with industry	**1**	1					
Every presentation must be approved by institution	**1**				1		
Patent application hinders conference presentation	**3**	1	1	1			
Problem with presenting restrictions	**2**	2					
People taking photos of posters at conferences requires caution regarding contents	**3**		1		1		1
Presenting only published data decreases the relevance of conferences	**6**	1		3	1	1	
No experience with presenting commercially exploitable results	**1**	1					
TOTAL	**18**	**7**	**2**	**4**	**3**	**1**	**1**
Impact of KT on formal knowledge sharing – joint projects							
In collaborative projects IP issues were defined, no practical problems	**5**	1	1	1		1	1
IP agreement with multiple partners in a project is very much complicated and lengthy, and handled by lawyers	**4**		1	1			2
Restrictions related to background IP defined already in the beginning of the projects	**1**			1			
Lawyers, not scientists in academia and industry, delayed and ultimately prevented agreement execution	**1**				1		
Joint patenting with another laboratory caused many difficulties with lawyers' negotiations	**1**						1
No experience	**5**	2	1	1			1
TOTAL	**17**	**3**	**3**	**4**	**1**	**1**	**5**
Impact of KT on formal knowledge sharing – material transfer agreements (MTAs)							
MTAs not restrictive as long as the mutual rights and obligations incl. publishing are well defined	**6**	1		1	3	1	
MTAs good for preventing further distribution and unintended use of materials	**3**		2	1			

(table continues)

(continued)	**All**	**Cro**	**Slo**	**Ger**	**USA**	**Ita**	**Isr**
MTAs are required when a lot of money was spent on some discovery and it is complicated to make	**1**				1		
MTAs long due to avoidance of responsibility and law suits	**1**			1			
MTAs more complex when sharing with industry than with academia	**1**				1		
MTAs did not slow down sharing	**5**	2	1		1	1	
MTAs can slow down the flow of materials	**8**	3	1	1	1		2
MTAs limit sharing quantity	**2**	2					
MTAs prevent free research	**2**	1					1
Never follow institutional MTA regulations - they are nonsense	**1**			1			
TOTAL	**30**	**9**	**4**	**5**	**7**	**2**	**3**
Impact of KT on formal knowledge sharing – personnel exchange							
Depends on area of work	**1**	1					
Less negative impact if basic science (animal models)	**1**	1					
No sharing restrictions	**3**	2					1
No experience with such situations	**6**		2		3		1
TOTAL	**11**	**4**	**2**	**0**	**3**	**0**	**2**
Impact of KT on formal knowledge sharing – publishing – PhD students							
With industry-sponsored research in lab PhD or diploma students needed prior consent from the business partner for publishing the thesis results	**5**	2	2		1		
Industry-sponsored research should not be used to support student theses because of the conflict of academic and industry interests	**1**				1		
With industry-sponsored research in lab PhD committee members needed to sign non-disclosure agreement due to industry demand	**1**				1		
Industry demands for secrecy resulted in dropping of KT aspect of the project from the student thesis	**1**				1		
Decision not to go for patent application due to necessity of thesis publication	**1**		1				
Students' interest for thesis publication should be in front of commercial interest by academic structures	**4**		1	1	2		
In spin-offs students had to sign confidentiality agreements and published only limited amount of data	**1**	1					
Academic institution with industry orientation stopped hiring PhD students due to publishing restriction	**1**			1			
TOTAL	**15**	**3**	**4**	**2**	**6**	**0**	**0**
Impact of KT on formal knowledge sharing – publishing - timing							
Problem with publication delay in case of work in the business sector	**6**	1		2	1	1	1
Some authors lost priority in publication due to patenting	**1**		1				
Lost priority in publishing because of delays	**1**			1			
Problem with publication delays related to patenting	**6**	1	1		1		3
Harmful if KT project only or main project of the research group	**2**		1	1			
Delays due to patenting were not substantial	**7**	1	2	2	2		
To give priority to KT instead of publishing priority is a matter of informed, conscious decision of researcher and calculated risk	**2**	1	1				
Agreement with industry on a certain delay of limited duration in publishing is logical	**2**		1				1
No negative impact as patenting and publishing can be done in parallel	**8**	3	1	1	1	1	1
No experience with KT in academia, no experience with publication delays	**2**	2					
TOTAL	**37**	**9**	**8**	**7**	**5**	**2**	**6**
Impact of KT on formal knowledge sharing – publishing - contents							
Any paper related to industry work requires prior approvals from industry	**4**	1	1	1	1		
Industry publishes only the things they are no longer interested in	**1**				1		
Publications can be written in a way to circumvent industry-related results	**2**	1	1				
TOTAL	**7**	**2**	**2**	**1**	**2**	**0**	**0**
TOTAL ALL	**180**	**46**	**35**	**33**	**35**	**10**	**21**

Direct exchange of research data, information and materials (specific knowledge sharing)
As elaborated above, direct exchange of information and materials is the form of knowledge sharing most frequently reported by our respondents. When acting as knowledge requesting parties, our respondents could sometimes not be certain about the reason for non-compliance, as their requests were often ignored. But, when acting as providing parties, they reported their experience with knowledge transfer as a reason for the inability to comply with requests:

> *"Sometimes when we commercialize, we cannot give it because we commercialized it to a company, so even with an MTA, we cannot give it. But, the details depend on the company we work with. Sometimes the easiest solution is not to send it..."*

Most of our respondents considered it logical that the industry required having the exclusive rights to using the product if it had invested some funds to create new knowledge, which then restricted the access to knowledge. However, the general view is that such data must ultimately end up in a public domain, as a general knowledge.

General knowledge sharing – presentations at conferences
Concerning the dissemination of findings at scientific conferences, attitudes of interviewees differed considerably. While some respondents simply did not attend conferences if they were not allowed to disclose information or did not present the results of the research done in collaboration with the industry, others had difficulty with accepting the new obligation of meeting with the patent attorneys before making the presentations for the scientific meetings due to the "pressure on core academic mission". Another interesting point was that "scientists more and more often keep their cards close to their chest", which reflects the perception that scientists do not want to talk about unpublished data at the scientific meetings anymore. This lack of openness about unpublished work resulted in the regular dissemination of data with which other researchers had already previously become familiar – through publications.

Formal knowledge sharing – joint projects
A significant number of respondents mentioned the experience in which academic-industry knowledge transfer affected the implementation of their collaborative projects with the academic colleagues. Their major concern was related to lengthy negotiations on IP-related issues between the legal representatives of institutions; this is well explained in several quotes:

> *"The funny thing is that the scientists had no problems with the idea of discussing it but the lawyers on both sides could never come to an agreement. That particular part of the project never went anywhere and to this day I do not know what they found…It is really a shame" (US respondent).*

Such experience occurred regardless of cultural context.

> *"Their lawyers have one idea, our lawyers have another idea - they have time; normally in the courtyards these things are running for years and years. But, we do not have it; we have to finish the project soon" (Slovenian respondent).*

> *"We are currently setting up the agreement proposal in an EU project that has just started and it has 14 partners, all of which have to sign such an agreement…it is an agreement of many, many pages and our lawyers are working on it and they are saying it is really terrible. I decided I would never read this agreement." (German respondent)*

Formal sharing of research materials – use of material transfer agreements (MTAs)
Our interviewees usually viewed MTAs in a positive light, since they understood that intellectual property rights related to research materials needed to be protected whether these were patented or not. Here we present several supporting statements from German, US and Italian scientists:

> *"I realized that if you sign an MTA, you need to describe what you are going to do with the material and this way you limit yourself in a way…so it is not so bad, because if you give something to someone, you can be certain that this person will not use it in the same type of experiments as you do..."*

> *"I have never asked folks that I have given stuff to, to sign MTAs, although I would under certain conditions, but almost everything that I received, I had to sign an MTA before. I am fine with that; I think it is a matter of trust. I think the field is getting a lot more competitive, there is a lot of backstabbing and you cannot trust people anymore…you have to have MTAs then."*

> *"If you spend extremely high amounts of money to generate something, and some things are very complicated to make, for example transgenic mice, you cannot just send them to other labs and let them do what they wish with them…this is why MTAs exist and they regulate the use of materials."*

> *"I collaborate on a daily basis with other labs….if it is something really important, we always ask for signing a material transfer agreement…this is a routine…Because, it eventually may become a patent issue…so, we try increasingly, more and more to do that."*

Yet, the respondents also reported that accessing mice, cell lines and other inputs for further research was sometimes problematic despite the fact that non-profit institutions should be able to freely obtain these for their research. As one of our respondents, a German technology transfer specialist, noted:

> *"MTAs can be a problem and are still a problem. We are now in the 11th year of trying to use them…researchers use them more and more because they are forced to use them, but they do not like them, because it is paperwork and they have a feeling that everything lasts so long until they can get the material…therefore, I think this is still seen as a restrictive and time-consuming."*

Knowledge sharing through personnel exchange
Unlike our industry respondents, only a few academic respondents reported problems with sharing restrictions with personnel exchanged with other researchers' laboratories during the involvement of the laboratory in academic-industry knowledge transfer activities. In most cases, these respondents hosted only the young researchers affiliated to the groups of their close collaborators:

> "*We have been doing this only with the groups that we can really trust on a personal basis.*"

Knowledge sharing related to publishing of PhD students
Contractual relationships with the business sector strictly prohibited information disclosing for the purpose of protection of company interests, and this was reflected in conflicting situations for the doctoral students, who had been obliged and under pressure to publicly report the results of their theses' experiments. Sometimes this problem was solved by simply obtaining prior consent from the company, but in other cases the "overemphasized confidentiality" was perceived as unnecessary and disruptive.

"Companies wanted to have control over who has access to that information, so this extended to the thesis committee, faculty members on the thesis committee and the student. Two things had to happen: either the faculty has to sign non-disclosure agreements that they would keep this confidential or two, it couldn't be revealed to the faculty members, in which case the student doesn't have any work to discuss. My own feeling was that we shouldn't allow these things to happen because we are giving away academic rights to some lawyer at some company who can exercise power of what is in and what not in the thesis…to me, this does not sound right. That should be completely within the purview of the university, with its academic structure and its way of evaluating student's progress and thesis work and not a right that we should give away to a company. So, this debate went on for a while at our university because there are two conflicts: you want to have the money, but you want to know what the restrictions could be. In the end we agreed to agree on that this type of grant should not be used to support the thesis work" (US respondent).

"So, in the end, it is a problem because we had to drop that aspect of the project from my student's thesis because the commercial interest overrides the academic interest, that is, free and open interchange" (US respondent).

"There were even some PhD students in this company….and this was a real problem, because they had to make presentations for their theses but that was evaluated as confidential and then they showed only sequences, like xxxx, always everything confidential…they managed to publish, but only stuff that was out of the subject and studies….kind of playing around" (Croatian respondent).

"In Slovenia we have a grant scheme called industrial PhD. People are employed by the industry, do a PhD at a university, very applied science. There are delays with respect to publishing…I had one patent ready and I decided not to even go to the patent office because the girl had to graduate" (Slovenian respondent).

"I still have today PhD students that are paid by industry, and I always look in that case for contracts which allow them to freely publish what they find" (German respondent).

Interestingly, some laboratories that decided to take a more applied research direction and started receiving a substantial amount of funding from industry decided not to employ doctoral students, but only technicians and post-doctoral researchers, who had been informed in advance that they would not be able to publish the research results without limitations.

Knowledge sharing to the general audience – publishing timing

When it comes to the impact of knowledge transfer activities on publication timing, the frequently reported experience was that publication delays due to protection of research results could be very risky and dangerous, particularly in the cases when the priority that is lost is related to work on a central project of the researcher.

"When I think of all the problems that we have had with this first patent application, with respect to publishing and presenting restrictions and delays…in the end, the success of all this is really dubious….you have to deal with the army of lawyers, who will easily question your patent. Then, from the patent that originally had 150 pages you can protect one function that is practically irrelevant…" (Croatian respondent)

"It happened also to me two times last year that there was a group publishing some things ahead of us. You cannot do anything afterwards, we are the second ones…you cannot protect

these results." (Slovenian respondent)

However, experience of some respondents indicated that the fear of losing priority in publication due to filing a patent application was irrational, since these two processes could practically be done in parallel and no substantial delays occur.

"When industry is involved, one or two months of delay are inevitable, depending on the agreement, and this is the time they need to review the publication, and decide whether it is in accordance with their company policy." (Slovenian respondent)

Knowledge sharing to the general audience – publication contents
Our respondents reported that it was possible to avoid publication problems in the case of work with the industry by circumventing industry-related results and that in most cases industry required the review of the manuscripts comprising commercially interesting results prior to submission.

"We were involved in some research with a company…every time we wanted to report our basic research findings, we had to send the abstract to the company and their lawyer had to give OK, before we could do something….but our research was not endangered in any way…for us, it worked…I know some people where such collaboration caused greater hurdles, but for us, it was OK." (German respondent)

In summary, the analysis of interview data points to the existence of knowledge sharing restrictions due to academic-industry knowledge transfer activities of life scientists, but with different levels of negative effects perceived by researchers. Of particular interest for our study is the observation by several of our respondents that the extent of impact of knowledge transfer on knowledge sharing depends on the knowledge transfer activity in question. For example, negative impact is seen as possible if knowledge transfer is privatized (as in spin-offs):

"While for example public-private partnership is built strictly within institutional framework, spin-off company can bring financial damage to the basic institution, despite the fact that it can bring royalties or similar. I personally dislike the idea that researchers who work on developmental projects found spin-off companies, since this draws their focus of interest away from basic research, which should be in the primary focus." (Croatian respondent)

Therefore, academic-industry knowledge transfer activities may or may not include active participation of academic researchers and their institutions in the commercialization process, or academic entrepreneurship. In the first case, different forms of university–industry collaboration have increased in magnitude primarily due to the heavy reliance of the biotechnology industry on the expertise and social capital of basic academic researchers (Murray 2004, Colyvas 2007, Jong 2008). These activities may include collaborative research projects, sponsored research, consulting, personnel exchange, joint supervision of PhD students or joint publishing (see Blumenthal et al. 1996, Davis and Lotz 2006, Gaughan and Corley 2010).

In the second case, the expansion of proprietary interests to a broader range of scientific findings in the life sciences and biotechnology as well as to new parties, academic and other non-profit institutions, created various new opportunities for active entrepreneurial scientific development (Colyvas 2007) with the help of activities such as patenting, licensing, spin-off companies founding and marketing of new products and services generated through the use of academic-based resources.

As discussed before, prior research offers ambiguous evidence on the nature and extent of relationship between particular types of knowledge transfer and knowledge sharing restrictions. Also, it is practically silent regarding the relationship of knowledge transfer and formal knowledge sharing between researchers, in the form of collaborative research projects, collaborative publishing or personnel exchange.

Based on the literature review and findings from our qualitative study, we propose:

> *Proposition 1*: The involvement in academic-industry knowledge transfer activities will be positively associated with the extent of general, specific, formal and informal knowledge sharing restrictions, but the strength of relationship will vary depending on the knowledge transfer type under consideration.

2.3.3 Role of the institutional context in knowledge transfer-knowledge sharing relationship

Considering that the majority of studies of academic-industry knowledge transfer build on empirical data obtained from US respondents (Baldini 2008), and that there are very limited studies with the focus on more than one country setting (Haeussler 2011, Haeussler 2014, Walsh and Huang 2014), in our discussions with the interviewees we paid particular attention to the role of institutional environment in which they operate.

In assessing the role of governments and institutional technology transfer policies, we primarily relied on the data obtained directly from our respondents, and only partially on data available from other sources (Escoffier et al. 2011, Geuna and Rossi 2011, 2013, Messer-Yaron 2014). Appendix J shows the full results of our content analysis. Codes that are associated to multiple statements from respondents from different settings are presented in blue color, to facilitate interpretation.

As expected, respondents located in the USA report most positive impact of their environment on encouraging knowledge transfer activities. Our respondents evaluate the US system as the most efficient globally: the government and academic institutions have developed various incentive systems to boost academic-industry knowledge transfer and academic entrepreneurship. 35 years after the adoption of the Bayh-Dole Act, it is the setting where the necessity of knowledge transfer activities is no longer an issue for discussion. Although some of our US respondents warn that not all technology transfer supporting institutions are providing adequate support to researchers, this is not the respondents' biggest concern. In contrast to other settings, what they find disturbing is the increasing pressure of universities to patent as much as possible, which leads to many redundant patents. As noted by one of the respondents:

> *"As the state and federal governments are decreasing funding for universities, there has been a major push for universities for trying to patent and license technologies that they developed among their own activities. This I think led to a lot of irrelevant activity; there was so much pressure to patent something and develop something at the academic level; which really was getting to the point that it was interfering with research. The problem is I think basically that they did not have an effective pipeline to really critically evaluate central technologies, either patentable or licensable…I am incredibly disappointed that there is not a vibrant discussion about this problem going on."*

The problem of commercially irrelevant patenting has already been studied in the USA (Jensen et al. 2003) and resulted in several policy recommendations for reconsideration of the existing technology transfer policies in the direction of alternative IPR regimes (Henderson et al. 1998, Kenney and Patton 2009, Dorsey ER 2010, Hoffenberg 2010). One of these, return to inventor ownership system, was suggested as motivating for academic researchers also by our respondents from Croatia, Slovenia and Italy. Most European countries have adopted their IPR legislations and technology transfer policies in line with the US example (Geuna and Nesta 2006, Crespi GA 2010, Geuna and Rossi 2011), however, there are exceptions: Italy for example still has the so called professor's privilege, which gives university employees the IPRs to their inventions. In addition, university ownership has usually been weakly enforced at European institutions, thus in reality leaving the decision on ownership to be negotiated (Crespi GA 2010).

The responses provided by our interviewees are in line with the previous findings. Despite policy changes, in Croatia and Slovenia as ex-socialist countries there is still weak awareness about the importance of intellectual property rights and their exploitation. Croatian respondents are the only group of interviewees that provided almost exclusively negative statements about the role of the environment in knowledge transfer activities. Not only that they criticized the lack of national funding programs that would encourage industry involvement; they also frequently expressed their opinion that academic institutions lacked the real system of incentives and mostly concentrated on bureaucracy, while success stories with academic-industry interactions mostly resulted from individual efforts, and not from the systematic approach.

The statements provided by Slovenian respondents were most similar to the Croatian situation, with the difference in the emphasized long tradition of collaboration between academic institutions and bio-pharmaceutical companies. In addition, like US and German respondents, they positively spoke about the existence of institutional incentives for involvement in knowledge transfer activities. One concern frequently reported by European respondents was the lack of private investment that would boost knowledge transfer in life sciences, in contrast to the US situation.

Considering the focus of this paper on knowledge transfer-knowledge sharing interactions, it was also of our interest to compare the views of respondents on the role of their operating environment in this regard. US respondents reported most concerns over the possible interference of the aggressive university technology transfer policies with the norms of open science in academic institutions. In addition, they discussed the problem of potential conflict of interest of academic researchers working on industry-related projects related to clinical trials, which has however been strictly regulated by US academic institutions.

Prior findings showing the direct relationship between the technology transfer policy of the researchers' organization and knowledge sharing restrictions are very scant. Technology transfer offices' (TTOs) direct interactions with their researchers' collaborative endeavors usually refer to the requests to maintain secrecy regarding the inventions and discoveries to ensure patent protection and prevent potential intellectual property from being compromised through premature disclosure in conferences (Jain et al. 2009). Despite the positive role of TTOs in the knowledge transfer process, there is evidence of delays and more difficulties with fulfilling material transfer requests as well as more restrictions in publishing when the TTO gets involved in the process (Walsh et al. 2007). Thus, our second proposition is as follows:

> *Proposition 2:* The more strictly the institutional policies regulate the behavior of academic researchers with respect to academic-industry knowledge transfer, the more they will be engaged in knowledge sharing restrictions for all forms of knowledge sharing.

2.3.4 Building the conceptual model of knowledge transfer-knowledge sharing interactions

The analysis of the results of the empirical study allows us to develop the theoretical framework for assessing knowledge transfer-knowledge sharing interactions, presented in Figure 4. This model captures the relationship between restrictions in particular types of knowledge sharing among academic researchers and particular forms of knowledge transfer activities.

The model also comprises personal and context-specific determinants of knowledge sharing restrictions in the academic communities and is controlled for certain demographic and professional traits of researchers. These other determinants in our model have been identified following the extensive literature review and analysis of the interview data (see Appendix I). Here we only briefly report the main findings with regard to some of these additional possible predictors of knowledge sharing restrictions as an in-depth analysis of the hypothesized relationships with knowledge sharing restrictions is out of the scope of this paper.

Personal determinants of knowledge sharing restrictions: human and social capital

Personality traits
Our respondents agreed that sharing restrictions more often happen due to objective reasons rather than due to envy or other specific personality traits, although the latter have also been frequently reported. The respondents specified the personal characteristics such as egocentrism, carelessness, laziness, paranoia and mistrust as barriers to different forms of knowledge sharing. Concerning the latter, the concepts of trust, mistrust and distrust have not been new to the literature on knowledge sharing: as observed by Blau (1964), trust occurs when past positive interactions lead to expectations about positive future interactions, which builds good exchange relationships and positively contributes to the levels of sharing (see also Bouty 2000).

Reciprocity
Reciprocity is reported as another important determinant of knowledge sharing. As indicated by one of our respondents: "*every sharing must be of mutual benefit, information provider must receive returns, either financial or co-authorship or additional research results*". This is in line with the results of the previous studies on direct exchange of data and materials in academic settings (Shibayama et al. 2012, Amayah 2013, Haeussler 2014). Interestingly, reciprocity is shown to be both a positive (Chiu et al. 2006) and a negative (Wasko and Faraj 2005) determinant of knowledge sharing in virtual communities. This is explained by the lack of shared history or personal contacts, as well as by the fact that the rewards for sharing, such as co-authorship or acknowledgement, are not relevant factors in such communities.

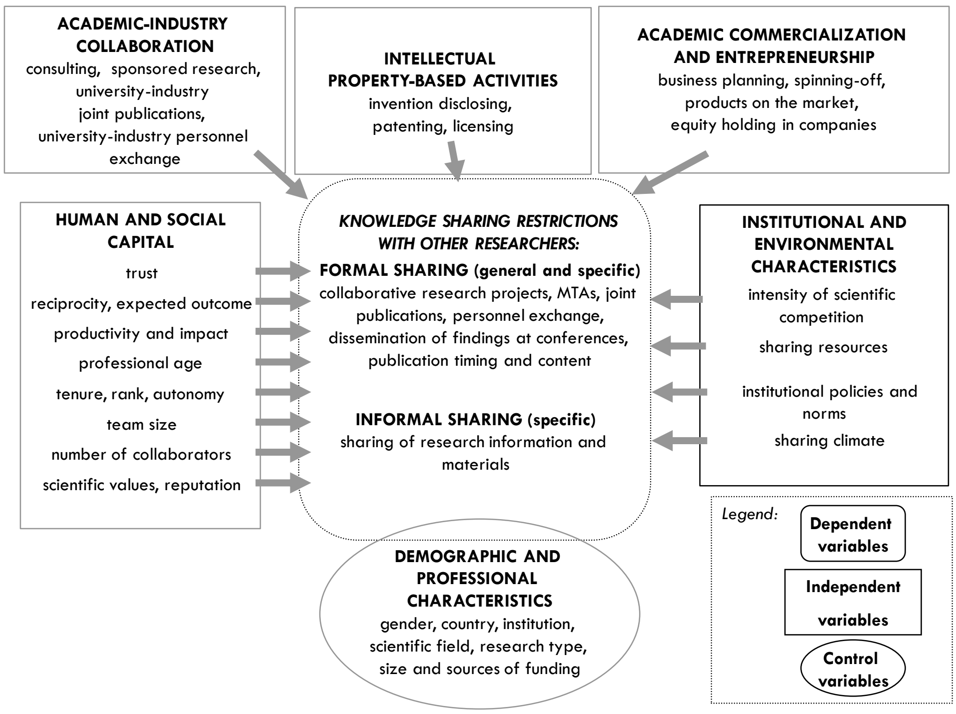
Scientific values
According to the traditional Mertonian view (1973), the outcomes of the scientists' profession such as publications, citations and peer status emerge from adherence to the open science system. In line with this, most of our respondents emphasized the importance of openness, priority in publishing as a basis for scientific promotion, grants and credit, academic prestige, reputation and complete freedom to do research as their key operating values. This is compliant with the previous studies, which showed the significance of sharing for sustaining and increasing the actors' reputation in their communities (Wasko and Faraj 2005, Amayah 2013). At the same time, the respondents often indicated the conflict in values between academic and business sector when commercial value (protection for getting a return on investment) overrides academic value (academic credit).

Contextual determinants of knowledge sharing restrictions
Competition
Competition in research, or high pressure related to priority in publishing, is viewed as a primary reason for the lack of openness in the life science communities. This has been broadly discussed and confirmed by all of our respondents, completely in line with the prior studies (Blumenthal et

al. 1997, Bouty 2000, Campbell et al. 2002, Louis et al. 2002, Blumenthal et al. 2006, Hong and Walsh 2009, Haeussler 2014).

Sharing resources
According to our respondents, the frequent objective reasons for knowledge sharing restrictions refer to the lack of time and physical resources. For example, in some laboratories there is a several months long waiting list for experiments to be done on exclusive equipment. These observations are corresponding to prior research findings, which put limited resources and logistical difficulties (in addition to competition) ahead of knowledge transfer activities when assessing their impact on knowledge sharing (Walsh et al. 2007).

Figure 4. Conceptual individual-level model of knowledge transfer-knowledge sharing interactions



2.4 Conclusions

The aim of this research was to contribute to the understanding of determinants of knowledge sharing restrictions in the international life science academic communities on the level of individual researchers, considering their increasing interactions with the business sector and involvement in entrepreneurial activities. Extensive literature review and in-depth analysis of data about 38 cases obtained through semi-structured interviews yielded a grounded conceptual framework and 2 associated key research propositions.

First, academic-industry knowledge transfer activities are shown to contribute to restrictions in knowledge sharing among life scientists; however, the extent of impact is not the same for all such activities: when academic researchers actively engage in collaboration with industry, commercialization and business activities in order to exploit their own research results, these activities occupy more and more of their time and other resources and consequently, substantial knowledge sharing restrictions may arise. When academic researchers act merely as advisors to industry or conduct commercial activities as a minor part of their workload, the restrictions in knowledge sharing are limited only to the information protected by confidentiality agreements with the industry. Our results teach us that it is essential to consider the characteristics of particular academic-industry knowledge transfer activities when assessing their impact on knowledge sharing restrictions, or more broadly, on adherence to the norms of open science.

Second, we observe that different restrictions occur with specific and general, formal and informal knowledge sharing, and that each of these forms of knowledge sharing can be predicted by a different group of determinants. With our empirical study we thus contribute to the body of knowledge on determinants of sharing restrictions among academic life scientists. Here, we also show evidence that supports the view on the present science system as a hybrid between open science and secrecy (Mukherjee and Stern 2009), not only because of the increased importance of commercial exploitation of academic research results, but also due to the intense scientific competitiveness, or battle for priority in disseminating results and consequently, prestige and research funding.

Third, by including into our analysis the respondents from six different empirical settings, we contribute to the understanding of the role of professional environment of academic researchers. We show that the institutional norms and policies related to academic-industry knowledge transfer also affect the academic researchers' knowledge sharing behavior.

Researchers, public institutions' managers and policy makers are increasingly interested in the impact of knowledge transfer activities on knowledge sharing in science following the change in the traditional academic "research and teaching" agenda towards commercial activities. Knowledge and technology transfer have become widely understood as desirable and appropriate sources of financing at research universities (Colyvas and Powell 2006). At the same time concerns over potential negative impacts of these activities on the norms of open science have arisen. The biggest controversy concerns patenting of research tools or inputs for subsequent research as well as expansion of proprietary rights to life forms (Caulfield and Ogbogu 2008). As a response, funding agencies have increasingly been requesting from scientists to follow the open science policy, to allow other researchers to replicate or further develop their results (Franzoni and Sauermann 2014).

Encouraged by increasing debates, scholars have sought to investigate whether information flows have truly been compromised due to knowledge transfer activities, and if so, to explore the consequences of these limitations on the progress of science. The evidence from the conducted studies is mixed, which calls for further research. With this study we extended the work of other scholars that discuss the conflicts between the norms of free circulation of knowledge and the rules of market competition (Calderini et al. 2007). Our findings contribute to the estimation of whether the present concerns of scholars and policy makers over increasing secrecy in life science fields have been targeting the factual cause of problems. We show that, while knowledge transfer activities have undoubtedly influenced the way modern science functions, there are also other, both personal and context-specific factors that have been significantly affecting different forms of knowledge sharing restrictions.

3 DETERMINANTS OF KNOWLEDGE SHARING RESTRICTIONS IN LIFE SCIENCES: TESTING A ROLE OF ACADEMIC-INDUSTRY KNOWLEDGE TRANSFER, PERSONAL AND CONTEXT-SPECIFIC FACTORS [3]

3.1 Introduction

Knowledge sharing between scientists in academic communities has been considered essential for the progress of science. Open sharing of knowledge increases an overall efficiency of the science system, as it reduces the need for the duplication of research efforts, enables the reproducing of research results and overall, faster accumulation of scientific discoveries (Shibayama et al. 2012). The traditional normative framework for studying science system (Merton 1973) views scientific activity as universal to all its participants, with common ownership of generated intellectual property (communalism), lack of secrecy, no interest in the personal gains of individual participants (disinterestedness) and organized skepticism - rigorous critical approach in the validation of research results and methodology. Yet, important changes in the functioning of the academic science system in the past decades have challenged open science principles. An increasing reliance on the "publish or perish" paradigm in academic science funding policies has led to the situation in which academic researchers have been under constant pressure for a fast publishing of their research results in order to secure research funding and to be promoted within tenure-track system (Hackett 1990). An existence of fierce competition for priority in publishing and obtaining grant funds enables a society to recognize top talents; it also enables excellent scientists to advance in their career and gain resources for their new research ideas, which is beneficial in terms of the progress of different scientific fields. However, the "publish or perish" system can at the same time seriously compromise the adherence of researchers to the norms of open science.

Moreover, legislative and policy changes in the past thirty-five years have pushed universities and other academic sector institutions in many countries towards more intensive collaboration with industry and an active role in the commercialization of academic research. Thus, academic institutions have been encouraged to take a more entrepreneurial role in the society as their "third academic mission" in addition to the traditional missions of teaching and research (Etzkowitz and Leydesdorff 2000). As a result, the academic sector has been intensively involved in activities such as consulting the business sector, patenting, licensing and founding spin-off companies. Participation in academic-industry knowledge transfer activities can facilitate the path from basic research to innovations, bring additional sources of funding to researchers and academic institutions and help remove the borderline between basic and applied research (Czarnitzki et al. 2009). At the same time, operating in accordance with the open science norms can become increasingly difficult for academic researchers involved in interactions with industry, in the case they need to cope with different sharing restrictions imposed in order to protect the commercial value of the generated research results (Dasgupta and David 1994, Geuna and Nesta 2006, Baldini 2008).

Given that the core paradigm of the science system has changed, an attempt to investigate determinants of knowledge sharing in the academic communities is a challenging one. Many scholars have incorporated academic-industry interactions into the studies of knowledge sharing, and the studies have shown that involvement in these activities can be associated with knowledge sharing restrictions (Blumenthal et al. 1997, Campbell et al. 2000, Blumenthal et al. 2006, Vogeli

[3] This chapter of the dissertation will be submitted in the form of a paper to an international peer-reviewed journal. The paper was written in co-autorship with Prof. Dr. Mateja Drnovšek.

et al. 2006, Walsh et al. 2007). Yet, only few studies have taken into account that academic-industry knowledge transfer can occur in a variety of forms. Moreover, there are only a few empirical analyses of determinants of different types of knowledge sharing in academia, despite the fact that academic scientists exchange knowledge in numerous ways, such as publications, presentations, projects, informal communication and visits, and each of these can be influenced by different factors (Gerbin and Drnovšek 2015). Most such studies have investigated either knowledge sharing via publications or through direct exchange of research data and materials, with only a few exceptions (Haeussler et al. 2014). For example, Walsh and Huang (2014) investigate how commercialization of academic science (industry funding and patenting) affects publication secrecy of research results (not publishing, partial publication and publication delay). Blumenthal and colleagues (1997) study the relationship between involvement in academic-industry research and engagement in the commercialization of university research and publication delays and refusal to share research results upon request.

In this research we explore determinants of seven different types of knowledge sharing restrictions in the academic community: restrictions in the content of publications, timing of publications (delays), content of publications co-authored with other academic researchers, timing restrictions of co-authored publications, sharing restrictions during presentations of research results, sharing restrictions with the exchange of unpublished knowledge (information, data and materials) and sharing restrictions with the exchange of published knowledge. In the study we consider three different types of academic-industry knowledge transfer as possible predictors of knowledge sharing restrictions: industry collaboration-based activities, such as sponsored research, collaborative projects, consulting or presentations for the industry; intellectual property-based activities, such as patenting and licensing, and academic entrepreneurship and business-related activities, such as business planning or setting up companies. We also empirically assess the role of a variety of individual (scientific values, sharing outcome expectations, trust, reputation, scientific output, professional age, team size, rank and gender) and contextual (institutional sharing climate, competition) determinants of knowledge sharing restrictions in the academic community.

We analyze a sample of 212 life science researchers from Croatia to find that restrictions in each type of knowledge sharing on the level of individual academic researchers are predicted by different forms of academic-industry knowledge transfer and different individual and contextual factors. To our knowledge, this is one of the first studies that conceptualize and test academic-industry knowledge transfer-knowledge sharing relationship by considering the heterogeneity of different forms of academic knowledge transfer and knowledge sharing. Drawing from our findings we make important policy implications by showing that not all forms of academic-industry knowledge transfer are associated with all types of knowledge sharing restrictions. We also show that even in the settings with a relatively low level of engagement of researchers in academic-industry knowledge transfer, these activities can be positively associated with knowledge sharing restrictions. The study contributes to the body of knowledge on determinants of sharing restrictions among academic life scientists, as it takes into account a broad range of individual and context-specific predictors of knowledge sharing restrictions.

In the next section, we discuss theory and hypotheses. The third section describes the research methodology, data and measures. In the fourth section we present the results of the empirical analysis, while in the last section we discuss the findings and policy implications of our study as well as provide conclusions.

3.2 Literature and hypotheses

3.2.1 Academic-industry knowledge transfer and knowledge sharing restrictions

When investigating how the involvement in academic-industry interactions is associated with restrictions in the sharing of scientific knowledge, most scholars focus on the role of patenting. In life sciences, patenting is mostly an investment incentive since the development of new biopharmaceutical products is highly risky – involves high investments of time and financial resources (Kneller 2001). At the same time, the debates have evolved around the concern that patenting and exclusive licensing of life science research discoveries used broadly in academic science as research tools, or inputs for future research, can increase the costs of basic research and inhibit free sharing of knowledge and innovation processes (Heller and Eisenberg 1998, Rai and Eisenberg 2003). Murray and Stern (2007) find modest evidence of the negative impact that patenting has on knowledge diffusion drawing from their analysis of citation rates of scientific publications before and after the patents were granted.

Most authors have not supported a negative relationship between the involvement of scholars in patenting and their scientific output, measured by the number of publications (Agrawal and Henderson 2002, Van Looy et al. 2006, Fabrizio and DiMinin 2008). On the contrary, scientifically more productive scientists are generally more likely to become inventors (Caulfield and Ogbogu 2008, Breschi and Catalini 2010). However, when knowledge sharing is measured as the direct exchange of research materials and information between the members of the academic community, empirical studies emphasize possible restrictions in the extent to which researchers are involved in patenting activity. For example, Walsh and colleagues (2003) find a negative relationship in case of patenting genetic diagnostics. Walsh and colleagues (2007) show that US biomedical researchers in genomics and proteomics have more difficulties in accessing tangible (materials, reagents) than intangible research inputs. Caulfield and colleagues (2008) and Davis and colleagues (2011) point out negative attitudes of Canadian and Danish life scientists towards the impact university patenting has on the norms of open science and academic research although they do not find much proof that sharing restrictions and patenting are directly associated.

In addition to patenting, some studies also investigate what role involvement of academic researchers in commercial activities has on knowledge sharing restrictions in academic science. Campbell and colleagues (2002) find that involvement in commercialization of university-based research, measured by the level of industry research funding, patenting, licensing, spinning-off and/or new product development, is significantly associated with an increased likelihood of data withholding (also confirmed by Blumenthal et al. 1996, Louis et al. 2001, Walsh et al. 2007). In addition, Blumenthal and colleagues (1997) find that both, involvement in academic-industry research relationship and engagement in the commercialization of university research, are associated with publication delays but only the latter is associated with refusal to share research results upon request. In a later study (2006) they show that various active involvements with industry, such as industry research support, commercialization endeavors or consulting, have a negative effect on verbal or publishing data sharing in life sciences. Shibayama (2012) finds that commercial activity facilitates secretive publications and non-compliant behaviors in material transfer between Japanese scientists, but no significant effects are shown for collaboration with industry and funding from industry. These findings are important as they support a premise that the relationship between academic-industry knowledge transfer and knowledge sharing restrictions varies according to a type of interaction and knowledge sharing mode.

Prior literature unveils that only certain forms of knowledge sharing restrictions, such as direct informal sharing of materials and data between researchers and publishing, have been so far in the research focus. On the other hand, empirical research on other forms of knowledge sharing restrictions, such as in collaborative research projects, publishing co-authored with academic collaborators from other research groups, presentations at scientific conferences or via material transfer agreements, has been scant (Rodriguez et al. 2007, Shibayama et al. 2012, Haeussler 2014).

In this research we focus on the role that three different forms of academic-industry knowledge transfer - industry collaboration, intellectual property-related activities and academic entrepreneurship-related activities have in knowledge sharing restrictions.

Researchers can collaborate with industry in various formats, such as through collaborative research projects, sponsored research, consulting and presentations for the industry, personnel exchange, joint supervision of PhD students or joint publishing (see Blumenthal et al. 1996, Davis and Lotz 2006, Gaughan and Corley 2010). Since commercial interests are at stakes, it is usually expected that the industry will refrain academic researchers from publishing research results developed throughout such collaborations until it is clear what commercialization potential such results involve. Since manuscripts' content is typically subject to industry evaluation, restrictions during the publication process are expected. Similar restrictions are expected in cases when researchers plan to disseminate results from collaborative research with other academic laboratories. Moreover, we propose that similar motivation will lead academic researchers in restricting knowledge sharing during public presentations at scientific conferences, as well as with informal sharing of research materials and information with other researchers in the academic community. We propose:

> **Hypothesis 1a**: The more a researcher is involved in collaboration with industry, the more he/she is likely to restrict all forms of knowledge sharing with other researchers in the academic community.

When intellectual property-related academic-industry knowledge transfer activities are concerned, such as invention disclosing, patenting and licensing, either at the individual or institutional level through technology transfer offices (TTOs), prior research evidence suggest that knowledge sharing restrictions are primarily associated with time restrictions in dissemination of publications. In specifics, TTOs typically require several months to review research results that are filed, assess their patentability and prepare the patent application. During this time period the results need to be kept confidential. For similar reasons, during this time period academic researchers are refrained from publicly presenting their research results at scientific conferences and other public events.

> **Hypothesis 1b**: The more a researcher is involved in intellectual property protection-related knowledge transfer activities, the more he/she is likely to experience knowledge sharing restrictions regarding the timing of his/her publications and during public presentations of his/her research results.

Researchers can also actively engage in commercial activities through setting up one's own business and/or managing spin-off companies through a market dissemination of their research results. Such activities are likely to take substantially more of their time than involvement in industry collaboration or patenting activities. This is why such researchers have less time to respond to requests from other academic researchers for their research materials and data, both published and unpublished. Moreover, when researchers start earning revenues by commercializing their research results, these will generally no longer be accessible on a non-commercial, free-of-charge, collaborative basis to other academic researchers.

Hypothesis 1c: The more a researcher is actively involved in academic entrepreneurship-related activities, the more he/she is likely to restrict direct, informal sharing of his/her unpublished and published research results.

3.2.2 Sharing motivations and knowledge sharing restrictions

Social capital theory (Bourdieu 1986, Coleman 1990) describes motivations of individuals for sharing knowledge with other members in a community or in an organization. The theory analyzes what value different aspects in a structure of an individual's social network have in facilitating actions of actors within the network. Nahapiet and Ghoshal (1998) distinguish between the structural, relational and cognitive dimensions of social capital; the first referring to the social interactions, the second to trust, norm of reciprocity and identification, and the third to shared understanding – vision and language – between interacting parties.

The focus of our research is on trust as a component of the relational dimension of social capital. According to Blau (1964), trust occurs when past positive interactions lead to expectations about positive future interactions, which builds good exchange relationships and positively contributes to the levels of sharing (see also Bouty 2000). When examining behaviour of business students, Connelly and colleagues (2012) find a direct relationship between distrust (as a distinct construct from trust) and different forms of knowledge hiding. We see trust as an important determinant of knowledge sharing restrictions in informal, direct exchange of unpublished and published information and materials. When researchers have negative past experience in interactions with knowledge requesting parties, they are less willing to share knowledge in the future. The negative past experience can refer to a lack of acknowledgement in the publication of the requesting researcher to which the academic researcher previously contributed with own research results, data or materials. Also, lack of trust can be caused simply by a lack of personal acquaintance with knowledge requesting parties. In contrast, the more an academic researcher perceives academic community as trustworthy and expects other researchers to act consistently in communication, fewer restrictions in sharing of scientific knowledge are expected. Similar reasoning is expected for sharing when it comes to publishing in co-authorship with other research groups, where content and timing restrictions are expected in the case of the lack of trust in the collaborating parties. Moreover, if a researcher believes that academic community will normally not take advantage of him/her, even if the opportunity arises, she/he is expected to engage in sharing restrictions during public presentations of scientific results to a lesser extent. This reasoning leads us to propose:

Hypothesis 2: The extent of trust a researcher has is negatively related to knowledge sharing restrictions with the exchange of published and unpublished knowledge (information, data and materials), content and timing of publications co-authored with other academic researchers and during public presentations of research results.

Prior literature suggests that knowledge sharing is likely to be driven by outcome expectations. Following Chiu and colleagues (2006), we empirically examine a role of two types of outcome expectations in knowledge sharing restrictions in an academic community: personal outcome expectations and community-related outcome expectations. In the context of this study, personal outcome expectations refer to consequences an academic researcher expects for himself/herself as a result of his/her involvement in knowledge sharing. Community-related outcome expectations refer to consequences a researcher expects for the academic community to which he/she belongs. We expect that both types of outcome expectations are likely to be negatively related to all forms of knowledge sharing restrictions. When a scientist feels that by sharing knowledge he/she becomes happier, more accomplished and better connected with the academic community he/she belongs to, she/he is less inclined to impose sharing restrictions. Likewise, when a scientist perceives sharing as beneficial for the accumulation of knowledge and growth of the academic community in which he/she operates, she/he is less likely to restrict access to his/her knowledge.

> **Hypothesis 3a**: Personal outcome expectations are likely to be negatively related to all forms of knowledge sharing restrictions with other researchers in the academic community.

> **Hypothesis 3b**: Community-related outcome expectations are likely to be negatively related to all forms of knowledge sharing restrictions with other researchers in the academic community.

Reputation among peers is another potentially important predictor of knowledge sharing behaviour of academic researchers. In our study, with reputation we refer to the relevance the academic researchers attach to different indicators of scientific performance, such as the number of publications, journal impact factor, number of received citations and number of awards. Haeussler and Colyvas (2011) find that reputation based on publications is positively related to general sharing, through for example public presentations. The assumption based on this empirical evidence is that when researchers openly share their research results with the general public, they communicate their progress to the audience and increase their recognition among peers, or awareness about their achievements. Other studies also showed the significance of sharing for sustaining and increasing the actors' reputation in their communities (Wasko and Faraj 2005, Amayah 2013). In contrast, one could also argue that if scientists wish to be better than their peers in terms of the number of publications, especially in highly ranked journals, they will be more likely to restrict knowledge sharing in order to protect the scientific priority. Still, we hypothesize that open sharing of knowledge, both via publications and presentations and through direct exchange of research data and materials, increases the number of opportunities the researchers have for new collaborations with other research groups, which can consequently lead to better scientific performance and better reputation among peers:

> **Hypothesis 4**: Reputation will be negatively related to all forms of knowledge sharing restrictions with other researchers in the academic community.

3.2.3 Scientific values and knowledge sharing restrictions

According to the traditional Mertonian view (1973), the outcomes of the scientists' profession such as publications, citations and peer status emerge from adherence to the open science system. Merton argued that "the communism of the scientific ethos is abstractly incompatible with the definition of technology as 'private property' in a capitalistic economy." Due to changes in the institutional norms and policies, an overall attitude of many scientists towards commercial involvement has evolved from a resistance to compliance, and to acceptance. Yet, significant concerns regarding delay and secrecy have remained present. Some researchers are concerned about the freedom in disseminating results, selecting collaborators or entering informal cooperation when involved in academic-industry knowledge transfer activities (Etzkowitz 2002 in Jain et al. 2009).

In their survey on sharing among researchers in genetics, Louis and colleagues (2002) find that scientists with no industry relationships are more likely than scientists with interactions with industry to "completely agree" with the statement that "academic scientists should be motivated by the desire for knowledge and discovery rather than by financial gain". Boardman and Ponomariov (2009) show that scientists that adhere to the scientific norms of communalism (common ownership of generated research results) and disinterestedness (lack of interest in the personal gains resulting from research) are generally less likely to interact with the business sector, although the effect of adherence to the norm of communalism is less pronounced than the effect of disinterestedness. Shibayama (2012) shows that although some entrepreneurial activities have produced a negative impact on collaborative relationships between scientists, they do not implicate a negative effect on the traditional norm of open science. Haeussler and colleagues (2014) find that the more the scientists believe that their research field functions in line with the norms of open science, the greater is the expected level of both specific (direct) and general (public) sharing of their knowledge.

Drawing from prior literature we argue that researchers' attitudes and beliefs about how the science system should function are likely to be related with how they share their knowledge. Similarily, scientists that believe that the primary motivation should be a desire for knowledge will differ from scientists that find financial rewards more salient. Scientists that are more inclined to the norms of open science are less likely to omit relevant research results from their manuscripts and any public dissemination of results. Moreover, they are less likely to decline requests for disclosure of research materials and information to other researchers.

> **Hypothesis 5a**: The extent to which a researcher identifies with the norm of disinterestedness is negatively related with the extent of all forms of knowledge sharing restrictions with other researchers in the academic community.

> **Hypothesis 5b**: The extent to which a researcher identifies with the norm of communalism is negatively related with the extent of all forms of knowledge sharing restrictions with other researchers in the academic community.

3.2.4 Contextual factors and knowledge sharing restrictions

Blumenthal and collegues (2006) find that perception of competitiveness of the scientific field, or high pressure related to priority in publishing, is positively associated with publishing withholding among genetics researchers. The survey conducted by Caulfield and colleagues (2008) identifies competition as a primary reason for refusals to share research materials among stem cell researchers. Vogeli (2006) shows that scientific trainees in highly competitive research groups are more likely than trainees in low-competition groups to report having denied requests for information, data and materials from other researchers. Walsh (2007) fnds that an increase in the number of competitors is associated with greater denials of sharing research materials. The study by Haeussler (2014) reports that the perception of a degree of competitiveness in a specific scientific field is negatively associated with both, general and specific sharing of knowledge.

Based on the evidence, we hypothesize that academic researchers who perceive their scientific field as highly competitive are more likely to engage in all forms of investigated knowledge sharing restrictions. The more competitive a research environment is, the more restrictions with the publishing activity of academic researchers are expected. They are more likely to intentionally omit research results from the manuscript when submitting it for review or publication in order to protect their scientific lead in the field. Restricting knowledge sharing is a way of buying one's time to generate additional research results that can ncrease their chances for publishing in highly ranked journals in the future. Furthermore, academic researchers are less willing to openly disclose their newest findings at scientific conferences, as they are afraid that the competition might receive valuable information that has not yet been published. Similarly, they are more likely to refrain from responding to requests for both, their unpublished and published knowledge from other academic researchers, as they perceive that the competitors may gain advantage in their research projects and ultimately publish the related findings before them.

Hypothesis 6: Perception of competitiveness of the scientific field will be positively related with the extent of all forms of knowledge sharing restrictions with other researchers in the academic community.

How researchers behave with respect to knowledge sharing may also be related to the general sharing climate in their immediate working environment. Following Fullwood (2013), we argue that attitudes, behaviours and actions of leaders and managers of research groups the academic researchers belong to define the common sharing norms of the research groups and individual researchers in the group. If their supervisors and colleagues support restrictive practices in knowledge sharing, it is expected that academic researchers are more likely to be involved in knowledge restrictive behaviours themselves.

We hypothesize that the role of the institutional sharing climate is significantly related with informal exchange of published and unpublished knowledge (information, data and materials) and with content and timing of publications co-authored with other academic researchers. With these forms of knowledge sharing researchers directly, personally interact with other research groups, which is why the influence of their co-workers in the laboratory is expected to be of significance in their sharing decisions.

Hypothesis 7: Institutional climate in support of sharing is likely to be negatively related to knowledge sharing restrictions with the exchange of published and unpublished knowledge and content and timing of publications co-authored with other academic researchers.

3.3 Data and methods

3.3.1 Sample and data

To test our hypotheses, we gathered a sample of life scientists in Croatia for whom we expected to be to some extent involved in knowledge sharing activities. We sampled from life sciences' researchers because prior research suggests that they are the most active group in academic-industry knowledge transfer (Blumenthal et al. 1996, Powell and Owen.-Smith 1998, McMillan et al. 2000, Owen-Smith et al. 2002, Stuart and Ding 2006). We sampled academic researchers - researchers affiliated to universities and other non-profit research institutions.

Our sample comprised 9 life science fields, following the categorization of the European Research Council (ERC), the pan-European organization for funding the highest quality research. These include: molecular and structural biology and biochemistry; genetics, genomics, bioinformatics and systems biology; cellular and developmental biology; physiology, pathophysiology and endocrinology; neurosciences and neural disorders; immunity and infection; diagnostic tools, therapies and public health; evolutionary, population and environmental biology and applied life sciences and non-medical biotechnology. Most of our respondents (23%) perform research in the field of diagnostic tools, therapies and public health; 12% are involved in evolutionary, population and environmental biology research, whereas 11.8% belong to neurosciences and neural disorders field.

We sampled from those life science researchers who hold a doctoral degree and who have been active in research in the past five years. We obtained a database of all life scientists with a doctoral degree in Croatia from the Ministry of Science, Education and Sports. The database initially comprised 2,956 unique names, with the indicated year of birth and last known affiliation. Next to each name in the database we manually entered the associated e-mail address, following the internet search, mostly through the official institutional web pages. The e-mail addresses of in total

406 scientists could not be found, and the internet search revealed that these either retired, moved to the non-academic sector, relocated abroad or worked in the clinics without active participation in scientific activities. The survey instrument was developed based on literature review, prior surveys and semi-structured interviews with 38 key informants - scientists, entrepreneurs and technology transfer specialists from six countries: Croatia, Slovenia, Italy, Germany, Israel and the USA. To validate the instrument, we conducted pilot interviews with five scientists to remove potential inclarities from the instrument. The survey was originally prepared in English language and then translated into Croatian using the back-to-back translation method (see Appendices K and L).

The final version of the survey was e-mailed to 2,550 respondents via online survey platform LimeSurvey. The data collection process lasted approximately one month and was completed in July 2016. In total 255 e-mail invitations to participate in the survey were returned as undeliverable, whereas 21 respondents refused to participate or informed us that they had not been able to participate, mostly due to a lack of time. Out of 2,274 respondents that received the invitation and did not explicitly refuse to participate, 456 or 20.05% opened the survey and 227 (or 9.98%) completed all questions of the survey. In total 16 respondents specified that they no longer worked in Croatia and were thus excluded from analysis. Two respondents were also excluded from analysis due to the incorrectly completed questionnaire. Additional 3 respondents that completed more than 70% of the survey were included into analysis, adding up to in total 212 responses included into analysis.

In order to test a potential non-response bias we first compared answers to the dependent variables of knowledge sharing restrictions between early and late respondents, following Armstrong and Overton (1977) recommendations. Considering that most of the data were non-normally distributed, we conducted the analysis using the Kolmogorov-Smirnov non-parametric test. We compared the responses of the first 20% of respondents with the last 20% of respondents and found no significant differences between the two groups for any of the dependent variables. We also compared the scientific productivity data between scientists from the response and non-response group. We randomly selected 50 researchers from the response group and 50 researchers from the non-response group and using the Web of Science and Croatian Scientific Bibliography (CROSBI) databases, obtained the number of publications in the past five years for all researchers. We found no significant difference in publication productivity between the two groups (10.24 respondent vs. 9.06 non-respondent publications per year, $p = 0.59$).

3.3.2 Measures

Dependent variables

Knowledge sharing restrictions. With our survey we investigated 18 different forms of knowledge sharing restrictions in the life science academic communities: (1) Publication content restrictions; (2) Publication timing restrictions; (3) Co-authored publication content restrictions; (4) Co-authored publication timing restrictions; (5) Formal projects sharing restrictions; (6) Outgoing secondments sharing restrictions; (7) Incoming secondments sharing restrictions; (8) Presentations restrictions; (9) Unpublished data and information sharing restrictions (own); (10) Unpublished materials sharing restrictions (own); (11) Published data and information sharing restrictions (own); (12) Published materials sharing restrictions (own); (13) Unpublished data and information sharing restrictions (other researchers); (14) Unpublished materials sharing restrictions (other researchers); (15) Published data and information sharing restrictions (other researchers); (16) Published materials sharing restrictions (other researchers); (17) Material transfer agreement (MTA)-related sharing restrictions (outgoing) and (18) MTA-related sharing restrictions (incoming). In the Results section we briefly report the main descriptive statistics results obtained for each of these forms of knowledge sharing restrictions. In multivariate analysis we use seven of these as dependent variables.

Knowledge sharing restrictions variables included in multivariate analyses

Publication content restrictions refer to the number of articles the respondents prepared in the past five years with which they experienced the situation that they had to omit some relevant content (research results) from the manuscript when submitting it for review or publication. *Publication timing restrictions* variable measures the number of scientific articles that the respondents prepared in the past five years with which they experienced the situation that they had to delay publishing of the research results for more than 6 months. *Co-authored publication content restrictions* variable measures the number of articles published in the last five years in co-authorship with other research groups from the academic sector in which the respondents had to exclude some relevant content (research results) from the manuscript. When measuring *Co-authored publication timing restrictions* we asked the respondents to estimate in how many of the articles published in the last five years in co-authorship with other research groups from the academic sector they had to delay publishing for more than 6 months.

Knowledge sharing through presentations (oral or poster) can occur at seminars at other departments of the respondents' institution, at other academic institutions and at professional meetings. To measure Presentations restrictions, we asked the respondents at how many presentations they intentionally excluded some relevant content (unpublished research results), either during the presentation or questions & answers session from the audience.

Knowledge sharing restrictions in direct, informal exchange of knowledge refer to the number of times the respondents denied (explicitly rejected or ignored) the requests for information (e.g., laboratory techniques or protocols, genetic sequences or protein structures), data (e.g., database or software) and materials (e.g., reagents, chemical compounds, cell lines, tissues, model organisms, proteins, genes, plasmids) that they had got from other academic researchers in the past five years informally, via e-mail or personally (without the contractual relationship). We separately investigated knowledge sharing restrictions for unpublished and published materials and published and unpublished data and information. In multivariate analyses, we constructed two variables, one measuring the number of denials of unpublished information and materials and the other measuring the number of denials of published information and materials. We also measured the extent of denials in the opposite direction, i.e. when respondents act as a knowledge requesting party.

Knowledge sharing restrictions variables not included in multivariate analyses

Formal knowledge sharing is in the context of this research defined as knowledge sharing in frame of collaborative research projects with other research groups from the academic sector, where "formal" implies the existence of a contractual relationship, such as the collaboration agreement, partnership agreement, consortium agreement, etc. To measure the associated knowledge sharing restrictions, we asked the respondents with how many of such projects they experienced the situation that they restricted knowledge (information, data, materials) sharing with their project collaborators.

Outgoing secondments sharing restrictions refer to the number of times the respondents restricted knowledge sharing during the secondments to their academic collaborators' laboratories in the past five years. *Incoming secondments sharing restrictions* measures the number of times the respondents restricted knowledge sharing during the secondments of their academic collaborators' team members to their laboratory in the past five years.

Material transfer agreement (MTA)-related sharing restrictions were measured as the number of times the negotiations over the execution of material transfer agreements (MTAs) as a prerequisite for the exchange of research materials between academic researchers lasted more than a month, in both directions, i.e. when the respondent was the material sending and material requesting party.

Independent variables

Academic-industry knowledge transfer activities. The extent of involvement in academic-industry knowledge transfer was measured by considering 20 different types of such activities in which the respondents could have been involved, either as a team leader or team member, during the last five years. In developing the questions we drew from the prior literature investigating the impact on knowledge transfer on knowledge sharing (Walsh et al. (2007), (Campbell et al. 2000, Campbell et al. 2002, Campbell et al. 2004), Martinelli et al. (2008), Walsh and Huang (2014)). The 20 questions were grouped into three categories of academic-industry knowledge transfer activities: industry collaboration (8 questions), intellectual property-based (6 questions) and academic entrepreneurship (6 questions). The examples of questions are: How many companies have you consulted (independently or as an advisory board member)? In how many university-industry joint research projects (FP7, Horizon 2020 or similar) have you been involved? (category 1); How many patent applications have been submitted for the inventions with you as an inventor or co-inventor? How many licensing agreements have been signed by you or your institution based on your non-patented research results? (category 2); In how many business plans or other activities related to starting a new firm have you been involved? How many companies (related to your research work) have you founded? (category 3) The full list of questions can be found in the Appendix K. The composite continuous variables of industry collaboration, intellectual property-based activities and academic entrepreneurship were constructed by adding up the responses to all questions in each academic-industry knowledge transfer activity category.

Sharing motivations and values, contextual factors

Variables Personal outcome expectations, Community-related outcome expectations, Trust, Reputation and Institutional sharing climate are constructs that were measured using multiple items. All measurement items were adapted from subscales already validated in previous literature (Bock et al. 2005, Chiu et al. 2006, Haeussler 2011, Fullwood et al. 2013), and minor modifications were made simply to account for the specific context of knowledge sharing in the academic community. Table 9 below shows Cronbach's reliability estimates for each construct as well as means, standard deviations and loadings (after rotations) for all items following the conducted principal components analysis (PCA) and principal axis factoring analyses with SPSS (Tabachnick 1996, Pallant 2001). The suitability for performing factor analysis (Hair 2009) was confirmed after the inspection of the correlation matrix, the Kaiser-Meyer-Oklin test (the value was 0.876, which is above the recommended value of 0.6) and the Bartlett's Test of Sphericity (Sig. = 0.000). Although initially included, the construct Reciprocity was excluded from further analysis due to significant cross-loadings of its items. For the same reason, one item of the Institutional sharing climate construct was excluded from further analysis.

Based on Boardman and Ponomariov (2009), variables Scientific values – Disinterestedness and Scientific values – Communalism were measured as responses (on a scale from 1 to 7) to the statements "Worrying about possible commercial applications distracts one from doing good research" and "I would rather double my citation rate than double my salary", respectively.

To assess the role of the sharing context, Competition variable was measured as a response (on a scale from 1 to 5, where 1 stands for "not at all competitive" and 5 stands for "extremely competitive") to the question: "How would you characterize the overall level of competition for recognition or scientific priority in your specific area of research?", following Blumenthal et al. (2006), Vogeli et al. (2006) and Haeussler et al. (2014).

Table 9. Summary of measurement scales (principal axis factoring)

Construct	Measure	Mean	St. Dev.	Loading
Personal outcome expectations (POE) composite reliability = 0,920				
POE1	Sharing my knowledge will help me to make friends with other researchers in the academic community.	5.36	1.522	0.668
POE2	Sharing my knowledge will give me a feeling of happiness.	5.21	1.746	0.626
POE3	Sharing my knowledge can build up my reputation with other researchers in the academic community.	5.33	1.572	0.804
POE4	Sharing my knowledge will give me a sense of accomplishment.	5.19	1.647	0.799
POE5	Sharing my knowledge will strengthen the tie between other researchers in the academic community and me.	5.66	1.334	0.828
POE6	Sharing my knowledge will enable me to gain better cooperation from the outstanding members in the academic community.	5.41	1.456	0.767
Community-related outcome expectations (COE) composite reliability = 0,971				
COE1	Sharing my knowledge will be helpful to the successful functioning of the academic community.	6.02	1.269	0.812
COE2	Sharing my knowledge would help the academic community continue its operation in the future.	6.01	1.233	0.874
COE3	Sharing my knowledge would help the academic community accumulate or enrich knowledge.	6.14	1.178	0.862
COE4	Sharing my knowledge would help the academic community grow.	6.04	1.338	0.813
Trust (TR) composite reliability =0,963				
TR1	Members of the academic community to which I belong will not take advantage of others even when the opportunity arises.	3.48	1.702	0.778
TR2	Members of the academic community to which I belong will always keep the promises they make to one another.	3.47	1.613	0.912
TR3	Members of the academic community to which I belong would not knowingly do anything to disrupt the communication.	3.49	1.754	0.914
TR4	Members of the academic community to which I belong behave in a consistent manner.	3.71	1.675	0.895
TR5	Members of the academic community to which I belong are truthful in dealing with one another.	3.44	1.698	0.928
Reputation (REP) composite reliability =0,916				
REP1	How important for your reputation among peers is the number of articles published in peer reviewed journals?	4.09	0.972	0.875
REP2	How important for your reputation among peers is the impact factor of the journals where your articles appear?	3.97	1.078	0.947
REP3	How important for your reputation among peers is the number of citations published articles receive?	3.91	1.105	0.901
REP4	How important for your reputation among peers are scientific awards?	3.60	1.070	0.684
Institutional sharing climate (ISC) composite reliability = 0,805				
ISC2	My direct supervisor thinks that I should share my knowledge with other researchers in the academic community.	3.43	1.215	0.744
ISC3	My colleagues in the research group think I should share knowledge with other researchers in the academic community.	3.58	1.040	0.821

Control variables

The control variables included gender, academic rank, professional age (total number of years of employment), team size (number of full-time research team members the respondents are supervising), scientific output (number of publications in Web of Science database in the past five years), research impact (total number of citations in Web of Science database in career) and percentage of total working time involved in research-related activities. For multivariate analyses referring to particular forms of knowledge sharing restrictions in the past five years, we also controlled for the number of associated knowledge sharing activities in the respective period. For example, when measuring presentations restrictions, we controlled the model for the number of presentations the respondents held in the past five years. When measuring the restrictions in sharing published and unpublished knowledge, we controlled the model for the number of requests received for published and unpublished knowledge.

With our survey we collected additional valuable information from our respondents, including on total funding and funding sources, which have however not been included as variables in the econometric model. The summary statistics for variables used in multivariate analysis are shown in Table 10, while the summary statistics for the whole analysis are shown in Appendix M.

3.4 Results

3.4.1 Descriptive analyses

The majority of our respondents (64%) are female. The largest proportion of them (36%) hold position of assistant professor or equivalent, whereas 27% are full professors or equivalent and 24% are associate professors or equivalent. The rest refers to postdoctoral researchers (10%) and other categories (3%). Most of the respondents (84%) are affiliated to only one institution and 16% have multiple affiliations. Their most frequently reported affiliations are pre-clinical departments of higher education institutions (34%), public health institutions – hospitals, clinics (24%), clinical departments of higher education institutions (20%) and public research institutes (17%). On average, our respondents have 22.5 years of professional experience, out of which 20.6 in the non-profit sector and 18.2 in the current institution of employment. They directly supervise on average 9.5 personnel, 4.9 of which are research personnel. The mean number of publications for the last five years was 11.3, and the career-total number of citations (excluding self-citations) received was on average 194.5.

Research activities

In the survey, the respondents were asked to indicate how they allocate their overall working time (in a typical work week) across six groups of activity. On average, they spend most time (26.5%) on research and research-related activities (includes planning of experiments, laboratory time, preparation of publications), work with patients (24.7%) and teaching (22.9%). Close to 14% of time is spent on project-related activities (includes grant proposals preparation, coordination of project activities, writing reports) and 9.3% on other activities (including participation in committees, administration). Only 2.6% of working time is on average allocated to activities related to academic-industry knowledge and technology transfer.

Concerning the perception of nature of the research they perform, the respondents report most research working time involvement (51.7%) in applied research, followed by basic research (40.5%) and lastly, experimental development (7.8%).

Next, respondents were asked to estimate the percentage of different sources of funding for the activities in which they had been involved in the last five years as research group members (but not necessarily directly responsible for the expenditure of funds as a team supervisor, principal investigator or activity leader). National government-related and other national competitive project granting programs, agencies and foundations (e.g., National Science Foundation) are the most important reported source of funding (50.4%), whereas on average 19.5% comes from other sources, 14.7% from EU and international competitive project granting funds, programs, agencies and foundations (e.g., European Commission's FP7 and Horizon 2020, National Institutes of Health USA, international associations), 7.9% from market revenues (sales, professional services, royalties, etc.) and 7.5% from industry sponsors. The same order of importance was reported by the respondents for the sources of funding that they received in the last five years for activities of the research team they had been supervising, however, with the slightly different shares: whereas national sources accounted for 53.4% of the total funding, 15.4% came from other sources, 14.6% from EU and international funds, 8.5% from market revenues and 8.1% from industry sponsors. The reported average annual amount of funding that the respondents had received for their research activities or research activities of the research team they had been supervising in the last five years was EUR 44,894.

Engagement in academic-industry knowledge transfer activities

The results of the data analysis show that 68% of academic researchers have been involved in at least one form of academic-industry knowledge transfer, yet with an overall low level of involvement. Most activities are reported in the industry collaboration category, on average 10.2 activities in the past five years. Presentations for the business sector are the most frequently reported form of academic-industry knowledge transfer in this category, followed by publications in co-authorship with the business sector and consulting of enterprises, as an independent expert of advisory board member. On the other hand, secondments between the academic and the private sector have been rarely practiced.

The intellectual property-based academic-industry knowledge transfer activities are conducted very rarely, on average only 0.84 per respondent. The most frequently reported form of activity in this category are negotiations over rights and commercialization of inventions.

The involvement of researchers in the third category of academic-industry knowledge transfer, academic entrepreneurship, is also very low, with an average 1.67 activities per respondent. The respondents most frequently reported the experience with products directly based on their research results under regulatory review and on the market, whereas establishment, co-ownership and management of spin-off companies were the least common.

Knowledge sharing and associated restrictions

The average number of collaborators of our respondents in the academic community is the same (1.83) when it comes to collaborators from other research groups in the same institution and other research groups in the country, and slightly higher (1.92) with regard to the collaborators from the international academic community.

Publication content and timing restrictions. Respondents on average experienced content restrictions with 0.83 articles, mostly in order to protect their scientific lead in the field (e.g., to generate additional research results that will increase the chances for publishing in a highly ranked journal). Timing restrictions occurred with on average 0.93 manuscripts, mostly because the respondents needed to protect their scientific lead, protect the scientific priority of a team member (doctoral or postdoctoral student) or respect the provisions of an agreement with a collaborator. On the other hand, reasons related to commercialization or interactions with the business sector were very rarely reported.

Co-authored publication content and timing restrictions. On average, the respondents published more than 50% of articles in co-authorship with other academic groups; yet, content restrictions were low, with only 0.26 articles per respondent. Timing restrictions with co-authored articles, or delays of publishing for more than six months, were slightly higher, with an average 0.47 articles per respondent.

Knowledge sharing restrictions in formal relationships. Our respondents were involved, either as a team leader or team member, in on average 2.6 formal projects with other research groups from the academic sector during the past five years. In less than 4% of the projects they restricted knowledge (information, data, materials) sharing with their project collaborators. The results thus point to a very low extent of formal projects sharing restrictions.

Knowledge sharing restrictions in secondments. Knowledge sharing restrictions associated with secondments to other academic laboratories are also very rare. Our respondents report having been seconded to on average 1.1 academic collaborators' laboratories during the past five years and in less than 2% of secondments they restricted knowledge sharing with the academic collaborators' team members. In the opposite direction, on average 2.3 academic collaborators were seconded to the respondents' laboratories during the past five years, with only 1% cases where they restricted knowledge sharing with the academic collaborators' team members.

Knowledge sharing restrictions in presentations. Our respondents presented their research work at on average 12 occasions during the past five years. In on average 1.6 occasions (or 13%) they intentionally excluded some relevant content (unpublished research results) during the presentation or questions & answers session from the audience. The results indicate that restrictions are common with knowledge sharing through presentations.

Knowledge sharing restrictions in direct, informal exchange of knowledge. When it comes to direct, informal (without the contractual relationship) exchange of research information, data and materials between the members of the life science academic community, we separately investigated knowledge sharing restrictions for unpublished and published knowledge. In accordance with our expectations, our respondents received most requests for published materials (on average 9.8 in the past five years) and published data and information (8.9) from other researchers, while the received requests for unpublished information and materials were fewer (on average 3.4 and 1.5, respectively). At the same time, most sharing restrictions were encountered with unpublished materials, where the respondents denied (explicitly rejected or ignored) close to 13% (or on average 0.2 per respondent) of requests. The rejection rate amounts to 8% for requested unpublished data and information, while for published materials and information this rate is lower, and amounts to 6% and 5.4%, respectively.

We also asked the respondents about their experiences with unwillingness to share when they act as a knowledge requesting party. Supporting prior findings, researchers sent most requests for published materials (on average 6.2 in the past five years) and published data and information (5.4), while they sent on average 2.4 requests for unpublished information and 1.4 for unpublished materials. Interestingly, the experienced request incompliance rate is the highest for published data and information (14% or 0.8 denials per respondent), even though the rates for unpublished information (11%) and materials (12%) as well as published materials (10%) are also relatively high. Moreover, considering the relatively long period of observation of our survey (5 years), the presented results indicate the overall low level of direct, informal exchange of knowledge between the members of the Croatian life science academic community and other academic researchers.

Knowledge sharing restrictions and material transfer agreements. Finally, we asked the respondents about their experiences with material transfer agreements (MTA) upon exchange of research materials with other life scientists. They required on average 0.49 MTA when having been asked for materials in the past five years; however, the distribution of the responses is highly skewed, as only 6% of respondents required MTA at all. Also, more than 50% of negotiations over MTAs lasted more than one month. In the opposite direction, the respondents were asked to sign an MTA on average 0.44 times, whereas in 27% of the cases negotiations lasted more than one month. We can conclude from this part of the analysis that MTAs are rarely used by Croatian life science researchers, but when they are, in a significant number of cases they require longer time to process before the receipt of the materials. This indicates that MTAs, or more accurately, legal and administrative procedures followed for MTAs, can be seen as one of the factors that may slow down the open and free exchange of research materials.

We were also interested to know what motivates knowledge sharing restrictions of life science researchers. The respondents were asked to rate the importance of particular reasons behind their knowledge sharing restrictions in the past five years, on a scale from 1 to 5, where 1 stands for "not at all important" and 5 stands for "extremely important". As shown on Figure 5, in line with the previous findings, the most highly ranked reasons behind knowledge sharing restrictions are related to competitiveness in research, or the need to protect one's ability to publish, as well as limited resources - too much time, money or other resources needed to prepare or produce the requested information, data and materials. For those life scientists that work in health institutions, the need to preserve confidentiality of patients was among more highly ranked reasons for sharing restrictions. The reasons related to academic-industry knowledge transfer were of lower importance compared to the reason related to reciprocity in science – lack of acknowledgement by the requesting party following the previous request for information, data or materials.

Figure 5. Reasons behind knowledge sharing restrictions in the life science academic community

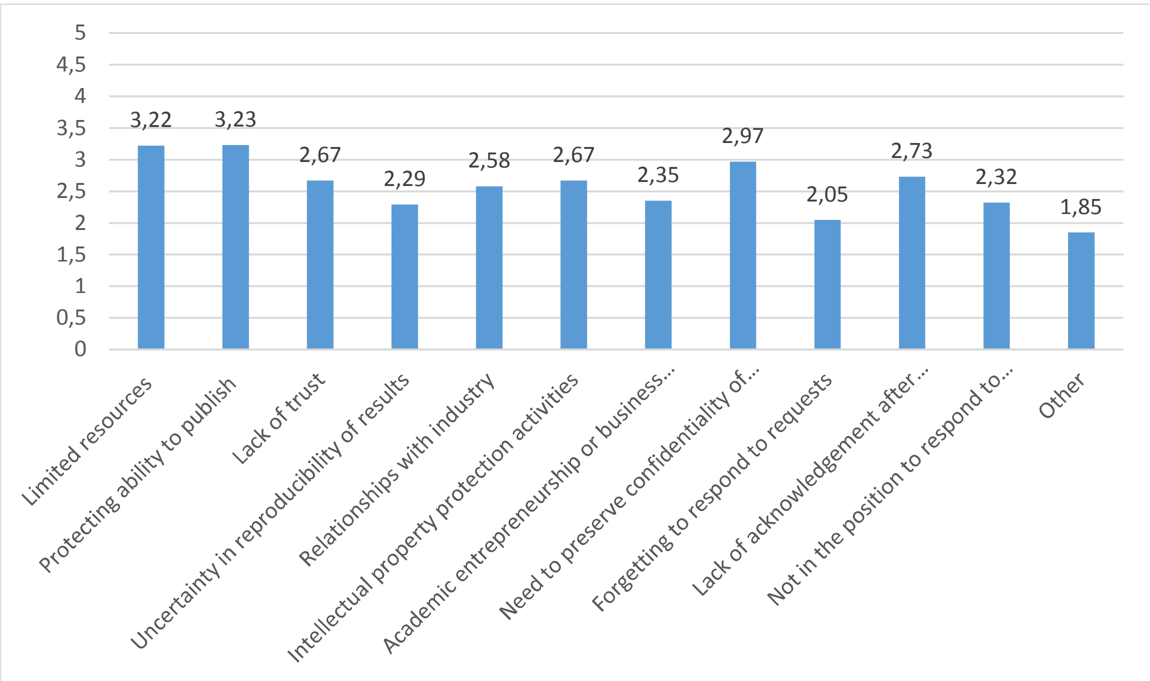


Table 10. Summary statistics (dependent, independent and control variables)

Variable	No. obs.	Mean	St. Dev.	Min	Max
Dependent variables					
Publication content restrictions [CONTRES]	212	0.830	2.541	0	30
Publication timing restrictions [TIMRES]	212	0.934	3.560	0	43
Co-authored publication content restrictions [COCOO]	212	0.264	0.824	0	5
Co-authored publication timing restrictions [COTIO]	212	0.467	2.854	0	40
Presentations restrictions [PRESREO]	212	1.566	13.795	0	200
Unpublished knowledge sharing restrictions [UNPRED]	212	0.476	2.981	0	40
Published knowledge sharing restrictions [PRED]	212	1.066	4.293	0	45
Independent variables					
Academic-industry knowledge transfer activities					
Industry collaboration [INDCOL]	212	10.208	22.595	0	169
Intellectual property-based [IPBASE]	212	0.839	4.027	0	46
Academic entrepreneurship [ACAENT]	212	1.669	7.910	0	100
Sharing motivations and values					
Personal outcome expectations [POEXP]	212	5.362	1.311	1	7
Community-related outcome expectations [COEXP]	212	6.052	1.205	1	7
Trust [TRUST]	212	3.517	1.575	1	7
Reputation [REPUT]	211	3.893	0.945	1	5
Disinterestedness [DISIN]	211	3.729	1.833	1	7
Communalism [COMM]	211	3.431	1.882	1	7
Sharing context					
Competitiveness perception [COMP]	211	3.431	0.995	1	5
Institutional sharing climate [ISCLIM]	211	3.507	1.035	1	5
Control variables					
Research productivity [PUBQTY]	212	11.264	10.536	0	82
Share of co-authored publications with other academic groups [COAU]	212	52.651	36.750	0	100
Received requests for unpublished knowledge [UNREQ]	212	4.967	32.625	0	450
Received requests for published knowledge [PUBREQ]	212	18.651	72.863	0	1,000
Academic rank – full professor [RANK]	209	0.268	-	-	-
Professional age [PRAGE]	209	22.536	8.165	5	42
Number of research subordinates [TEAMSIZE]	209	4.876	13.454	0	150
Gender – female [GEN]	212	0.637	-	0	1

3.4.2 Results from econometric analyses

In this section, we present results of regression analyses performed in order to test relationship between the three forms of academic-industry knowledge transfer and personal and context specific factors in seven different types of knowledge sharing restrictions. In particular, in the first multivariate model we predict the number of publication content restrictions as a function of: a) number of industry collaboration activities, b) number of intellectual property-based academic-industry knowledge transfer activities, c) number of academic entrepreneurship-related knowledge transfer activities, d) personal outcome expectations, e) community-related outcome expectations, f) reputation, g) scientific values – disinterestedness, h) scientific values – communalism, i) perception of competition in the field, j) institutional sharing climate. We control the model for publication quantity, professional age, team size, gender and academic rank. All these variables are included as predictors in the other six models. In addition, trust is added as a predictor variable in the models with co-authored publications content restrictions, co-authored publications timing restrictions, presentations restrictions, unpublished knowledge sharing restrictions, and unpublished knowledge sharing restrictions as dependent variables. The models predicting co-authored publications content and timing restrictions are controlled for the share of co-authored publications (with other laboratories) in the total number of publications. The model predicting unpublished knowledge sharing restrictions is controlled for the number of requests received for unpublished data and materials, whereas the model predicting published knowledge sharing restrictions is controlled for the number of requests received for published data and materials. The correlation matrix is presented in the table in Appendix N.

Considering that our dependent variables do not follow a normal distribution, we estimate the model using a negative binomial regression, which accounts for the overdispersion of count variables (Hausman 1984, Walsh et al. 2007). Table 11 shows the results of the analyses. The incidence rate ratio (IRR) greater than one shows a positive effect of the regressor on the level of sharing restrictions, whereas a ratio less than one shows a negative effect.

Table 11. Negative binomial regression analyses of knowledge sharing restrictions

Variable	**CONTRES**	**TIMRES**	**COCOO**	**COTIO**	**PRESREO**	**UNPRED**	**PRED**
INDCOL	1.030* (0.068)	1.033* (0.066)	1.020* (0.0074)	1.023* (0.007)	1.021* (0.0052)	1.019 (0.0103)	1.012* (0.0060)
IPBASE	0.932 (0.0654)	0.954 (0.0607)	1.022 (0.085)	1.175* (0.0752)	1.114* (0.0559)	0.330* (0.3584)	0.864* (0.0676)
ACAENT	1.008 (0.0354)	1.003 (0.0335)	1.004 (0.0413)	0.954 (0.0393)	0.966 (0.0298)	0.988 (0.0639)	1.085* (0.0319)
POEXP	0.773* (0.1237)	0.746* (0.1263)	0.666* (0.1983)	0.552* (0.1925)	0.771* (0.1254)	0.706 (0.1864)	1.303* (0.1297)
COEXP	0.932 (0.1391)	1.139 (0.1508)	1.056 (0.2034)	1.404 (0.1945)	1.293 (0.1381)	1.213 (0.2225)	0.961 (0.1330)
TRUST	-	-	0.790 (0.1515)	0.578* (0.1679)	0.805* (0.1066)	0.845 (0.1318)	1.058 (0.0896)
REPUT	0.832 (0.1485)	0.748* (0.1475)	0.942 (0.2289)	-	1.169 (0.1615)	1.230 (0.2381)	0.892 (0.1517)
DISIN	1.193* (0.0707)	1.222* (0.0741)	1.471* (0.123)	1.140 (0.1154)	1.102 (0.730)	0.936 (0.1086)	0.756* (0.0746)
COMM	1.262* (0.0737)	1.180* (0.0780)	1.226 (0.1107)	1.154 (0.1104)	1.084 (0.768)	0.823 (0.1031)	0.930 (0.0647)
COMP	1.366* (0.1515)	1.589* (0.1501)	1.108 (0.2245)	1.046 (0.1759)	1.431* (0.1558)	0.952 (0.2136)	1.411* (0.1490)
ISCLIM	0.999 (0.1316)	0.942 (0.1369)	0.693 (0.2196)	0.474* (0.1935)	0.774 (0.1499)	1.028 (0.2039)	0.870 (0.1354)
PUBQTY	0.999 (0.0147)	0.993 (0.0142)	1.017 (0.0194)	1.004 (0.0186)	1.029* (0.0127)	0.927* (0.0308)	0.952* (0.0150)
COAU	-	-	1.011* (0.0058)	1.018* (0.0055)	-	-	-
UNREQ	-	-	-	-	-	1.048* (0.0131)	-
PUBREQ	-	-	-	-	-	-	1.005 (0.0038)
PRAGE	0.978 (0.0182)	0.967 (0.0190)	0.935* (0.0295)	0.967 (0.0255)	0.957* (0.0194)	0.972 (0.0241)	1.035 (0.0183)
TEAMSIZE	1.015 (0.0091)	1.016 (0.0086)	1.014 (0.011)	0.999 (0.0114)	0.999 (0.116)	1.009 (0.0189)	1.000 (0.0094)
FEMALE	0.880 (0.2614)	0.752 (0.2641)	0.583 (0.399)	1.025 (0.407)	0.845 (0.2867)	0.536 (0.3794)	0.836 (0.2415)
RANK (full professor = ref.)	1.278 (0.3545)	0.897 (0.3572)	1.224 (0.5258)	1.434 (0.5144)	0.805 (0.347)	0.708 (0.537)	0.639 (0.3265)
N	209	209	209	209	209	209	209
Pearson Chi Square (value/df)	1.637	1.585	1.116	1.150	1.858	2.324	4.258
Omnibus test (sig.)	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Note: Estimates shown as IRRs (incidence rate ratios); standard errors in parentheses
* $p < 0.05$

In accordance with our first group of hypotheses, involvement in academic-industry knowledge transfer is associated with a greater extent of knowledge sharing restrictions. Yet, the results differ depending on the academic-industry knowledge transfer form in question. Industry collaboration is associated with all forms of knowledge sharing restrictions, except with the extent of denials of unpublished data and materials. For every unit increase in the level of interaction with industry (e.g., consulting the business sector, holding presentations for the industry or engagement in industry-sponsored research), there is a 3% increase in publication content restrictions (incidence rate), 3% increase in publication timing restrictions (delays), 2% increase in content restrictions with co-authored publications, 2% increase in timing restrictions with co-authored publications, 2% increase in sharing restrictions during presentations and 1% increase in restrictions with sharing published data and materials. Thus, with the exception of sharing unpublished data and materials, we show support for Hypothesis 1a.

Results regarding intellectual property-based academic-industry knowledge transfer activities are less straightforward: for a unit increase in the level of these activities, there is a 17.5% increase in co-authored publication timing restrictions and an 11% increase in the level of sharing restrictions during presentations, supporting Hypothesis 1b. Surprisingly, intellectual property-based academic-industry knowledge transfer is negatively associated with restrictions with sharing unpublished and published data and materials, which means that the more the researchers are involved in patenting and licensing activities, the less they deny access to their research results to other academic researchers. IP-based activities are shown not to be significantly associated with the other three forms of knowledge sharing restrictions, publication content and timing restrictions as well as content restrictions with co-authored publications.

Involvement in academic entrepreneurship-related activities is significantly associated only with restrictions with sharing published data and materials, with 8.5% more restrictions for every unit increase in the level of business activities. Thus, our results partially support hypothesis 1c, as the significant coefficients are obtained for published, but not for unpublished knowledge sharing.

Of all independent variables measuring motivators to share, personal outcome expectations are shown to be the most important predictor of knowledge sharing restrictions: in accordance with our hypothesis 3a, they are negatively associated with publication content restrictions (23% decrease in the level of restrictions for every unit increase), publication timing restrictions (25% decrease), content restrictions with co-authored publications (33% decrease), timing restrictions with co-authored publications (45% decrease) and sharing restrictions during presentations (23% decrease). Yet, the coefficient of the personal outcome expectations variable in the model predicting restrictions with sharing published data and materials points to the opposite effect: for a unit increase in personal outcome expectations, there is a 30% increase in the level of restrictions. Interestingly, the community-related outcome expectations variable is not significantly associated with any of the forms of knowledge sharing restrictions, which is why we cannot support Hypothesis 3b.

Trust is significantly negatively associated with two forms of knowledge sharing restrictions (partial support for Hypothesis 2): timing restrictions with co-authored publications (42% decrease in the level of restrictions for every unit increase) and sharing restrictions during presentations (19.5%), whereas reputation is only significantly associated with publication timing restrictions (25% decrease), which is why we are not able to support Hypothesis 4.

Scientific values are also shown to be important predictors of some forms of knowledge sharing restrictions but not invariably. Whereas disinterestedness is positively associated with publication-related knowledge sharing restrictions (content, timing and co-authored publications content), such relationship is negative in the case of restrictions with sharing published data and materials.

Communalism is also, surprisingly, positively associated with publication-related knowledge sharing restrictions. Therefore, we cannot support hypotheses 5a and 5b.

In accordance with previous studies and in line with our Hypothesis 6, the higher the perception of competitiveness of the research field, the higher the level of knowledge sharing restrictions in most of the examined dependent variables: for example, for a unit increase in the competition variable, there is a 43% increase in sharing restrictions during presentations. Institutional sharing climate is shown to be significantly associated only with timing restrictions with co-authored publications, where the more supportive the institutional environment (supervisor and colleagues) towards sharing, the fewer are the restrictions with this form of sharing. Thus, we show partial support for Hypothesis 7.

Control variables included in regression (gender, academic rank and research group size) are not significantly associated with knowledge sharing restrictions. Professional age is significantly associated only with sharing restrictions during presentations and content restrictions with co-authored publications, where the older the researchers, the less they restrict knowledge sharing. Scientific output, measured by the number of publications in the past five years, is significantly positively related to the extent of sharing restrictions during presentations and significantly negatively related to restrictions with sharing unpublished and published data and materials. Finally, in accordance with our expectations, the more requests the researchers receive for unpublished data and materials, the greater the level of restrictions with sharing such data and materials. Also, the greater the percentage of articles published in co-authorship with other academic researchers, the greater the level of content and timing restrictions with co-authored publications.

3.5 Discussion and conclusions

Our study yields several important insights. We show an overall positive relationship between involvement in academic-industry knowledge transfer and knowledge sharing restrictions. The more the academic researchers involve in academic-industry knowledge transfer, the more they are likely to restrict open and free knowledge sharing with other members of the academic community. This supports findings from prior research (Blumenthal et al. 1997, Louis et al. 2001, Campbell et al. 2002, Walsh et al. 2007). Going beyond what we have known so far, we show that a nature of such relationship depends on the type of academic-industry knowledge transfer activity and form of knowledge sharing in question. When it comes to industry collaboration, the positive relationship with knowledge sharing restrictions is straightforward. Researchers that conduct joint projects with the industry, publish together with industry researchers or consult the business sector are more likely to omit relevant content from their publications and publications in co-authorship with other academic researchers, delay publishing of their publications and publications in co-authorship with other academic researchers, exclude relevant content during the public presentations of their research results and deny requests for access to their published data and materials. This is because contracts with industry request confidentiality provisions.

In line with our hypothesizing, we find that relationship between intellectual property-based academic-industry knowledge transfer activities and sharing restrictions (in terms of co-authored publication timing restrictions and public presentations) is significant and positive. We contribute this finding to the fact that the current legislative framework in most countries declares that the inventions at work are owned by the employer. Most of the academic institutions have formally established TTOs, which are responsible for the receipt of invention disclosures, evaluation of the commercial potential of inventions, suggesting the appropriate intellectual property protection mode and management of intellectual property, including the negotiations with industry. Our reasoning is that, if these TTOs are relatively inexperienced, it takes them more time to review the disclosed research results, assess their patentability and prepare the patent application. During this time the researchers must keep their findings undisclosed to the public, which is why they encounter delays with the publishing of their research results and restrictions with the contents of their public presentations. Somewhat unexpected are the results for restrictions with sharing unpublished and published information, data and materials, which have significant and negative coefficients. One possible explanation for such findings is that only a minor part of the academic researchers' research results is covered by patents or licensing agreements or under consideration for intellectual property protection, which is why the access to their research results, data and materials is generally not negatively affected by involvement in intellectual property-related knowledge transfer activities.

We also show that the involvement in academic entrepreneurship-related activities is significantly associated solely with restrictions with sharing published data and materials. This may be due to the fact that when researchers actively engage in commercial activities they have less time to respond to requests from other academic researchers for their research materials and data. They are also more likely to start charging the price for obtaining their products (in the case they sell them directly through their company or indirectly, via distributors), so these products are generally no longer accessible on a free-of-charge, collaborative basis to other academic researchers.

Importantly, the role of the institutional context must always be taken into account when discussing the study results (Walsh and Huang 2014). In our study, we show that the majority of life scientists in Croatia have had experience with academic-industry knowledge transfer, but the extent of involvement in such activities has been very low. As previously discussed by Radas and Vehovec (2006), although Croatian scientists show strong interest in the collaboration with industry, the perceived obstacles in terms of the organization of academic life (e.g., industry collaboration is not included in the criteria for academic promotion) prevent them from more actively engaging in interactions with the business sector.

Research results are in general difficult to disseminate because of the confidentiality provisions in contracts with industry, which discourages them from more actively engaging in interactions with the business sector. We show that life scientists mostly interact with industry through consulting, collaborative publications and presentations for the business sector. At the same time they have particularly poor level of experience with intellectual property-related knowledge transfer activities, such as negotiations over the rights to intellectual property, patenting and licensing. As discussed by Gerbin and Drnovšek (2016), despite the existing legislative and policy framework, in ex-socialist countries as Croatia is, there is still a weak awareness about the importance of intellectual property rights and their exploitation in the academic community. Academic entrepreneurship and business activities of Croatian academic researchers are also very rare, which is not surprising considering that they spend most of their working time in traditional academic activities of research, teaching and work with patients, the latter in the case of life scientists working in health institutions.

When it comes to other determinants of knowledge sharing restrictions, personal outcome expectations are shown to be the negative predictor of most of the investigated forms of sharing restrictions in our study: publication content restrictions, publication timing restrictions, content restrictions with co-authored publications, timing restrictions with co-authored publications and sharing restrictions during presentations. In other words, the more the researchers find that by sharing they gain personally through the feelings of happiness, accomplishment and closer ties with other researchers in the academic community, the less they will engage in knowledge sharing restrictions. It is difficult to explain the significant and positive coefficient when it comes to restrictions with sharing published data and materials, so additional research is needed to confirm the results obtained in the context of this study. Interestingly, community-related outcome expectations do not seem to explain any of the forms of restrictions in knowledge sharing. In other words, researchers' perceptions of the consequences that sharing behavior may produce in the academic community are not associated with their sharing decisions, the relationship which does not hold in case of sharing consequences they expect for themselves.

One of the most interesting findings of our study concerns the relationship between scientific values and knowledge sharing restrictions. Although we expected that the more the academic researchers were inclined to the traditional scientific norms of disinterestedness and communalism, the less likely are to involve in different forms of knowledge sharing restrictions, the empirical findings are mixed. Disinterestedness is shown to be positively associated with publication-related knowledge sharing restrictions (content, timing and co-authored publications content), and negatively related with restrictions with sharing published data and materials. This finding is intuitive – when a researcher is not interested in the personal gains resulting from research, she/he will have no problems with free and open sharing of their published research results. Many science funding agencies (for example, US National Institutes of Health) actually oblige researchers to openly share research tools developed using public funds for research. However, the explanation for the former results is more difficult. It is possible that scientists that scored higher on the statement "Worrying about possible commercial applications distracts one from doing good research" in the survey actually find themselves to be very competitive and engage in knowledge sharing restrictions with the content and timing of publications in order to protect their scientific lead in the field – if they wish to get more time to generate additional research results that will increase their chances for publishing in a top journal. Moreover, surprisingly, communalism is shown to be positively associated with publication-related knowledge sharing restrictions. Again, scientists who prefer citation scores to financial incentives (e.g. increase in salary) associated with commercial exploitation of their intellectual property are likely to be more inclined to knowledge sharing restrictions with regards to the publication content and timing for reasons related to scientific competition.

Another interesting result is that trust does not seem to be significantly related to the sharing restrictions with direct, informal exchange of unpublished and published information, data and materials. When researchers do not generally trust the knowledge requesting parties, either because of negative past experiences or lack of personal acquaintance, they are less willing to respond to requests. Instead, trust is shown to be significantly related with timing restrictions in case of co-authored publications and sharing restrictions during presentations, which supports our predictions. For example, if academic researchers generally perceive an academic community as truthful and reliable, they are less likely to engage in sharing restrictions during public presentations of their scientific results as they trust their audience. Reputation among peers does not seem to be an important predictor of knowledge sharing restrictions in the academic community investigated in our study since majority of coefficients is not significant. The more importance the academic researchers attach to the number of awards and publications, their impact and citations, the less they will delay the publishing of their research results.

Concerning other contextual factors, scientific competition has been identified in our study as an important predictor of sharing restrictions when it comes to publishing, public presentations and direct sharing of published data and materials with other researchers. Although we expected that institutional climate in support of sharing is likely to be negatively related to knowledge sharing restrictions with the exchange of published and unpublished knowledge (information, data and materials), content and timing of publications co-authored with other academic researchers, results of the empirical analysis support significance of relationship in case of timing restrictions with co-authored publications. It seems that in the context of our study the sharing behaviour of the respondents' immediate supervisors and colleagues in the department mostly does not have any significant role in their sharing decisions.

Finally, it is also interesting to take a look at the results of the study when it comes to control variables. The literature from the management area shows the positive relationship between the level of professional expertise and knowledge sharing (Wasko and Faraj 2005). Our results for the scientific output, measured by the number of publications in the past five years, show that the more the researchers publish, the more they will restrict sharing during public presentations of their research results. Less productive researchers will perhaps be more open due to the need for feedback on their work in progress from the audience at conferences. On the other hand, the more the scientists publish, the less they will deny other researchers' direct, informal requests for unpublished and published data and materials. This is in contrast with some previous studies, which have shown that more productive scientists are less likely to respond to requests due to the increase of the opportunity cost of compliance, or time limitations (Blumenthal et al. 1997, Campbell et al. 2000, Campbell et al. 2002, Walsh et al. 2003, Walsh et al. 2007, Hong and Walsh 2009, Shibayama et al. 2012). We do not find a significant relationship between scientific productivity and sharing restrictions related to publishing. In this regard, previous studies also do not reach definitive conclusions, as they show both the positive (Blumenthal et al. 1997, Shibayama 2012) and negative (Haeussler 2014) relationship of productivity with publication withholding.

The relationship of academic rank and knowledge sharing restrictions has not been significant in our study. Previous studies have produced mixed results: while some indicate that untenured faculty is less likely to directly share materials and data than tenured faculty (Haeussler 2014), others find no significant relationship between sharing restrictions and respondents' academic rank (Blumenthal et al. 1997, Campbell et al. 2000, Louis et al. 2001). In contrast, Shibayama (2012) finds that full professors are more likely than associate professors to deny material transfer to colleague researchers. Also, previous studies have mostly found no significant effect of academic rank on knowledge sharing with the general audience (Shibayama 2012, Haeussler 2014). Yet, Blumenthal and colleagues (1997) find that higher academic rank is associated with publication delays. We explain this conflicting evidence by the differences in sample sizes, scientific fields examined and cultural settings in each of these studies.

Knowledge sharing restrictions could also be related to the size of the researchers' teams or the number of their direct subordinates, however, in our study, none of the coefficients is significant. Haeussler (2014) yields mixed results for the number of team members, with the positive relationship with specific (private) sharing and negative relationship with general (public) sharing. She explains the results with the larger need of researchers in smaller teams to disseminate their knowledge generally in order to collect feedback that bigger teams can collect within their laboratory.

Finally, as reported in the Results section, professional age is significantly associated only with sharing restrictions during presentations and content restrictions with co-authored publications, where the older the researchers, the less they restrict knowledge sharing. This is explained by the fact that scientists with longer professional track record will normally be more deeply embedded into international scientific networks and thus less likely to experience non-compliant behaviors regarding sharing (Campbell et al. 2000). At the same time, the possibility of encountering problems or restrictions with different dimensions knowledge sharing is greater for younger researchers, who had less time to develop networks of professional contacts and build their intellectual and social capital and thus have lower recognition in the scientific community. On the other hand, one can also argue that older researchers may have less motivation to unconditionally contribute to the scientific community (Shibayama 2012) as well as be more susceptible to various "games" in sharing practices, moderated by scientific competition. The institutional environment, characterized by more or less pressure for scientific productivity, could moderate this relationship.

Overall, our study has several important implications for the theory and practice. The main theoretical contribution of the study is that it conceptualizes and tests academic-industry knowledge transfer-knowledge sharing relationship by considering the heterogeneity of different forms of academic knowledge transfer and knowledge sharing. The study also contributes to the body of knowledge on determinants of sharing restrictions among academic life scientists, as it takes into account a broad range of individual and context-specific predictors of knowledge sharing restrictions. The obtained results have important policy implications as they show that not all forms of academic-industry knowledge transfer are associated with all types of knowledge sharing restrictions as well as that different forms of knowledge sharing restrictions are predicted by different individual and contextual factors. What we also show is that even in the settings with a relatively low level of engagement of researchers in academic-industry knowledge transfer, these activities can be positively associated with knowledge sharing restrictions. However, even more importantly, the results show that when examining the barriers to open knowledge sharing in the academic communities, researchers and policy makers should not consider only the role of interactions of academic researchers with industry and their commercial activities. Instead, they should also take into account other factors, such as personal characteristics of researchers, their motivations and values, as well as context-specific determinants of knowledge sharing restrictions. Such approach will facilitate the designing of science policies that stimulate academic-industry knowledge transfer and at the same time support the characteristics of the open science system.

3.6 Limitations and future research avenues

The first limitation of the study refers to the use of interviews and questionnaire survey for the empirical part of our research on academic-industry knowledge transfer-knowledge sharing interactions. The use of questionnaire surveys represents a less objective method when compared to scientometrics, due to its reliance on self-reporting as well as the absence of the introduction of a longer time dimension in the analyses (Azoulay et al. 2006). Scientometrics have been used extensively in the literature relying on co-authorship of scientific papers to analyse knowledge exchange among researchers, both within and across individual companies and academic research groups, as well as to investigate social networks of academic scientists (Murray and Stern 2007, Rosell and Agrawal 2009). On the other hand, the use of questionnaire surveys and interviews enables better insights into causes and effects of particular behaviours (Campbell et al. 2002, Walsh et al. 2007).

The second limitation of our study relates to the potential reverse causality problem in the empirical testing of determinants of knowledge sharing restrictions in the academic community. Following the econometric analysis, we report the associations, and not the causal relationships, between different forms of academic-industry knowledge transfer, individual and contextual factors, and different forms of knowledge sharing restrictions. We mitigated this problem to a certain extent by also directly asking our survey respondents about the causes of different restrictions in their knowledge sharing behaviors. The obtained results were presented in this article and complement the analysis based on correlations between dependent and independent variables. Similar studies in the field have also identified this problem. Gaughan and Corley (2010) investigate the impact of university research center-affiliation on industrial activities and acknowledge the unknown causal relationship between these two variables as a limitation of the study. They justify their approach by pointing to other studies of the topic, which have had difficulty with estimating the endogeneity bias due to inexistence of longitudinal data that would allow specifying temporal priority. Some studies succeed in specifying temporal priority by using only the most recent experiences of survey respondents as a measure of knowledge sharing restrictions. For example, Walsh and colleagues (2007) use regression analyses to test the reasons for non-compliance with requests for materials by assessing the factors (including the patent status of the requested material) conditioning whether a respondent's most recent request for materials was satisfied. In our study, we decided not to consider only the most recent experience with knowledge sharing, but instead collected the data from respondents that refer to the period of last five years. This enabled us to get insights into the general patterns of sharing behaviors of academic researchers. Future empirical research should consider temporal priority in the assessment of the impact of academic-industry knowledge transfer, individual and contextual factors on different forms of knowledge sharing restrictions in academia. Moreover, considering that our quantitative study is based on a single sample from Croatia, the model should also be tested in other national contexts. Finally, future studies could consider different types of knowledge when assessing the relationship between academic-industry knowledge transfer and knowledge sharing restrictions. In particular, a distinction between exchange of explicit (codified) and tacit knowledge could further contribute to our understanding of determinants of knowledge sharing restrictions in academic communities.

4 HOW DO UNIVERSITY IPRS AND R&D FUNDING MECHANISMS AFFECT INNOVATION PERFORMANCE IN THE HEALTHCARE BIOTECHNOLOGY INDUSTRY? EVIDENCE FROM EUROPE AND THE USA[4]

4.1 Introduction

Recently, an increasing research interest has been directed to the healthcare biotechnology industry because it has been seen as an important driver of economic growth (Powell et al. 1996). In this industry, new value is created through a lengthy, costly and risky process of research and development (R&D), clinical trials, regulatory approvals and final commercialization of findings. The success of this process depends on valuable inputs provided by key stakeholders - universities, venture capitalists, pharmaceutical firms, governments and emerging firms (Ebers and Powell 2007). Previous studies of the determinants of innovation performance in biotechnology, although substantial, have mostly been devoted to investigating collaborative networks and spatial dimensions of innovation (Powell et al. 1996, Owen-Smith et al. 2002). Table in Appendix O of the paper summarizes the key findings in this research area. We outline key dependent variables analysed and pertinent findings.

In this paper, we extend the existing research on biotechnology innovation by focusing on three groups of factors that have been suggested in prior research as important: university-derived intellectual property rights (IPRs), public investments into knowledge base at universities and other research institutions and commercialization funding mechanisms.

There are two main contributions of the study. First, in order to develop an overall overview of driving forces of innovation performance in healthcare biotechnology, we compare the dynamics in the US and the European biotechnology sectors. Our comparative analysis is conceptually grounded in neoclassical financial theory and the theory of innovative enterprise (Lazonick and O'Sullivan 2000). The predominant neoclassical financial theory assumes shareholder value maximization as a guiding principle in doing business while technologies and market conditions are given constraints in the system. The newer theory of innovative enterprise builds on the resource-based view foundations to propose that enterprises actively use R&D investment strategy and organizational structure to transform technological, market, cognitive, and behavioural conditions to generate performance outcomes, such as innovations. It offers an alternative, critical view on innovation creation, by investigating how the capital markets have profiled strategic priorities of biotech companies (Andersson et al. 2010). The rationale for choosing these two divergent theories in the comparative analysis is to allow for the conjecture that each highlights a specific aspect of the biotechnology business development, while applied together, they contribute to a better understanding of the whole process. We make contribution by using the two theories as complementary views in assessing how university-generated intellectual property rights, public investments into knowledge base and business funding mechanisms affect biotechnology innovation performance.

Second, in this study we combine findings from the neoclassical financial theory and the theory of innovative enterprise with statistical data in comparing the US and the European biotechnology

[4] This chapter of the dissertation was presented as a working paper at the DRUID 2012 conference in Copenhagen. The paper was published in 2013 in Periodicum Biologorum (115(1); 79-95), peer-reviewed journal, Web of Science indexed (WoS, IF 2013 = 0,18, 5-year IF = 0,243, Q4).
The paper was written in co-autorship with Prof. Dr. Mateja Drnovšek.

industries. Although the widely accepted US biotechnology business model was questioned after the collapse of speculative markets in the financial crises of 2001 and 2008-2009, recently there have been clear tendencies to emulate the US model in the European biotechnology industry. By identifying key determinants that drive and motivate the biotechnology innovation performance, we develop specific managerial implications regarding success factors of companies that compete in European environments.

The paper is structured as follows. We begin by a short overview of the emergence of biotechnology industry. We review the impact of intellectual property rights on commercial exploitation of inventions, taking into account both the growing interest in the academic institutions' role in this process and ongoing debates concerning its wider repercussions for the progress of science. We continue by focusing on the role of knowledge base investments in biotechnology innovation. Finally, we provide an overview of commercialization funding mechanisms and compare the US and the European healthcare biotechnology industries through the conceptual lenses of the neoclassical theory and the theory of innovative enterprise. The paper concludes by discussion of our main findings and implications to practitioners.

4.2 The emergence of biotechnology industry

Biotechnology industry emerged in the USA in the late 1970s, preceded by the discovery of the double helix in 1953. It quickly spread to the UK, continental Europe and Asian-Pacific nations. Healthcare is a specific domain of research within biotechnology. It is based on complex macromolecules (recombinant proteins, genetically engineered vaccines; therapeutic monoclonal antibodies; and nucleic acid based therapeutics) derived from recombinant DNA technology, cell fusion, or processes involving genetic manipulation (Pharmahorizons 2001). What makes healthcare biotechnology industry different from others is strong reliance on resources of multiple parties in commercializing the life science research results. The focus of this study is on the specific healthcare segment of biotechnology industry.

The reasons for the commercial attractiveness of the healthcare biotechnology industry are multiple: first, innovative technologies of genetic, protein, and cell and tissue engineering hold great promise in many biomedical application areas. Venture capitalists originally considered the biotechnology industry to have both attractive market potential and lasting importance (Dibner et al. 2003) due to steadily aging population and expected increasing demand for age-related pharmaceuticals and therapeutics. Also, large pharmaceutical companies are less effective innovators than biotechnology firms due to spending more money on R&D, yet putting fewer drugs into the pipeline and thus, biotechnology companies help fill the need for innovation (Howell et al. 2003). The interests of investors in the biotechnology industry have in the past decade shifted from genomics, proteomics and bioinformatics companies towards companies that can produce therapeutics, as opposed to those offering tools and databases (Dibner et al. 2003). In this respect, recent years have also been marked with the shift of interest from small-molecule "blockbuster" therapeutic products towards niche products, including orphan drugs (drugs which target rare diseases) and vaccines for developing countries, based on recombinant proteins, monoclonal antibodies and stem cells technologies (Mittra et al. 2011).

As shown in Table 12, in 2010 Europe had more biotechnology companies than the United States. However, the United States had almost as twice as many publicly listed companies; more than twice as many employees, spent more than three times more on R&D and generated three times as much revenue in total (Ernst&Young 2011). According to the same report (Ernst&Young 2011), "commercial leaders" (companies that had 2009 revenues exceeding US$500 million) in the USA had positive net income, whereas the other companies mostly had negative income; however, the latter had higher growth rates (13%) when compared to the former (9%). Interestingly, the commercial leaders increased R&D spending by 7% in the respective period, while the other companies reduced R&D by 1%. Thus, emerging companies, which have historically been a vital source of innovation, started decreasing their R&D expenditures. In Europe, both commercial leaders' and other companies' growth was 12%; however, both groups increased R&D expenditures (commercial leaders for 7% and other companies for 4%). At the same time, net income increased for the commercial leaders, while for the other companies it continued decreasing.

Table 12. Overview of the US and European healthcare biotechnology in figures, 2009-10

	USA (US$b)			Europe (US$b)			Croatia (US$b)		
	2010	2009	% change	2010	2009	% change	2010	2009	% change
Public company data									
Product sales	52.6	48.1	9%	n/a	n/a	n/a	0.015	0.029	-47%
Revenues	61.6	56.2	10%	17.26	15.40	12%	0.016	0.029	-43%
R&D expense	17.6	17.1	3%	4.51	4.29	5%	n/d	n/d	n/d
Net income (loss)	4.9	3.7	33%	(0.61)	(0.62)	-2%	(0.002)	(0.001)	-63%
Market capitalization	292.0	271.6	8%	78.89	62.94	25%	n/d	n/d	n/d
Number of employees	112,200	106,600	5%	49,060	48,660	1%	344	360	-4%
Financings									
Capital raised by public companies	16.3	13.5	21%	2.47	2.78	-11%	n/d	n/d	n/d
Number of IPOs	15	3	400%	10	3	233%	0	0	0%
Capital raised by private companies	4.4	4.6	-3.2%	1.36	1.05	29%	n/a	n/a	n/a
Number of companies									
Public companies	315	314	0.3%	172	167	2%	1	1	0%
Private companies	1,411	1,389	2%	1,662	1,675	-1%	1	1	0%
Public and private companies	1,726	1,703	1%	1,834	1,842	-0.5%	2	2	0%

**The data for Croatia are also shown, for illustrative purposes.*
Source: Adapted from Ernst & Young (Ernst&Young 2011), Croatian Competition Agency (2011), EuropaBio (Critical-I-comparative-study-for-EuropaBio 2006) and Venture Evalutation (EuropaBio-VentureValuation 2009)

Most European biotechnology companies are micro or small, research-intensive firms, smaller than their US counterparts. We argue that such differences are partially due to a significantly greater availability of risk capital and debt provision in the USA as well as a longer tradition of the US biotechnology and venture capital industry. Also, the lower availability of venture capital in Europe than in the USA has largely been due to the under-development of European stock markets that would list the young entrepreneurial firms, and consequently, a lack of "exit strategy" possibilities for investors in firms (Dibner et al. 2003).

Based on the in-depth review of literature on driving forces of innovation in the healthcare biotechnology industry we identified three gaps in the existing body of knowledge. Little is known about how intellectual property rights system facilitates innovation performance (Orsenigo et al. 2006). Intellectual property rights (in what follows IPRs) have gained particular attention in the literature on biotechnology innovation after they have been widely used in new areas of scientific discoveries - life forms (such as genetically modified organisms) and new actors (academic and other non-profit research institutions). However, studies that explore how patenting activities at academic institutions produce innovations yield mixed findings. Most of the studies implicate that "locking up" of an increasing number of upstream life science inventions in patents negatively affects scientific progress and innovation (Dasgupta and David 1994, Heller and Eisenberg 1998, Henderson et al. 1998, Nightingale and Martin 2004, Orsenigo et al. 2006, Murray and Stern 2007). These findings allude to potential deficiencies in the present IPR system as an innovation-driving force at universities.

Although it is believed that innovation in the biotechnology industry is facilitated through public investments into knowledge base at universities and other research institutions, there is only limited evidence in support of this assumption (Toole 2012). Toole (2012) points to the scant empirical verifications and finds that basic research funded by the US National Institutes of Health (NIH) has a significant and economic effect on the pharmaceutical innovation in the form of entry of new therapeutics to the market.

Finally, only few studies try to capture the relationship between funding mechanisms and innovation performance in healthcare biotechnology industry (Coriat and Orsi 2002, Andersson et al. 2010, Lazonick and Tulum 2011). Most of them build on the fact that biotechnology companies have been characterized by the overall lack of innovations entering the market and subsequent profitability, and at the same time "bubbling" capital injections, predominantly in the USA over the past decade (Pisano 2006).

4.3 The role of university-assigned intellectual property rights in biotechnology innovation performance

The adoption of the Patent and Trademark Amendments of 1980 in the USA (Bayh-Dole Act) is historically viewed as an event that marked the beginning of the global upsurge of knowledge and technology transfer activities from academic and other non-profit research institutions to the business sector. The Bayh-Dole Act gave non-profit institutions and small businesses the privilege to retain the property rights to inventions deriving from the state-funded research and hence relaxed government control over the commercial use of the results of publicly-funded research (Lazonick and Tulum 2011).

This new legislation was later adopted in most countries in Europe (Geuna and Nesta 2006), although not with the same clarity: whereas in the USA ownership of university-generated IPRs obviously belongs to the university, some countries in Europe (for example, Austria, Denmark, Finland, Germany and Norway) traditionally had the so-called professor privilege, which gives university employees the IPRs to their inventions. Even though most of these countries in the 1990s and 2000s changed their legislation by assigning ownership to the university (see Table 13), university ownership has usually been weakly enforced, thus in reality leaving the decision on ownership to be negotiated (Crespi et al. 2010).

Table 13. Ownership of IPRs at European universities

Country	Institution	Inventor	Country	Institution	Inventor
Austria	♦ (2002)		Italy		♦ (2001/2005)
Belgium	♦ (1997/98)		The Netherlands	♦ (1995)	◊
Czech Republic	♦ (1990)		Norway	♦ (2002)	
CROATIA	♦ (1996)		Poland	♦ (2000)	
Denmark	♦ (2000)		Slovak Republic	♦ (2000)	
Finland	♦ (2007/2010)	◊	Slovenia	♦ (2006)	
France	♦ (1982)		Spain	♦ (1986)	
Germany	♦ (2002)	◊	Sweden		♦ (1949)
Greece	♦ (1995)	◊	Switzerland	♦ (1911)	
Hungary	♦ (2006)		United Kingdom	♦ (1977/1985)	

♦ Ownership assignment of inventions.
◊ Inventor ownership is assigned on certain types of inventions.
In brackets: years in which last change in regulation took place.
Source: Adapted from Geuna and Rossi (2011)

The expansion of proprietary interests and commercial considerations to new actors and new scientific fields (Jonjic 2010) has been evaluated as desirable and appropriate for both the academic and the biotech industrial partners. The benefits include the expansion of basic research funding sources, less strict borders between basic and applied research and facilitated transfer of knowledge that supports the creation and growth of new technology firms (Mowery and Ziedonis 2002). It was argued that many state-funded inventions would be left unexploited unless the conditions for the transfer of intellectual property were made less restrictive (Lazonick and Tulum 2011).

The most important challenge associated with the current IPR regime relates to patenting and exclusive licensing of fundamental technologies or upstream discoveries with broad application in life sciences. Dasgupta and David (1994), Murray and Stern (2007) and others argue that such practices can restrict, and not stimulate future innovation, measured by the number of new useful products for human health. With an increasing body of upstream knowledge covered by patents, they claim, the costs of research increase, access to technologies is hindered and free flow of scientific knowledge needed for subsequent research becomes compromised. What is more, these changes can lead to redirection of research efforts towards other priorities. This concern has been captured in the phrase “the tragedy of the anti-commons”, which has been used extensively to point to the problem of existence of multiple holders of rights to separately patentable inputs which combined form one product or resource (Heller and Eisenberg 1998). Exclusive licensing of broadly useful patented research tools seems to be particularly problematic from the social welfare perspective. If a single patent holder exploits the invention himself exclusively, it limits new entrants who would compete to produce more efficient and cheaper medicines (Lazonick and Tulum 2011), leaving the research and commercial potential of an upstream discovery in subsequent research largely unexploited. Alternatively, society benefits more if such discoveries are made broadly available (Walsh et al. 2003).

Other challenges related to the expansion of IPRs and commercial activities at academic institutions are discussed by Henderson and colleagues (1998), Kenney and Patton (2009) and others. These authors argue that legal systems introduced to encourage academia-industry knowledge transfer indeed increased the number of university-assigned patents in the USA.

However, one of the consequences of the increased demands for patenting is a growing number of low quality or commercially irrelevant patents in hands of university technology transfer offices. Building from these findings we contend that the change in the IPR regime towards patenting of life forms and university-assigned patenting has facilitated technology transfer from universities to the private sector, mostly through the creation of new biotechnology companies. What is more, the strong dependence of the healthcare biotechnology sector on science base, manifested primarily through monetization of IPRs (Pisano 2006, Andersson et al. 2010), has increased its attractiveness to venture capitalists and private equity investors. Since the development of new biopharmaceutical products is a lengthy and unpredictable process, the biotechnology sector has usually been marked as critically dependent on the enforcement of patents as a means of protecting the future economic returns of inventions. However, we find that despite the positive impact on industry expansion, the new IPR regime does not necessarily increase biotech innovative performance (see Table Appendix P for the summary of key findings in the literature). In this sector, IPRs are used by new companies to attract established companies, which in return enter into alliances with them or acquire them. IPRs thus enable young companies to send positive signals to investors, which are essential to obtain funding or quickly exit to capital markets through initial public offerings (IPOs), despite the fact that they typically lack products close to the market. This widely accepted operating principle may not go along with increased innovation performance. Indeed, recent studies show that strong intellectual property protection is a weaker determinant of successful development of innovative products than innovative capabilities of biotechnology firms to translate new technologies into innovative products and processes (Orsenigo et al. 2006). The critical importance of patents as a means of providing market advantage declines with the longer product development timelines, due to their limited term. This poses the need for development of capabilities of companies to absorb new technologies and to transform them into innovative products and processes. In addition, it was shown that the change in the IPR regime towards patenting of life forms and university patenting leads to “locking up” of an increasing number of broadly used inventions in patents, not necessarily commercially valuable. This increases the costs of subsequent research and potentially restricts innovation.

The described findings suggest some deficiencies in the present IPR system as a biotech innovation-driving force in the USA and Europe. In the final section we propose several solutions that, we argue, might overcome the problems related to misaligned interests of academic researchers-inventors, universities, technology transfer offices and licensees-biotechnology companies.

4.4 The role of public investments into knowledge base in biotechnology innovation

Biotechnology requires both the support of large and small enterprises that supply the critical inputs required in commercializing the industry's high-quality health products at low unit costs and a unique knowledge base that depends on intense interactions among scientists in research institutes and business enterprises (Lazonick and Tulum 2011). Despite the fact that many scholars acknowledge the importance of public investments into science base at universities and other research-performing organisations for biotech innovation performance (Chandler 2005), very few have shown empirical evidence in support of this claim (Toole 2012). An overview of the key studies investigating this relationship is provided in Table in Appendix Q. The results generally indicate a high reliance of the biotechnology industry on public science. A particularly challenging discussion is presented by Angell (2004) who finds that more than one-third of the medicines marketed by big “pharma” are either licensed from universities or small biotech companies and that those few therapeutics that are truly innovative are usually based on taxpayer-supported research done in non-profit academic medical centres or at the National Institutes of Health.

Furthermore, Stevens and colleagues (2011) find that 9.3% of medicines approved by the US Food and Drug Administration (FDA) in the last 40 years were discovered by public sector research institutions. According to this view, the bearers of innovative activities in healthcare biotechnology are institutions funded by governments, which implies that biopharmaceutical companies overstate the development costs of new medicines, and consequently, product prices. However, one must not neglect the fact that a substantial part of experiments required to develop the efficient medicine, including the clinical trials, is done by the private sector.

In what follows, the US and the European practices of public investments into life science base are compared. The US National Institutes of Health (NIH) have been the major and, historically viewed, stable provider of funding for basic biomedical research at academic research laboratories, government research institutes and small businesses worldwide. Unlike venture capital and stock market investments, which have fluctuated widely from year to year, NIH funding increased in nominal terms in every single year from 1970 to 2009, except for a small decline in 2006 (Lazonick and Tulum 2011). In 2011, NIH provided funds for more than 40.000 competitive research grants and more than 325.000 research personnel at more than 3.000 research institutions and small businesses (Collins 2011). In 2007, the investments by NIH represented 27% of the total biomedical research expenditures in the USA, making it the second largest contributor to biomedical research, next to industry (58%) (Dorsey et al. 2010). These investments are indispensable for the development of biotech industry knowledge base and consequently, responsible for venture capital and public equity flows into the sector (McMillan et al. 2000, Lazonick and Tulum 2011).

Unlike in the USA, in the European Union (EU) there is no single major public provider of funding of biomedical research. The majority (85%) of public funding is provided by various national funding organisations, while the remaining 15% is funded at the supranational level. The European Commission complements national policies primarily through its Framework Programmes (FP) and the European Research Council (ERC). In addition to the fragmented research, another difference from the USA refers to the concentration of funding in only a few countries, like Germany, France, UK or Finland (Berghmans et al. 2011). Moreover, the major part of R&D funding in Europe is for “top-down” activities, whereas the USA favours "bottom-up” investigator-initiated research (Philipson 2005). In Table 14 we compare Europe and the USA with respect to public investments in biomedical research. The figures show the lead of the USA over Europe. Looking at the time trends, the investments in Europe have mostly steadily grown between 1995 and 2007; however, an overall increase of 170% over that period was not sufficient to match a much stronger growth in the USA (Berghmans et al. 2011).

Taken altogether, the healthcare biotechnology sector highly depends on public investments into knowledge base. Since the private sector needs a rapid return on invested capital, it cannot afford to support basic research. NIH, the European Commission and other governments' agencies worldwide thus produce a broad portfolio of fundamental discoveries, which provide pharmaceutical and biotechnology companies with expanded opportunities to transform these into diagnostic and therapeutic products. We have also discussed how very few studies have empirically assessed the actual impact of public investments into science base on biotechnology innovation performance. The most often used indicator of innovation performance is the number of approvals of new molecular entities (NMEs). Until the end of 1990s, the European biopharmaceutical industry was the major global developer of NMEs. As shown on Figure 6, the USA has taken the lead in the past decade, with 47.68% of all NME approvals in the period from 2006-2010 as compared to Europe’s 32.45% (Berghmans et al. 2011).

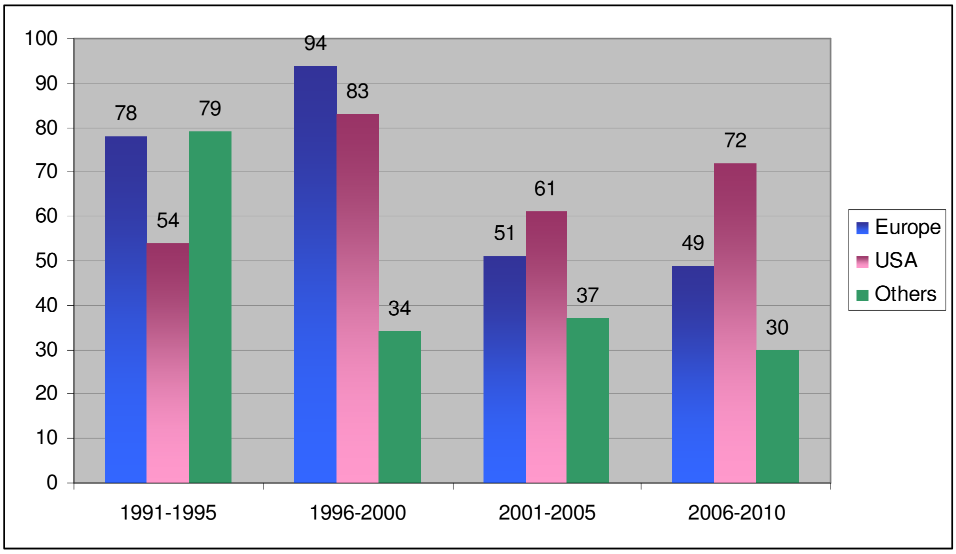
Table 14. Public investments in biomedical research in the USA and Europe

	USA	EU	CROATIA*
Major public provider of funding	National Institutes of Health (NIH)	No single major provider: - national organisations (85%) - EU (15%)	Ministry of Science, Education and Sports
Health R&D expenditures in the non-profit sectors, PPP US$b (2007)	32,0	20,3	0,045
Budget for health of the major public provider of funding, US$b (2011)	30,7 (NIH)	0,86 (European Commission)	0,044
% of public funding going to biomedical research (2011)	50%	30%	10%
% of GDP committed to public funding of health research (2008)	0,222%	0,054%	0,069%

** The data shown for Croatia refer to 2009.*
Source: Adapted and compiled from Wiecek (2011), Berghmans, et al. (2011), the European Public Health Association (2011) and the Croatian Bureau of Statistics (2011)

Another interesting trend that can be observed from Figure 6 is the decreasing number of total NME approvals over the past 15 years. Thus, the increase in funding levels was not accompanied by an increase in approvals of molecular entities, including medicines (Dorsey et al. 2010). One explanation for this trend is the increasing cost and complexity of research, accompanied by increased regulatory requirements (Berghmans et al. 2011, Ernst&Young 2011). Others find that research productivity should not be measured solely by the number of NME approvals, since broader factors, such as lower death rates, longer life expectancy and improved quality of life, are also relevant consequences of biomedical research investments (Dorsey et al. 2010).

Figure 6. Overview of NME approvals in the USA, Europe and other countries (includes Japan and Canada), 1991-2010



Source: Adapted from Berghmans (2011)

4.5 The role of commercialization funding mechanisms in fostering biotechnology innovation

This section investigates the impact of funding mechanisms deployed by the US and the European healthcare biotechnology companies on innovation performance in the sector. The review addresses two periods: the period of dramatic increases in investments in the biotechnology industry and followed by rapid loss of trust of investors in this sector.

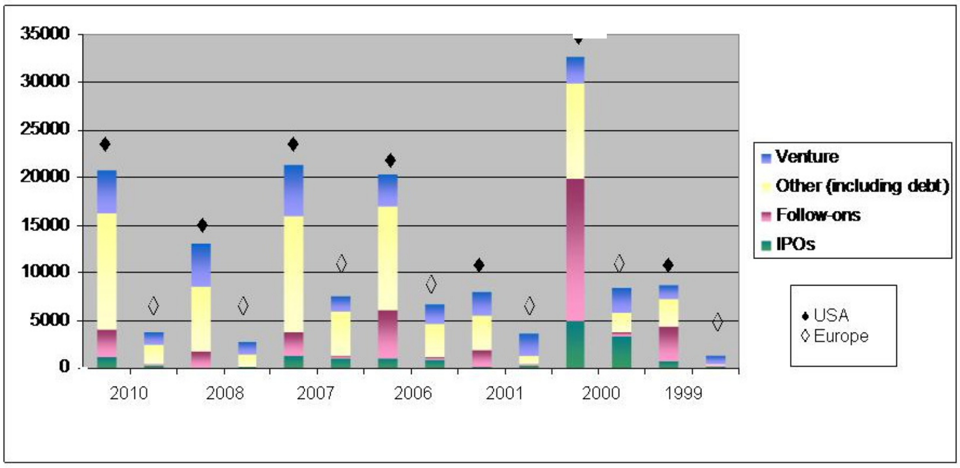
4.5.1 Triggers to the biotechnology "boom" and relations to innovation

Before and during 2000s, healthcare biotechnology industry in both the USA and Europe was characterized by a "boom" in investments, primarily from venture capital (VC) firms and R&D alliances with established pharmaceutical companies. In the period between 1999 and 2010, the largest jump in the level of investment occurred in 2000 in relation to 1999, amounting to 273% in the USA and 525% increase in Europe (Ernst&Young 2011). These substantial investments were present despite the fact that the industry mostly lacked market-ready products and profitability, with the exception of few commercially successful companies, such as Amgen and Genentech in the USA (Pisano 2006). Following the literature review we identify two major explanations for this phenomenon: existence of initial public offerings (IPOs) and use of stock-based executive compensations.

First, IPOs have had two primary roles in the biotechnology industry: first, to quickly and lucratively attract funds for further therapeutic development (Lazonick 2007), and second, to provide venture capitalists and pharmaceutical companies with the opportunity to exit from their investments, often with a considerable return, without having to wait for product regulatory approvals and market entry (Lazonick and Tulum 2011). It is known that the development of new medicines requires a process that can take up to 20 years, with highly uncertain prospects for success (Lazonick and Tulum 2011). In contrast to the direct private investment in innovation, which involves facing technological, market and competitive uncertainty, and where "patient capital" is needed from investors, public shareholders' investments have been characterized by "short-termness", or need for financial liquidity. The operating principle becomes speculation, which produces gains for investors based on their assumption of existence of "greater fools", who will remain ready to buy the over-priced shares on the market. The accumulation of innovative capabilities is here set aside since more effort is often devoted to reaching an IPO than to commercialization (Lazonick 2007).

Second, in the USA, stock markets for new technologies have had longer tradition and higher relevance than in Europe. Only minorities of European companies have managed to access stock markets, primarily through IPOs (2006). Even though the share of IPOs in the total European biotechnology financing rarely exceeded 15%, in 2000 it was almost 40%, compared with the US 15% in the same period (Ernst&Young 2011). Figure 7 shows the extent and distribution of biotechnology financings in the USA and Europe in selected years over the period between 1999 and 2010. In addition to the significant difference in the level of financing, the USA and Europe differed in the relative importance of funding mechanisms. While "other" sources, mostly debt, dominated in the USA in Europe venture capital generally had the highest relative importance. Moreover, secondary ("follow-on") stock offerings on the public markets were common in the USA and rare in Europe.

Figure 7. Overview of biotechnology industry financings in selected years (USA and Europe)



Source: Adapted from Ernst&Young (2011)

Although underdeveloped, fragmented, illiquid and without the necessary support structures (European-Communities 2009), stock markets were a playground for speculations in Europe. Cooke's (2001) analysis of top European biotechnology companies pointed to unusual difference between valuation (market capitalization) and their much lower turnover, which was assigned to the speculative confidence of stock market investors in the industry characterized by non-profitability of the majority of its enterprises. Similarly, in her case study of Swedish biotechnology companies, Nilsson (2001) reported much stock speculation and value fluctuation for some of the companies due to limited patience of stock market investors, which led to a stance that it might have been wiser to postpone going public until agreements with established pharmaceutical companies had been reached. The result of such an approach are loss-making biotechnology companies on the stock market, with strong research results, alliances with large pharmaceutical firms, or products going through clinical trials, using stock market valuations to ensure the expansion of firm activities (Casper and Kettler 2001). Both in Europe and in the USA, speculative stock markets have been highly sensitive to media news and expectations at every stage of the product development process, and particularly concerning the results of the clinical trials of potential therapeutics (Andersson et al. 2010).

The second explanation for the occurrence of substantial investment capital in the biotechnology industry can be related to the exercise of executives' stock-based compensations. This practice stems from the USA and was gradually expanded to non-executive employees, as an instrument to attract highly skilled personnel to high-tech start-up companies (Lazonick 2007). The European legal and tax systems discouraged stock options until the beginning of the 21st century (Cooke 2001). However, empirical evidence shows that stock-based compensations to executives and employees are at present regularly exercised also in Europe (Lazonick and Sakinc 2010). As discussed by Casper, and Kettler (2001), the legalization of stock options as performance incentives in the UK has been as dangerous as stimulating, since they are highly dependent on the stock price of public companies and lowering of stock prices may motivate entrepreneurial scientists to seek performance rewards in established pharmaceutical companies, rather than in biotech companies. Moreover, Lazonick and colleagues (Lazonick and Sakinc 2010, Lazonick and Tulum 2011) argue that stock-based compensations can stimulate stock manipulation through buybacks due to their short-term orientation, and in that way challenge the extent of investments of biotechnology companies in generation of innovative products. Specifically, by making resource allocation decisions in a way that productive resources are not developed or utilized, but deployed to make primarily personal gains, top managers may jeopardize new value creation and long-term stability and growth of their companies.

In summary, IPOs and stock-based executive compensations mechanisms largely facilitated the industry attractiveness regardless of its overall lack of products close to the market and subsequently, lack of profitability.

4.5.2 Triggers and consequences of the burst of the "biotechnology bubble"

This section identifies two major origins of the burst of the "biotechnology bubble": substantial dependence of the industry on speculative stock markets and inadequate expertise of investors.

The first cause of sharp decreases in investments in the biotechnology industry is the dependence of companies on stock markets for funding commercialization-related activities. The finance-driven innovation model (Coriat and Orsi 2002) mostly disregards the need of the biotechnology industry for "patient" capital as the main motivation of investors remains a quick exit from their investments through speculations and securing of gains in the short term. This leads to discrepancy between the companies' value on the stock markets and actual performance, which disrupts the long-term sustainability of the industry. Although specific for the USA, the reliance on speculative stock markets has been present in Europe as well. One illustrative example is British Biotechnology, formerly Europe's largest biotechnology company in terms of market capitalization and R&D costs, which experienced a stock market decline of $2 million in 1997 because of delays in gaining approval for its two leading products. This event highly affected the level of confidence of the European investors in the sector (Cooke 2001). Following the crash of NASDAQ at the beginning of the 21st century, many European stock markets collapsed (Lazonick and Sakinc 2010). For example, the German *Neuer Markt* collapsed after only five years of existence, after it had lost 96% of its value in two years (Howell et al. 2003). The facilitated access to stock markets is therefore estimated as positive with respect to necessary fund raising, but it can also be problematic for companies without capacity to meet expectations and cause dissatisfaction on the stock market, which easily spills over to other biotechnology firms notwithstanding their performance, as it occurred in 2001 and 2008 (see Table 15). Investors in the biotechnology industry were then no longer motivated to invest because of weaker exit opportunities and IPOs seriously decreased (Dibner et al. 2003, Lazonick and Tulum 2011).

Table 15. Capital raised in the biotechnology industry in USA and Europe, 2000-10 (US$m)

		2010	2009	2008	2007	2006	2005	2004	2003	2002	2001	2000
IPOs	**USA**	1,097	697	6	1,238	944	626	1,618	448	456	208	4,997
	Europe	219	137	100	978	905	1,066	484	42	191	280	3,294
Follow-ons	**USA**	2,971	5,165	1,715	2,494	5,114	3,952	2,846	2,825	838	1,695	14,964
	Europe	207	792	40	263	279	377	273	584	65	171	499
Other	**USA**	12,242	7,617	6,832	12,195	10,953	6,788	8,964	8,306	5,242	3,635	9,987
	Europe	2,044	1,845	1,245	4,714	3,452	1,493	2,183	1,708	236	908	1,983
Venture	**USA**	4,409	4,556	4,445	5,464	3,302	3,328	3,551	2,826	2,164	2,392	2,773
	Europe	1,355	1,049	1,368	1,606	2,006	1,895	2,017	1,226	1,768	2,250	2,670
TOTAL USA		**20,719**	**18,035**	**12,998**	**21,391**	**20,313**	**14,694**	**16,979**	**14,405**	**8,700**	**7,930**	**32,721**
TOTAL Europe		**3,825**	**3,823**	**2,753**	**7,561**	**6,642**	**4,831**	**4,959**	**3,561**	**2,260**	**3,609**	**8,447**
TOTAL USA + Europe		**24,544**	**21,858**	**15,751**	**28,952**	**26,955**	**19,525**	**21,938**	**17,966**	**10,960**	**11,539**	**41,168**

Source: Adapted from Ernst&Young (2011)

The second cause of the lost trust in the biotechnology industry was more dominant in Europe than in the USA. It springs from the lack of industry expertise of investors. The Critical I study of biotechnology in Europe (2006) discusses Europe's "localized and inward-looking" investors and not sufficiently mature industry to attract debt finance for growth-by-acquisition strategy of the US biotechnology industry. Moreover, venture capitalists are evaluated as investors that inhibit innovation, because of their weak specialization, or support of too many companies with insufficient funding. This is closely related to the fragmentation of the European venture capital industry (European-Communities 2009), not only in countries with no tradition in biotechnology entrepreneurship, such as Portugal, Spain and Italy, but also in mature ones, like Germany (Casper and Kettler 2001).

Funding crises produced the following effects: increased concentration of funding, change in investment targets, more prominent role of the public sector, increasing share of debt financing, and cost-cutting. First, increased concentration of funding in a smaller number of companies is observed both in the USA and in Europe. In 2010 in the USA, top 20% companies in raising funds received 82.6% of capital (compared to 78.5% in 2009 and 68.7% in 2005), whereas the bottom 20% of companies raised only 0.4% of funds (compared to 0.6% in 2009). Moreover, funding often represented reinvestments in existing portfolio companies rather than in new ones (Ernst&Young 2011). The rising unevenness in funding allocation distribution is expected to result in the return to quality, at the expense of the number of IPOs, but with larger amounts of funds on average raised than had been the case in the period of a "boom" (Lazonick 2007). Thus, restrictions in the access to funding forces companies to focus their resources to a more narrow set of technologies. They are required to concentrate on achieving short-term milestones to satisfy their investors, which have become more careful in assessing regulatory and commercial risks earlier in a product's development cycle. Short-term milestones enable the VC investors exiting earlier even in the period of higher caution and higher selectivity of IPO investors, preferably through mergers and acquisitions (M&As), which may not always be in the interest of a company (Ernst&Young 2011).

Second, another effect of the burst of the "bubble" is refocused investors' preference towards investments of lower risk. An example is their preference for late-stage clinical trials rather than for discovery of therapeutics. According to Dorsey and colleagues (2010), such practice is accompanied by a more frequent purchasing of small biotechnology firms by large pharmaceutical companies as an alternative to in-house investing to early stage, discovery research. This trend is problematic because higher risk investments are essential to fill the gap between government-sponsored research and commercial research.

Third, public sector takes a bigger role in industry financing, particularly in Europe. By launching new national and supranational funding and fiscal initiatives (European-Communities 2009), the governments aim to bridge biotechnology financing gaps. Moreover, recent initiatives in frame of the European Framework Programmes for Health recognize the deficiencies of the generalist measures and recognize the need for a narrower-scope specialized approach in defining funding priorities.

Fourth, identified consequence of the burst of the biotechnology "bubble" is increasing importance of debt financing, specifically in the USA. Even though the most recent industry reports show that in 2010 biotechnology companies managed to attract amounts of funding similar to those raised during the "boom" preceding the second crisis (Ernst&Young 2011), this recovery mostly came from debt funding of mature profitable companies, to refinance existing debt and for stock buybacks and acquisitions. If these funding sources are excluded, "innovation capital" raised by US companies was in fact in decline by 21% in 2010.

Finally, a very frequent effect of the crisis, both in the USA and in Europe, is cost-cutting, primarily in R&D expenditures. In 2009, 64% of US companies and 55% of European companies decreased their R&D spending. With this step, restructuring of the companies with a subsequent negative impact on employment becomes apparent and future innovation in the form of new products in the pipeline becomes compromised (European-Communities 2009). According to a report published in Nature Biotechnology (2011), those companies that increase their R&D expenditures explain their strategy of constant product innovation as indispensable to survive, in particular in a time when a significant number of marketed products are losing patent protection.

The evidence presented in this section indicates that not all commercialization funding mechanisms increase biotech innovation performance. This primarily refers to stock-market-related practices that foster short-term gains of executives and investors and thus disregard the need of the biotechnology industry for “patient” capital.

We find that the European biotechnology industry has been largely following the US practice, driven by stronger performance of the latter in terms of R&D expenditures, patented inventions, revenues and new molecular entity approvals. Second, a thorough analysis of the industry dynamics revealed the deficiencies of the present IPR system tailored to boost the exploitation of academic research results, a decrease in the “innovation capital” levels and industry innovative performance (measured by the number of new molecular entities) despite the increased overall funding levels, and the fragility of the finance-driven business model in both regions observed. This suggests that the present “shareholder value-oriented” system may not be compatible with the long-term sustainability of the biotechnology industry.

4.6 Innovation in the US and the European biotechnology industry: a comparative analysis

We compare the US and the European industries using the neoclassical financial theory and the theory of innovative enterprise to propose an overview of driving forces of innovation in healthcare biotechnology. In specifics, we critically compare the US and the European practices with respect to innovation determinants identified in this paper: university-generated intellectual property rights, public investments into knowledge base and commercialisation funding mechanisms.

The main characteristic of the neoclassical financial theory is that it takes market price signals and shareholder value maximization as guiding principles in doing business, while it treats technology and market conditions as exogenous factors. In contrast, the theory of innovative enterprise builds on the resource-based view roots and treats technology, market and other conditions as dynamic, transformable, endogenous factors. It further argues that innovative capacity to create new products and processes is what drives innovations and economic growth (Lazonick and O’Sullivan 2000). The innovative performance depends on “organisational integration” of participants in a specialized division of labour, who collaborate toward the achievement of common goals, “strategic control” in executive-made resource allocation decisions, and “financial commitment” of resources to sustain the innovation process until it can generate viable products that can produce financial returns (Lazonick 2003).

By selecting these two theories as a framework for our analysis, we recognize that although the neoclassical financial theory is commonly accepted in modern theory and practice, it mostly does not consider the role of different in-house and environmental conditions that have been shaping innovation performance in the healthcare biotechnology industry. The theory of innovative enterprise is relevant because it combines theory and history in investigating how conditions such as financial markets or government investments impact strategic priorities of biotechnology companies (Andersson et al. 2010). Applied together, these two theories provide a crucial contribution in understanding why biotechnology evolved into a "shareholder value-oriented" industry and how this dominant practice has been affecting the industry innovative performance. Methodologically, we perform this critical comparison by combining empirical evidence from the US and the European settings with theoretical discussions on the role of university IPRs, public investments into knowledge base and commercialisation funding mechanisms in stimulating innovation performance. The results are summarized in Table 16 below (refer to Table in Appendix R for a more detailed overview).

As discussed in the table, the neoclassical theory promotes broad university patenting as a means of securing optimal innovation performance and maximisation of investor rewards while the theory of innovative enterprise evaluates broad IPRs and exclusive licensing as harmful in regards to efficient exploitation of inventions in subsequent research. According to the latter theory, biotech enterprises should instead focus on development of innovative capabilities and academic institutions in both regions reconsider their "patent-as-much-as-possible" policies. Next, unlike the neoclassical theory, which views public investments into science base as market failure correction mechanisms, the theory of innovative enterprise acknowledges the vital role of government basic research funding and subsidies in stimulating the development of the US and European biotech industry. Both theories acknowledge that commercial success is boosted by opportunities for accessing high-risk finance and attracting and motivating entrepreneurial scientists and managers (Casper and Kettler 2001). So far, the US companies have been more successful in translating research into biopharmaceutical end products than EU companies (Jonsson 2007). However, both in the USA and in Europe there has been a dominant stance on the side of investors that the most favourable way to maximize the shareholder value in the short-run is "selling to revenue-hungry pharmaceutical companies that have to complement their internal R&D efforts by looking externally for breakthrough innovations and products, rather than by pursuing high risk R&D" (Ernst&Young 2011). According to the theory of innovative enterprise, the consequence of this strategy is an increasing gap between the high values announced and the funds actually deployed for development and utilization of productive resources to increase innovative performance.

Table 16. Innovation-influencing factors: a comparison of the US and the European biotechnology industries

Innovation-influencing factor	**USA**	**Europe**	**Theoretical framework**
University-generated IPRs	IPR laws boosted academic research exploitation (Lazonick and Tulum 2011). Academic patenting increased, but its importance decreased (Nightingale and Martin 2004).	Most countries emulate the US Bayh-Dole Act (Geuna and Nesta 2006). High costs and heavy administration related to patenting impede innovation (Jonsson 2007).	**Neoclassical financial theory:** Without IPRs on publicly funded research, the innovative output will be suboptimal and innovators will be under-rewarded (Orsenigo et al. 2006). Broadening the scope is desirable - it maximises the reward to investors (Dempsey 1999). **Theory of innovative enterprise**: In the case of public research, the incentive in the form of IPR laws is not needed because invention has already been paid for (Orsenigo et al. 2006). With upstream discoveries, exclusive exploitation of a patent limits new entrants who would compete to produce more efficient and cheaper medicines (Lazonick and Tulum 2011).
Public investments into knowledge base	Substantial government investment in knowledge base has financed US biotechnology and motivated equity investors throughout the history (Angell 2004, Lazonick and Tulum 2011).	Biotechnology development is boosted through government-initiated technology transfer initiatives, seed funding schemes, and taxation schemes (2006).	**Neoclassical financial theory:** Government policy should be limited to market failure situations. One example is government funding of basic research, which overcomes the reluctance of firms to fund their own research because of their inability to appropriate all the benefits (Salter and Martin 2001). **Theory of innovative enterprise**: Governments have a critical role in developing the knowledge base indispensable for international competitiveness of biotechnology, through infrastructural investments that are of far too broad scope for companies (Lazonick 2007).
Funding mechanisms *Speculative stock markets* *- IPOs*	Industry funding mechanisms have been characterized by stock market investors investing in IPOs of R&D companies (Lazonick and Tulum 2011)	To a lesser extent than in the US, but equity investors are also motivated by speculative gains, extract value, even though the products are not yet market-close (Lazonick and Sakinc 2010).	**Neoclassical financial theory:** The healthcare biotechnology business model is financialized, shareholder distribution-oriented; products in pipeline and firms trade for shareholder value in speculative processes (Andersson et al. 2010). **Theory of innovative enterprise**: The extent of financial commitment required to sustain an investment strategy depends on the size of the investments in productive resources and duration of time required to generate financial returns (Lazonick 2003).
- Stock buybacks *Debt and venture capital* *Established pharma companies*	Stock-based compensations are regular (Lazonick and Sakinc 2010). Companies are supported by stock markets and financial institutions lending money secured only by stock. Debt funding dominates the sector. In order to maximize shareholder value, firms are typically acquired by big pharma, instead of pursuing high-risk R&D (Ernst&Young 2011).	The industry is not mature enough to attract debt finance for growth-by-acquisition strategy of the US industry (2006). Venture capital industry is fragmented, with weak specialization (2009). Companies mostly license out their inventions to big pharma, get acquired by US companies or move to the USA to access their markets and thus export value-creating R&D (2006).	**Neoclassical financial theory:** Short-term earnings per share and share price are the most important measures of corporate performance. Only shareholders are "residual claimants" as they do not have "guaranteed contractual stakes" (Lazonick 2007). By giving managers stock-based compensation, shareholders mitigate the principal-agent problem - ensure that managers allocate resources efficiently (Jensen and Meckling 1976). **Theory of innovative enterprise**: Shareholders are not the only "residual claimants" - state is also without guaranteed return on investment, to taxpayers (Lazonick 2007). Productivity problems of the US biotechnology industry were not due to a shortage of funding, but due to the highly monetized business model which undermines innovation (Lazonick and Tulum 2011). Acquisitions of small companies by established pharma companies as a dominant business strategy prevent Europe from developing self-sustainable, larger biotech companies and endangers the extent of future innovation (Jonsson 2007). In both regions, this trend negatively affects the investments in early stage research by big pharma (Dorsey et al. 2010).

4.7 Discussion

The aim of this paper was to analyse the role of university-generated intellectual property rights, public investments into knowledge base and commercialization funding mechanisms in stimulating innovation performance in healthcare biotechnology industry. We focused our research on these three determinants of innovation performance following the in-depth literature review, which pointed to limited knowledge on key determinants that drive the development of this sector. In our analysis we directly compared the US and the European healthcare biotechnology industries, relying on conceptualization extended by statistical data. Our conceptual frameworks were two grounding theories, neoclassical financial theory and the theory of innovative enterprise, which were contrasted assuming the theoretical and practical dominance of the former and historical perspective of the latter in evaluating innovation-influencing factors in the biotechnology industry. In this concluding section, we summarize our findings and develop implications for practitioners and future research avenues.

Legislation regarding intellectual property rights was changed in order to allow universities and other entities involved in life science research to protect their discoveries by patents, initially in the USA and later in most countries in Europe. Evaluated as beneficial for commercial exploitation of university-generated research results, biotechnology venture creation and (particularly by neoclassical economists) necessary in order to protect the future economic returns of inventions, patenting with wide scope and exclusive licensing of upstream discoveries in this field was also discussed as harmful for future innovative output. This is primarily due to its blocking impact on efficient use of protected results in subsequent research. Even though the change in the IPR regime positively affected the extent of university patenting, it has also led to a lot of commercially irrelevant patents. Another deficiency in the present IPR system as an innovation-driving force is related to the substantial use of patents by new biotech companies to attract acquisitions by established companies, which enables them to quickly exit to capital markets, despite the lack of products close to the market. The theory of innovative enterprise argues that patents are a weaker determinant of successful development of innovative products when compared to innovative capabilities to translate new technologies into innovative products and processes.

The theory of innovative enterprise also acknowledges that public investments into knowledge base at universities and other research institutions are indispensible for the development of innovative activities in the biotechnology industry and its competitiveness, as companies lack resources and often specific knowledge to invest in basic infrastructure and research projects aimed to reveal the fundamental mechanisms in molecular biology, which are in the background of discovery of any diagnostic tool or therapeutic agent. For that reason, companies rely on investments by governments, in the form of research grants through universities or direct grants to the company, as well as on knowledge available at academic and other non-profit research institutions. The US National Institutes of Health are the major provider of funding for basic biomedical research, not only in the USA, but also globally, while in Europe the majority of basic funding is provided at the level of member countries. Neoclassical theory also stipulates the importance of government investments into knowledge base; however, it argues that the reason for government involvement is related to the existence of market failures, which discourage biotechnology firms from funding their own research due to high risks and long terms specific for the industry and their inability to appropriate all the benefits.

Finally, the analysis of different mechanisms of funding of biotechnology commercialization process revealed that speculative stock markets attracted substantial funding flows into this sector in the USA, and less so in Europe, primarily through IPOs and exercise of stock-based compensations. Substantial investments were present due to quick exit opportunities for investors, and regardless of the fact that most companies involved were principally R&D companies, with the lack of profitability and virtually no products on the market. This, in practice still dominant business model, highly relies on the neoclassical financial theory and its emphasis on short-term maximisation of shareholder value in an industry characterized by long terms and high risks. However, it was questioned after the collapse of speculative markets in the financial crisis of 2008-2009, which largely affected the USA. The crisis affected European biotechnology industry as well, however, not only because of its attempts to emulate the US speculative stock markets, but also because of the generally weak expertise and fragmentation of investors, primarily venture capitalists. We concluded our analysis with the identification of effects of the funding crises in the USA and Europe, which include increased concentration of funding, change in investment targets, more prominent role of the public sector, increasing share of debt financing, and cost-cutting. Some of these effects, like increasing share of debt financing, cost-cutting and refocusing of investors' preferences towards investments of lower risk, were evaluated as unfavourable for the extent of future innovation.

4.8 Conclusions and implications

Our study has indicated that the US biotech business model relies heavily on monetization of IPRs generated at academic institutions, government investments in high-risk research, public capital markets and financial institutions. Its European counterpart has been striving to emulate that model because of its better performance in most of the indicators. Yet, we also provided evidence that the financial markets-driven US sector impedes innovation performance due to its focusing on short-term financial gains, tied to stock-price fluctuations and stock-based compensations, in the industry which demands "patient" capital. This questions the long-term sustainability of the biotechnology industry and calls for several recommendations for enterprises that compete in the European environment.

First, most European countries have adopted their IPR legislations and technology transfer policies in line with the US example, driven by the quick expansion of the US biotech industry thanks to its excellent connections with the academic institutions, as generators of basic discoveries. However, since the conducted empirical studies revealed an increasing number of commercial irrelevant university-generated patents, we propose that European academic institutions should reconsider their present technology transfer policies: instead of "pushing" their technology transfer offices to patent as much as possible in a "monolithic way", universities should invest in developing effective pipelines for critical evaluation of potentially patentable inventions. In that way, they will reduce irrelevant activities in technology transfer offices; reduce the pressure on basic academic research and decrease the costs of legal services associated with IP protection (e.g., application filing, enforcement). On top of that, there have recently been attempts to propose alternative IPR regimes. These include the return to inventor ownership and compulsory non-exclusive licensing (Kenney and Patton 2009, Dorsey et al. 2010, Hoffenberg 2010). Recently initiated in the USA and already existing in Germany, compulsory licensing should enable innovative companies to receive a return on their investment in research. At the same time, users would have access to technology at reasonable prices.

Second, an area where the European industry should emulate the US biotechnology is bigger interrelatedness of basic science and clinical development, as proposed already by Owen-Smith and colleagues (2002). They showed that the US public research organizations and small biotechnology companies conduct decentralized R&D across multiple areas and stages of the development process, while Europe has regional specialization with a less diverse group of public research organizations working in a smaller number of areas, with a considerably more centralized funding within nations. Europe thus needs to make changes in the division of labour in order to support innovation.

Third, in order to encourage the sustainable development, the European biotech industry should invest more effort in the direction of strategic selection of fewer funding priorities and long-term focus on therapeutic and diagnostic products that have the potential for viable commercial success (Commission 2007). An opportunity exists in the development of biosimilars (which assume an R&D-intensive activity, unlike the production of generic pharmaceuticals), due to the fact that the patent protection of many biotechnology medicines will expire in the forthcoming years. Developing treatments for conditions with very small patient populations, or rare diseases, represents an opportunity that has already been recognized on both sides of the Atlantic (Ernst&Young 2011) as a response to the challenge of unsustainable "blockbuster" medicines. Such strategies should be accompanied by adequate policies, which would promote greater specialisation and the need for "patient" capital to venture capitalists and other types of investors. As discussed by Casper and Kettler (2001) in their comparison of the US, UK and German settings, due to limited skills in technology transfer and bottlenecks in the supply of personnel in relation to the science base, UK was shown to be unsuccessful in emulating the US "high-return but high-risk radical innovation" model, despite the developed capital markets. In the same period, the German biotechnology sector benefited from the "long-term and incremental innovation" business models, by combining entrepreneurial endeavours with stable institutional frameworks featured by government incentives, regulatory labour laws and "stakeholder" supervision.

Finally, we point to some avenues for prospective research. Since there are still too few studies empirically assessing the impact of public investments into science base on innovation performance, we propose that future efforts should take this direction. Namely, it would be very interesting to investigate further why the most recent industry reports point to decreases in new molecular entity approvals despite the increasing R&D and commercialisation funding levels in both regions included in this study. Also, one limitation of this research is that it does not take into account the diversity of national biotechnology industries across Europe in assessing the determinants of innovative performance. Instead, the study deploys a "big picture" approach in comparing the two regions which represent the key global players in the biotech industry. Future research endeavours should consider the heterogeneity of European national IPR as well as R&D and commercialisation funding systems.

GENERAL DISCUSSION AND CONCLUSION

This chapter of the dissertation summarizes the key findings with reference to the main research goals listed in the Introduction and discusses the main limitations of the study, implications and future research avenues.

Summary of main findings

The aim of the dissertation was to contribute to the better understanding of academic-industry knowledge transfer process in life sciences by (1) providing a systematic review of the accumulated body of knowledge on academic-industry knowledge transfer and developing a conceptual framework for studying academic-industry knowledge transfer and evaluating its effectiveness and impact on public science; (2) exploring how different knowledge transfer processes between academia and industry impede formal and informal co-operation in different institutional contexts of life science academic communities, with the purpose of developing a theoretical framework for individual knowledge transfer-knowledge sharing interactions; (3) testing the role of academic-industry knowledge transfer activities, personal and context-specific factors in different forms of knowledge sharing restrictions in the life science academic communities; (4) analysing the determinants of innovation performance in the healthcare biotechnology industry.

In the next paragraphs, the main findings with reference to each specific research goal are discussed.

Research goal 1: To provide a systematic review (identification, evaluation, extraction and summarizing) of the accumulated body of knowledge on academic-industry knowledge transfer in life sciences.

The systematic review included 135 articles published between 1980 and 2014. We clustered the studies into several categories based on the emerging common themes. We content analyzed the papers within each cluster and compared them with reference to the obtained results and deployed research methods, variables and empirical settings in their focus. We then summarized the findings and drew general conclusions for each of the six identified principal academic-industry research topics: involvement predictors and motivators, role of incentives, institutional performance determinants, knowledge transfer institutionalization, relationship with scientific output and impact on open science.

Research goal 2: To develop a general conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science.

The emerging themes that we identified following the systematic literature review on academic-industry knowledge transfer targeted both the determinants and the consequences of academic-industry knowledge transfer interactions for public science institutions. With our analysis and the resulting conceptual model we showed that, when assessing the effectiveness of academic-industry knowledge transfer interactions, researchers, managers and policy makers need to consider individual factors (researchers' scientific productivity, professional status, demographic characteristics, social capital, attitudes, motivations and previous knowledge transfer experience) as well as external factors (research resources, characteristics of the immediate work environment, formal policy framework, previous industry funding, technology opportunities and location), including technology characteristics. These factors affect the involvement of individual researchers in academic-industry knowledge transfer as well as the overall institutional technology transfer performance. The developed conceptual framework also comprises the implications of academic-industry knowledge transfer for the researchers' productivity and interactions with other members of the academic community.

Research goal 3: To explore the heterogeneity of academic-industry knowledge transfer and knowledge sharing mechanisms in academic life science communities.

We performed an extensive review of the existing literature and collected qualitative data from 38 in-depth interviews with academics, industry professionals and technology transfer specialists from six countries. The aim was to reveal their experiences and attitudes regarding the role of academic-industry knowledge transfer in interactions with other members of the life science academic community. In the transcribed interviews we first identified the main analytical categories on the basis of the main research questions and interview questions, followed by coding, using pre-developed coding scheme, and categorization. Then we identified more specific emerging themes within categories and categorized quotes into appropriate themes. With the help of the Atlas.ti software (version 6.2), we compared the data across the categories of respondents and institutional settings. The data analysis indicated that knowledge sharing restrictions in academia occur in relation to involvement of academic researchers in different types of knowledge transfer activities, ranging from industry collaboration and intellectual property protection to entrepreneurship and business activities. Moreover, academic-industry knowledge transfer was shown to be related with a range of knowledge sharing restrictions in academia: direct exchange of research data, information and materials (specific knowledge sharing), presentations at conferences (general knowledge sharing), collaborative research projects (formal knowledge sharing), use of material transfer agreements (MTAs) (formal sharing of research materials), knowledge sharing through personnel exchange, knowledge sharing related to publishing of PhD students, publication contents and publishing timing (knowledge sharing to the general audience).

Research goal 4: To explore the role of the institutional context in academic-industry knowledge transfer-knowledge sharing relationship.

Considering that the majority of studies of academic-industry knowledge transfer build on empirical data obtained from US respondents (Baldini 2008), and that there are very limited studies with the focus on more than one country setting (Haeussler 2011, Haeussler 2014, Walsh and Huang 2014), in our discussions with the interviewees we paid particular attention to the institutional environment in which they operate. By including into our analysis the respondents from six different empirical settings, we contributed to the understanding of the role of professional environment of academic researchers in their involvement in academic-industry knowledge transfer activities. In assessing the impact of governmental and institutional technology transfer policies, we primarily relied on the data obtained directly from our respondents, and only partially on data available from other sources (Escoffier et al. 2011, Geuna and Rossi 2011, 2013, Messer-Yaron 2014). We showed that institutional norms and policies related to academic-industry knowledge transfer also affect academic researchers' knowledge sharing behavior. US respondents reported most concerns over the possible interference of the aggressive university technology transfer policies with the norms of open science in academic institutions compared to respondents from other investigated empirical settings.

Research goal 5: To develop the comprehensive individual-level knowledge transfer-knowledge sharing conceptual model.

The analysis of the results of the empirical study enabled us to develop the theoretical framework for assessing knowledge transfer-knowledge sharing interactions. This model captured the relationship between restrictions in particular types of knowledge sharing among academic researchers and particular forms of knowledge transfer activities. Although academic-industry knowledge transfer activities were emphasized in interviews as the foremost reason for knowledge sharing restrictions, several other important factors were also identified following the extensive literature review and analysis of the interview data. Thus, the model also comprises personal and context-specific determinants of knowledge sharing restrictions in the academic communities and is controlled for certain demographic and professional traits of researchers. We also show evidence that supports the view on the present science system as a hybrid between open science and secrecy (Mukherjee and Stern 2009), not only because of the increased importance of commercial exploitation of academic research results, but also due to the intense scientific competition for priority in disseminating results, prestige and research funding.

Research goal 6: To determine the relationship between different forms of academic-industry knowledge transfer and different forms of knowledge sharing restrictions in life sciences.

We explored the determinants of seven different types of knowledge sharing restrictions in the academic community: restrictions in the content of publications, timing of publications (delays), content of publications co-authored with other academic researchers, timing restrictions of co-authored publications, sharing restrictions during presentations of research results, sharing restrictions with the exchange of unpublished knowledge (information, data and materials) and sharing restrictions with the exchange of published knowledge. As our main independent variables, we considered three different types of academic-industry knowledge transfer: industry collaboration-based activities, intellectual property-based activities and academic entrepreneurship and business-related activities. Drawing from prior studies we hypothesized that the involvement in academic-industry knowledge transfer would be positively associated with knowledge sharing restrictions, but the strength of the relationship would vary depending on academic-industry knowledge transfer activity type and knowledge sharing form in question. To test our hypotheses, we developed a survey instrument based on literature review, prior surveys and semi-structured interviews with 38 key informants. To validate the instrument, we conducted pilot interviews with five scientists to detect unclear or inappropriate questions. The survey was originally prepared in English language and then translated into Croatian using the back-to-back translation method. The survey was e-mailed via online survey platform LimeSurvey to in total 2,550 respondents, Croatian life scientists who hold a doctoral degree and who have been active in research in the past five years. The response rate was 20.05%, and 212 responses were included in the econometric analysis. The results of negative binomial regressions showed that the more the academic researchers involve in academic-industry knowledge transfer, the more they will restrict knowledge sharing with other members of the academic community. However, the characteristics of this relationship depend on the type of academic-industry knowledge transfer activity and form of knowledge sharing in question. When it comes to industry collaboration, the positive relationship with knowledge sharing restrictions was shown for most of the investigated forms of sharing. The relationship between intellectual property-based academic-industry knowledge transfer activities and sharing restrictions was significant and positive in the case of co-authored publication timing restrictions and sharing restrictions during presentations. On the other hand, the results for restrictions with sharing unpublished and published knowledge had significant and negative coefficients. We also showed that the involvement in academic entrepreneurship-related activities was significantly associated only with restrictions with sharing published data and materials.

Research goal 7: To provide evidence on the role of different individual and contextual predictors of knowledge sharing restrictions in life sciences.

We included into our empirical analysis a range of hypothesized personal and context-specific predictors of knowledge sharing restrictions in the academic community in addition to academic-industry knowledge transfer. On a sample of 212 life scientists from Croatia, we showed that personal outcome expectations are the negative predictor of most of the investigated forms of sharing restrictions. On the other hand, community-related outcome expectations do not seem to explain any of the forms of restrictions in knowledge sharing. Although hypothesized, trust was not shown to be significantly related to sharing restrictions with direct, informal exchange of unpublished and published information, data and materials. Instead, it was shown to be significantly related with timing restrictions with co-authored publications and sharing restrictions during presentations. Reputation among peers was generally not shown to be an important predictor of knowledge sharing restrictions in the academic community. The study shows mixed results concerning the relationship between scientific values and knowledge sharing restrictions. Scientific competition was identified in our study as an important predictor of sharing restrictions when it comes to publishing, public presentations and direct sharing of published data and materials with other researchers. Concerning the institutional climate in support of sharing, we showed the significant relationship only with timing restrictions with co-authored publications, which means that the sharing behaviour of scientists' immediate supervisors and colleagues in the department mostly does not have any significant role in their sharing decisions. Our results for the scientific output, measured by the number of publications in the past five years, showed that the more the researchers publish, the more they will restrict sharing during public presentations of their research results, and the less they will deny other researchers' direct, informal requests for unpublished and published data and materials. Professional age is significantly associated only with sharing restrictions during presentations and content restrictions with co-authored publications, where the older the researchers, the less they restrict knowledge sharing. Overall, we found that restrictions in each type of knowledge sharing on the level of individual academic researchers are predicted by different individual and contextual factors.

Research goal 8: To describe the role of university-derived intellectual property rights and research and development funding mechanisms in innovation performance of the healthcare biotechnology industry.

In order to reach this research goal, we relied on conceptualization extended by statistical data to point to specific differences between Europe and USA. We built from a body of literature investigating the historical development of the biotechnology industry, its expansion to new entities and new scientific fields and the role of different sources of funding of biomedical commercialization process. We used the theory of innovative enterprise and the "maximizing shareholder value" concept to elucidate determinants of biotechnology innovation performance. Concerning university-derived intellectual property rights, we pointed to their several deficiencies as an innovation-driving force, with Europe broadly emulating the US model. Using the framework of the theory of innovative enterprise, we argued that patents are a weaker determinant of successful development of innovative products when compared to innovative capabilities to translate new technologies into innovative products and processes. We also showed how the theory of innovative enterprise and neoclassical theory explain differently why public (government) investments into knowledge base at universities are necessary for development of innovations. Finally, the analysis of different mechanisms of funding of biotechnology commercialization process revealed that speculative stock markets attracted substantial funding flows into this sector in the USA, and less so in Europe, primarily through initial public offerings (IPOs) and exercise of stock-based compensations. We discussed how substantial investments were present due to quick exit opportunities for investors, and regardless of the fact that most companies involved were principally R&D companies, with the lack of profitability and virtually no products on the market. This business model highly relied on the neoclassical financial theory and its emphasis on short-term maximisation of shareholder value in an industry characterized by long terms and high risks.

Summary of main implications

The doctoral dissertation contributes to the theoretical and empirical work on academic-industry knowledge transfer as well as to science policy.

Theoretical implications

The first theoretical implication refers to the development of a new conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science. Although numerous studies have investigated benefits and challenges of academic-industry knowledge transfer process, the general framework for evaluating the effectiveness of academic-industry knowledge transfer and its implications for public science has not been conceptualized yet. With our systematic review analysis and the resulting conceptual model we showed that, when assessing the effectiveness of academic-industry knowledge transfer interactions, researchers, managers and policy makers need to consider individual factors (researchers' scientific productivity, professional status, demographic characteristics, social capital, attitudes, motivations and previous knowledge transfer experience) as well as external factors (research resources, characteristics of the immediate work environment, formal policy framework, previous industry funding, technology opportunities and location), including technology characteristics. These factors affect the involvement of individual researchers in academic-industry knowledge transfer as well as the overall institutional technology transfer performance. The developed conceptual framework also comprises the implications of academic-industry knowledge transfer for the researchers' productivity and interactions with other members of the academic community.

The second theoretical implication relates to the conceptualization and empirical testing of academic-industry knowledge transfer-knowledge sharing relationship by considering the heterogeneity of different forms of academic knowledge transfer and knowledge sharing. Despite the abundance of articles published in the field, only a limited number has dealt thoroughly with a complex problem of restrictions in informal and formal sharing of knowledge among the members of the scientific community, in relation to scientists' involvement in academic-industry knowledge transfer and commercialisation activities. Also, most studies in this field have focused on the impact of patenting or knowledge transfer activities in general, without distinguishing between different mechanisms of academic-industry knowledge transfer. We develop and test a comprehensive individual-level knowledge transfer-knowledge sharing model and show that not all forms of academic-industry knowledge transfer are associated with all types of knowledge sharing restrictions. Our results teach us that it is essential to consider the characteristics of particular academic-industry knowledge transfer activities when assessing their impact on knowledge sharing restrictions in the academic communities. Related to this, by including into our empirical analysis the respondents from six different settings, we also contribute to the understanding of the role of professional environment of academic researchers. We show that the institutional norms and policies related to academic-industry knowledge transfer also affect the academic researchers' knowledge sharing behavior.

The third theoretical implication of the study is that it contributes to the body of knowledge on determinants of sharing restrictions among academic life scientists, as it takes into account a broad range of individual and context-specific predictors of knowledge sharing restrictions. Drawing from the social capital theory, existing research mostly investigates a limited range of determinants of knowledge sharing restrictions in life science academic community, which provides a limited knowledge of this important phenomenon. We identify and empirically assess a variety of both personal and context-specific predictors of knowledge sharing restrictions and show that different forms of knowledge sharing restrictions are predicted by different individual and contextual factors.

The fourth theoretical implication of the study is its contribution to understanding of driving forces of innovation performance in healthcare biotechnology. We analyzed the role of university-generated intellectual property rights, public investments into knowledge base and commercialization funding mechanisms in stimulating innovation performance in healthcare biotechnology industry. We focused our research on these three determinants of innovation performance following the in-depth literature review, which pointed to limited knowledge on key determinants that drive the development of this sector. In our analysis we directly compared the US and the European healthcare biotechnology industries, relying on conceptualization extended by statistical data. Our conceptual frameworks were two grounding theories, neoclassical financial theory and the theory of innovative enterprise, which were contrasted assuming the theoretical and practical dominance of the former and historical perspective of the latter in evaluating innovation-influencing factors in the biotechnology industry.

Methodological implications

This study is the first to introduce several measures to capture the extent of both formal and informal knowledge sharing restrictions among the members of the life science community. This is important considering that existing studies have mostly measured only the existence (Blumenthal et al. 1997, Campbell et al. 2000) or frequency (Campbell et al. 2002, Walsh et al. 2007) of data and materials withholding, without trying to at the same time capture the effect of knowledge transfer activities on formal knowledge sharing among scientists.

Second, this is one of the first studies that comprehensively explores an instrumental role of the institutional context in knowledge transfer-knowledge sharing interactions. By including into our analysis the respondents from six different empirical settings, we contributed to the understanding of the role of professional environment of academic researchers in their involvement in academic-industry knowledge transfer activities. This represents an important contribution because so far, the majority of the published articles in the field have focused only on one country, predominantly the USA (Baldini 2008).

Third, in four chapters of the dissertation we combined a variety of qualitative and quantitative research methods, including in-depth literature review, systematic review, in-depth semi-structured interviews, univariate statistics, bivariate statistics as well as multivariate analyses. We deployed systematic review (identification, evaluation, extraction and summarizing) of 135 articles published between 1980 and 2014 with the purpose of development of a general conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science. In-depth literature review was combined with semi-structured interviews with 38 academics, industry professionals and technology transfer specialists from six countries in order to explore the heterogeneity of academic-industry knowledge transfer and knowledge sharing mechanisms in academic life science communities. We used quantitative research techniques for testing the relationship between different forms of academic-industry knowledge transfer, individual and context-specific factors and different forms of knowledge sharing restrictions in the academic community. We deployed univariate statistics (frequencies, means and standard deviations), bivariate statistics (correlations) as well as multivariate analyses (regression analyses).

Practical implications

The dissertation provides several implications for policy makers and business practice. The first group of implications follows from the conducted systematic review, which enabled us to develop a new conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science. This framework should serve as a useful tool for practitioners involved in knowledge transfer activities at academic institutions, who have been highly interested in the factors driving academic-industry knowledge transfer and the consequences of these activities for the public science following the intensive research and innovation policy changes over the recent years.

More specifically, concerning knowledge transfer motivators, our study showed that policy makers should try to develop mechanisms to stimulate the involvement of non-tenured researchers in knowledge transfer activities, as in most cases, their participation had so far been less pronounced compared to more senior researchers, with stable positions. Specifically-tailored training and funding programs can be developed with the view to increase the business and managerial skills of these personnel and therefore create favourable conditions for their future involvement in commercialization projects. The same refers to female researchers, who are shown to be less likely to engage in different forms of knowledge transfer than their male colleagues.

Next, our systematic review showed that academically most productive researchers are less likely to be intensively involved in knowledge transfer with industry than less productive researchers. On the other hand, empirical studies in several settings reveal that less scientifically productive researchers can also positively contribute to the level of patenting at academic institutions. In our opinion, these findings need to be considered with caution, as institutions should give advantage to quality, rather than quantity, in assessing knowledge transfer performance. This recommendation also applies to national and EU policy makers, who should expand the existing list of knowledge transfer performance indicators by including also those that promote quality and not merely the number of outputs, such as new patents, licensing agreements and generated spin-offs.

When defining the incentives for researchers to engage in knowledge transfer, academic institutions should bear in mind that financial incentives are not the only available mechanism, since life science researchers sometimes more highly value the opportunity to receive industry funds to expand the research activities of their laboratory than only receiving the financial compensation from royalties. Furthermore, institutional managers should not neglect the fact that knowledge transfer also occurs outside the formal institutional structures, such as technology transfer offices. Instead, they should investigate to what extent and why their faculty sustains from establishing contacts with the technology transfer administrators, regardless of the existence of regulations and other formal documents, which insist on this knowledge transfer process route.

In addition, institutional policies promote the establishment of academic spin-off companies partly or fully in their ownership, but often fail to consider their management and team structures and market attractiveness of spin-off technologies. As shown in our study, the consequence is a high failure rate of academic spin-offs. Technology managers at academic institutions should thus carefully assess the readiness of university inventions for commercialization via establishment of new ventures.

We also showed that knowledge transfer activities do not necessarily yield only positive results, such as increased revenues for academic institutions and better exploitation of university-generated research results. In fact, this is the case for only a minor part of the institutions, especially in Europe. Policies at academic institutions must therefore not promote unconditional commercialization; exactly the opposite, they should carefully consider the scientific interests of academic researchers and characteristics of inventions before proceeding to the contractual relationships with the business sector.

The second group of practical implications is based on the conceptualization and empirical testing of determinants of knowledge sharing restrictions in the life science academic community. Knowledge and technology transfer have become widely understood as desirable and appropriate sources of financing at research universities (Colyvas and Powell 2006). At the same time concerns over potential negative impacts of these activities on the norms of open science have arisen. The biggest controversy concerns patenting of research tools or inputs for subsequent research as well as expansion of proprietary rights to life forms (Caulfield and Ogbogu 2008). As a response, funding agencies have increasingly been requesting from scientists to follow the open science policy, to allow other researchers to replicate or further develop their results (Franzoni and Sauermann 2014). Our results imply that when examining the barriers to open knowledge sharing in the academic communities, research organisations managers and policy makers should consider the role of different forms of interactions of academic researchers with industry and their commercial activities. Moreover, they should take into account other factors, such as personal characteristics of researchers, their motivations and values, as well as context-specific determinants of different forms of knowledge sharing restrictions. Such approach will facilitate the designing of science policies that stimulate academic-industry knowledge transfer and at the same time support the characteristics of the open science system. We show evidence that supports the view on the present science system as a hybrid between open science and secrecy (Mukherjee and Stern 2009), not only because of the increased importance of commercial exploitation of academic research results, but also due to the intense scientific competitiveness as well as other, both personal and context-specific factors that have been significantly affecting different forms of knowledge sharing restrictions.

The third group of practical implications of our study follows from the analysis of the role of university-derived intellectual property rights and research and development funding mechanisms in innovation performance of the healthcare biotechnology industry. Our study indicated that the US biotech business model relies heavily on monetization of IPRs generated at academic institutions, government investments in high-risk research, public capital markets and financial institutions. Its European counterpart has been striving to emulate that model because of its better performance in most of the indicators. Yet, we also provided evidence that the financial markets-driven US sector impedes innovation performance due to its focusing on short-term financial gains, tied to stock-price fluctuations and stock-based compensations, in the industry which demands "patient" capital, which questions the long-term sustainability of the biotechnology industry.

Since the conducted empirical studies revealed an increasing number of commercial irrelevant university-generated patents, we propose that European academic institutions should reconsider their present technology transfer policies: instead of "pushing" their technology transfer offices to patent as much as possible in a "monolithic way", universities should invest in developing effective pipelines for critical evaluation of potentially patentable inventions. In that way, they will reduce irrelevant activities in technology transfer offices; reduce the pressure on basic academic research and decrease the costs of legal services associated with IP protection (e.g., application filing, enforcement). On top of that, there have recently been attempts to propose alternative IPR regimes. These include the return to inventor ownership and compulsory non-exclusive licensing (Kenney and Patton 2009, Dorsey et al. 2010, Hoffenberg 2010). Recently initiated in the USA and already existing in Germany, compulsory licensing should enable innovative companies to receive a return on their investment in research. At the same time, users would have access to technology at reasonable prices.

Moreover, an area where the European industry should emulate the US biotechnology is bigger interrelatedness of basic science and clinical development, as proposed already by Owen-Smith and colleagues (2002). They showed that the US public research organizations and small biotechnology companies conduct decentralized R&D across multiple areas and stages of the development process, while Europe has regional specialization with a less diverse group of public research organizations working in a smaller number of areas, with a considerably more centralized funding within nations. Europe thus needs to make changes in the division of labour in order to support innovation.

Finally, in order to encourage the sustainable development, the European biotech industry should invest more effort in the direction of strategic selection of fewer funding priorities and long-term focus on therapeutic and diagnostic products that have the potential for viable commercial success (Commission 2007). An opportunity exists in the development of biosimilars (which assume an R&D-intensive activity, unlike the production of generic pharmaceuticals), due to the fact that the patent protection of many biotechnology medicines will expire in the forthcoming years. Developing treatments for conditions with very small patient populations, or rare diseases, represents an opportunity that has already been recognized on both sides of the Atlantic (Ernst&Young 2011) as a response to the challenge of unsustainable "blockbuster" medicines. Such strategies should be accompanied by adequate policies, which would promote greater specialisation and the need for "patient" capital to venture capitalists and other types of investors.

Summary of limitations and future research opportunities

The first limitation of our study refers to the systematic review of the literature on academic-industry knowledge transfer, based on which we developed a new conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science. We discussed the predictors of involvement of researchers in different forms of academic-industry knowledge transfer and predictors of academic-industry knowledge transfer performance of research instutions. We devoted attention to determinants of academic entrepreneurship as a specific form of academic-industry knowledge transfer, but more research is needed with the focus on the composition of spin-off management teams, in order to elucidate the role of the scientist-inventor and external, non-academic managers and entrepreneurs in the technology commercialization and company growth. Also, when investigating the implications of academic-industry knowledge transfer for public science, we observed an overall lack of studies that compare the performance of systems that rely on the institutional management of academic-industry knowledge transfer activities (dominant) with those that favor the exploitation by individual researchers (professor's privilege). This should be addressed in the future empirical studies on academic-industry knowledge transfer performance of academic research institutions.

The second limitation of the study refers to the use of interviews and questionnaire survey for the empirical part of our research on academic-industry knowledge transfer-knowledge sharing interactions. The use of questionnaire surveys represents a less objective method when compared to scientometrics, due to its reliance on self-reporting as well as the absence of the introduction of a longer time dimension in the analyses (Azoulay et al. 2006). Scientometrics have been used extensively in the literature relying on co-authorship of scientific papers to analyse knowledge exchange among researchers, both within and across individual companies and academic research groups, as well as to investigate social networks of academic scientists (Murray and Stern 2007, Rosell and Agrawal 2009). On the other hand, the use of questionnaire surveys and interviews enables better insights into causes and effects of particular behaviours (Campbell et al. 2002, Walsh et al. 2007).

The third limitation of our study relates to the potential reverse causality problem in the empirical testing of determinants of knowledge sharing restrictions in the academic community. Following the econometric analysis, we report the associations, and not the causal relationships, between different forms of academic-industry knowledge transfer, individual and contextual factors, and different forms of knowledge sharing restrictions. We mitigated this problem to a certain extent by also directly asking our survey respondents about the causes of different restrictions in their knowledge sharing behaviors. The obtained results are presented in this dissertation and complement the analysis based on correlations between dependent and independent variables. Similar studies in the field have also identified this problem. Gaughan and Corley (2010) investigate the impact of university research center-affiliation on industrial activities and acknowledge the unknown causal relationship between these two variables as a limitation of the study. They justify their approach by pointing to other studies of the topic, which have had difficulty with estimating the endogeneity bias due to inexistence of longitudinal data that would allow specifying temporal priority. Some studies succeed in specifying temporal priority by using only the most recent experiences of survey respondents as a measure of knowledge sharing restrictions. For example, Walsh and colleagues (2007) use regression analyses to test the reasons for non-compliance with requests for materials by assessing the factors (including the patent status of the requested material) conditioning whether a respondent's most recent request for materials was satisfied. In our study, we decided not to consider only the most recent experience with knowledge sharing, but instead collected the data from respondents that refer to the period of last five years. This enabled us to get insights into the general patterns of sharing behaviors of academic researchers. Future empirical research should consider temporal priority in the assessment of the impact of academic-industry knowledge transfer, individual and contextual factors on different forms of knowledge sharing restrictions in academia. Moreover, considering that our quantitative study is based on a single sample from Croatia, the model should also be tested in other national contexts.

The fourth limitation of the study refers to the analysis of biotechnology industry innovation performance determinants. Since there are still too few studies empirically assessing the impact of public investments into science base on innovation performance, we propose that future efforts should take this direction. Namely, it would be very interesting to investigate further why the most recent industry reports point to decreases in new molecular entity approvals despite the increasing R&D and commercialisation funding levels in both regions included in our study. Also, a limitation of our research is that it does not take into account the diversity of national biotechnology industries across Europe in assessing the determinants of innovative performance. Instead, the study deploys a "big picture" approach in comparing the two regions which represent the key global players in the biotech industry. Future research endeavours should consider the heterogeneity of European national IPR as well as R&D and commercialisation funding systems.

Concluding remarks

Academic-industry knowledge transfer has received much attention in the science policy, innovation and entrepreneurship literature over the past thirty years. Scholars have been highly interested in benefits and challenges of involvement of academic researchers and their institutions in interactions with the business sector, particularly in relation to the implications of such actvities for science system. This dissertation yields important contributions to the existing literature on academic-industry knowledge transfer. It proposes a new conceptual framework for assessment of the effectiveness of academic-industry knowledge transfer and its impact on public science. It conceptualizes and empirically tests academic-industry knowledge transfer-knowledge sharing relationship by considering the heterogeneity of different forms of academic knowledge transfer and knowledge sharing. It also comprehensively explores the role of the institutional context in knowledge transfer-knowledge sharing interactions. The dissertation takes into account a broad range of individual and context-specific predictors of knowledge sharing restrictions, which enables the generation of specific science policy recommendations. Finally, by using two divergent theories in assessment of how university-generated intellectual property rights, public investments into knowledge base and business funding mechanisms affect biotechnology innovation performance, the study contributes to our understanding of driving forces of innovation performance in healthcare biotechnology.

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APPENDICES

LIST OF APPENDICES

Appendix A: Overview of key studies on academic-industry knowledge transfer motivations of academic researchers

Authors	Study type	Level of analysis	Setting	Key findings
Cluster 1 - Industry collaboration predictors - individual level, internal and external				
Louis et al. (1989)	Quantitative (questionnaire survey and interview)	Individual scientists (778) and administrators (40)	USA	The most important predictors of supplemental income are **individual characteristics and attitudes**, while active involvement in commercialization is most associated with **local group norms**. University policies and structures have weak effect on academic-industry knowledge transfer.
Zucker and Darby (1996)	Quantitative (scientometric analysis of publications)	Individual researchers	USA	**Star scientists**, or most productive authors of research articles, played a disproportionately significant role in the commercialization of life science inventions.
Lee (2000)	Quantitative (questionnaire surveys)	Individual researchers (427) and managers of firms (140)	USA	The most significant motivators of academic researchers for collaborating with industry are related to their basic research, which they want to sustain by **securing funds for doctoral students and laboratory equipment**.
Oliver (2004)	Quantitative (questionnaire survey)	Individual scientists (291)	Israel	Scientists with more than two patents have significantly more **students** at all levels, **higher tenure** and at least **one postdoctoral student**. Scientists with at least one patent also have more **international collaborations** and more **areas of interest** than non-inventors.
Davis and Lotz (2006)	Quantitative (questionnaire survey)	Individual scientists (264)	Denmark	There is a highly significant relationship between **strong publication records** and **experience with patent** and cooperation with industry (contract research, joint project, consulting).
Renault (2006)	Qualitative (interviews), quantitative (survey)	Individual (98 researchers at 12 universities)	USA	Support for academic capitalism is positively related to industry collaboration, patenting and spinning-off engagement; publishing is positively related only to patenting; institutional policy on revenue splits with inventors is positively related to patenting and spinning-off.
Boardman and Ponomariov (2009)	Quantitative (survey)	Individual scientists (1,643)	USA	University scientists **with industry grants**; affiliations with **university research centers**; who **support students with grants-based funds**; are engineers, computer or agricultural scientists; have **tenure**; whose attitudes towards science are **not closely aligned** with traditional **Mertonian scientific values**; and who are **non-minorities** are more likely to have interactions of any type with industry.
Haeussler and Colyvas (2011)	Quantitative (questionnaire survey)	Individual scientists (2,294)	UK, Germany	**Professional security (post-tenure career stage), advantage (more team members) and productivity** are strong predictors for a greater involvement of life scientists in academic entrepreneurship, but not for all analyzed forms of technology transfer. The **level of reputational importance placed on scientific compared to commercial achievements** affects commercial involvement extent.

(table continues)

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
Abreu and Grinevich (2013)	Quantitative (questionnaire survey)	Individual scientists (22,556)	UK	Academic entrepreneurship (including formal activities, e.g. patenting, spinouts, licensing, and informal activities, such as consulting or contract research), is explained by **demographic factors, type of research and academic discipline, previous entrepreneurial experience and institutional support and entrepreneurial training**. Senior academics are more likely to be involved in all types of entrepreneurship than younger academics, but the difference is greatest for informal activities. Female academics are less likely to be involved in entrepreneurship than their male colleagues, but the gender gap is larger for informal activities. Applied research-oriented academics are more likely to engage in entrepreneurship, particularly in informal and non-commercial activities. Former ownership of a company is positively associated with involvement in informal and non-commercial activities. Institutional support (training) and greater value given to research and commercial activities is positively associated with involvement in non-commercial activities and contract research, respectively.
Tartari et al. (2014)	Quantitative (survey, database)	Individual researchers (1,192)	UK	**Peer effects** influence academic scientists' industry engagement through the mechanism of social comparison, and the effects are stronger for early career individuals and weaker for star scientists.
Cluster 2 - Patenting and licensing predictors - individual level, internal and external				
Louis et al. (1989)	Quantitative (questionnaire survey and interview)	Individual scientists (778) and administrators (40)	USA	The most important predictors of supplemental income are **individual characteristics and attitudes**, while active involvement in commercialization is most associated with **local group norms**. University policies and structures have weak effect on academic-industry knowledge transfer.
Owen-Smith and Powell (2001)	Qualitative (interviews)	Individual scientists and licensing professionals (68) at 2 universities	USA	Researcher's patenting decisions depend on their perceptions of the **personal** (finance, curiosity) and **professional** (prestige, validation of basic research) **benefits of patenting**; **time and resource costs** of interacting with TTOs; their immediate **environment** (awareness, support, recognition in academic career).
Oliver (2004)	Quantitative (questionnaire survey)	Individual scientists (291)	Israel	Scientists with more than two patents have significantly more **students** at all levels, **higher tenure** and at least **one postdoctoral student**. Scientists with at least one patent also have more **international collaborations** and more **areas of interest** than non-inventors.
Renault (2006)	Qualitative (interviews), quantitative (survey)	Individual (98 researchers at 12 universities)	USA	Support for academic capitalism is positively related to industry collaboration, patenting and spinning-off engagement; publishing is positively related only to patenting; institutional policy on revenue splits with inventors is positively related to patenting and spinning-off.
Azoulay et al. (2007)	Quantitative (patents and publications)	Individual scientists (3,862)	USA	Patenting is preceded by **intensive publishing**, which depends on the context, such as the presence of **co-authors who patent** and the patent stock of the **scientist's university**.
Landry et al. (2007)	Quantitative (questionnaire survey)	Individual researchers (479 in engineering and 449 in life sciences)	Canada	**Research novelty** and **laboratory size** explain patenting and spin-off formation in both engineering and life sciences. **Network capital** explains spin-off formation in both disciplines, but patenting only in life sciences. *(table continues)*

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
Calderini et al. (2007)	Quantitative (scientometric analysis of patents and publications)	Individual scientists (1,276)	Italy	Scientists working on **applied research** produce industrial applications easier than their colleagues working on fundamental research. The probability to patent is a positive function of **productivit**y, basicness or impact for **low-to-moderate-high values of the variables**, and a negative function for high values. For scientists that publish very basic or **very high-impact research**, every increase in productivity results in a reduced probability to patent - academic activity is in a rival relationship with patenting.
Baldini et al. (2007)	Quantitative (questionnaire survey)	Individual scientists (208)	Italy	Respondents start patenting to enhance their **reputation**, and look for new **motivations for their research**; personal earnings do not represent a main incentive.
Bercovitz and Feldman (2008)	Quantitative (interviews, database)	Individual researchers (1,780) at 15 departments of medical schools of 2 universities	USA	Researchers are more likely to disclose inventions if they have been **trained** at institutions (local environment) that had actively accepted technology transfer initiatives, if their **department chair** is active in technology transfer and if they observe **others that they identify with** involving in technology transfer (localized social norms). The **longer the time** since graduate training, the less likely the individual was to actively accept the new commercialization norm.
Boardman and Ponomariov (2009)	Quantitative (survey)	Individual scientists (1,643)	USA	University scientists **with industry grants**; affiliations with **university research centers**; who **support students with grants-based funds**; are engineers, computer or agricultural scientists; have **tenure**; whose attitudes towards science are **not closely aligned** with traditional **Mertonian scientific values**; and who are **non-minorities** are more likely to have interactions of any type with industry.
Haeussler and Colyvas (2011)	Quantitative (questionnaire survey)	Individual scientists (2,294)	UK, Germany	**Professional security (post-tenure career stage), advantage (more team members) and productivity** are strong predictors for a greater involvement of life scientists in academic entrepreneurship, but not for all analyzed forms of technology transfer. The **level of reputational importance placed on scientific compared to commercial achievements** affects commercial involvement extent.
Cluster 3 - Academic entrepreneurship predictors - individual level, internal and external				
Louis et al. (1989)	Quantitative (questionnaire survey and interview)	Individual scientists (778) and administrators (40)	USA	The most important predictors of supplemental income are **individual characteristics and attitudes**, while active involvement in commercialization is most associated with **local group norms**. University policies and structures have weak effect on academic-industry knowledge transfer.
Audretsch and Stephan (1996)	Quantitative (databases)	54 firms affiliated with 445 university-based scientists	USA	The influence of **geographic proximity** in establishing relationships between university-based scientists and companies depends on the role played by the scientist – location is more relevant in the case of founders than members of scientific advisory boards.
Shane (2000)	Qualitative (case study)	Individual researchers-entrepreneurs (8)	USA	In exploiting new technologies, entrepreneurs' **individual differences** influence the opportunities they discover, how they organize entrepreneurial efforts and how the government can influence the process. *(table continues)*

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
Nicolaou and Birley (2003)	Qualitative	n/a	n/a	Proposition that academic inventor's embeddedness in a **network of connections** influences the type of spinout initiated (orthodox, hybrid or technology).
Kenney and Goe (2004)	Qualitative (historical analysis, survey, internet search)	Individual scientists (24) in 2 universities	USA	The involvement of professors in entrepreneurial activity is influenced by the **culture and regulations of institutional departments** they belong to.
Renault (2006)	Qualitative (interviews), quantitative (survey)	Individual (98 researchers at 12 universities)	USA	Support for academic capitalism is positively related to industry collaboration, patenting and spinning-off engagement; publishing is positively related only to patenting; institutional policy on revenue splits with inventors is positively related to patenting and spinning-off.
Stuart and Ding (2006)	Quantitative (scientometric analysis of publications, databases)	Individual researchers-entrepreneurs (917)	USA	**Social influences** (commercial science orientation of colleagues and co-authors) and **human capital** (productivity, patents, proximity to commercial science, past job mobility) influence the probability of researchers for transitioning to for-profit science.
Landry et al. (2007)	Quantitative (questionnaire survey)	Individual researchers (479 in engineering and 449 in life sciences)	Canada	**Research novelty** and **laboratory size** explain patenting and spin-off formation in both engineering and life sciences. **Network capital** explains spin-off formation in both disciplines, but patenting only in life sciences.
Krabel and Mueller (2009)	Quantitative (interview survey)	Individual researchers (2,604)	Germany	Entrepreneurial activities of scientists depend on **patenting activity, entrepreneurial experience** and **personal opinions** about the benefits of commercializing research and **close personal connections to industry**.
Boardman and Ponomariov (2009)	Quantitative (survey)	Individual scientists (1,643)	USA	University scientists **with industry grants**; affiliations with **university research centers**; who **support students with grants-based funds**; are engineers, computer or agricultural scientists; have **tenure**; whose attitudes towards science are **not closely aligned** with traditional **Mertonian scientific values**; and who are **non-minorities** are more likely to have interactions of any type with industry.
Aldridge and Audretsch (2010)	Quantitative (databases)	Individual scientists-inventors (392)	USA	Scientists choosing **commercialization route** without assigning patents to their university tend to rely on the commercialization mode of starting a new firm, while scientists who select the TTO route by assigning their patents to the university tend to rely on the commercialization mode of licensing.
Fini et al. (2010)	Quantitative (interview survey)	Individual researchers (11,572)	USA	Academic entrepreneurs who started their businesses based on patents tend to be **younger** than those who started their businesses not based on patents. There is a trade-off between commercial activities on the one hand, and **research and teaching** on the other, for patent-based academic entrepreneurship, but not for non-patent-based academic entrepreneurship. Starting businesses based on patents is more likely to occur in the **biosciences**, while starting businesses not based on a patent is more likely for departments related to social sciences and behavioral studies.

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Authors	Study type	Level of analysis	Setting	Key findings
Prodan and Drnovsek (2010)	Quantitative (questionnaire survey)	Individual researchers (547)	UK, Slovenia	**Entrepreneurial self-efficacy**, **type of research, perceived role models, number of years spent at an academic institution, and patents** are significantly related to the formation of academic-entrepreneurial intentions, regardless of the cultural context.
Haeussler and Colyvas (2011)	Quantitative (questionnaire survey)	Individual scientists (2,294)	UK, Germany	**Professional security (post-tenure career stage), advantage (more team members) and productivity** are strong predictors for a greater involvement of life scientists in academic entrepreneurship, but not for all analyzed forms of technology transfer. The **level of reputational importance placed on scientific compared to commercial achievements** affects commercial involvement extent.
Astebro et al. (2012)	Quantitative (questionnaire survey), case studies	Start-ups by individual respondents (3,732), universities (3)	USA	**Recent graduates** are twice as likely as their faculty to create a start-up within three years of graduation, which is why national and university policies should not only consider faculty spin-offs, but think of effective ways to stimulate entrepreneurial activities through educational programs.
Nelson (2014)	Qualitative (interview, case study)	Individual actors in commercialization process (11)	USA	**Organizational context** defines the decision to engage in entrepreneurship and also the approach taken to commercialization processes: the same individuals adopted very different behaviors and perspectives in the different organizational contexts.
Abreu and Grinevich (2013)	Quantitative (questionnaire survey)	Individual scientists (22,556)	UK	Academic entrepreneurship (including formal activities, e.g. patenting, spinouts, licensing, and informal activities, such as consulting or contract research), is explained by **demographic factors, type of research and academic discipline, previous entrepreneurial experience, institutional support and training**. Senior academics are more likely to be involved in all types of entrepreneurship than younger academics, but the difference is greatest for informal activities. Female academics are less likely to be involved in entrepreneurship than male colleagues, but the gender gap is larger for informal activities. Applied research-oriented academics are more likely to engage in entrepreneurship, particularly in informal and non-commercial activities. Former ownership of a company is positively associated with involvement in informal and non-commercial activities. Institutional support and greater value for research and commercial activities is positively associated with non-commercial activities and contract research.
Cluster 4 - Composite predictors - individual level, internal and external				
Blumenthal et al. (1996)	Quantitative (questionnaire survey)	Individual scientists (2,052)	USA	Compared to scientists without industry support, those **with industry funding** are much more likely to have applied for a patent, had a patent granted or licensed, had a product under review or on the market, or started a company.
Mowery et al. (2001)	Quantitative (databases)	Universities (3)	USA	**The change of legislation** (Bayh-Dole Act) was not the decisive factor that stimulated the upsurge of knowledge transfer activities in life science area. Additional influencing factors include the **development of biotechnology industry and changes in institutional policies**.
Owen-Smith and Powell (2001)	Qualitative (interviews)	Individual scientists (80) at 2 universities	USA	Life science commercialization is driven by **new funding opportunities, changing institutional mandates for universities, and novel research technologies** that bring closer basic research and product development.

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Authors	Study type	Level of analysis	Setting	Key findings
Murray (2004)	Qualitative (interviews), quantitative (analysis of publications and patents)	Individual scientists-inventors and entrepreneurs (25) in 12 companies	USA	**Social capital** of academic scientists (local laboratory network and wider, global network of colleagues and co-authors) is essential for companies because it can be transformed into their scientific networks.
Boardman and Ponomariov (2009)	Quantitative (survey)	Individual scientists (1,643)	USA	University scientists **with industry grants**; affiliations with **university research centers**; who **support students with grants-based funds**; are engineers, computer or agricultural scientists; have **tenure**; whose attitudes towards science are **not closely aligned** with traditional **Mertonian scientific values**; and who are **non-minorities** are more likely to have interactions of any type with industry.
Jain et al. (2009)	Qualitative (interviews)	Individual researchers and tech transfer specialists (28)	USA	University scientists seek to actively preserve their **academic role identity** even while they participate in technology transfer. They usually embrace a **hybrid role identity** that includes a core academic self and a secondary commercial self, using two mechanisms – delegating (commercial tasks) and buffering (aimed at preserving values associated with being an academic even when involved in technology transfer).
Aldridge and Audretsch (2010)	Quantitative (databases)	Individual scientists-inventors (392)	USA	Scientists choosing **commercialization route** without assigning patents to their university tend to rely on the commercialization mode of starting a new firm, while scientists who select the TTO route by assigning their patents to the university tend to rely on the commercialization mode of licensing.
Gaughan and Corley (2010)	Quantitative (questionnaire survey)	Individual scientists (1,868)	USA	Affiliation with a **university research center** increases the industrial involvement of both men and women researchers.
Giuliani et al. (2010)	Quantitative (interview survey)	Individual scientists (135)	Chile, South Africa, Italy	Researchers' individual characteristics, such as **centrality in the academic system (number of collaborators), age and sex**, matter more than publishing records or formal degrees for establishing university-industry interactions. **Institutional specificities at country level (policies)** also play a role in defining the proclivity of researchers to involve with industry.
Haeussler and Colyvas (2011)	Quantitative (questionnaire survey)	Individual scientists (2,294)	UK, Germany	**Professional security (post-tenure career stage), advantage (more team members) and productivity** are strong predictors for a greater involvement of life scientists in academic entrepreneurship, but not for all analyzed forms of technology transfer. The **level of reputational importance placed on scientific compared to commercial achievements** affects commercial involvement extent.
Schuelke-Leech (2013)	Quantitative (questionnaire survey, database)	Individual scientists (1,636), departments	USA	**The quality of human capital in a researcher's department (number of team members, productivity and research impact), non-federal R&D expenditures and direct industry funding, having tenure, number of years since earning a PhD, and being a native U.S. citizen** are positively related to industry involvement diversity and intensity. **Individual academic productivity** reduces the likelihood of high industry involvement intensity.

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Authors	Study type	Level of analysis	Setting	Key findings
Abreu and Grinevich (2013)	Quantitative (questionnaire survey)	Individual scientists (22,556)	UK	Academic entrepreneurship (including formal activities, e.g. patenting, spinouts, licensing, and informal activities, such as consulting or contract research), is explained by **demographic factors, type of research and academic discipline, previous entrepreneurial experience and institutional support and entrepreneurial training**. Senior academics are more likely to be involved in all types of entrepreneurship than younger academics, but the difference is greatest for informal activities. Female academics are less likely to be involved in entrepreneurship than their male colleagues, but the gender gap is larger for informal activities. Applied research-oriented academics are more likely to engage in entrepreneurship, particularly in informal and non-commercial activities. Former ownership of a company is positively associated with involvement in informal and non-commercial activities. Institutional support (training) and greater value given to research and commercial activities is positively associated with non-commercial activities and contract research, respectively.
Aschhoff and Grimpe (2014)	Quantitative (questionnaire survey)	Individual researchers (355)	Germany	A biotechnology scientist's involvement in collaboration with industry increases with the **orientation of the scientist's department toward industry** („localized peer effect"). The scientist's age moderates this effect: the localized peer effect decreases with age and turns negative for most senior scientists. A scientist's involvement increases with the industry **orientation of the scientist's co-authors** ("personal peer effect"), irrespective of the scientist's age. In case both types of social influence are in conflict, younger scientists will revert to localized norms, while more experienced scientists will orient themselves more toward their personal collaborators.

Appendix B: Internal and external knowledge transfer predictors and motivators

Knowledge transfer activity / Internal predictor - motivator	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Scientific productivity and impact	**Positive** (5) Zucker and Darby 2006, Davis and Lotz 2006, Haeussler and Colyvas 2011, Tartari et al. 2014, Louis et al. 1989 **Not significant** (1) Renault 2006	**Positive** (5) Bercovitz and Feldman (2008), Haeussler and Colyvas 2011, Renault 2006, Louis et al. 1989, Azoulay 2007 **Mixed** (1) (positive for low-to-moderate-high values, negative for high values) Calderini et al. 2007 **Negative** (1) Landry et al. 2007 (but not controlled for quality of publications and sub-areas)	**Positive** (2) Haeussler and Colyvas 2011, Stuart and Ding 2006 **Negative** (1) Aldridge and Audretsch 2010 **Not significant** (2) Renault 2006, Louis et al. 1989	**Positive** (2) Haeussler and Colyvas 2011, Aschoff and Grimpe 2014 **Not significant** (1) Giuliani et al. 2010 **Negative** (1) (with intensity) Schuelke-Leech 2013
Professional status				
Tenure, number of years since PhD	**Positive** (4) Boardman and Ponomariov 2009, Haeussler and Colyvas 2011, Abreu and Grinevich 2013, Tartari et al. 2014 - professor **Negative** (1) Tartari et al. 2014 (number of years since training) **Not significant** (1) Renault 2006	**Positive** (4) Oliver 2004, Landry et al. 2007, Haeussler and Colyvas 2011 Bercovitz and Feldman 2008 - rank **Mixed** (1) Landry et al. 2007 (associate professor rather than full professor) **Negative** (1) Bercovitz and Feldman (2008) (number of years since training) **Not significant** (2) Boardman and Ponomariov 2009, Renault 2006	**Positive** (4) Landry et al. 2007 (more probable if directors), Krabel and Mueller 2009, Haeussler and Colyvas 2011 (but less than for other types), Prodan and Drnovsek 2010 **Not significant** (3) Boardman and Ponomariov 2009, Abreu and Grinevich 2013, Renault 2006 **Negative** (1) Astebro et al. 2012 (compared to recent graduates)	**Positive** (6) Boardman and Ponomariov 2009, Gaughan and Corley 2010, Haeussler and Colyvas 2011, Schuelke-Leech 2013, Abreu and Grinevich 2013, Aschoff and Grimpe 2014 (years) **Not significant** (2) Giuliani et al. 2010, Aschoff and Grimpe 2014 (tenure)

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Knowledge transfer activity / **Internal predictor - motivator**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Jobs in career			**Positive** (1) Stuart and Ding 2006 (2006)	
Management / entrepreneurship training in addition to scientific training	**Positive** (1) Abreu and Grinevich 2013 **Not significant** (1) Haeussler and Colyvas 2011	**Not significant** (1) Haeussler and Colyvas 2011	**Positive** (2) Haeussler and Colyvas 2011, Abreu and Grinevich 2013	**Positive** (1) Haeussler and Colyvas 2011 **Not significant** (1) Abreu and Grinevich 2013
Demographic characteristics				
Ethnicity - non-minorities			**Less likely** (1) Krabel and Mueller 2009	**More likely** (2) Boardman and Ponomariov 2009, Schuelke-Leech 2013
Age - senior	**Positive** (3) Davis and Lotz 2006, Boardman and Ponomariov 2009, Abreu and Grinevich 2013 **Not significant** (1) Haeussler and Colyvas 2011 **Mixed** (1) Louis et al. 1989 (positive for supplemental income, not significant for industry funding)	**Positive** (2) Boardman and Ponomariov 2009, Haeussler and Colyvas 2011 **Not significant** (1) Louis et al. 1989	**Not significant** (5) Boardman and Ponomariov 2009, Aldridge and Audretsch 2010, Abreu and Grinevich 2013, Haeussler and Colyvas 2011, Louis et al. 1989 **Negative** (1) Astebro et al. 2012 (compared to recent graduates)	**Positive** (1) Haeussler and Colyvas 2011 **Not significant** (2) Boardman and Ponomariov 2009, Gaughan and Corley 2010 **Negative** (2) Giuliani et al. 2010, Abreu and Grinevich 2013
Gender – female	**Less likely** (2) Boardman and Ponomariov 2009, Abreu and Grinevich 2013 **Not significant** (1) Haeussler and Colyvas 2011	**Less likely** (2) Azoulay 2007, Haeussler and Colyvas 2011	**Less likely** (4) Landry et al. 2007, Boardman and Ponomariov 2009, Haeussler and Colyvas 2011, Abreu and Grinevich 2013 **Not significant** (2) Aldridge and Audretsch 2010, Krabel and Mueller 2009	**More likely** (1) Giuliani et al. 2010 (only when controlled for peer effect) **Less likely** (3) Gaughan and Corley 2010, Haeussler and Colyvas 2011, Abreu and Grinevich 2013 **Not significant** (2) Boardman and Ponomariov 2009, Aschoff and Grimpe 2014 *(table continues)*

(continued)

Knowledge transfer activity / Internal predictor - motivator	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Social capital				
Number of local and international collaborators		**Positive** (2) Oliver 2004, Landry et al. 2007	**Positive** (1) Landry et al. 2007	**Positive** (2) Murray 2004 Giuliani et al. 2010 **Not significant** (1) Boardman and Ponomariov 2009
Strength of partnerships with users			**Negative** (1) Landry et al. 2007	
Networks with industry			**Positive** (1) Krabel and Mueller 2009	
Attitudes				
With hybrid role identity				**Positive** (1) Jain et al. 2009
Closely aligned with Mertonian (open science) values	**Negative** (3) Haeussler and Colyvas 2011, Renault 2006, Louis et al. 1989 **Positive** (1) Tartari et al. 2014 (different measurement)	**Negative** (2) Renault 2006, Louis et al. 1989 **Not significant** (1) Haeussler and Colyvas 2011	**Negative** (3) Krabel and Mueller 2009, Haeussler and Colyvas 2011, Renault 2006 **Not significant** (1) Louis et al. 1989	**Negative** (3) Boardman and Ponomariov 2009, Haeussler and Colyvas 2011, Schuelke-Leech 2013
Entrepreneurial self-efficacy			**Positive** (1) Prodan and Drnovsek 2010	
Perceived role models			**Positive** (1) Prodan and Drnovsek 2010	
Motivations				
Reputation with scientific peers	**Positive** (1) Haeussler and Colyvas 2011	**Positive** (3) Owen-Smith and Powell 2001b, Baldini et al. 2007, Haeussler and Colyvas 2011	**Positive** (1) Haeussler and Colyvas 2011 **Not significant** (1) Krabel and Mueller 2009	**Positive** (1) Haeussler and Colyvas 2011
Valuation of scientific awards for reputation	**Not significant** (1) Haeussler and Colyvas 2011	**Not significant** (1) Haeussler and Colyvas 2011	**Positive** (1) Haeussler and Colyvas 2011	**Positive** (1) Haeussler and Colyvas 2011
Financial (funds for the laboratory)	**Positive** (2) Lee 2000, Tartari et al. 2014	**Positive** (1) Baldini et al. 2007		

(table continues)

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Knowledge transfer activity / Internal predictor - motivator	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Curiosity to validate or find application for basic research	Positive (2) Davis and Lotz 2006, Lee 2000	Positive (2) Owen-Smith and Powell 2001b, Baldini et al. 2007		
Research type (applied)	**Positive** (2) Abreu and Grinevich 2013, Tartari et al. 2014 **Not significant** (1) Davis and Lotz 2006	**Positive** (1) Calderini et al. 2007	**Positive** (2) Abreu and Grinevich 2013, Prodan and Drnovsek 2010	**Positive** (2) Abreu and Grinevich 2013, Aschoff and Grimpe 2014
Research discipline (life sciences)		**More likely** (1) Owen-Smith and Powell 2001b **More likely** – diversity (1) Oliver 2004		**Less likely** (1) Gaughan and Corley 2010
Previous academic-industry knowledge transfer or business experience	**Positive** (4) Davis and Lotz 2006, Abreu and Grinevich 2013, Tartari et al. 2014, Louis et al. 1989	**Positive** (4) Oliver 2004, Landry et al. 2007, Bercovitz and Feldman 2008, Louis et al. 1989	**Positive** (5) Krabel and Mueller 2009, Abreu and Grinevich 2013, Louis et al. 1989, Stuart and Ding 2006, Prodan and Drnovsek 2010 **Not significant** (1) Boardman and Ponomariov 2009	**Positive** (3) Blumenthal et al. 1996, Boardman and Ponomariov 2009, Abreu and Grinevich 2013 **Not significant** (1) Aschoff and Grimpe 2014
Entrepreneurship in family	**Positive** (1) Haeussler and Colyvas 2011	**Positive** (1) Haeussler and Colyvas 2011	**Positive** (1) Haeussler and Colyvas 2011	**Positive** (1) Haeussler and Colyvas 2011

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Knowledge transfer activity / External predictor - motivator	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Research resources				
Students and postdoctoral researchers		**Positive** (1) Oliver 2004		**Positive** (1) Boardman and Ponomariov 2009
Team members in laboratory	**Positive** (1) Oliver 2004 **Mixed** (1) Haeussler and Colyvas 2011 (positive for small labs, decreases for large labs)	**Positive** (1) Landry et al. 2007 **Mixed** (1) Haeussler and Colyvas 2011 (inverted U-shaped)	**Positive** (1) Landry et al. 2007 **Not significant** (1) Haeussler and Colyvas 2011	**Mixed** (1) Haeussler and Colyvas 2011 (inverted U-shaped) **Not significant** (1) Giuliani et al. 2010
Scientific quality of department	**Not significant** (1) Tartari et al. 2014 **Negative** (1) Louis et al. 1989	**Positive** (1) Bercovitz and Feldman 2008 **Not significant** (1) Louis et al. 1989	**Positive** (1) Stuart and Ding 2006 **Not significant** (1) Louis et al. 1989	**Positive** (1) Schuelke-Leech 2013 **Not significant** (1) Aschoff and Grimpe 2014
Public R&D expenditure				**Not significant** (1) Schuelke-Leech 2013
Institutional norms and support structures				
Local norms, awareness, support, training, recognition in academic career	**Positive** (1) Louis et al. 1989 **Mixed** (1) Abreu and Grinevich 2013 (positive for contract research, negative for informal activities with industry)	**Positive** (3) Owen-Smith and Powell 2001b, Bercovitz and Feldman 2008, Louis et al. 1989	**Positive** (3) Kenny and Goe 2004, Abreu and Grinevich 2013, Louis et al. 1989	**Positive** (1) Abreu and Grinevich 2013
TTO presence in the process		**Not significant** (1) Azoulay et al. 2007	**Positive** (1) Stuart and Ding 2006 **Negative** (1) Aldridge and Audretsch 2010	**Positive** (1) Aldridge and Audretsch 2010
Patent stock of the institution	**Positive** (1) Tartari et al. 2014	**Positive** (1) Azoulay et al. 2007		

(table continues)

(continued)

Knowledge transfer activity / External predictor - motivator	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing)	**Composite** (broad approach: industry collaboration, patenting, licensing patents to existing companies and/or spinning-off)
Scientific productivity of colleagues with business work experience			**Positive** (1) Stuart and Ding 2006	
Affiliation with university research centre		**Not significant** (1) Boardman and Ponomariov 2009	**Not significant** (1) Boardman and Ponomariov 2009	**Positive** (2) Boardman and Ponomariov 2009, Gaughan and Corley 2010
Institutional and departmental policies, regulations and incentives	**Not significant** (1) Renault 2006 **Not significant or weakly significant (positive)** (1) Louis et al. 1989	**Positive** (2) Baldini et al. 2007, Renault 2006 **Not significant or weakly significant (positive)** (1) Louis et al. 1989	**Positive** (2) Kenny and Goe 2004, Renault 2006 **Not significant or weakly significant (positive)** (1) Louis et al. 1989	**Positive** (3) Owen-Smith and Powell 2001a, Giuliani et al. 2010, Mowery et al. 2001
New funding programmes and opportunities				**Positive** (1) Owen-Smith and Powell 2001a
Technology opportunities				
New technologies, invention value			**Positive** (1) Aldridge and Audretsch 2010	**Positive** (1) Owen-Smith and Powell 2001a
Development of biotechnology industry				**Positive** (1) Mowery et al. 2001
Geographic proximity to firms			**Positive** (1) Audretsch and Stephan 1996 (more positive in case of active role in the company than advisory role)	

Appendix C: Overview of key studies on faculty-awarding mechanisms and knowledge transfer (cluster 5)

Authors	Study type	Level of analysis	Setting	Key findings
Louis et al. (1989)	Quantitative (questionnaire survey and interview)	Individual scientists (778) and administrators (40)	USA	University policies and structures have weak effect on academic-industry knowledge transfer.
Jensen and Thursby (2001)	Quantitative (survey, game theoretical modeling)	University (technology managers from 62 universities)	USA	**Lump-sum payments** do **not provide** an incentive for the inventor to continue putting efforts into the development of the invention after licensing agreements are signed.
Colyvas et al. (2000)	Qualitative (case studies)	Individual (11 projects)	USA	**Financial incentives play little or no role** in motivating faculty to involve in invention-yielding research projects; professional interests of researchers were more relevant.
Di Gregorio and Shane (2003)	Quantitative (survey)	Universities (116)	USA	A **high inventor share** of (licensing) royalties is a **disincentive** to potential inventor-entrepreneurs (start-up founders).
Goldfarb and Henrekson (2003)	Qualitative (literature review)	Institutional systems	USA, Sweden	While academics in the US are relatively free to respond to market incentives for the commercialization of their ideas, in Sweden, researchers risk being **penalized** for attempting to commercialize their ideas. To facilitate involvement in commercialization activities, academic inventor must not be faced with strong **disincentives in university environment**.
Van Looy et al. (2003)	Qualitative (literature review), quantitative (databases)	Institutional systems	European countries, USA	**Entrepreneurial indicators** (e.g. number of patents) should be considered when assessing the knowledge-generating institutions, but by taking into account the specificities of innovation systems of particular countries.
Lach and Schankerman (2004)	Quantitative (survey)	Universities (102)	USA	Higher **inventors' royalty shares** are associated with higher licensing income at the university.
Markman et al. (2004)	Qualitative (interviews), quantitative (database, surveys)	Universities (128 TTO directors)	USA	While **monetary rewards to TTO staff** are significantly and positively related to equity licensing and to firm creation, **royalty payments to scientists and their departments** are negatively related to university-based technology transfer.
Link and Siegel (2005)	Quantitative (databases, interviews)	Universities (113)	USA	Universities that allocate a **higher percentage of royalty payments** to faculty members, tend to be more efficient in technology transfer activities.
Renault (2006)	Qualitative (interviews), quantitative (survey)	Individual (98 researchers at 12 universities)	USA	Institutional policies, such as **revenue splits with inventors**, can affect entrepreneurial behavior of researchers (patenting and spinning-off).
Baldini et al. (2007)	Quantitative (questionnaire survey)	Individual scientists (208)	Italy	Increase in inventors' revenues shares does not represent an important patenting incentive.
Arundel et al. (2013)	Quantitative (survey)	Universities (322)	Europe	**Non-monetary incentives are rather ineffective** in terms of knowledge transfer performance of European public research institutions. Probably due to a heterogeneous IP ownership situation for university researchers in Europe and a lower degree of IPR law enforcement than in the USA, **the percentage given to inventors** is not related to performance, contrary to studies that deploy the US AUTM dataset.

Appendix D: Overview of key studies on knowledge transfer success rates and success factors

Authors	Study type	Level of analysis	Setting	Key findings
Knowledge transfer performance of public research institutions (cluster 6)				
Mowery and Ziedonis (2002)	Quantitative (database)	Universities (3)	USA	The analysis of university patenting shows that the patents issued to institutions that entered into patenting and licensing after the effective date of the Bayh–Dole act are **less significant** (in terms of the rate and breadth of their subsequent citations) and **less general** than the patents issued before and after 1980 to US universities with longer experience in patenting.
Carlsson and Fridh (2002)	Quantitative (questionnaire survey)	Universities (12 + 170)	USA	Only about half of the invention disclosures resulted in patent applications, and only half of the applications resulted in actual patents. Furthermore, only a fraction of patents yield license income. **The distribution of income-yielding licenses is highly skewed**.
Campbell et al. (2004); Annual AUTM Survey 1999-2000	Quantitative / qualitative (literature review)	Universities	USA	The majority of the top ten institutions' licensing income is derived from a **small number of highly profitable licenses**. Considering the concentration of revenues, revenues from many institutions' technology transfer activity fail to cover expenses.
Geuna and Nesta (2006)	Qualitative (literature review)	Universities	Europe	University patenting is driven more by the growing technological opportunities in biotechnology and pharmaceuticals than by intellectual property policy changes affecting the universities. Most universities **do not generate positive net incomes** from technology transfer.
Leydesdorff and Meyer (2010)	Quantitative (scientometric analysis)	University patents	USA, Europe, Japan	Since the 2000s university patenting in the most advanced economies has been on the decline both as a percentage and in absolute terms, possibly due to saturation effects, institutional learning, and the lack of institutional incentives due to the new regime of university ranking which disregards patents and spin-offs.
Geuna and Rossi (2011)	Qualitative (literature review, database)	Universities	Europe	There has been a general increase in university patenting since 1990 in European countries, with a significant slowdown (and even reduction in some countries) after early 2000s accompanied by a switch in academic patents ownership in favor of university ownership, at the same time by preserving the high company ownership of academic-invented patents. Higher **university ownership** is not correlated with higher use of academic patents.
Jacobsson et al. (2013)	Qualitative (policy review, databases)	Universities	Sweden, UK, USA	Swedish **professor's privilege system** results in the good performance of academics in terms of commercialization: Sweden, on a per capita basis, generates more direct university spin-offs than the USA. Transfer of property rights from the researcher to the University leads to several risks: for strong university–industry networks, biasing technical change, reducing entrepreneurial activities and generating higher costs.
Arundel et al. (2013)	Quantitative (questionnaire survey, databases)	Universities (430 in Europe)	Europe, USA (AUTM data)	US public research institutions are more efficient producers of invention disclosures, patent applications and license income than European institutions - while European universities spend €113.5 million to generate €1 million in license income, American public research institutes only spend €24.4 million to generate €1 million in license income. Conversely, European performance exceeds that of the US for the number of start-ups and the number of license agreements.

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Authors	Study type	Level of analysis	Setting	Key findings
Industry collaboration success factors (cluster 7)				
Zucker and Darby (1996)	Quantitative (scientometric analysis of publications)	Individual researchers, companies	USA	**Star scientists**, or most productive authors of research articles, play a disproportionately significant role in the commercialization of life science inventions and development of biotechnology industry.
Thursby et al. (2001)	Quantitative (survey)	University (technology managers at 62 universities)	USA	The higher the TTO size, the higher the number of executed licenses. If TTO values technology as important, sponsored research is more likely to be included in the license.
Bercovitz et al. (2001)	Qualitative, quantitative (case studies, interviews)	Universities (3)	USA	Different **organizational forms** of technology transfer offices (information processing capacity, coordination capability and incentive alignment) affect technology transfer performance.
Jensen et al. (2003)	Quantitative (questionnaire survey)	Universities (62); research projects disclosed to TTOs	USA	Universities with **higher quality faculty** have a higher proportion of disclosures licensed in the proof of concept stage, as do universities with **higher fractions of inventions from medicine** and nursing or from engineering. Universities with **greater net income** have a **smaller proportion of disclosures licensed in the proof of concept stage**. The share of **royalty income allocated to inventor**s is **lower** for universities **with higher quality faculty**. Some of the best inventions may not be disclosed because the most productive researchers are less likely to invest time to disclose inventions. Many inventions disclosed to TTOs are of questionable value.
Van Looy et al. (2011)	Quantitative (database, survey, scientometrics)	Universities (105)	Europe	**Scientific productivity** of universities is positively associated with entrepreneurial performance (patenting, contract research and spin-offs).
Invention disclosing, patenting, licensing success factors (cluster 8)				
Bercovitz et al. (2001)	Qualitative, quantitative (case studies, interviews)	Universities (3)	USA	Different **organizational forms** of technology transfer offices (information processing capacity, coordination capability and incentive alignment) affect technology transfer performance.
Thursby et al. (2001)	Quantitative (survey)	University (technology managers at 62 universities)	USA	The higher the TTO size, the higher the number of executed licenses. If TTO values technology as important, sponsored research is more likely to be included in the license.
Owen-Smith and Powell (2001)	Qualitative (interviews)	Individual scientists (68) at 2 universities	USA	Researchers' invention disclosing decisions depend on their perceptions of the **costs** of **interacting with TTOs** and licensing professionals.
Thursby and Thursby (2002)	Quantitative (survey)	Universities (64), licensing companies (112)	USA	There is a positive relationship between **willingness of faculty to license**, **business reliance on external R&D** and licensing growth. A shift in faculty research is less relevant than the other two variables in explaining licensing growth.

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Authors	Study type	Level of analysis	Setting	Key findings
Shane (2002)	Quantitative (database)	University (1), patents (1,397)	USA	There is a positive relationship between **patent effectiveness** (a 4-item scale) and licensing likelihood, commercialization likelihood and royalties to inventions licensed to non-inventors.
Carlsson and Fridh (2002)	Quantitative (questionnaire survey)	Universities (12 + 170)	USA	Those universities that spend the most **money on R&D** are also the ones that have the largest number of active licenses and patents and the highest royalty income.
Siegel, Waldman and Link (2003)	Qualitative (interviews), quantitative (database)	113 universities; individual entrepreneurs, scientists, and administrators (98) at five research universities	USA	**Environmental and institutional** factors predict TTO performance. The most critical **organizational factors** are **faculty reward systems, TTO staffing/compensation practices, and cultural barriers** between universities and firms.
Jensen et al. (2003)	Quantitative (questionnaire survey)	Universities (62); research projects disclosed to TTOs	USA	Universities with **higher quality faculty** have a higher proportion of disclosures licensed in the proof of concept stage, as do universities with **higher fractions of inventions from medicine** and nursing or from engineering. Universities with **greater net income** have a **smaller proportion of disclosures licensed in the proof of concept stage**. The share of **royalty income allocated to inventor**s is **lower** for universities **with higher quality faculty**. Some of the best inventions may not be disclosed because the most productive researchers are less likely to invest time to disclose inventions. Many inventions disclosed to TTOs are of questionable value.
Owen-Smith and Powell (2003)	Quantitative (database, bibliometrics)	Universities (89), patents (6,196)	USA	**Network relationships with industry** enable institutions to develop higher impact patent portfolios, but too tight connections limit patent impact.
Powers (2004)	Quantitative (databases)	Universities (104)	USA	**Federal R&D funding** and **faculty quality** have a significant impact on the number of licenses with small firms and with large firms, while industry R&D support is not a significant predictor.
Siegel et al. (2004)	Qualitative (interviews), quantitative (database)	Individual entrepreneurs, scientists, and administrators (98) at 5 research universities	USA	There are **cultural and informational** barriers among the three key stakeholder types (university administrators, academics, and firms/entrepreneurs), regarding **TTO staffing and compensation practices**, and **inadequate rewards** for faculty involvement.
Lach and Schankerman (2004)	Quantitative (survey)	Universities (102)	USA	There is evidence of a positive relationship between the **age of a TTO** and the success of a TTO (measured with licensing revenue) and no evidence of relationship between the size of the TTO and its performance,.
Link and Siegel (2005)	Quantitative (databases, interviews)	Universities (113)	USA	Universities that allocate a **higher percentage of royalty payments** to faculty members, tend to be more efficient in technology transfer activities.

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Authors	Study type	Level of analysis	Setting	Key findings
Chapple, Lockett, Siegel and Wright (2005)	Quantitative and qualitative (questionnaire survey)	Universities (122)	UK	Universities located **in regions with higher levels of R&D** and GDP are more efficient in technology transfer, implying the importance of regional spillovers. **Larger** and **older** TTOs appear to be **less successful** than younger and smaller TTOs. Moreover, the **broader the research scope** of a university is, the **less successful** a TTO is likely to be. TTOs of large universities suffer from being generalists and may be differentiated by establishing divisions focused on sectors.
Markman et al. (2005)	Quantitative (interview survey)	Universities (91 TTO directors)	USA	The greater the **innovation speed of TTOs**, the greater their licensing revenues streams and the more new spin-off ventures.
Shane and Somaya (2007)	Qualitative (interviews), quantitative (database)	Individual technology licensing officers (13)	USA	**Patent litigation** has an **adverse** effect on university licensing efforts.
Warren, Hanke and Trotzer (2008)	Quantitative (databases); qualitative (interviews)	University technology transfer offices (75)	USA	Universities that are **geographically isolated** from supportive infrastructures have reduced efficiency in transferring technology.
Breschi and Catalini (2010)	Quantitative (social network analysis)	Paper co-authorship-patent co-invention networks on the level of individual researchers	European Patent Office-registered patents	The extent of the connectedness among scientists and inventors is quite large, and authors-inventors who bridge the boundaries between the two domains are fundamental to ensuring this connectivity and occupy strategically important positions within each community.
Crespi et al. (2010)	Quantitative (database, survey, scientometric analyses)	Patents (433)	6 European countries	There are only very small differences between university-owned and university-invented patents in terms of their rate of commercialization or economic value.
Van Looy et al. (2011)	Quantitative (database, survey, scientometrics)	Universities (105)	Europe	**Scientific productivity** of universities is positively associated with entrepreneurial performance (patenting, contract research and spin-offs).
Arundel et al. (2013)	Quantitative (survey, databases)	Public research organizations (602)	Europe	**The size of the TTO** has a significant and positive impact on the number of invention disclosures, license agreements, license income and start-ups.
Malik (2013)	Quantitative (databases)	Biopharmaceutical companies (256)	24 countries	While **education, social and religious differences** act as enablers of university-industry international technology transfer (measured by the number of patents of the firm associated with the relationship), **national language and industrial distance** act as barriers.

(table continues)

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Academic entrepreneurship success factors (cluster 9)				
Large et al. (2000)	Quantitative (questionnaire survey)	34 technology transfer cases	Canada	Factors contributing to successful technology transfer include committed key team members and teams composed of both public and private sector members.
Heslop, McGregor and Griffith (2001)	Quantitative (survey)	Technology transfer managers (168)	USA, Canada	Strengths of **technology** itself, **market attractiveness, commercialization mechanism and management support** are proposed as indicators for assessment of commercial success probability of a new technology.
Carlsson and Fridh (2002)	Quantitative (questionnaire survey)	Universities (12 + 170)	USA	Those universities that spend the most **money on R&D** are also the ones that have the largest number of active licenses and patents and the highest royalty income.
Shane and Stuart (2002)	Quantitative (databases)	Spin-off companies (134)	USA	Spin-offs with social relations to venture capitalists are "most likely to receive venture funding and are less likely to fail.
Di Gregorio and Shane (2003)	Quantitative (survey)	Universities (116)	USA	**Intellectual eminence** and **policies of making equity investments** in start-ups and maintaining **a low inventor's share of royalties** increase new firm formation. There is no evidence that the number of venture capital investments or the presence of university **venture capital funding** is related to the amount of university spin-off activity.
Nerkar and Shane (2003)	Quantitative (survey)	Academic knowledge-based firms (128)	USA	**Technological radicalness and patent scope** reduce new academic firm failure, but only in fragmented markets.
Markman et al. (2004)	Qualitative (interviews), quantitative (database, surveys)	Universities (128 TTO directors)	USA	**Experienced TTOs** are negatively related to entrepreneurial activity (potentially due to inertia to deal with start-ups).
Ensley and Hmieleski (2005)	Quantitative (survey)	University start-ups (102) and independent high-technology new ventures (154)	USA	University-based start-ups tend to be comprised of more homogenous top management teams, with **less developed dynamics** and **lower financial performance** than independent new ventures.
Lockett and Wright (2005)	Quantitative (questionnaire survey)	Universities (48)	UK	The number of spin-outs is positively associated with expenditure on **intellectual property protection**, the **business development capabilities** of technology transfer offices (skills of university commercialization staff; clear process for due intellectual property; clear process for spinning-out; and availability of university technology transfer staff) and the **royalty regime** (% of revenue going to inventor) of the university.
Markman et al. (2005)	Quantitative (interview survey)	Universities (91 TTO directors)	USA	The greater the **innovation speed of TTOs**, the greater their licensing revenues streams and the more new spin-off ventures.
O'Shea et al. (2005)	Quantitative (questionnaire survey, databases)	Universities (141)	USA	The number of generated spin-offs is related to the **past technology transfer success**, **faculty quality**, size and orientation of science and engineering **funding** and **commercial capability** (size of TTO and invested resources).

(table continues)

(continued)				
Authors	**Study type**	**Level of analysis**	**Setting**	**Key findings**
Powers and McDougall (2005)	Quantitative (archival sources)	Universities (120)	USA	The number of start-up companies formed and the number of newly public companies are associated with **more established and older TTOs**, **faculty quality** (measured by article citations), R&D **investment by industry**, **venture capital funding** in the university's immediate geographical vicinity.
Crespi et al. (2010)	Quantitative (database, survey, scientometric analyses)	Patents (433)	6 European countries	There are only very small differences between university-owned and university-invented patents in terms of their rate of commercialization or economic value.
Van Looy et al. (2011)	Quantitative (database, survey, scientometric analyses)	Universities (105)	Europe	**Scientific productivity** of universities is positively associated with entrepreneurial performance (patenting, contract research and spin-offs).
Arundel et al. (2013)	Quantitative (survey, databases)	Public research organizations (602)	Europe	**The size of the TTO** has a significant and positive impact on the number of invention disclosures, license agreements, license income and start-ups.
Rasmussen et al. (2014)	Qualitative (case study, interviews)	Spin-off companies (8), individuals involved in spin-off (58)	UK, Norway	Initial **departmental support** from management and senior academics for gaining commercial experience and spending **time exploring the commercial opportunity** have a positive impact on the spin-off development, regardless of university level policies and practices.
Predictors of composite indicators of knowledge transfer performance (cluster 10)				
Harmon et al. (1997)	Qualitative (interviews)	University (1), 23 cases	USA	In most instances of successful commercialization the academic inventor had either prior work experience with the company (formal relationship), was close friends with the companies' staff (informal relationships) or established contact with companies' representatives in a professional setting such as a conference.
Rogers, Yin and Hoffmann (2000)	Quantitative (questionnaire survey)	Universities (131)	USA	Universities more effective in technology transfer have higher average **faculty salaries**, a larger number of **staff for technology** licensing, a higher value of **private gifts**, **grants and contracts**, and more **R&D funding** from industry and government.
Colyvas et al. (2002)	Qualitative (case studies)	Individual (11 projects)	USA	In ten out of eleven technology transfer cases from Columbia University and Stanford University the scientists involved were members of a network of researchers that included industry professionals.
Thursby and Kemp (2002)	Quantitative (survey)	Universities (112)	USA	The **lower the research quality** of a university, the more efficient (output – licenses, royalties, patents, industry funding / inputs – research funding, number of TTO professionals) is the university in commercial activity, probably due to greater specialization in basic research of the higher quality research faculty.
Palmintera (2005)	Qualitative (case study) and quantitative (survey)	Universities (10)	USA, UK	Technology transfer success factors are: **strong research base, federal R&D funding, champions (chancellors), private funds; early-stage capital for start-ups, entrepreneurial culture, networking, incubators and parks.**

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
O'Shea et al. (2005)	Quantitative (questionnaire survey, databases)	Universities (141)	USA	The number of generated spin-offs is related to the past technology transfer success, faculty quality, size and orientation of science and engineering funding and commercial capability (size of TTOand invested resources).
Crespi et al. (2010)	Quantitative (database, survey, scientometric analyses)	Patents (433)	6 European countries	There are only very small differences between university-owned and university-invented patents in terms of their rate of commercialization or economic value.

Appendix E: Knowledge transfer performance predictors

Knowledge transfer performance output / **Performance predictor**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	**Composite** (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
Characteristics and quality of inventors and teams				
Scientific productivity and impact	**Positive** (1) Van Looy et al. 2011 **Negative** (1) Thursby et al. 2001	**Positive** (6) Thursby et al. 2001, Jensen et al. 2003, Owen-Smith and Powell 2003, Powers 2004, Van Looy et al. 2011, Owen-Smith and Powell 2001b **Not significant** (1) Lach and Schankerman 2004	**Positive** (4) Van Looy et al. 2011, O'Shea et al. 2005, Powers and McDougall 2005, Di Gregorio and Shane 2003	**Positive** (1) Palmintera 2005 **Negative** (1) Thursby and Kemp 2002
Faculty size, team size	**Positive** (1) Van Looy et al. 2011	**Positive** (2) Powers 2004, Van Looy et al. 2011 **Not significant** (1) Lach and Schankerman 2004	**Positive** (1) Ensley and Hmieleski 2005 **Not significant** (3) Van Looy et al. 2011, Powers and McDougall 2005, O'Shea et al. 2005	
Involvement in the process		**Positive** (1) Thursby and Thursby 2002	**Positive** (2) Nerkar and Shane 2003, Ensley and Hmieleski 2005	
Characteristics and quality of inventions and technologies				
Novelty, technological radicalness, market attractiveness			**Positive** (1) Nerkar and Shane 2003	
Patent complexity		**Positive** (1) Crespi et al. 2010 **Not significant** (1) Crespi et al. 2010	**Positive** (1) Nerkar and Shane 2003 **Not significant** (1) Crespi et al. 2010	
Stage of development (later)	**Negative** (1) Thursby et al. 2001	**Positive** (1) Thursby et al. 2001 **Negative** (1) Jensen et al. 2003		
Effectiveness of protected invention		**Positive** (1) Shane 2002	**Positive** (1) Shane and Stuart 2002	
Cooperation with industry in R&D		**Negative** (1) Crespi et al. 2010 **Not significant** (1) Crespi et al. 2010	**Not significant** (1) Crespi et al. 2010	

(table continues)

(continued)

Knowledge transfer performance output / **Performance predictor**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	**Composite** (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
Institutional capabilities and resources				
Support structures, skills and incentives of "intermediary" human resources, top management and public-private team	**Positive** (1) Jensen et al. 2003	**Positive** (4) Siegel, Waldman and Link 2003(2003), Siegel et al. 2004 Owen-Smith and, Powell 2001b, Jensen et al. 2003	**Positive** (4) Heslop, McGregor and Griffith 2001(2001), Large et al. 2000, Rasmussen et al. 2014, Lockett and Wright 2005	**Positive** (1) Palmintera 2005
Entrepreneurial culture		**Positive** (1) Owen-Smith and Powell 2001b		**Positive** (1) Palmintera 2005
TTO age		**Positive** (4) Owen-Smith and Powell (2001)2001b, Owen-Smith and Powell 2003, Lach and Schankerman 2004, Siegel, Waldman and Link 2003 **Negative** (3) Link and Siegel 2005, Lach and Schankerman 2004, Chapple, Lockett, Siegel and Wright 2005 **Not significant** (3) Siegel, Waldman and Link 2003, Markman et al. 2005, Chapple, Lockett, Siegel and Wright (2005)	**Positive** (2) Markman et al. 2005, Powers and McDougall 2005 **Negative** (1) Markman et al. 2004 **Not significant** (2) Markman et al. 2004, Lockett and Wright 2005	

(table continues)

(continued)

Knowledge transfer performance output / **Performance predictor**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	**Composite** (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
TTO size	**Not significant** (1) Van Looy et al. 2011	**Positive (9)** Thursby et al. 2001, Powers 2004, Owen-Smith and Powell 2001b, Carlsson and Fridh 2002, Siegel, Waldman and Link 2003, Lach and Schankerman 2004, Chapple, Lockett, Siegel and Wright 2005, Markman et al. 2005, Arundel et al. 2013 **Negative (1)** Thursby and Thursby 2002 **Not significant (3)** Van Looy et al. 2011, Siegel, Waldman and Link 2003, Lach and Schankerman 2004	**Positive (5)** Carlsson and Fridh 2002 Van Looy et al. 2011, Markman et al. 2005 Arundel, et al. 2013 O'Shea et al. 2005 Not significant (1) Lockett and Wright 2005	**Positive (1)** Rogers, Yin and Hoffmann 2000 **Negative (1)** Thursby and Kemp 2002
TTO salary			**Positive** (1) Markman et al. 2004 **Not significant** (1) Markman et al. 2004	
TTO organisational forms (information processing and coordination capability)	**Positive** (1) Bercovitz et al. 2001	**Positive** (1) Bercovitz et al. 2001		

(table continues)

(continued)

Knowledge transfer performance output / **Performance predictor**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	**Composite** (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
Traditional TTO organizational structure		**Negative** (1) Markman et al. 2005	**Negative** (1) Markman et al. 2005	
TTO evaluation of KT activity significance	**Positive** (1) Thursby et al. 2001	**Not significant** (1) Thursby et al. 2001		
Institutional / government R&D funding / expenditure		**Positive** (6) Carlsson and Fridh 2002, Shane 2002, Powers 2004, Crespi et al. 2010, Lach and Schankerman 2004, Chapple, Lockett, Siegel and Wright 2005 **Not significant** (3) Powers 2004, Lach and Schankerman 2004, Crespi et al. 2010	**Positive** (4) Markman et al. 2004 Carlsson and Fridh 2002, Lockett and Wright 2005, O'Shea et al. 2005 **Not significant** (2) Crespi et al. 2010, Lockett and Wright 2005	**Positive** (2) Rogers, Yin and Hoffmann 2000, Palmintera 2005 **Not significant** (1) Thursby and Kemp 2002
IPR expenditures of TTO		**Positive** (2) Siegel, Waldman and Link 2003, Chapple, Lockett, Siegel and Wright 2005 **Negative** (2) Siegel, Waldman and Link 2003 Shane and Somaya 2007 **Not significant** (1) Chapple, Lockett, Siegel and Wright 2005	**Positive** (1) Lockett and Wright 2005	

(table continues)

(continued)

Knowledge transfer performance output / Performance predictor	Industry collaboration (consulting, sponsored research, joint projects)	Intellectual property-based (invention disclosing, patenting, licensing)	Academic entrepreneurship (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	Composite (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
Industry funding private gifts, grants and contracts		**Positive** (3) Lach and Schankerman 2004, Shane 2002, Jensen et al. 2003 **Not significant** (1) Powers 2004	**Positive** (3) O'Shea et al. 2005, Powers and McDougall 2005, Di Gregorio and Shane 2003	**Positive** (2) Rogers, Yin and Hoffmann 2000, Palmintera 2005
Quality of an institution's patent portfolio (patent importance)			**Not significant** (1) Powers and McDougall 2005	
Prior knowledge transfer experience	**Positive** (1) Van Looy et al. 2011	**Not significant** (1) Van Looy et al. 2011	**Positive** (3) Van Looy et al. 2011, Large et al. 2000, Shane and Stuart 2002	
Network ties to industry and investors		**Positive** (1) Owen-Smith and Powell 2003	**Positive** (1) Shane and Stuart 2002	**Positive** (3) Palmintera 2005, Harmon et al. 1997, Colyvas et al. 2002
Geographic proximity to supporting infrastructure and industry				
Access to science incubators / parks			**Not significant** (2) Di Gregorio and Shane 2003, O'Shea et al. 2005	**Positive** (1) Palmintera 2005
Access to venture capital / seed capital		**Positive** (1) Warren, Hanke and Trotzer (2008) **Not significant** (1) Powers (2004)	**Positive** (2) Shane and Stuart 2002. Powers and McDougall 2005 **Negative** (1) Nerkar and Shane (2003) **Not significant** (1) Di Gregorio and Shane 2003	**Positive** (1) Palmintera 2005
Business reliance on external R&D		**Positive** (1) Thursby and Thursby 2002		

(table continues)

(continued)

Knowledge transfer performance output / **Performance predictor**	**Industry collaboration** (consulting, sponsored research, joint projects)	**Intellectual property-based** (invention disclosing, patenting, licensing)	**Academic entrepreneurship** (spin-off founding / equity holding, product launch and marketing. technology managers' perception of commercial success of new product)	**Composite** (broad approach: industry collaboration, number of invention disclosures, patenting, licensing patents to existing companies and/or spinning-off)
R&D intensity of the local setting	**Not significant** (1) Van Looy et al. 2011	**Positive** (3) Siegel, Waldman and Link 2003, Chapple, Lockett, Siegel and Wright 2005, Lach and Schankerman 2004 **Not significant** (2) Van Looy et al. 2011, Siegel, Waldman and Link 2003 **Negative** (1) Lach and Schankerman 2004	**Positive** (1) Van Looy et al. 2011 **Not significant** (1) Lockett and Wright 2005	
Broader institutional setting (education, social and religious differences, national language and industrial distance, political distance)		**Mixed** (1) Malik 2013		

Appendix F: Overview of key studies on knowledge transfer-scientific output relationship

Authors	Study type	Level of analysis	Setting	Key findings
Knowledge transfer-research type relationship (cluster 12)				
Positive				
Ranga et al. (2003)	Quantitative (scientometric analysis of publications)	Research groups (22)	Belgium	Academic research groups with industry collaboration have developed a record of applied publications without affecting their basic research publications.
Van Looy et al. (2004)	Quantitative (scientometric analysis of publications)	Divisions (14), individual scientists	Belgium	Researchers who systematically engage in contract research publish more in applied fields than their colleagues who do not engage, but not at the expense of the publications of a more basic nature.
Van Looy et al. (2006)	Quantitative (scientometric analysis of publications)	Individual scientists-inventors (32), non-inventors	Belgium	
Negative				
Blumenthal et al. (1996)	Quantitative (questionnaire survey)	Individual scientists (2,052)	USA	Researchers with industry funding are more likely than those without to report that their choice of research topic had been influenced somewhat or greatly by the likelihood of the results having commercial application.
Louis et al. (2001)	Quantitative (questionnaire survey)	Individual life scientists (847 clinical and non-clinical faculty in 49 universities)	USA	Clinical faculty is more likely to say that potential commercial application and industry funding have influenced their choices of research topics.
Bekelman et al. (2003)	Quantitative (database)	MED-LINE-indexed studies	USA	11 published studies show that industry-sponsored research tends to yield conclusions in favor of industry.
Azoulay et al. (2006)	Quantitative (scientometric analysis of patents and publications)	Individual scientists (3,862)	USA	Patenters may be shifting their research focus to questions of commercial interest.
Neutral				
Gulbrandsen and Smeby (2005)	Quantitative (questionnaire survey)	Individual scientists (1,967)	Norway	Researchers with industrial funding perform applied research to a greater extent than researchers without such funding. However, almost 40 percent of those that had received industrial funding categorized their research as primarily basic.
Rodriguez et al. (2007)	Quantitative (co-word analysis)	Documents (7,536)	Belgium	It is not possible to conclude that agreements signed by industry and government affect research agenda setting in academia.

(table continues)

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
Patenting-scientific output relationship (cluster 13)				
Positive				
Agrawal and Henderson (2002)	Quantitative (scientometric analysis of patents and publications) and qualitative (interviews)	Patents (640) and publications (5,132) of two departments of one university, with patents and publications citing them (56,776)	USA	The number of patents is positively related to the number of paper citations, after controlling for the number of papers, and years the researcher has been active.
Sampat et al. (2003)	Quantitative (scientometric analysis)	Patents	USA	Analysis of citations to university patents before and after the Bayh–Dole Act using a longer stream of data shows that there is no decline in the quality of university patents during the 1980s. Previous research indicated the decline of quality due to truncation of the citations data and a change in the inter-temporal distribution of citations to university patents, rather than a significant change in the total number of citations the patents receive.
Carayol and Matt (2004)	Quantitative	Laboratories (83)	France	Patenting activity is linked to and supported by publication performance.
Azoulay et al. (2006)	Quantitative (scientometric analysis of patents and publications)	Individual scientists (3,862)	USA	Patenting has a positive effect on the rate of publication of journal articles, but no effect on the quality of these publications.
Stephan et al. (2007)	Quantitative (survey)	Individual scientists	USA	Patents are positively and significantly related to the number of publications.
Breschi et al. (2008)	Quantitative (databases)	Individual academic inventors (592)	Italy	Academic inventors publish more and better quality papers than their non-patenting colleagues, and increase their productivity after patenting. This effect is stronger for serial academic inventors and in pharmaceutical field.
Breschi and Catalini (2010)	Quantitative (social network analysis)	Paper co-authorship-patent co-invention networks on the level of individual researchers	European Patent Office-registered patents	The extent of connectedness among scientists and inventors is quite large, and authors-inventors who bridge the boundaries between the two domains are fundamental to ensuring this connectivity and occupy strategically important positions within each community.
Mixed				
Crespi et al. (2008)	Quantitative (databases, survey)	Individual scientists (1,528)	UK	Academic patenting complements publishing up to a certain level of patenting output, after which there is some evidence of a substitution effect.
Fabrizio and Di Minin (2008)	Quantitative (scientometric analysis of patents and publications)	Individual inventors (166)	USA	Publication and patenting are complementary, not substitute, activities for academic researchers. Average citations to publications, however, decline for repeat patenters, suggesting either a re-focus on applied research or restrictions on use associated with patent protection.

(table continues)

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
Czarnitzki et al. (2009)	Quantitative (scientometric analysis of patents and publications)	Patents (corporate vs. non-profit institutions-assigned by university professors) (36,223)	Germany	Heterogeneity in patenting is relevant: patents assigned to non-profit organizations (incl. individual ownership of the professors themselves) complement publication quantity and quality; patents assigned to corporations are negatively related to quantity and quality of publication output.
Negative				
Henderson et al. (1998)	Quantitative (scientometric analysis)	Patents	USA	During the 1980s, university patents decreased in importance (number of citations received) and generality (the degree of concentration of citing patents across technological classes), due to both an increase in the share of university patents without citations, and to universities producing patents of lower quality.
Murray and Stern (2007)	Quantitative	Patent-paper pairs (169)	Nature Biotechnology articles	Citations received decline by between 9 and 17% after the patent grant.
Rosell and Agrawal (2009)	Quantitative (scientometric analysis of patents)	Patents (194,500 – knowledge outflows; 203,521 – knowledge inflows)	USA	University diffusion premium (the degree to which university knowledge outflows, measured by patent citations, are more widely distributed than those of firms) declined by more than half during the 1980s in life science area. University diversity premium (the degree to which knowledge inflows used by universities are drawn from a more widely distributed set of prior art holders than those used by firms) also declined by more than half.
Knowledge transfer-scientific output relationship (cluster 14)				
Positive				
Blumenthal et al. (1996)	Quantitative (questionnaire survey)	Individual scientists (2,052)	USA	Life-science faculty with industry funding publishes many more articles in peer-reviewed journals than faculty without industry funding.
Hicks and Hamilton (1999)	Quantitative (database)	Publications (2.1 million)	USA	The number of citations of single-university research has been increasing, suggesting that the quality of university research has not been compromised. University-industry papers are more highly cited on average than single-university research.
Gulbrandsen and Smeby (2005)	Quantitative (questionnaire survey)	Individual scientists (1,967)	Norway	Researchers with industrial funding report more scientific publications as well as more frequent entrepreneurial results than researchers without such funding.
Lin and Bozeman (2006)	Quantitative (two datasets – CVs and survey)	Individual scientists (443)	USA	The persons who populate university-industry centers publish at rates comparable to those with more traditional academic career trajectories but appear to bring added value in terms of larger grants and more student support.
Lowe and Gonzalez-Brambila (2007)	Quantitative (scientometric analysis of publications)	Individual scientists-entrepreneurs (117) and a control sample	USA, Canada	Scientists-entrepreneurs in general are more productive researchers than control groups and their productivity does not decrease after the company formation.

(table continues)

(continued)				
Authors	**Study type**	**Level of analysis**	**Setting**	**Key findings**
Neutral				
Godin and Gingras (2000)	Quantitative (database)	Publications	Canada	Industry orientation is complementary with academic values and activities (publishing quantity and quality).
Louis et al. (2001)	Quantitative (questionnaire survey)	Individual life scientists (847 clinical and non-clinical faculty in 49 universities)	USA	Entrepreneurial faculty is not less productive in their faculty roles.
Mixed				
Louis et al. (1989)	Quantitative (questionnaire survey and interview)	Individual scientists (778) and administrators (40)	USA	Entrepreneurial behavior is not incompatible with maintaining the outward manifestations of academic behavior. However, scientific productivity is not an important predictor of the more commercial forms of entrepreneurship, which supports the argument that they may be less compatible with traditional university values.
Buenstorf (2009)	Quantitative (databases)	Director-invention pairs (854)	Germany	There is a positive effect of inventing commercially useful technologies, but negative effect of spin-off founding, on publication quantity and quality.
Hottenrott and Thorwarth (2011)	Quantitative (questionnaire survey, databases)	Individual scientists (678) from 46 universities	Germany	A higher budget share from industry reduces publication output quantity and quality of professors in subsequent years. On the other hand, industry funding has a positive impact on the quality of applied research if measured by patent citations.
Negative				
Toole and Czarnitzki (2010)	Quantitative (scientometric analysis, database)	Individual scientists-entrepreneurs (89)	USA	There is a significant decrease in the research performance of academic entrepreneurs after they begin working in for-profit firms for all indicators (journal publications, impact factor weighted publications, the value of National Institutes of Health (NIH) research awards), except university patenting.

Appendix G Overview of key studies on knowledge transfer-open science relationship

Authors	Study type	Level of analysis	Setting	Key findings
Patenting-open science (collaborations, dissemination) relationship (narrow focus) (cluster 15)				
Negative				
Balconi et al. (2004)	Quantitative (scientometric analysis of patents and publications)	Inventors (919) and patents (1,475)	Italy	Academic inventors are more central and better **connected in the networks** than non-academic ones.
Oliver (2004)	Quantitative (questionnaire survey)	Individual scientists (291)	Israel	The number of patents assigned to the scientist has a negative impact on the number of academic, international, and total **collaborations**.
Gulbrandsen and Smeby (2005)	Quantitative (questionnaire survey)	Individual scientists (1,967)	Norway	Nearly 20 percent report that industry contracts are problematic with regards to autonomy and **independence of research**.
Geuna and Nesta (2006)	Qualitative (literature review)	Universities	Europe	Most European technology transfer policies present only the benefits of technology transfer, without any supporting statistical empirical evidence and assessment of possible risks. The data available on university patenting for the European countries are unreliable and not useful for assessing the potential impact on **open research** of increased university patenting.
Baldini et al. (2007)	Quantitative (questionnaire survey)	Individual scientists (208)	Italy	Faculty inventors rate the "**open science** mentality of the university" as the most important obstacle (on a twelve-item scale) suffered during their patenting activity.
Jain et al. (2009)	Qualitative (interviews)	Individual researchers and tech transfer specialists (28)	USA	Some respondents had concerns about **delay in the dissemination of results** and possible **interference with academic pursuits** that could arise from commercial involvement. Often, the TTO requested them to **maintain secrecy** regarding their discovery to ensure patent protection and prevent potential intellectual property from being compromised through premature disclosure in conferences.
Davis et al. (2011)	Quantitative (survey)	Individual scientists (239)	Denmark	A substantial proportion of scientists are skeptical about the impact of university patenting. The most skeptical respondents are basic research scientists, particularly the less productive ones, recipients of research council grants, scientists with close relations to industry, and full professors.
Neutral				
Walsh et al. (2003)	Qualitative (interviews)	Individual biotech IP attorneys, business managers, scientists and technology transfer officers (70)	USA	There is little evidence that **university research** has been impeded by concerns about patents on research tools, with the exception of patented genetic diagnostics and delays associated with negotiating access to patented research tools. Coping with the increased number of patented tools includes: taking licenses, inventing around patents, infringement or invoking a research exemption, developing and using public tools, and challenging patents in court.

(table continues)

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
Colyvas (2007)	Qualitative (archival data reviews, interviews)	University; invention	USA	In the early years of technology transfer at Stanford University, the debates were focused on purpose of commercialization; patenting scope (only technologies vs. all biological inventions with industry applications); inventorship (collective effort vs. individual inventorship); revenue allocation (laboratory vs. individuals); boundary between academic science and industry work, in relation to the principal investigator's scientific reputation (clear vs. blurred; faculty vs. non-faculty careers of inventors; conventions of sharing materials among scientists and use by industry). Although the investigators' attitudes followed from adherence to academic norms, their experience with commercialization showed that science and business were not necessarily in conflict.
Forti et al. (2013)	Quantitative (database)	Individual inventors (53) and non-inventors (53)	Italy	There is no evidence that inventive activities are associated with a broader **co-authorship network** in the pre-invention phase or with a more central and brokering position of the inventors (i.e. that after patenting inventors isolate or close their networks). The ego-networks of the inventors are denser than those of non-inventors.
Knowledge transfer-open science (collaborations, data and material sharing, dissemination) relationship (broader focus) (cluster 16)				
Positive				
Gulbrandsen and Smeby (2005)	Quantitative (questionnaire survey)	Individual scientists (1,967)	Norway	Researchers with industrial funding **collaborate** more with other researchers both in academia and in industry.
Neutral				
Campbell et al. (2002)	Quantitative (survey)	Individual scientists (1,849)	USA	The investigation could not explain the frequent **lack of openness** among genetics researchers with increased commercialization or industrial contacts. They point instead to limited resources (too much effort required) and professional priorities (protection of their ability or the ability of a junior researcher to publish).
Rodriguez et al. (2007)	Quantitative (bibliometric and network analysis)	Documents (817) at the institutional level (58)	Belgium	Material transfer agreements might not have interfered in such a way to limit **co-publication activity** of research organizations in biotechnology research networks.
Boardman and Ponomariov (2009)	Quantitative (survey)	Individual scientists (1,643)	USA	Certain interactions with industry do not necessarily conflict with widespread **scientific norms**, i.e. more traditional academic roles.
Negative				
Gluck et al. (1987)	Quantitative (questionnaire survey)	Individual students	USA	Industry support is associated with **fewer or delayed publications**, inhibition of **scientific communication** on the part of some trainees, and some restrictions on **students' and fellows' research**.
Blumenthal et al. (1997)	Quantitative (questionnaire survey)	Individual life scientists (2,167)	USA	Involvement in academic-industry research relationship and engagement in the commercialization of university research are both associated with **publication delays**, while only the latter is associated with refusal to **share research results** upon request. Withholding is more common among the most productive scientists.

(continued)

Authors	Study type	Level of analysis	Setting	Key findings
Blumenthal et al. (1996)	Quantitative (survey)	Individual scientists (2,052)	USA	Life scientists with industrial support were more academically productive, participated in more administrative activities in their institutions or disciplines, and were more commercially active than faculty members without such funding, but were at least twice as likely to engage in **trade secrets or to reject requests** from other academic scientists to share research results or biomaterials as are their colleagues without such support. Faculty members receiving more than two thirds of their research support from industry were less academically productive than those receiving a lower level of industrial support.
Audretsch DB, Stephan PE (1999)	Quantitative (database)	Individual scientists (101 scientific founders of 52 firms)	USA	The spillover of knowledge from the source creating it, such as a university, to a new-firm startup facilitates the **appropriation of knowledge** for the individual scientist(s) but not necessarily for the organization originally creating that new knowledge.
Campbell et al. (2000)	Quantitative (survey)	Individual scientists (2,366)	USA	Researchers who were most likely to be victims of data withholding were those who have withheld research results from others, published more than 20 articles in the last 3 years, to have applied for a patent, had been issued a patent or who had licensed a patent, or spent more than 40 hours per week in research activities.
Louis et al. (2001)	Quantitative (questionnaire survey)	Life scientists (847 clinical and non-clinical faculty in 49 universities)	USA	The non-clinical faculty that is more involved in knowledge transfer is more likely to be **secretive** about their research. Clinical faculty is less likely to have been denied access to research results or products.
Hoedemaekers (2001)	Qualitative (case studies)	Genetic test (case)	Europe	**Ethical implications** exist at all stages of commercial development in biotechnology, from R&D and patenting to product launch, which requires a detailed moral assessment in parallel with technology assessment.
Louis et al. (2002)	Quantitative (questionnaire survey)	Individual life scientists (1,170)	USA	Geneticists with industry relationships are less likely to **share** than scientists with no relationships or relationships limited to funding their university work. Sharing restrictions can be more attributed to other factors than industry relationships, such as competition, lack of reciprocity and effort related to sharing.
Blumenthal et al. (2006)	Quantitative (survey)	Individual life scientists, geneticists and other (1,849)	USA	Industry relationships are associated with increased likelihood of withholding, but the pattern of association varies by type of relationship and research field: other relationships with industry, such as serving as a consultant, or on industry board or owning equity are associated with increased likelihood for data withholding. Industry support is associated with **publishing withholding** among other life scientists. Other industry involvement is associated with publishing withholding among geneticists. Commercial involvement is significantly associated only with **verbal withholding** among geneticists. Academic scientists are more likely to withhold data from colleagues in relation to publishing than in verbal communications regarding unpublished work.

(table continues)

(continued)				
Authors	**Study type**	**Level of analysis**	**Setting**	**Key findings**
Bekelman et al. (2003)	Quantitative review (database)	MED-LINE-indexed studies (37)	USA	Researchers with connections to industry are more likely to engage in **data withholding and publication delays**.
Vogeli et al. (2006)	Quantitative (survey)	Individual scientists (1,077)	USA	Trainees with industry support were significantly more likely than those without industry support to have been denied **access to both published and unpublished information, data, and materials**.
Walsh et al. (2007)	Quantitative (survey)	Individual scientists (507)	USA	**Access to knowledge inputs** is largely unaffected by patents, but accessing other researchers' **materials and/or data** is more problematic, due primarily to scientific competition, the cost of providing materials, prior commercial activity on the part of the supplier, and whether the material in question is a drug.
Caulfield et al. (2008)	Quantitative (survey)	Individual scientists (108)	Canada	Although about half of the researchers agreed that patents adversely impact research by increasing secrecy, only very few of them have experienced negative impacts in practice. A majority (59%) of the researchers had been denied a request for research materials, but academic competition, unwillingness to pay patent royalties, and lack of time to deal with requests were the primary reasons for such refusals. **Withholding research information** in order to protect potential patents was also frequently reported.
Martinelli et al. (2008)	Quantitative (survey)	Individual scientists (173)	UK	Researchers without external links with industry have more negative attitudes about the impact of knowledge transfer on **academic science** than those with industry links.
Shibayama et al. (2012)	Quantitative (survey)	Individual life scientists (698)	Japan	High involvement in academic entrepreneurship is associated with less reliance on the **generalized (unconditional) sharing** and more reliance on **direct (return-based) exchange**, as well as a lower overall frequency of sharing.
Walsh and Huang (2014)	Quantitative (survey)	Individual life scientists (984 in Japan and 834 in the USA)	USA, Japan	There is a negative relationship between patenting and **openness (partial publication and publication delay)** in both countries, but with lower impact on academic secrecy in Japan.
Haeussler et al. (2014)	Quantitative (survey)	Individual scientists (1,173)	Germany, UK	The importance of patents for a scientist's reputation reduces both general and specific sharing, and the effect is greater for general information sharing.
Mixed				
Hong and Walsh (2009)	Quantitative (comparison of data from several questionnaire surveys conducted over years)	Individual life scientists (1,947 + 399)	USA	**Secrecy** has increased in the US experimental biology community during the past 30 years, but industry-related activity has a mixed effect, with having industry funding related to greater secrecy, and having industry collaborators associated with less secrecy. However, this increased secrecy seems to result from a combination of increasing commercial linkages and increased pressures from scientific competition.
Shibayama (2012)	Quantitative (questionnaire survey)	Individual scientists (698)	Japan	Not all types of entrepreneurial activities induce non-compliant behaviors: while commercial activity facilitates s**ecretive publications and non-compliant behaviors in material transfer,** no significant effects are shown for collaboration with industry.

Appendix H: Descriptive statistics – academic-industry knowledge transfer experience (past 3 years)

Academic researchers (N=28)	**Average**	**Min**	**Max**	**Median**
Consulting of the industry	0.86	0	5	0
Industry-sponsored research	1.18	0	5	1
Companies with products based on their research in which they hold equity	0.25	0	4	0
University-industry joint research grants	1.14	0	3	1
Joint publications with the industry	0.75	0	10	0
Academia-industry personnel exchange	0.71	0	10	0
Inventions disclosed	1.18	0	6	0
Patents granted	0.57	0	4	0
Licensing agreements signed	0.39	0	5	0
Business plans related to spin-off ventures	0.14	0	1	0
Spin-off companies founded	0.11	0	1	0
Products under regulatory review	0.11	0	2	0
Products on the market	0.32	0	7	0
TOTAL ALL	**7.71**	**0**	**31**	**5**
Industry respondents (N=6)	**Average**	**Min**	**Max**	**Median**
Consulting with the academia	0.67	0	2	1
Sponsored research for the academia	1.17	0	2	1
Companies with products based on their research in which they hold equity	0.83	0	4	0
University-industry joint research grants	1.50	0	5	1
Joint publications with academia	1.50	0	7	1
Academia-industry personnel exchange	1.00	0	4	0
Inventions disclosed	1.00	0	2	1
Patents granted	0.33	0	1	0
Licensing agreements signed	1.00	0	5	0
Business plans related to spin-off ventures	1.50	0	7	1
Spin-off companies founded	0.67	0	2	1
Products under regulatory review	0.67	0	1	1
Products on the market	4.00	0	17	1
TOTAL ALL	**15.83**	**4**	**33**	**12**
Technology transfer specialists (N=3) – mediation in activities	**Average**	**Min**	**Max**	**Median**
Consulting with the academia	14.67	3	35	6
Sponsored research for the academia	17.33	2	40	10
Companies with products based on their research in which they hold equity	1.33	0	4	0
University-industry joint research grants	2.33	0	6	1
Joint publications with academia	4.33	0	10	3
Academia-industry personnel exchange	6.00	0	18	0
Inventions disclosed	15.67	0	35	12
Patents granted	6.00	0	10	8
Licensing agreements signed	3.00	0	9	0
Business plans related to spin-off ventures	1.67	1	2	2
Spin-off companies founded	0.33	0	1	0
Products under regulatory review	1.67	0	5	0
Products on the market	0.00	0	0	0
TOTAL ALL	**74.33**	**19**	**111**	**93**

Appendix I: Reasons for knowledge sharing restrictions among academic researchers

Reasons (summary of codes)	All	Cro	Slo	Ger	USA	Ita	Isr
Scientific competition-related reasons (context-specific)							
Competitiveness	**24**	5	4	4	4	3	4
Fear of losing priority	**8**	5	1		1		1
Highly competitive areas	**1**	1					
Priority in publishing brings more funds to laboratory, leads to skepticism and secrecy	**2**	1			1		
Reject when requested materials in which a lot of effort invested and which belong to key discovery	**2**			1			1
Data not yet published	**8**		2	4	2		
Careers at stake, dependent on publication	**2**				1	1	
Editors are to blame as they encourage discussions about unpublished data, but at the same time will not publish if something has been published already elsewhere	**3**				1	2	
Editors sometimes cover conference report by including preliminary data without the agreement of authors and thus jeopardize careers of students	**1**				1		
TOTAL	**51**	**12**	**7**	**9**	**11**	**6**	**6**
Resource-related reasons (context-specific)							
Logistical reasons (e.g. long waiting list for experiments on sophisticated apparatuses, complicated procedures of mice transfer)	**5**	1		2	2		
Lack of time (to respond or produce materials, mice)	**14**	2	1	3	3	2	3
Journal articles not freely accessible due to journal policy	**1**		1				
In the case of many requests, scientists should be charged a small processing fee for material production and transfer as it costs a lot the lab	**1**			1			
Mistrust in laboratories in less developed settings	**2**				1	1	
Too large requested quantity	**1**						1
Published reagents should not be freely distributed if their generation cost a lot of money	**2**		1	1			
TOTAL	**26**	**3**	**3**	**7**	**6**	**3**	**4**
Scientific misconduct-related reasons (human and social capital-related)							
Material recipients sometimes lie about the intended use of materials	**1**				1		
Non-reproducibility of published results	**6**		1	2	2	1	
TOTAL	**7**	**0**	**1**	**2**	**3**	**1**	**0**
Knowledge transfer-related reasons							
Data not owned by researcher	**1**	1					
More restrictions in applied science	**3**	1		2			
Institutions working with companies often do not publish before IP protection	**1**	1					
Protection of commercial interest with unpublished results	**4**	2		1		1	
Reagent not accessible due to ownership of a company	**4**	2		1		1	
Concealing information at conferences due to the sensitive methods used in research	**1**	1					
Institutional pressure for patenting led to misbehavior of collaborator (attempt of patenting of their results)	**1**			1			
Patented product is never sent to anyone	**1**					1	
TOTAL	**16**	**8**	**0**	**5**	**0**	**3**	**0**
Personal traits (human and social capital-related)							
Personal traits	**5**		1	2		1	1
Carelessness	**1**	1					
Laziness	**1**						1
Egocentrism	**3**	1	2				
Mistrust, fear of data spread without control	**1**	1					
Protecting own work out of jealousy	**2**	1	1				
Paranoia	**2**	1			1		
Inter-departmental collaboration often hampered by department chairs' conflicts	**1**				1		
Younger researchers more open than seniors	**1**				1		
TOTAL	**17**	**5**	**4**	**2**	**3**	**1**	**2**
Reciprocity (human and social capital-related)							
Lack of acknowledgement in paper of material recipient results in non-sharing with them next time	**4**		2		2		
Lack of personal contact	**3**		1			1	1
Depends on collaborators and purpose of collaboration	**2**			2			
If difficult to reproduce, I ask for collaboration as a prerequisite for sharing	**1**						1
Preference for particular collaborators	**1**			1			
TOTAL	**11**	**0**	**3**	**3**	**2**	**1**	**2**
Other	**2**	**2**					
TOTAL ALL	**130**	**30**	**18**	**28**	**25**	**15**	**14**

Appendix J: Role of institutional environment in academic-industry knowledge transfer: number of quotations to which the codes are applied

Summary of codes - CROATIA	All respondents
Negative role of institutions in which respondents operate	
Many formal regulatory documents and support offices of institutions, no real system of incentives and no real KT (Slo, Ger)	11
IPR regulations only in recent years, not in the socialist period (Slo)	3
IPR regulations exist, but no one adheres	1
Weak financial effect of KT due to underdeveloped IP protection	3
Awareness about IPRs not well developed (Slo)	1
Problem of IPR-related legal relationship between the institute and the spin-off company	2
Universities not aware of attractive revenues from royalties	1
University IP revenue distribution system not incentivizing	2
University ownership of IP generated by researchers not reasonable as it demotivates researchers (Slo, Ita)	1
Difficulties of universities to define IP distribution formula	1
Percentage of revenues from KT going to institutions viewed as necessary evil	1
Institutions primarily interested in publishing, not patenting (Slo, Ger, Ita)	2
Scientific productivity viewed as the only scientific promotion factor (Slo)	1
Papers mostly published before the check of patentability (Ita)	1
Principle "patent as much as possible" or "patent or perish" leads to many irrelevant patents (USA)	1
People not educated in KT regulations	2
Few commercially exploitable patents	1
Institutional efforts to increase visibility to industry are missing	1
More proactive role of TTOs needed	3
Researchers sustain from KT as it takes too much time due to a lack of support; less bureaucracy needed	4
Researchers feel they need to do everything alone (Slo, USA, Italy)	2
Weak logistic support at institutions (Slo, USA, Italy)	3
Complete inefficiency of tech transfer offices (Slo, Isr)	3
No real KT, business building from facilities of bankrupt companies	1
Often resistance in institutional management	4
Only individual efforts, no systematic approach (Ita)	4
TOTAL	**60**
Positive role of government policies	
Government improved education and institutional framework, at least declaratively	4
TOTAL	**4**
Negative role of government policies	
Government has not done anything	3
Lack of government funding programmes	1
Unclear legal relations discourage venture capitalists and other investors	2
No real KT due to non-existing bio-pharma industry	7
Government must define science funding priorities (Slo)	2
Academic education has not followed industry needs	1
TOTAL	**16**
Negative role of scientific community	
Personal gains are primary with academic spin-offs	1
No academic community interesting to industry	1
No serious basic research	2
Privatized commercial projects with poor scientific quality	1
Envy that spin-off founders could get rich	1
Researchers rarely think about applicability of research, mostly about self-sufficiency of science or promotion (Slo)	2
Resistance of many academic researchers (Slo, Ger, Ita)	2
TOTAL	**10**
Role of culture	
KT-oriented research policy is not the right way	2
Neglected academic entrepreneurship (Slo)	1
TOTAL	**3**
Role of environment in knowledge sharing	
Closed to collaboration compared to Germany	1
Informal collaboration rare	1
Aggressive IP protection policy of institutions hinders informal collaboration	1
TOTAL	**3**
Other	**18**
TOTAL ALL	**114**

(continued)

Summary of codes - SLOVENIA	All respondents
Positive role of institutions in which respondents operate	
Every KT must be reported to tech transfer office (Ger, USA)	1
Broad-minded institutional management encouraging KT	1
Incentive system developed (Ger, USA)	2
Patenting included as a criterion for scientific promotion	1
Researchers more aware about importance of KT than in Croatia, although also not forced to involve in KT	1
Tradition of academic-industry collaboration	1
TOTAL	**7**
Negative role of institutions in which respondents operate	
Many formal regulatory documents and support offices of institutions, no real system of incentives and no real KT (Cro, Ger)	3
Awareness about IPRs not well developed (Cro)	2
IPR regulations only in recent years, not in the socialist period (Cro)	1
Institutions founding spin-offs want to have all IP although the risk is on company acting in unsecure setting	1
University ownership of IP generated by researchers not reasonable as it demotivates researchers (Cro, Ita)	1
No real KT results of institutions	1
Complete inefficiency of tech transfer offices (Cro, Isr)	1
Institutions primarily interested in publishing, not patenting (Cro, Ger, Ita)	1
Scientific productivity viewed as the only scientific promotion factor (Cro)	2
Many researchers interested in KT, but discouraged by bureaucracy (USA)	1
Researchers feel they need to do everything alone (Cro, USA, Italy)	1
Weak logistic support at institutions (Cro, USA, Italy)	1
TTOs in Europe are rarely successful and keep repeating mistakes (Ger)	1
TOTAL	**17**
Negative role of government policies	
Abundance of public venture capital let to a lot of bad quality spin-off projects	1
Government must prepare infrastructure and motivate people	1
Government must define science funding priorities (Cro)	1
Government provided seed funding, but of insufficient size and duration taking into account the long development in bio-pharma industry	2
Government should stimulate KT by limiting traditional funding and opening funding that requires academic-industry collaboration	3
Government supports resistance of researchers to KT and easy-going day-to-day business, not related to the real world	1
Incubators are not ideal as they are not well linked with the next stages of company growth	1
Rigid legislation makes working both for academia and spin-off difficult	1
Complicated legislation requires approval of government for funding a university spin-off	1
TOTAL	**12**
Negative role of scientific community	
Innovative collaborations resulting in new products rare	1
Envy that spin-off founders could get rich (Ger)	1
Researchers rarely think about applicability of their research, mostly about self-sufficiency of science or promotion (Cro)	3
Resistance of many academic researchers (Cro, Ger, Ita)	3
TOTAL	**8**
Role of culture	
Lack of entrepreneurial culture in Europe compared to USA	1
Neglected academic entrepreneurship (Cro)	1
TOTAL	**2**
Role of environment in knowledge sharing	
Environment not keen in doing KT, so not many sharing restrictions due to KT compared to other environments	1
Bad leadership leads to restrictions (USA)	1
TOTAL	**2**
Other	**12**
TOTAL ALL	**60**

(table continues)

(continued)

Summary of codes - GERMANY	All respondents
Positive role of institutions in which respondents operate	
University ownership of research results: obligation of reporting all inventions; if they are not interested, then researchers can patent alone (Slo, USA)	2
Incentive system developed (Slo, USA)	3
Incentive system developed at institution for bridging the basic-applied gap	2
Institutional management is important for defining priorities and encouraging researchers attract more funding, not so much for applied research	1
No pressure for KT because of a governmental institution	1
No pressure of TTOs for patenting, leave the decision to researchers (Isr)	1
TOTAL	**10**
Negative role of institutions in which respondents operate	
Many formal regulatory documents and support offices of institutions, no real system of incentives and no real KT (Cro, Slo)	1
Unlike in the USA, where universities support spin-off founding, in Germany the relation between researcher, institution and spin-off is still not exactly defined by rules in terms of conflict of interest	1
Institutions primarily interested in publishing, not patenting (Cro, Slo, Ita)	1
TTOs in Europe are rarely successful and keep repeating mistakes (Slo)	1
TOTAL	**4**
Positive role of government policies	
Government has developed incentive programmes	2
Governmental institutes must report KT activities to the government and return them part of the revenues	1
Governments support research institutes of applied orientation and business orientation	1
TOTAL	**4**
Negative role of government policies	
Academic career not attractive due to budgetary cuts	1
Problem of lack of private investors in Europe compared to USA (Ita)	1
TOTAL	**2**
Negative role of scientific community	
Incentives do not necessarily lead to KT as researchers prefer basic research	1
Envy that spin-off founders could get rich (Slo)	1
Resistance of many academic researchers (Cro, Slo, Ita)	1
TOTAL	**3**
Other	**6**
TOTAL ALL	**29**

Summary of codes – USA	All respondents
Positive role of institutions in which respondents operate	
Most efficient academic KT system	1
Some universities developed a very effective and comprehensive KT support to researchers	4
Developed KT infrastructure	2
Incentive system developed (Slo, Ger)	3
Academic spinning-off encouraged for further development of initial discoveries	1
Every KT must be reported to tech transfer office (Slo, Ger)	3
Improved KT education for scientists (Ita)	2
TOTAL	**16**
Negative role of institutions in which respondents operate	
US universities redundant as they patent everything	2
Principle "patent as much as possible" or "patent or perish" leads to many irrelevant patents	2
Instead of in research, academia invested in attorneys; more people realise that the model of pushing of attorneys for patenting is not right, as it increases bureaucracy; slow and bureaucratic KT process	3
Many researchers interested in KT, but discouraged by bureaucracy (Slo)	1
Researchers feel they need to do everything alone (Cro, Slo, Ita)	2
Weak logistic support at institutions (Cro, Slo, Ita)	2
Not satisfied with university TTO efficiency (Cro, Slo, Isr, Ita)	3
Lack of effective pipeline to evaluate patentable technologies	2
TOTAL	**17**

(table continues)

(continued)

Role of government policies	
Government has a hands-off approach on KT, stays away from business	1
Government passively approves KT	1
Government has invested in KT programmes as a political means to justify public spending on research (generation of new jobs and businesses)	1
National incentives like SBIR/STTR and NCATS developed to facilitate KT	2
Due to decreased public funding, push for universities to patent and license generated technologies	1
Most start-ups get funded from government grants and wait to be bought by bigger companies, since medical products cannot be developed by small companies	1
TOTAL	**7**
Role of culture	
Entrepreneurial culture	1
TOTAL	**1**
Role of environment in knowledge sharing	
In US collaboration more open and comprehensive than in e.g. Croatia	1
Increased pressure on researchers to do KT leads to interfering with research	2
Lack of discussions on impact of KT on research and teaching	1
Some institutions forbid working both for companies and for clinical departments due to conflict of interest potential	1
Institutions insist on conflict of interest reporting forms related to interactions with companies	1
Bad leadership leads to restrictions (Slo)	1
TOTAL	**7**
Other	**6**
TOTAL ALL	**54**

Summary of codes - ITALY	All respondents
Positive role of institutions in which respondents operate	
Despite professor's privilege, obligation to inform university	1
Professor's privilege	2
Beneficial for KT are institutions that enable from bench to bedside approach	1
Improved KT education for scientists (USA)	1
TOTAL	**5**
Negative role of institutions in which respondents operate	
University ownership of IP generated by researchers not reasonable as it demotivates researchers (Cro, Slo)	1
Difficult negotiations on royalties with universities	1
Increased pressure of universities for higher ranking (publications) reduces time available for KT, which is not evaluated (Cro, Slo, Ger)	1
Papers mostly published before the check of patentability (Cro)	1
Only individual efforts; no systematic approach (Ita)	2
Universities with too small critical mass to actively involve in KT	1
Universities often lack funds to pursue patent maintenance	1
European universities stop KT work with patenting	1
Not satisfied with university TTO efficiency (Cro, Slo, USA, Isr)	1
Researchers feel they need to do everything alone (Cro, Slo, USA)	1
Weak logistic support at institutions (Cro, Slo, USA)	1
TOTAL	**12**
Negative role of government policies	
KT hampered by a lack of quality industry	1
Problem of lack of private investors in Europe compared to USA (Ger)	2
TOTAL	**3**
Role of culture	
Weak knowledge of risky ideas exploitation	1
Weak knowledge transfer culture	3
TOTAL	**4**
Negative role of scientific community	
Researchers not interested in KT, only in publications	1
Resistance of many academic researchers (Cro, Slo, Ger)	1
Unlike in Germany, weak relationships of industry with academia	1
TOTAL	**3**
Other	**6**
TOTAL ALL	**33**

(table continues)

(continued)

Summary of codes - ISRAEL	All respondents
Positive role of institutions in which respondents operate	
All inventions belong to university (USA, Slo, Ger)	3
All KT goes through institution (USA, Slo, Ger)	1
No pressure of TTOs for patenting, leave the decision to researchers (Ger)	2
TOTAL	**6**
Negative role of institutions in which respondents operate	
Institutional TTO pressure for KT more prominent in institutes than in universities	1
No institutional incentives	3
Researchers at university do not get particular benefits (relinquish from teaching, sabbatical or similar) for involvement in KT	2
Complete inefficiency of tech transfer offices (Cro, Slo)	1
TOTAL	**7**
Role of culture	
In Israel more creativity and climate for KT than in Europe	1
TOTAL	**1**
Role of environment in knowledge sharing	
University policy defines sharing restrictions	1
TOTAL	**1**
TOTAL ALL	**15**

Appendix K: English version of the questionnaire for knowledge transfer-knowledge sharing strudy

Introductory question:

Is the organization to which you are currently **primarily** affiliated located in Croatia?

YES
NO

If no, you will be directed to finishing the survey by clicking "submit". If yes, continue with the survey.

Research activities

1. In which of the following fields of life science research have you been **primarily** involved: FIELD

Molecular and Structural Biology and Biochemistry: Molecular synthesis, modification and interaction, biochemistry, biophysics, structural biology, metabolism, signal transduction	□	1
Genetics, Genomics, Bioinformatics and Systems Biology: Molecular and population genetics, genomics, transcriptomics, proteomics, metabolomics, bioinformatics, computational biology, biostatistics, biological modelling and simulation, systems biology, genetic epidemiology	□	2
Cellular and Developmental Biology: Cell biology, cell physiology, signal transduction, organogenesis, developmental genetics, pattern formation in plants and animals, stem cell biology	□	3
Physiology, Pathophysiology and Endocrinology: Organ physiology, pathophysiology, endocrinology, metabolism, ageing, tumorigenesis, cardiovascular disease, metabolic syndrome	□	4
Neurosciences and Neural Disorders: Neurobiology, neuroanatomy, neurophysiology, neurochemistry, neuropharmacology, neuroimaging, systems neuroscience, neurological and psychiatric disorders	□	5
Immunity and Infection: The immune system and related disorders, infectious agents and diseases, prevention and treatment of infection	□	6
Diagnostic Tools, Therapies and Public Health: Aetiology, diagnosis and treatment of disease, public health, epidemiology, pharmacology, clinical medicine, regenerative medicine, medical ethics	□	7
Evolutionary, Population and Environmental Biology: Evolution, ecology, animal behaviour, population biology, biodiversity, biogeography, marine biology, ecotoxicology, microbial ecology	□	8
Applied Life Sciences and Non-Medical Biotechnology: Applied plant and animal sciences; food sciences; forestry; industrial, environmental and non-medical biotechnologies, bioengineering; synthetic and chemical biology; biomimetics; bioremediation	□	9
Other (specify field) ____________________	□	10

2. Estimate the percentage of your working time involvement (in a typical work week) in: WORKTIME

Research and research-related activities (includes planning of experiments, laboratory time, preparation of publications)	__%	WTRES
Project-related activities (includes grant proposals preparation, coordination of project activities, writing reports)	__%	WTPRO
Teaching	__%	WTTEA
Activities related to academic-industry knowledge and technology transfer*	__%	WTTEC
Work with patients (medical)	__%	WTPAT
Other (including participation in committees, administration)	__%	WTOTH
TOTAL	**100%**	

** Activities related to academic-industry knowledge and technology transfer may include: consulting industry, performing industry-sponsored research or research projects in collaboration with industry, invention disclosing to technology transfer office, activities related to filing patent applications, activities related to licensing (including negotiations with industry), activities related to academic entrepreneurship (writing business plans, setting up companies, including spin-offs, managing and/or advising companies, developing products, commercial activities related to products based on own research)*

3. How do you perceive the nature of your research? Estimate the percentage of your **research working time** involvement in: RESWTIME

Basic research (experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view)	__%	BASRE
Applied research (original investigation undertaken in order to acquire new knowledge, but directed primarily towards a specific practical aim or objective)	__%	APPRE
Experimental development (systematic work, drawing on existing knowledge gained from research and/or practical experience, which is directed to producing new materials, products or devices, to installing new processes, systems and services, or to improving substantially those already produced or installed)	__%	EXPRE
TOTAL	**100%**	

4. For the activities in which you have been involved in the **last five years** as a research group member (but where you were not necessarily directly responsible for the expenditure of funds as a team supervisor, principal investigator or activity leader), estimate the percentage of each of these sources in the total funding: FUND

National government-related and other national competitive project granting programs, agencies and foundations (e.g., National Science Foundation)	__%	NATG
EU and international competitive project granting funds, programs, agencies and foundations (e.g., European Commission's FP7 and Horizon 2020, National Institutes of Health USA, international associations)	__%	EUIN
Industry sponsors	__%	INDF
Market revenues (sales, professional services, royalties, etc.)	__%	OWNF
Other (specify source): _________________	__%	OTHF
TOTAL	**100%**	

5. Estimate the percentage of each of these sources in the total funding that you received in the **last five years** for activities of **the research team that you are supervising***: SFUND

National government-related and other national competitive project granting programs, agencies and foundations (e.g., National Science Foundation)	__%	SNAT
EU and international competitive project granting funds, programs, agencies and foundations (e.g., European Commission's FP7 and Horizon 2020, National Institutes of Health USA, international associations)	__%	SEUI
Industry sponsors	__%	SIND
Market revenues (sales, professional services, royalties, etc.)	__%	SOWF
Other (specify source): _________________	__%	SOTH
TOTAL	**100%**	

** In the case you are participating in the above listed activities as a team member, but are not directly responsible for the expenditure of related funds as a team supervisor, principal investigator or activity leader, skip the question.*

6. Indicate the **average annual** amount of funding (in Euros), irrespective of the source, which you have received for your research activities or research activities of the research team you are supervising in the **last five years**: EUR ____________ TOTFUND

Please include only research projects for which you are responsible for and which are funded through your institution(s), and exclude overhead/indirect costs.

Involvement in academic-industry knowledge transfer activities

1. In **how many** of each of the following activities have you been involved, either as a team leader or team member, during the **last five years:** AIKT

How many private firms have your research results been sent to?	___	AIKT1
How many companies have you consulted (independently or as an advisory board member)?	___	AIKT2
In how many industry-sponsored research projects have you been involved?	___	AIKT3
In how many university-industry joint research projects (FP7, Horizon 2020 or similar) have you been involved?	___	AIKT4
How many talks or presentations for or in the business sector have you given?	___	AIKT5
How many joint publications with the industry have you published as a co-author?	___	AIKT6
How many members of the research team in which you work have been seconded to industry?	___	AIKT7
How many researchers from the business sector has the team in which you work hosted in your laboratory?	___	AIKT8
How many inventions with you as an inventor or co-inventor have been disclosed (to e.g. technology transfer office or patent office)?	___	AIKT9
How many patent applications have been submitted for the inventions with you as an inventor or co-inventor?	___	AIK10
How many patents have been granted to your institution or you as an inventor or co-inventor?	___	AIK11
How many patents granted to you or to your institution based on your research results have been licensed (exclusively or non-exclusively) to the business sector?	___	AIK12
In how many negotiations with different entities over rights and commercialization of your inventions have you been involved?	___	AIK13
How many licensing agreements have been signed by you or your institution based on your non-patented research results?	___	AIK14
In how many business plans or other activities related to starting a new firm have you been involved?	___	AIK15
How many companies (related to your research work) have you founded?	___	AIK16
How many companies (related to your research work) have you managed?	___	AIK17
How many companies with products based on your research in which you hold equity have been active?	___	AIK18
How many products directly based on the results of your research have been under regulatory review (e.g., for approval of new medicines)?	___	AIK19
How many products directly based on the results of your research have been on the market?	___	AIK20

Knowledge sharing

1. With how many research groups are you, either as a team leader or team member, currently collaborating in the **academic sector***: COL

** Academic sector includes public or private higher education establishments awarding academic degrees and public or private non-profit research organisations whose primary mission is to pursue research.*

Other departments of the same institution	___	COL1
Other groups in the same country	___	COL2
Research groups in other countries	___	COL3

2. With how many of the articles that you prepared in the past five years did you experience the situation that you had to omit some relevant content (research results) from the manuscript when submitting it for review or publication to: CONT

(a) protect your scientific lead in the field (e.g., you wish to generate additional research results that will increase your chances for publishing in a highly ranked journal) ____________ CONT1
(b) protect the scientific priority of a team member (doctoral or postdoctoral student) ____________ CONT2
(c) respect the provisions of an agreement with a collaborator ____________ CONT3
(d) protect its commercial value ____________ CONT4

3. With how many of these articles that you prepared in the past five years did you experience the situation that you had to delay publishing of your research results for more than 6 months to: TIM

(a) respect the provisions of an agreement with a collaborator ____________ TIM1
(b) protect your scientific lead ____________ TIM2
(c) protect the scientific priority of a team member (doctoral or postdoctoral student) ____________ TIM3
(d) to delay the dissemination of undesired results (e.g., the results are not in compliance with the research hypothesis) ____________ TIM4
(e) meet the requirements of a non-industrial sponsor (e.g., agency funding your research) ____________ TIM5
(f) meet the requirements of an industrial sponsor____________ TIM6
(g) allow time for a patent application____________ TIM7
(h) to protect the proprietary or financial value of the results (other than by patent application) ____________ TIM8
(i) to allow time for license agreements ____________ TIM9
(j) to resolve disputes over ownership of intellectual property ____________ TI10

4. What share (%) of **scientific papers** that you published in the **last five years** was in co-authorship with other research groups from the **academic sector?** ____________ COAU

5. With how many of these articles did you experience the situation that you had to exclude some relevant content (research results) from the manuscript? ____________ COCO

6. With how many of these articles did you experience the situation that you had to delay publishing for more than 6 months? ____________ COTI

7. In how many **formal* collaborative research projects** with other research groups from the **academic sector** have you been involved, either as a team leader or team member, during the **past five years**? ____________ FORM

** "Formal" implies the existence of a contractual relationship, such as the collaboration agreement, partnership agreement, consortium agreement, etc. FP7, Horizon 2020 and other collaborative projects can be included here.*

8. In how many of these projects did you experience situation that you restricted knowledge (information, data, materials) sharing with your project collaborators? ____________ FORMPRORES

9. In how many of your **academic collaborators' laboratories** have you been seconded during the **past five years**? ____________ OUTACSEC

10. In how many of these secondments did you restrict knowledge sharing with academic collaborators' team members? ____________ OUTSECRES

11. How many **academic collaborators** of your research team have been seconded to your laboratory during the **past five years**? ____________ INACSEC

12. In how many of these secondments did you restrict knowledge sharing with academic collaborators' team members? ____________ INSECRES

13. At how many occasions have you presented (orally or with a poster) your research results during the **past five years**? ____________ PRES

This refers to venues such as seminars at other departments of your institution, at other academic institutions and at professional meetings.

14. At how many of these occasions did you intentionally exclude some relevant content (unpublished research results) during the presentation or questions & answers session from the audience? ____________ PRESRES

15. **In the past five years**, how many requests for your

unpublished information and data ____________ REQ1
Information can include laboratory techniques or protocols, genetic sequences or protein structures.
Data can include database or software.

unpublished materials ____________ REQ2
Materials can include reagents, chemical compounds, cell lines, tissues, model organisms, proteins, genes, plasmids

published information and data ____________ REQ3

published materials ____________ REQ4

have you received **informally (without contractual relationship, e.g., via e-mail or personally)** from other research groups in the academic sector?

16. Of these requests, how many have you denied (explicitly rejected or ignored)?

unpublished information and data ____________ RED1

unpublished materials ____________ RED2

published information and data ____________ RED3

published materials ____________ RED4

17. **In the past five years**, how many times have you requested informally (without contractual relationship, e.g., via e-mail or personally) from other research groups in the academic sector:

unpublished information and data ____________ REO1

unpublished materials ____________ REO2
published information and data ____________ REO3

published materials ____________ REO4

18. How many of these requests have been denied to you (you were explicitly rejected or ignored)?

unpublished information and data ____________ ROD1

unpublished materials ____________ ROD2

published information and data ____________ ROD3

published materials ____________ ROD4

19. For how many of the requests for your research materials that you received from researchers from the academic sector in the last five years did you require a material transfer agreement (MTA) from the other party? ____________ MTAOUT

20. Of these, how many required negotiation lasting more than one month? ____________ MTANEGOUT

21. For how many of the requests for materials that you sent to other researchers from the academic sector in the last five years did they ask you to sign a material transfer agreement (MTA) before sending you the materials? ____________ MTAIN

22. Of these, how many required negotiation lasting more than one month? ____________ MTANEGIN

23. How important have been each of the following reasons behind your sharing restrictions **in the past five years** when it comes to sharing of information, data and materials with other researchers from the academic sector? Please rate the importance on a scale from 1 to 5, where 1 stands for "not at all important" and 5 stands for "extremely important". Zero refers to "not applicable". REA

Item	not at all important, not very important, moderately important, very important, extremely important					Not applicable	
	1	2	3	4	5	0	
Too much time, money or other resources needed to prepare or produce the requested information, data and materials							REA1
Protecting own or team members' ability to publish (fear of losing priority, competitiveness)							REA2
Lack of trust in research group requesting the information, data and material							REA3
Uncertainty in the reproducibility of generated results							REA4
Existing or planned relationships with industry (e.g., industry-sponsored research, consulting)							REA5
Existing or planned intellectual property protection activities (e.g., patenting, licensing)							REA6
Existing or planned academic entrepreneurship or business activities (e.g., start up founding)							REA7
Need to preserve confidentiality of patients							REA8
Forgetting to respond to requests							REA9
The person requesting the information, data or materials did not acknowledge my contribution (with co-authorship or acknowledgement) when (s)he previously requested the information or materials from me							RE10
I am not in the position to respond to requests personally, my supervisor does this							RE11
Other (specify)							RE12

24. As a result of sharing your information, data or materials with another academic scientist in the past five years how many times have you: CONS

(a) been scooped by another scientist _____________ CON1
(b) compromised the ability of a junior team member to publish _____________ CON2
(c) been unable to benefit commercially from your results _____________ CON3
(d) formed collaborations that led to joint publications _____________ CON4
(e) formed collaborations that led to joint granted projects _____________ CON5

Reciprocity

1. On a scale from 1 to 7, where 1 refers to "strongly disagree" and 7 refers to "strongly agree", please assess your general level of agreement with the following statements:

Item	strongly disagree - strongly agree							
	1	2	3	4	5	6	7	
When sharing information, data or materials with other researchers in the academic community, I believe that I will benefit from the relationship with the knowledge recipient in the future.								R1
I know that other researchers in the academic community will help me, so it is only fair to help them.								R2
I believe that other researchers in the academic community would help me if I needed it.								R3
When I share research results with other researchers in the academic community, I expect valuable feedback.								R4

Personal outcome expectations

1. On a scale from 1 to 7, where 1 refers to "strongly disagree" and 7 refers to "strongly agree", please assess your general level of agreement with the following statements:

Item	Strongly disagree - Strongly agree							
	1	2	3	4	5	6	7	
Sharing my knowledge will help me to make friends with other researchers in the academic community.								POE1
Sharing my knowledge will give me a feeling of happiness.								POE2
Sharing my knowledge can build up my reputation with other researchers in the academic community.								POE3
Sharing my knowledge will give me a sense of accomplishment.								POE4
Sharing my knowledge will strengthen the tie between other researchers in the academic community and me.								POE5
Sharing my knowledge will enable me to gain better cooperation from the outstanding members in the academic community.								POE6

Community-related outcome expectations

1. On a scale from 1 to 7, where 1 refers to "strongly disagree" and 7 refers to "strongly agree", please assess your general level of agreement with the following statements:

Item	Strongly disagree - Strongly agree							
	1	2	3	4	5	6	7	
Sharing my knowledge will be helpful to the successful functioning of the academic community.								COE1
Sharing my knowledge would help the academic community continue its operation in the future.								COE2
Sharing my knowledge would help the academic community accumulate or enrich knowledge.								COE3
Sharing my knowledge would help the academic community grow.								COE4

Trust

1. On a scale from 1 to 7, where 1 refers to "strongly disagree" and 7 refers to "strongly agree", please assess your general level of agreement with the following statements:

Item	Strongly disagree - Strongly agree							
	1	2	3	4	5	6	7	
Members of the academic community to which I belong will not take advantage of others even when the opportunity arises.								TR1
Members of the academic community to which I belong will always keep the promises they make to one another.								TR2
Members of the academic community to which I belong would not knowingly do anything to disrupt the communication.								TR3
Members of the academic community to which I belong behave in a consistent manner.								TR4
Members of the academic community to which I belong are truthful in dealing with one another.								TR5

Scientific values

1. On a scale from 1 to 7, where 1 refers to "strongly disagree" and 7 refers to "strongly agree", please assess your general level of agreement with the following statements:

Item	Strongly disagree - Strongly agree							
	1	2	3	4	5	6	7	
Worrying about possible commercial applications distracts one from doing good research.								DISIN
I would rather double my citation rate than double my salary.								COMM

Item	Strongly disagree - Strongly agree							
	1	2	3	4	5	6	7	
Scientists should share their results freely with all peers.								SV1
Scientists should be motivated primarily by a desire for knowledge.								SV2
I am personally very willing to share with other academic scientists.								SV3
Scientists should keep their newest findings secret to protect their priority.								SV4

Scientists should receive direct, personal benefits from their scientific discoveries.								SV5

Reputation

Please answer the following questions using a scale from 1 to 5, where 1 stands for "not at all important" and 5 stands for "extremely important":

Item	not at all important, not very important, moderately important, very important, extremely important					
	1	2	3	4	5	
How important for your reputation among peers is the number of articles published in peer reviewed journals?						REP1
How important for your reputation among peers is the impact factor of the journals where your articles appear?						REP2
How important for your reputation among peers is the number of citations published articles receive?						REP3
How important for your reputation among peers are scientific awards?						REP4

Competition (perception of competitiveness of field)

Please answer the following question using a scale from 1 to 5, where 1 stands for "not at all competitive" and 5 stands for "extremely competitive":

Item	Not at all competitive – extremely competitive					
	1	2	3	4	5	
How would you characterize the overall level of competition for recognition or scientific priority in your specific area of research?						COMP

Institutional sharing climate

Item	Strongly disagree - Strongly agree							
	1	2	3	4	5	6	7	
My Head of Department does not think that I should share my knowledge with other researchers in the academic community.								ISC1
My direct supervisor thinks that I should share my knowledge with other researchers in the academic community.								ISC2
My colleagues in the research group think I should share knowledge with other researchers in the academic community.								ISC3

Institutional knowledge transfer setting

For each of the following statements that are related to your **current institution of employment at which you perform most research activities** please indicate how strongly you personally agree or disagree with the statement. A “1” indicates that you strongly disagree, and a “5” indicates that you strongly agree.

Item	Strongly disagree - Strongly agree					
	1	2	3	4	5	
My institution places a great deal of weight on business or commercial activities. Adapted from						PIS1
My institution is too aggressive in exercising intellectual property rights.						PIS2
My institution provides facilities and access to research equipment for involvement in academic-industry knowledge transfer activities.						PIS3
The availability of a clear process for involvement in academic-industry knowledge transfer activities at my institution promotes the involvement in such activities.						PIS4
The availability of venture capital at my institution promotes the establishment of academic spin-off companies.						PIS5
My institution provides entrepreneurship training. Adapted from						PIS6
There are good sources of assistance within the institution if researchers are interested in involving in academic-industry interactions.						PIS7
My institution is supportive of academics who wish to commercialize their inventions.						PIS8
Marketing skills of the support staff involved in commercialisation promote the involvement in academic-industry interactions.						PIS9
Bureaucracy of the academic support staff involved in commercialization impedes the involvement in academic-industry interactions.						PI10
Technical skills of the support staff involved in commercialization promote the involvement in academic-industry interactions.						PI11
Inflexibility of the support staff involved in commercialization impedes the involvement in academic-industry interactions.						PI12
Negotiating skills of the support staff involved in commercialization promote the involvement in academic-industry interactions.						PI13

General questions

1. Indicate your gender: GEND

Female	□	1
Male	□	2

2. To what types of organization are you currently affiliated? AFF

Higher education institution – pre-clinical department	□	1
Higher education institution – clinical department	□	2
Public research institute	□	3
Private research institute	□	4
Government laboratory	□	5
Public health institution (hospital, clinic, health institute)	□	6
Private health institution (hospital, clinic, health institute)	□	7
Other (specify type) ______________________	□	8

3. How long have you been employed in your current primary institution of employment? ________ years YRSCUR

4. Specify your current academic rank: RANK

Full Professor / Professor Emeritus / Scientific Advisor or equivalent	□	1
Associate Professor / Higher Scientific Associate or equivalent	□	2
Assistant Professor / Scientific Associate or equivalent	□	3
Postdoctoral Researcher or equivalent	□	4
Other (specify rank) ____________________	□	5

5. How long have you in total worked in the **non-profit sector** (universities, hospitals or public research institutions)? _________ years YRSACA

6. Indicate the total number of years of your **professional experience** (starting from the year of your first employment): _________ years PRAGE

7. How many full-time **research team members** (scientists and support staff, e.g. laboratory engineers) are you currently supervising? _________ TEAMSIZE

8. How many full-time employees (all personnel categories) are you currently directly supervising? _________ SUBORDSIZE

Appendix L: Croatian version of the questionnaire for knowledge transfer-knowledge sharing strudy

Jeste li trenutno primarno zaposleni u Hrvatskoj? HR

DA

NE

Ako je odgovor ne, bit ćete usmjereni na završetak ankete. Ako da, nastavite s anketom.

Istraživačke aktivnosti

1. Koje od navedenih područja predstavlja Vaše **primarno** područje istraživanja: FIELD

Molekularna i strukturna biologija i biokemija: molekularna sinteza, modifikacije i interakcije, biokemija, biofizika, strukturna biologija, metabolizam, signalna transdukcija	□	1
Genetika, genomika, bioinformatika, sistemska biologija: molekularna i populacijska genetika, genomika, transkriptomika, proteomika, metabolomika, bioinformatika, računalna biologija, biostatistika, biološko modeliranje i simulacije, sistemska biologija, genetička epidemiologija	□	2
Stanična i razvojna biologija: stanična biologija, stanična fiziologija, signalna transdukcija, organogeneza, razvojna genetika, oblikovanje obrazaca u biljkama i životinjama (eng. pattern formation in plants and animals), biologija matičnih stanica	□	3
Fiziologija, patofiziologija i endokrinologija: fiziologija organa, patofiziologija, endokrinologija, metabolizam, starenje, tumorigeneza, kardiovaskularne bolesti, metabolički sindrom	□	4
Neurološke znanosti i neurološki poremećaji: neurobiologija, neuroanatomija, neurofiziologija, neurokemija, neurofarmakologija, neuroimaging, sistemska neuroznanost, neurološki i psihijatrijski poremećaji	□	5
Imunost i infekcije: imunološki sustav i vezani poremećaji, infektivni agenti i bolesti, prevencija i liječenje infekcija	□	6
Dijagnostički alati, terapije i javno zdravstvo: etiologija, dijagnostika i liječenje bolesti, javno zdravstvo, epidemiologija, farmakologija, klinička medicina, regenerativna medicina, medicinska etika	□	7
Evolucijska, populacijska i biologija okoliša: evolucija, ekologija, ponašanje životinja, populacijska biologija, bioraznolikost, biogeografija, biologija mora, ekotoksikologija, mikrobna ekologija	□	8
Primijenjene znanosti o životu i nemedicinska biotehnologija: primijenjene znanosti o bilju i životinjama, prehrambene znanosti; šumarstvo, industrijska, okolišna i nemedicinska biotehnologija, bioinženjering, sintetička i kemijska biologija, biomimetika, bioremedijacija	□	9
Ostalo (navedite područje) ____________________	□	10

2. Procijenite **udio** svake od sljedećih aktivnosti u Vašem ukupnom radnom vremenu (u tipičnom radnom tjednu): WORKTIME

Istraživanje i aktivnosti usko vezane uz istraživanje (uključuje planiranje pokusa, vrijeme u laboratoriju, pisanje znanstvenih publikacija)	__%	WTRES
Aktivnosti vezane uz projekte (uključuje pripremu projektnih prijedloga, koordinaciju projektnih aktivnosti, pisanje izvještaja)	__%	WTPRO
Nastava	__%	WTTEA
Aktivnosti vezane uz prijenos znanja i tehnologija iz akademskog u poslovni sektor*	__%	WTTEC
Rad s pacijentima (zdravstveni)	__%	WTPAT
Ostalo (uključuje sudjelovanje u odborima, administrativne aktivnosti)	__%	WTOTH
UKUPNO	**100%**	

** Aktivnosti vezane uz prijenos znanja i tehnologija iz akademskog u poslovni sektor mogu uključivati: savjetovanje poslovnog sektora, provedbu istraživanja sponzoriranog od strane poslovnog sektora ili istraživačkih projekata u suradnji s industrijom, razotkrivanje izuma uredu za transfer tehnologije, aktivnosti vezane uz podnošenje patentnih prijava, aktivnosti vezane uz licenciranje (uključujući pregovaranje s industrijom), aktivnosti vezane uz akademsko poduzetništvo (pisanje* *poslovnih planova, osnivanje poduzeća, uključujući spin-off poduzeća, upravljanje i/ili savjetovanje poduzeća, razvoj proizvoda, komercijalne aktivnosti vezane uz proizvode zasnovane na vlastitom istraživanju)*

3. Na koji način percipirate prirodu Vaših istraživanja? Procijenite koliko ste Vašeg **istraživačkog radnog vremena** (u %) uključeni u svaku od sljedećih aktivnosti: RESWTIME

Temeljna istraživanja (eksperimentalni ili teorijski rad poduzet prvenstveno kako bi se stekla nova znanja o temeljnim načelima fenomena i vidljivih činjenica, bez predviđene izravne tržišne primjene ili uporabe)	__%	BASRE
Primijenjena istraživanja (originalno istraživanje poduzeto kako bi se stekla nova znanja, ali usmjereno prvenstveno prema specifičnom praktičnom cilju)	__%	APPRE
Eksperimentalni razvoj (sustavni rad temeljen na postojećim znanjima dobivenim istraživanjem i/ili praktičnim iskustvom, usmjeren na proizvodnju novih ili značajno poboljšanje postojećih materijala, proizvoda ili uređaja, uspostavu novih procesa, sustava i usluga)	__%	EXPRE
UKUPNO	**100%**	

4. Procijenite **udio** svakog od sljedećih izvora financiranja u ukupnom financiranju koje ste dobili za aktivnosti **istraživačke grupe čiji ste član** (no ne i nužno izravno odgovorni za raspolaganje sredstvima kao voditelj tima, glavni istraživač ili voditelj aktivnosti) u posljednjih **pet godina**: FUND

Nacionalni vladini programi i ostali nacionalni programi za kompetitivno financiranje projekata, agencije i zaklade	__%	NATG
EU i međunarodni fondovi i programi za kompetitivno financiranje projekata, agencije i zaklade (npr. Sedmi okvirni program Europske komisije, Obzor 2020, Nacionalni instituti za zdravlje SAD-a, međunarodna udruženja)	__%	EUIN
Industrijski sponzori	__%	INDF
Tržišni prihodi (prodaja, stručne usluge, rojaliteti, itd.)	__%	OWNF
Ostalo (navedite izvor): _________________	__%	OTHF
UKUPNO	**100%**	

5. Procijenite **udio** svakog od sljedećih izvora financiranja u ukupnom financiranju koje ste dobili za aktivnosti **Vaše istraživačke grupe*** u posljednjih **pet godina**: SFUND

Nacionalni vladini programi i ostali nacionalni programi za kompetitivno financiranje projekata, agencije i zaklade	__%	SNAT
EU i međunarodni fondovi i programi za kompetitivno financiranje projekata, agencije i zaklade (npr. Sedmi okvirni program Europske komisije, Obzor 2020, Nacionalni instituti za zdravlje SAD-a, međunarodna udruženja)	__%	SEUI
Industrijski sponzori	__%	SIND
Tržišni prihodi (prodaja, stručne usluge, rojaliteti, itd.)	__%	SOWF
Ostalo (navedite izvor): _________________	__%	SOTH
UKUPNO	**100%**	

** Ukoliko sudjelujete u ovim aktivnostima kao član istraživačke grupe, ali niste izravno odgovorni za raspolaganje sredstvima kao voditelj tima, glavni istraživač ili voditelj aktivnosti, preskočite pitanje.*

6. Promatrajući razdoblje od posljednjih pet godina, navedite **prosječni godišnji** iznos financiranja (u eurima) istraživačkih aktivnosti, neovisno o izvoru, za Vas ili istraživačku grupu koju koordinirate: EUR ____________ TOTFUND

Molimo Vas da ovdje uključite samo istraživačke projekte za koje ste odgovorni, a koji se provode na instituciji (institucijama) Vašeg zaposlenja. Isključite neizravne / indirektne troškove projekata.

Uključenost u aktivnosti prijenosa znanja iz akademskog u poslovni sektor

1. Tijekom **posljednjih pet godina**, u koliko ste navedenih aktivnosti bili uključeni, bilo kao voditelj, bilo kao član tima: AIKT

U koliko privatnih poduzeća su poslani Vaši istraživački rezultati?	___	AIKT1
Koliko ste poduzeća savjetovali (kao nezavisni stručnjak ili član savjetodavnog odbora)?	___	AIKT2
U koliko projekata financiranih sredstvima industrije ste bili uključeni?	___	AIKT3
U koliko projekata (npr. FP7, Obzor 2020 ili slično) koji uključuju partnerstvo s poslovnim sektorom ste bili uključeni?	___	AIKT4
Koliko predavanja ili prezentacija ste održali za ili u poslovnom sektoru?	___	AIKT5
Koliko radova ste objavili u koautorstvu s istraživačima iz poslovnog sektora?	___	AIKT6
Koliko članova istraživačke grupe u kojoj radite je bilo na razmjeni u poslovnom sektoru?	___	AIKT7
Koliko istraživača iz poslovnog sektora je istraživačka grupa u kojoj radite ugostila u Vašem laboratoriju?	___	AIKT8
Koliko izuma u čijem ste pronalasku sudjelovali kao izumitelj ili su-izumitelj je bilo razotkriveno (npr. uredu za transfer tehnologije ili patentnom uredu)?	___	AIKT9
Koliko patentnih prijava je bilo podnešeno za izume u čijem ste pronalasku sudjelovali kao izumitelj ili su-izumitelj?	___	AIK10
Koliko patenata je odobreno Vašoj instituciji ili Vama za izume u čijem ste pronalasku sudjelovali kao izumitelj ili su-izumitelj?	___	AIK11
Koliko patenata odobrenih Vašoj instituciji ili Vama temeljenih na Vašim istraživačkim rezultatima je bilo licencirano (ekskluzivno ili ne-ekskluzivno) u poslovni sektor?	___	AIK12
U koliko pregovora s različitim entitetima o pravima i komercijalizaciji Vaših izuma ste bili uključeni?	___	AIK13
Koliko ugovora o licenciranju Vaših nepatentiranih istraživačkih rezultata ste potpisali Vi ili Vaša institucija?	___	AIK14
Koliko ste puta bili uključeni u pisanje poslovnih planova ili drugih aktivnosti vezanih uz osnivanje poduzeća?	___	AIK15
Koliko poduzeća u vezi s Vašim istraživačkim rezultatima ste osnovali?	___	AIK16
U rukovođenje koliko poduzeća u vezi s Vašim istraživačkim rezultatima ste bili uključeni?	___	AIK17
Koliko je bilo aktivnih poduzeća s proizvodima temeljenim na Vašim istraživačkim rezultatima u kojima imate vlasničke udjele?	___	AIK18
Koliko proizvoda izravno vezanih uz rezultate Vašeg istraživanja se nalazilo u postupku procjene regulatornih tijela (npr. za odobrenja za nove lijekove)?	___	AIK19
Koliko proizvoda izravno vezanih uz rezultate Vašeg istraživanja se nalazilo na tržištu?	___	AIK20

Dijeljenje znanja

1. S koliko istraživačkih grupa iz **akademskog sektora*** trenutno surađujete, bilo kao voditelj, bilo kao član tima: COL

** Akademski sektor uključuje javne i privatne ustanove visokog obrazovanja koje dodjeljuju akademske stupnjeve te javne i privatne neprofitne znanstvene organizacije čija je primarna misija provoditi istraživanja.*

Broj grupa iz drugih odjela Vaše institucije	___	COL1
Broj grupa iz drugih institucija u Vašoj zemlji	___	COL2
Broj grupa u drugim zemljama	___	COL3

2. **S koliko od članaka koje ste pripremali u posljednjih pet godina** ste imali situaciju da ste neki važan sadržaj (istraživačke rezultate) morali izostaviti prilikom predaje na recenziju ili objavu, kako biste: CONT

(a) zaštitili Vaše znanstveno vodstvo u području (npr. želite prikupiti dodatne rezultate koji će Vam povećati šanse za objavu u višerangiranom časopisu) ____________ CONT1 broj članaka
(b) zaštitili znanstveno prvenstvo člana Vaše istraživačke grupe (doktoranda ili poslijedoktoranda) ____________ CONT2
(c) ispoštovali odredbe ugovora sa suradnikom ____________ CONT3
(d) zaštitili komercijalnu vrijednost rezultata ____________ CONT4

3. **S koliko od članaka koje ste pripremali u posljednjih pet godina** ste imali situaciju da ste morali odgoditi objavu istraživačkih rezultata za više od šest mjeseci, kako biste: TIM

(a) ispoštovali odredbe ugovora sa suradnikom ____________ TIM1
(b) zaštitili Vaše znanstveno vodstvo u području ____________ TIM2
(c) zaštitili znanstveno prvenstvo člana Vaše istraživačke grupe (doktoranda ili poslijedoktoranda) ____________ TIM3
(d) odgodili objavu neželjenih rezultata (npr. rezultati nisu u skladu s postavljenom hipotezom) ____________ TIM4
(e) udovoljili zahtjevima sponzora koji nije iz poslovnog sektora (npr. agencije koja financira Vaša istraživanja) ____________ TIM5
(f) udovoljili zahtjevima sponzora iz poslovnog sektora ____________ TIM6
(g) ostavili dovoljno vremena za podnošenje patentne prijave ____________ TIM7
(h) zaštitili intelektualnu ili financijsku vrijednost istraživačkih rezultata (nevezano uz patentnu prijavu) ____________ TIM8
(i) ostavili dovoljno vremena za sklapanje ugovora o licenciranju ____________ TIM9
(j) riješili sporove vezane uz intelektualno vlasništvo ____________ TI10

4. Koliki **udio (%)** članaka koje ste objavili tijekom **posljednjih pet godina** je bio u koautorstvu sa znanstvenicima iz drugih istraživačkih grupa **u akademskom sektoru**? ____________ COAU

5. **S koliko od tih članaka** ste imali situaciju da ste neki važan sadržaj (istraživačke rezultate) morali izostaviti prilikom predaje na recenziju ili objavu? ____________ COCO

6. **S koliko od tih članaka** ste imali situaciju da ste morali odgoditi objavu istraživačkih rezultata za više od šest mjeseci? ____________ COTI

7. Tijekom **posljednjih pet godina**, u koliko **formalnih* kolaborativnih projekata** s drugim istraživačkim grupama **iz akademskog sektora** ste bili uključeni, bilo kao voditelj, bilo kao član tima? ____________ FORM

** "Formalno" podrazumijeva postojanje ugovornog odnosa, poput ugovora o suradnji, ugovora o partnerstvu ili konzorcijskog ugovora. Ovdje mogu biti uključeni i FP7, Obzor 2020 i drugi kolaborativni projekti.*

8. **S koliko od tih** projekata ste imali situaciju da ste na bilo koji način ograničavali dijeljenje znanja (informacija, podataka, materijala) prema Vašim projektnim suradnicima? ____________ FORMPRORES

9. Tijekom **posljednjih pet godina**, u koliko laboratorija različitih suradničkih istraživačkih grupa iz **akademskog sektora** ste bili na razmjeni? ____________ OUTACSEC

10. U **koliko od tih razmjena** ste imali situaciju da ste na bilo koji način ograničavali dijeljenje znanja s članovima suradničke istraživačke grupe? ____________ OUTSECRES

11. Tijekom **posljednjih pet godina**, koliko istraživača iz **akademskog sektora** je istraživačka grupa u kojoj radite ugostila u Vašem laboratoriju? ____________ INACSEC

12. U **koliko od tih razmjena** ste imali situaciju da ste na bilo koji način ograničavali dijeljenje znanja s razmijenjenim članovima suradničke istraživačke grupe? ____________ INSECRES

13. Tijekom **posljednjih pet godina**, koliko puta ste predstavili (usmeno ili posterom) Vaše istraživačke rezultate? ____________ PRES

Ovo se odnosi na prezentacije u drugim odjelima Vaše institucije, drugim akademskim institucijama ili na profesionalnim sastancima i skupovima.

14. U **koliko od tih predstavljanja** ste svjesno izostavili neki važan sadržaj (neobjavljene istraživačke rezultate) tijekom same prezentacije ili rasprave s publikom? ____________ PRESRES

15. Tijekom **posljednjih pet godina,** koliko zahtjeva ste zaprimili od drugih istraživačkih grupa iz akademskog sektora **neformalnim putem (bez ugovornog odnosa), primjerice e-mailom ili osobno,** za Vaše:

Neobjavljene informacije i podatke ____________ REQ1
Informacije mogu uključivati: laboratorijske tehnike ili protokole, genetičke sekvence ili proteinske strukture
Podaci mogu uključivati: baze podataka ili softver

Neobjavljene materijale ____________ REQ2
Materijali mogu uključivati: reagencije, kemijske komponente, stanične linije, tkiva, modelne organizme, proteine, gene, plazmide

Objavljene informacije i podatke ____________ REQ3
Objavljene materijale ____________ REQ4

16. Kojem broju takvih zahtjeva niste udovoljili (bilo eksplicitno bilo ignorirali)? RED

Neobjavljene informacije i podatke ____________ RED1

Neobjavljene materijale ____________ RED2

Objavljene informacije i podatke ____________ RED3

Objavljene materijale ____________ RED4

17. Tijekom **posljednjih pet godina,** koliko molbi ste Vi uputili drugim istraživačkim grupama iz akademskog sektora **neformalnim putem (bez ugovornog odnosa), primjerice e-mailom ili osobno,** za njihove: REO

Neobjavljene informacije i podatke ____________ REO1

Neobjavljene materijale ____________ REO2

Objavljene informacije i podatke ____________ REO3

Objavljene materijale ____________ REO4

18. Koliko takvih molbi Vam je odbijeno (bilo eksplicitno bilo ignoriranjem)? ROD

Neobjavljene informacije i podatke ____________ ROD1

Neobjavljene materijale ____________ ROD2

Objavljene informacije i podatke ____________ ROD3

Objavljene materijale ____________ ROD4

19. U slučajevima kada su druge istraživačke grupe iz akademskog sektora Vas molile Vaše istraživačke materijale **u posljednjih pet godina**, koliko puta ste zahtijevali ugovor o prijenosu materijala (eng. material transfer agreement, MTA)? ____________ MTAOUT

20. Od toga, koliko puta su pregovori oko potpisivanja MTA trajali dulje od mjesec dana? ____________ MTANEGOUT

21. U slučajevima kada ste Vi slali zahtjeve za istraživačkim materijalima drugim istraživačkim grupama iz akademskog sektora **u posljednjih pet godina**, koliko puta ste morali potpisati MTA prije dobivanja materijala? ____________ MTAIN

22. Od toga, koliko puta su pregovori oko potpisivanja MTA trajali dulje od mjesec dana? ____________ MTANEGIN

23. Na ljestvici od 1 do 5, pri čemu 1 označava „uopće nije važno“, a 5 „izuzetno je važno“, ocijenite koliko su važni bili pojedini **razlozi za situacije kada ste ograničavali dijeljenje znanja** (informacija, podataka i materijala) prema drugim istraživačima iz akademskog sektora u posljednjih pet godina. Opcija 0 označava „nije primjenjivo“.

Stavka	Uopće nije važno; nije značajno važno; umjereno je važno; vrlo je važno; izuzetno je važno					Nije primjenjivo	
	1	2	3	4	5	0	
Previše vremena, financijskih sredstava ili drugih resursa potrebno za pripremu ili proizvodnju traženih informacija, podataka ili materijala							REA1
Zaštita mogućnosti objave istraživačkih rezultata (vlastitih ili grupe) – strah od gubitka znanstvenog prvenstva, kompetitivnost							REA2
Nedostatak povjerenja u istraživačku grupu koja je tražila informacije, podatke ili materijale							REA3
Nesigurnost glede reproducibilnosti vlastitih istraživačkih rezultata							REA4
Postojeći ili planirani odnosi s poslovnim sektorom (npr. istraživanja financirana sredstvima industrije, savjetovanje industrije)							REA5
Postojeće ili planirane aktivnosti vezane uz zaštitu intelektualnog vlasništva (npr. patentiranje, licenciranje)							REA6
Postojeće ili planirane poslovne aktivnosti ili aktivnosti akademskog poduzetništva (npr. osnivanje start-up poduzeća)							REA7
Nužnost zaštite anonimnosti pacijenata							REA8
Zaboravim odgovoriti na zahtjeve							REA9
Osoba koja je zatražila informacije, podatke ili materijale nije uzela u obzir moj doprinos (putem davanja koautorstva ili zahvale u članku) kad je prethodno zatražila informacije, podatke ili materijale od mene							RE10
Nisam u poziciji osobno odgovarati na zahtjeve, moj nadređeni/a to obavlja							RE11
Ostalo							RE12

24. Koliko puta Vam se u posljednjih pet godina dogodilo da, nakon što ste podijelili informacije, podatke ili materijale s drugim istraživačima iz akademskog sektora: CONS

(a) ti drugi istraživači objave vezane rezultate istraživanja prije Vas ____________ CON1
(b) ugrozite mogućnost objavljivanja znanstvenog rada mlađeg člana Vaše istraživačke grupe ____________ CON2
(c) niste bili u mogućnosti imati komercijalne koristi od Vaših istraživačkih rezultata ____________ CON3
(d) uspostavite suradnje koje su rezultirale novim zajedničkim publikacijama ____________ CON4
(e) uspostavite suradnje koje su rezultirale novim zajedničkim financiranim projektima ____________ CON5

Reciprocitet

1. Na ljestvici od 1 do 7, pri čemu 1 označava „uopće se ne slažem“, a 7 „u potpunosti se slažem“, ocijenite Vaše opće slaganje sa sljedećim tvrdnjama:

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem							
	1	2	3	4	5	6	7	
Kad dijelim informacije, podatke ili materijale s drugim istraživačima u akademskoj zajednici, vjerujem da ću u budućnosti imati koristi od odnosa s osobom koja prima znanje.								R1
Znam da će drugi istraživači u akademskoj zajednici pomoći meni, stoga je jedino pošteno pomoći njima.								R2
Vjerujem da bi mi drugi istraživači u akademskoj zajednici pomogli ako bih trebao/la pomoć.								R3
Kad dijelim istraživačke rezultate s drugim istraživačima u akademskoj zajednici, očekujem korisnu povratnu informaciju.								R4

Očekivanja osobnih ishoda

1. Na ljestvici od 1 do 7, pri čemu 1 označava „uopće se ne slažem“, a 7 „u potpunosti se slažem“, ocijenite Vaše opće slaganje sa sljedećim tvrdnjama:

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem							
	1	2	3	4	5	6	7	
Dijeljenje znanja pomoći će mi sprijateljiti se s drugim istraživačima u akademskoj zajednici.								POE1
Dijeljenje znanja dat će mi osjećaj sreće.								POE2
Dijeljenje znanja može izgraditi moj ugled među drugim istraživačima u akademskoj zajednici.								POE3
Dijeljenje znanja dat će mi osjećaj postignuća.								POE4
Dijeljenjem znanja osnažit ću veze s drugim istraživačima u akademskoj zajednici.								POE5
Dijeljenje znanja omogućit će mi da ostvarim bolju suradnju s iskaknutim članovima akademske zajednice.								POE6

Očekivanja ishoda vezanih uz zajednicu

1. Na ljestvici od 1 do 7, pri čemu 1 označava „uopće se ne slažem", a 7 „u potpunosti se slažem", ocijenite Vaše opće slaganje sa sljedećim tvrdnjama:

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem							
	1	2	3	4	5	6	7	
Dijeljenjem znanja pomažem uspješnom funkcioniranju akademske zajednice.								COE1
Dijeljenjem znanja pomažem nastavljanju djelovanja akademske zajednice u budućnosti.								COE2
Dijeljenjem znanja pomažem akademskoj zajednici da akumulira ili obogaćuje znanje.								COE3
Dijeljenjem znanja pomažem akademskoj zajednici da raste.								COE4

Povjerenje

1. Na ljestvici od 1 do 7, pri čemu 1 označava „uopće se ne slažem", a 7 „u potpunosti se slažem", ocijenite Vaše opće slaganje sa sljedećim tvrdnjama:

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem							
	1	2	3	4	5	6	7	
Članovi akademske zajednice kojoj pripadam neće iskoristiti druge čak i kad se ukaže prilika.								TR1
Članovi akademske zajednice kojoj pripadam će uvijek održati obećanja koja daju jedni drugima.								TR2
Članovi akademske zajednice kojoj pripadam ne bi svjesno učinili ništa čime bi poremetili komunikaciju.								TR3
Članovi akademske zajednice kojoj pripadam ponašaju se dosljedno.								TR4
Članovi akademske zajednice kojoj pripadam su iskreni u postupanju jedni s drugima.								TR5

Znanstvene vrijednosti

1. Na ljestvici od 1 do 7, pri čemu 1 označava „uopće se ne slažem", a 7 „u potpunosti se slažem", ocijenite Vaše opće slaganje sa sljedećim tvrdnjama:

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem							
	1	2	3	4	5	6	7	
Briga o potencijalnim komercijalnim primjenama smetnja je kod obavljanja kvalitetnog istraživanja.								DISIN
Radije bih udvostručio/la citiranost vlastitih radova nego vlastitu plaću.								COMM

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem							
	1	2	3	4	5	6	7	
Znanstvenici bi trebali slobodno dijeliti svoje rezultate sa svim kolegama.								SV1
Znanstvenici bi trebali primarno biti motivirani željom za znanjem.								SV2
Osobno sam vrlo voljan/na dijeliti znanje s drugim znanstvenicima iz akademskog sektora.								SV3

Znanstvenici bi trebali svoja najnovija otkrića držati u tajnosti kako bi zaštitili prvenstvo.								SV4
Znanstvenici bi trebali dobivati izravne, osobne koristi od vlastitih znanstvenih otkrića.								SV5

Ugled

Koristeći ljestvicu od 1 do 5, pri čemu 1 označava „uopće nije važno", a 5 „izuzetno je važno", odgovorite na sljedeća pitanja:

Pitanje	Uopće nije važno; nije značajno važno; umjereno je važno; vrlo je važno; izuzetno je važno					
	1	2	3	4	5	
Koliko je za Vašu reputaciju među kolegama važan broj članaka objavljenih u recenziranim časopisima?						REP1
Koliko je za Vašu reputaciju među kolegama važan čimbenik odjeka (eng. impact factor) časopisa u kojima objavljujete radove?						REP2
Koliko je za Vašu reputaciju među kolegama važan broj citata koje dobivaju Vaši objavljeni radovi?						REP3
Koliko su za Vašu reputaciju među kolegama važne znanstvene nagrade?						REP4

Konkurencija (percepcija kompetitivnosti područja)

Na ljestvici od 1 do 5, pri čemu 1 označava „uopće nije kompetitivno", a 5 „izuzetno je kompetitivno", odgovorite na sljedeće pitanje:

Pitanje	Uopće nije kompetitivno – izuzetno je kompetitivno					
	1	2	3	4	5	
Kako biste opisali sveukupnu razinu kompetitivnosti u Vašem specifičnom području istraživanja (za priznanje i znanstveno prvenstvo među kolegama)?						COMP

Klima dijeljenja na instituciji

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem							
	1	2	3	4	5	6	7	
Voditelj odjela u kojem radim ne misli da bih trebao/la dijeliti svoje znanje s drugim znanstvenicima u akademskoj zajednici.								ISC1
Moj izravno nadređeni misli da bih trebao/la dijeliti svoje znanje s drugim znanstvenicima u akademskoj zajednici.								ISC2
Moji kolege u istoj istraživačkoj grupi misle da bih trebao/la dijeliti svoje znanje s drugim znanstvenicima u akademskoj zajednici.								ISC3

Institucionalno okruženje prijenosa znanja

Na ljestvici od 1 do 5, pri čemu 1 označava „uopće se ne slažem“, a 5 „u potpunosti se slažem“, ocijenite Vaše slaganje sa sljedećim tvrdnjama, koje se odnose na Vašu **trenutnu instituciju zaposlenja u kojoj obavljate najviše istraživačkih aktivnosti**:

Tvrdnja	Uopće se ne slažem – u potpunosti se slažem					
	1	2	3	4	5	
Moja institucija pridaje veliku važnost komercijalnim ili poslovnim aktivnostima.						PIS1
Moja institucija je suviše agresivna u provođenju zaštite intelektualnog vlasništva.						PIS2
Moja institucija osigurava infrastrukturu i pristup istraživačkoj opremi potrebnoj za suradnju s industrijom.						PIS3
Postojanje jasnog procesa (procedura, protokola) za aktivnosti komercijalizacije i suradnje s poslovnim sektorom na mojoj instituciji djeluje poticajno na uključivanje u takve aktivnosti.						PIS4
Dostupnost rizičnog kapitala na mojoj instituciji potiče osnivanje akademskih spin-off poduzeća.						PIS5
Moja institucija organizira usavršavanja u području poduzetništva.						PIS6
Postoje dobre potporne usluge unutar institucije ukoliko su istraživači zainteresirani za započinjanje suradnje s poslovnim sektorom.						PIS7
Moja institucija podupire znanstvenike koji žele komercijalizirati svoje izume.						PIS8
Marketinške vještine potpornog (administrativnog) osoblja uključenog u komercijalizaciju djeluju poticajno na ostvarivanje suradnje s poslovnim sektorom.						PIS9
Kompleksne procedure (birokracija) potpornog osoblja uključenog u komercijalizaciju sprječavaju ostvarivanje suradnje s poslovnim sektorom.						PI10
Tehničke vještine potpornog osoblja uključenog u komercijalizaciju djeluju poticajno na ostvarivanje suradnje s poslovnim sektorom.						PI11
Nefleksibilnost potpornog osoblja uključenog u komercijalizaciju sprječava ostvarivanje suradnje s poslovnim sektorom.						PI12
Pregovaračke vještine potpornog osoblja uključenog u komercijalizaciju djeluju poticajno na ostvarivanje suradnje s poslovnim sektorom.						PI13

Opća pitanja

1. Vaš spol je: GEND

Ženski	□	1
Muški	□	2

2. U kojim ste vrstama organizacija trenutno zaposleni (moguće je označiti više odgovora)? AFF

Visokoškolska ustanova – pretklinički zavod	□	1
Visokoškolska ustanova – klinički zavod	□	2
Javni istraživački institut	□	3
Privatni istraživački institut	□	4
Vladin laboratorij	□	5
Javna zdravstvena ustanova (bolnica, klinika, zdravstveni institut)	□	6

Privatna zdravstvena ustanova (bolnica, klinika, zdravstveni institut)	□	7
Ostalo (navedite vrstu) ____________________	□	8

3. Koliko godina ste zaposleni u Vašoj trenutnoj primarnoj organizaciji zaposlenja? _______ godina YRSCUR

4. Koje je Vaše akademsko zvanje? RANK

Redoviti profesor / profesor emeritus / znanstveni savjetnik ili ekvivalentno	□	1
Izvanredni profesor / viši znanstveni suradnik ili ekvivalentno	□	2
Docent / znanstveni suradnik ili ekvivalentno	□	3
Poslijedoktorand ili ekvivalentno	□	4
Ostalo (navedite zvanje) ____________________	□	5

5. Koliko ste ukupno godina radili **u neprofitnom sektoru** (sveučilišta, bolnice ili javne istraživačke institucije)? _________ godina YRSACA

6. Koji je ukupni broj godina Vašeg **profesionalnog iskustva** (počevši od godine Vašeg prvog zaposlenja): _________ godina PRAGE

7. Kojem broju **istraživačkog osoblja** (znanstvenika i znanstvenog tehničkog osoblja, npr. laboratorijskih inženjera) s punim radnim vremenom ste trenutno nadređeni? _________ TEAMSIZE

8. Kojem **broju zaposlenika** (sve kategorije osoblja) s punim radnim vremenom ste trenutno izravno nadređeni? _________ SUBORDSIZE

Appendix M: Summary statistics (all variables)

Variable	No. obs.	Mean	St. Dev.	Min	Max
Dependent variables					
Publication content restrictions [CONTRES]	212	0,830	2,541	0	30
Publication timing restrictions [TIMRES]	212	0,934	3,560	0	43
Co-authored publication content restrictions [COCOO]	212	0,264	0,824	0	5
Co-authored publication timing restrictions [COTIO]	212	0,467	2,854	0	40
Presentations restrictions [PRESREO]	212	1,566	13,795	0	200
Unpublished knowledge sharing restrictions [UNPRED]	212	0,476	2,981	0	40
Published knowledge sharing restrictions [PRED]	212	1,066	4,293	0	45
Independent variables					
Academic-industry knowledge transfer activities					
Industry collaboration [INDCOL]	212	10,208	22,595	0	169
Intellectual property-based [IPBASE]	212	0,839	4,027	0	46
Academic entrepreneurship [ACAENT]	212	1,669	7,910	0	100
Sharing motivations and values					
Personal outcome expectations [POEXP]	212	5,362	1,311	1	7
Community-related outcome expectations [COEXP]	212	6,052	1,205	1	7
Trust [TRUST]	212	3,517	1,575	1	7
Reputation [REPUT]	211	3,893	0,945	1	5
Disinterestedness [DISIN]	211	3,729	1,833	1	7
Communalism [COMM]	211	3,431	1,882	1	7
Sharing context					
Competitiveness perception [COMP]	211	3,431	0,995	1	5
Institutional sharing climate [ISCLIM]	211	3,507	1,035	1	5
Control variables					
Research productivity [PUBQTY]	212	11,264	10,536	0	82
Share of co-authored publications with other academic groups [COAU]	212	52,651	36,750	0	100
Received requests for unpublished knowledge [UNREQ]	212	4,967	32,625	0	450
Received requests for published knowledge [PUBREQ]	212	18,651	72,863	0	1.000
Academic rank – full professor	209	0,268	-	-	-
Professional age [PRAGE]	209	22,536	8,165	5	42
Number of research subordinates [TEAMSIZE]	209	4,876	13,454	0	150
Gender – male [GEN]	212	0,363	-	0	1
Knowledge sharing restrictions variables not included in multivariate analysis					
Formal projects sharing restrictions [FORMPRORO]	212	0,099	0,418	0	3
Outgoing secondments sharing restrictions [OUTSECRO]	212	0,019	0,217	0	3
Incoming secondments sharing restrictions [INSECREO]	212	0,024	0,152	0	1
Unpublished data and information sharing restrictions (own) [RED1]	212	0,283	1,613	0	20
Unpublished materials sharing restrictions (own) [RED2]	212	0,193	1,452	0	20
Published data and information sharing restrictions (own) [RED3]	212	0,476	1,951	0	20
Published materials sharing restrictions (own) [RED4]	212	0,589	3,100	0	40
Unpublished data and information sharing restrictions (other researchers) [ROD1]	212	0,264	1,183	0	10
Unpublished materials sharing restrictions (other researchers) [ROD2]	212	0,165	0,916	0	10
Published data and information sharing restrictions (other researchers) [ROD3]	212	0,759	3,849	0	50
Published materials sharing restrictions (other researchers) [ROD4]	212	0,613	1,996	0	15
MTA-related sharing restrictions (outgoing) [MTANEGOUT]	212	0,264	2,230	0	25
MTA-related sharing restrictions (incoming) [MTANEGIN]	212	0,118	0,803	0	10

(table continues)

(continued)

Other variables not included in multivariate analysis					
Reciprocity [RECIP]	212	5,312	1,502	1	7
Scientific sharing values [SCIVAL]	211	5,177	0,945	2,6	7
Institutional knowledge transfer setting [PISET]	211	2,071	0,798	1	4,44
Work time – research (%) [WTRES]	212	26,479	23,195	0	90
Work time – project-related (%) [WTPRO]	212	13,917	13,466	0	70
Work time – teaching (%) [WTTEA]	212	22,892	20,151	0	95
Work time – academic-industry knowledge transfer (%) [WTTEC]	212	2,637	5,785	0	50
Work time – patients (%) [WTPAT]	212	24,731	34,752	0	100
Work time – other (%) [WTOTH]	212	9,344	10,655	0	60
Research type – basic (%) [BASRE]	212	40,462	36,160	0	100
Research type – applied (%) [APPRE]	212	51,717	36,431	0	100
Research type – experimental [EXPRE]	212	7,821	13,685	0	90
Research group funding – national grants [NATG]	212	50,354	39,105	0	100
Research group funding – EU and international grants [EUIN]	212	14,698	25,807	0	100
Research group funding – industry sponsors [INDF]	212	7,491	20,361	0	100
Research group funding – market revenues [OWNF]	212	7,986	19,643	0	100
Research group funding – other [OTHF]	212	19,472	34,369	0	100
Own funding – national grants [SNAT]	164	53,359	38,892	0	100
Own funding – EU and international grants [SEUI]	164	14,591	26,110	0	100
Own funding – industry sponsors [SIND]	164	8,134	22,538	0	100
Own funding – market revenues [SOWF]	164	8,482	21,211	0	100
Own funding – other [SOTH]	164	15,433	31,616	0	100
Own annual funding (EUR) [TOTFUND]	196	44.893,53	157.087,35	0	1.500.000
Intra-institutional collaborators [COL1]	212	1,835	1,694	0	10
Intra-national collaborators [COL2]	212	1,835	1,677	0	10
International collaborators [COL3]	212	1,919	3,126	0	36
Formal collaborative projects with the academic sector [FORM]	212	2,580	4,014	0	50
Outgoing secondments to the academic sector [OUTACSEC]	212	1,061	2,014	0	20
Incoming secondments from the academic sector [INACSEC]	212	2,283	6,163	0	80
Presentations of research results [PRES]	212	11,995	16,721	0	200
Received requests for unpublished information and data [REQ1]	212	3,448	27,937	0	400
Received requests for unpublished materials [REQ2]	212	1,519	6,423	0	50
Received requests for published information and data [REQ3]	212	8,892	36,351	0	500
Received requests for published information and data [REQ4]	212	9,759	36,953	0	500
Sent requests for unpublished information and data [REO1]	212	2,443	14,933	0	200
Sent requests for unpublished materials [REO2]	212	1,387	6,125	0	50
Sent requests for published information and data [REO3]	212	5,387	11,504	0	100
Sent requests for published information and data [REO4]	212	6,151	17,581	0	200
Sent MTAs [MTAOUT]	212	0,495	3,912	0	50
Received MTAs [MTAIN]	212	0,443	2,079	0	20
Research impact [PUBCIT]	212	194,476	424,185	0	4.963
Affiliation – pre-clinical department of higher education institution [AFF]	209	0,344	-	-	-
Years in non-profit sector [YRSACA]	209	20,589	9,135	0	41
Years in current institution [YRSCUR]	209	18,163	9,259	1	41
Total number of subordinates [SUBORDSIZE]	209	9,488	24,004	0	250

Appendix N: Correlation matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13
CONTRES	1.000	.634**	.550**	.520**	.408**	.184**	0.001	.298**	.162*	.259**	-0.099	-0.071	-0.066
TIMRES	.634**	1.000	.467**	.500**	.454**	.142*	.157*	.302**	.194**	.213**	-0.078	-0.068	-.137*
COCOO	.550**	.467**	1.000	.666**	.513**	0.069	0.036	0.122	.135*	.182**	-.168*	-0.116	-.141*
COTIO	.520**	.500**	.666**	1.000	.391**	.155*	0.021	0.095	0.134	.146*	-.195**	-.144*	-.234**
PRESREO	.408**	.454**	.513**	.391**	1.000	0.069	0.073	.240**	.297**	.199**	-0.073	-0.011	-0.087
RED12	.184**	.142*	0.069	.155*	0.069	1.000	.202**	.156*	-0.080	-0.016	-0.056	-0.086	-0.088
RED34	0.001	.157*	0.036	0.021	0.073	.202**	1.000	0.133	0.003	0.070	-0.008	-0.025	-0.009
INDCOL	.298**	.302**	0.122	0.095	.240**	.156*	0.133	1.000	.278**	.473**	.207**	0.118	0.000
IPBASE	.162*	.194**	.135*	0.134	.297**	-0.080	0.003	.278**	1.000	.359**	-0.019	0.022	-0.043
ACAENT	.259**	.213**	.182**	.146*	.199**	-0.016	0.070	.473**	.359**	1.000	-0.021	0.005	0.017
POEXP	-0.099	-0.078	-.168*	-.195**	-0.073	-0.056	-0.008	.207**	-0.019	-0.021	1.000	.635**	.410**
COEXP	-0.071	-0.068	-0.116	-.144*	-0.011	-0.086	-0.025	0.118	0.022	0.005	.635**	1.000	.279**
TRUST	-0.066	-.137*	-.141*	-.234**	-0.087	-0.088	-0.009	0.000	-0.043	0.017	.410**	.279**	1.000
REPUT	0.008	-0.003	-0.013	0.024	0.085	-0.003	-0.078	0.042	-0.081	-0.061	.198**	.154*	0.126
SVA [DISIN]	0.104	0.084	.178**	0.094	0.043	0.017	-0.080	-0.054	-0.100	0.044	-0.016	0.055	0.076
SVA [COMM]	.201**	.152*	0.060	0.075	0.112	-0.082	-0.043	.147*	-0.051	0.034	.136*	0.044	.143*
COMP [COMP]	0.068	.145*	0.055	0.070	.151*	-0.025	0.035	0.057	0.075	-0.013	0.060	0.029	0.064
ISCLIM	-0.046	-0.103	-0.106	-.173*	-0.089	-0.040	-0.066	0.082	0.020	0.023	.248**	.366**	.315**
PUBQTY	0.066	0.093	0.034	0.022	.153*	-0.103	-0.054	0.133	0.074	-0.005	0.076	0.030	0.015
COAU	0.047	0.077	0.092	0.131	.149*	0.043	-.151*	0.039	0.062	0.003	0.113	0.108	-0.027
REQ12	.189**	.205**	0.133	.214**	0.105	.453**	0.017	.241**	0.000	0.012	0.118	0.048	0.011
REQ34	0.131	.183**	0.105	0.063	0.127	.163*	.198**	.239**	0.073	0.090	.148*	0.077	-0.060
PRAGE	-0.080	-0.035	-0.031	-0.042	-0.038	-0.046	0.042	0.080	0.078	0.090	-0.037	-0.071	-0.018
TEAMSIZE	0.127	.185**	0.095	0.094	.232**	0.023	0.007	.257**	.198**	.179**	0.073	0.036	0.022
GEN	0.049	0.040	0.107	0.021	-0.024	0.063	0.031	0.110	.165*	0.105	-0.029	-0.107	0.023
Full professor	-0.018	0.070	0.051	0.043	0.032	-0.048	0.068	0.060	.174*	0.005	0.020	0.002	0.057

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

	14	15	16	17	18	19	20	21	22	23	24	25	26
CONTRES	0.008	0.104	.201**	0.068	-0.046	0.066	0.047	.189**	0.131	-0.080	0.127	0.049	-0.018
TIMRES	-0.003	0.084	.152*	.145*	-0.103	0.093	0.077	.205**	.183**	-0.035	.185**	0.040	0.070
COCOO	-0.013	.178**	0.060	0.055	-0.106	0.034	0.092	0.133	0.105	-0.031	0.095	0.107	0.051
COTIO	0.024	0.094	0.075	0.070	-.173*	0.022	0.131	.214**	0.063	-0.042	0.094	0.021	0.043
PRESREO	0.085	0.043	0.112	.151*	-0.089	.153*	.149*	0.105	0.127	-0.038	.232**	-0.024	0.032
RED12	-0.003	0.017	-0.082	-0.025	-0.040	-0.103	0.043	.453**	.163*	-0.046	0.023	0.063	-0.048
RED34	-0.078	-0.080	-0.043	0.035	-0.066	-0.054	-.151*	0.017	.198**	0.042	0.007	0.031	0.068
INDCOL	0.042	-0.054	.147*	0.057	0.082	0.133	0.039	.241**	.239**	0.080	.257**	0.110	0.060
IPBASE	-0.081	-0.100	-0.051	0.075	0.020	0.074	0.062	0.000	0.073	0.078	.198**	.165*	.174*
ACAENT	-0.061	0.044	0.034	-0.013	0.023	-0.005	0.003	0.012	0.090	0.090	.179**	0.105	0.005
POEXP	.198**	-0.016	.136*	0.060	.248**	0.076	0.113	0.118	.148*	-0.037	0.073	-0.029	0.020
COEXP	.154*	0.055	0.044	0.029	.366**	0.030	0.108	0.048	0.077	-0.071	0.036	-0.107	0.002
TRUST	0.126	0.076	.143*	0.064	.315**	0.015	-0.027	0.011	-0.060	-0.018	0.022	0.023	0.057
REPUT	1.000	0.077	.139*	.376**	.144*	0.010	.242**	0.052	0.060	-0.054	-0.023	-0.133	0.024
SVA [DISIN]	0.077	1.000	.175*	0.041	0.063	-0.022	-0.003	-0.026	0.044	-0.043	-0.111	-0.018	0.026
SVA [COMM]	.139*	.175*	1.000	0.089	0.068	-0.035	-0.054	-0.016	-0.040	-.147*	0.017	-.149*	-0.060
COMP [COMP]	.376**	0.041	0.089	1.000	0.079	0.092	0.122	0.097	0.065	-0.015	.219**	-0.086	0.087
ISCLIM	.144*	0.063	0.068	0.079	1.000	-0.013	.163*	0.016	-0.034	-0.134	0.090	-0.084	0.006
PUBQTY	0.010	-0.022	-0.035	0.092	-0.013	1.000	.256**	0.065	.338**	0.115	.271**	0.107	.398**
COAU	.242**	-0.003	-0.054	0.122	.163*	.256**	1.000	.137*	.172*	-0.012	.198**	-0.083	0.086
REQ12	0.052	-0.026	-0.016	0.097	0.016	0.065	.137*	1.000	.367**	-0.052	0.122	0.129	0.106
REQ34	0.060	0.044	-0.040	0.065	-0.034	.338**	.172*	.367**	1.000	.165*	.220**	0.021	.286**
PRAGE	-0.054	-0.043	-.147*	-0.015	-0.134	0.115	-0.012	-0.052	.165*	1.000	.326**	0.075	.457**
TEAMSIZE	-0.023	-0.111	0.017	.219**	0.090	.271**	.198**	0.122	.220**	.326**	1.000	-0.067	.375**
GEN	-0.133	-0.018	-.149*	-0.086	-0.084	0.107	-0.083	0.129	0.021	0.075	-0.067	1.000	0.081
Full professor	0.024	0.026	-0.060	0.087	0.006	.398**	0.086	0.106	.286**	.457**	.375**	0.081	1.000

**. Correlation is significant at the 0.01 level (2-tailed). *. Correlation is significant at the 0.05 level (2-tailed).

Appendix O: Overview of key studies on networks and spatial dimensions of innovation in the biotechnology industry

Important authors	Setting	Key findings	Dependent variable(s)
Shan, Walker and Kogut (1994)	USA	While cooperative agreements with large firms affect innovation output of small firms, the opposite is not the case.	- innovative output of start-ups - number of agreements with commercial firms
Powell, Koput and Smith-Doerr (1996)	USA	Innovation and growth in industries with a complex and expanding knowledge base are achieved through networks of learning.	- subsequent number and diversity of R&D ties - network position in terms of central connectivity - rates of firm growth
Deeds and Hill (1996)	USA	There is an inverted U-shaped relationship between the number of strategic alliances and the rate of new product development.	- rate of new product development
Owen-Smith et al. (2002)	USA and Europe	In contrast to the USA, public research organizations and small biopharmaceutical companies in Europe are regionally specialized, less diverse, working in a smaller number of areas, with a more centralized funding within nations and weaker integration of basic and clinical studies.	
George, Zahra and Wood (2002)	USA	Companies having alliances with universities have lower R&D expenses and higher levels of innovative output, but not necessarily higher financial performance than similar firms without such alliances.	- number of patents - number of products in the market - number of products under development
Owen-Smith and Powell (2004)	USA	Membership in a geographically collocated network of collaborations, centrality in a geographically dispersed network and dominance of public research organizations in a network positively affect innovation.	- number of patents assigned to corporations
Faems, Van Looy and Debackere (2005)	Europe, Belgium	Interorganizational collaboration positively affects innovative performance, but varies depending on the type of the collaborators.	- proportion of turnover attributed to new and improved products
Phene, Fladmoe-Lindquist and Marsh (2006)	USA	Technologically distant knowledge of national origin has a curvilinear effect and technologically proximate knowledge of international origin has a positive effect on breakthrough innovation.	- breakthrough innovations (patents with the highest number of citations)

Appendix P: Overview of key studies on university-generated IPRs and innovation in biotechnology

Setting	Authors	Study type	Key findings	Dependent variable(s)
USA	Dasgupta and David (1994)	Conceptual	Growing "privatization of the scientific commons" may endanger scientific and technological progress, particularly by restricting access to upstream discoveries that are essential for subsequent research.	
USA	Heller and Eisenberg (1998)	Conceptual	Commercialization of biomedical research can stimulate private investments in science, but it can also produce a "tragedy of the anti-commons", through a rise of fragmented and overlapping intellectual property rights. This is due to the high transaction costs of bargaining, heterogeneous interests among owners, and cognitive biases of life science researchers.	
USA	Henderson, Jaffe and Trajtenberg (1998)	Empirical	Explosion in US university patenting in the period from 1965 to 1992 has been accompanied by a decrease in their importance, measured by patent citations.	- patent importance - patent generality
17 OECD countries	Furman, Porter and Stern (2002)	Empirical	Variation in innovativeness across countries is due to differences in the level of R&D personnel and spending, extent of IP protection and openness to international trade; share of research performed by academia and funded by the private sector.	- number of "international patents"
USA	Nightingale and Martin (2004)	Empirical	The "biotechnology revolution" model of technological change along the innovation path from basic research to clinical development is not supported by the empirical evidence: R&D expenditures increased tenfold, while patenting output increased only sevenfold, and only a handful of new chemical entities were approved by the FDA over the period 1983–2003. The slowdown in innovation is explained by difficulties in keeping pace with the increasingly complicated new scientific and technological base.	
USA, Europe, Japan, India	Orsenigo, Dosi and Mazzucato (2006)	Conceptual	A tighter IPR regime does not automatically lead to an increase in innovative activities in the countries which introduced substantial institutional changes in the IPR systems.	
Nat Biotech articles and USPTO patents	Murray and Stern (2007)	Empirical	Patenting has a modest negative effect on free flow of scientific knowledge; citation rate for a scientific publication falls after formal IP rights associated with that publication are granted.	- number of forward citations

Appendix Q: Overview of key studies on public investments into knowledge base and biotech innovation

Setting	Authors	Study type	Key findings	Dependent variable(s)
USA; top 10 biotech countries	Zucker and Darby (1996)	Empirical	The larger the extent of collaboration of a company with star scientists, the bigger its success, particularly in the USA.	- products in development - products on the market - employment growth
USA	McMillan, Narin and Deeds (2000)	Empirical	Biotechnology industry relies on public science much more heavily than other industries, including pharmaceutical, for very basic scientific research.	- non-patent references (NPRs) on patents
France	Autant-Bernard (2001)	Empirical	Public research produces positive effects in increasing innovation level; however, the positive externalities are limited to geographic space.	- patents
USA	Gittelman and Kogut (2003)	Empirical	Publication, collaboration, and science intensity are correlated with patented innovations; there is a negative relationship between important scientific papers and high-impact innovations.	- cumulative forward citation frequencies to an individual patent assigned to firms
USA	Angell (2004)	Conceptual	A large part of the upfront search and innovation costs are borne by the public sector. Truly innovative therapeutics almost always originate from publicly funded laboratories.	
USA	Toole (2012)	Empirical	NIH-funded basic research and market size have an economically and statistically significant effect on pharmaceutical innovation in the form of entry of new medicines.	- number of new medicines (new molecular entities) applications

Appendix R: Innovation-influencing factors: a comparison of the US and the European biotechnology industries

Innovation-influencing factor	USA	Europe	Theoretical framework
University-generated IPRs	Regulatory changes associated with IPRs, in particular the Bayh-Dole Act, encouraged commercialization of federally funded research at universities and establishment of new biotech start-ups (Lazonick and Tulum 2011). Although university patenting increased, its importance, measured by patent citations, decreased (Henderson et al., 1998; Nightingale and Martin, 2004).	Most countries emulate the US Bayh-Dole Act (Geuna and Nesta 2006, Hall 2007). However, high cost and heavy administration of filing and defending patents are identified as factors that impede innovation (Jonsson 2007). Most countries introduced patent protection in pharmaceuticals later than the USA, which has been characterized by strong IP protection in this sector (Orsenigo et al. 2006).	**Neoclassical financial theory:** Patents on publicly funded research serve the purpose of creating markets for knowledge (Orsenigo, et al. 2006). IPRs are incentive to invest based on excluding access to information. Without IPRs, the innovative output will be suboptimal and innovators will be under-rewarded, because markets are highly competitive and information is perfectly appropriable - easily transmitted to those not paying for its use. Broadening the scope of patents is desirable, as it is imposing higher penalties for infringement and if successfully marketed, maximises the reward to investors in the form of income from licensing and royalties (Dempsey 1999). **Theory of innovative enterprise**: In the case of public research, the incentive in the form of IPR laws is not needed because invention has already been paid for, by the public (Orsenigo et al. 2006). Information is a resource; innovation is not a bounded process, but involves many participants that interact in a learning process and that have limited knowledge and abilities (Dempsey 1999). IPRs are used by new biotech companies to attract acquisitions by established companies, which enables them to quickly exit to capital markets, despite the lack of products close to the market (Lazonick and Tulum 2011). Innovative capabilities of biotechnology firms to translate new technologies into innovative products and processes are a stronger determinant of successful new value creation than IPRs (Orsenigo et al. 2006). In the case of upstream discoveries, exclusive exploitation of a patent limits new entrants who would compete to produce more efficient and cheaper medicines from subsequent discoveries (Lazonick and Tulum 2011).
Public investments into knowledge base	Continuous and substantial government investment in knowledge base and subsidies have financed US biotechnology and motivated equity investors throughout the industry's history (Angell, 2004; Lazonick and Tulum, 2011).	Biotechnology development is boosted through government-initiated technology transfer initiatives, seed funding schemes, and taxation schemes (EuropaBio 2006).	**Neoclassical financial theory:** A purely market relation produces the optimal situation and government policy should be limited to situations where market failures have developed. One such market failure demands government funding of basic research, which overcomes the reluctance of firms to fund their own research because of their inability to appropriate all the benefits (Salter and Martin 2001). **Theory of innovative enterprise**: Governments have a critical role in developing the knowledge base indispensable for international competitiveness of the biotechnology industries, through infrastructural investments that are of far too broad scope to be done by companies, and different incentives to companies for investment in innovation (Lazonick 2007).

(table continues)

(continued)

Innovation-influencing factor	**USA**	**Europe**	**Theoretical framework**
Funding mechanisms *The role of speculative stock markets* *- IPOs*	Industry funding mechanisms have been characterized by stock market investors investing in IPOs of not-yet-commercially-present companies (Lazonick and Tulum 2011).	Similar to the USA, although to a lesser extent, equity investors are motivated by speculative gains, extract value from companies, especially after the IPO, even though the products are mostly not yet close to the market (Lazonick and Sakinç 2010).	**Neoclassical financial theory:** The healthcare biotechnology business model is financialized, shareholder distribution-oriented; companies are investment portfolios of innovations where products in pipeline and firms trade for shareholder value in speculative processes (Andersson et al. 2010). **Theory of innovative enterprise**: The extent of financial commitment required to sustain an investment strategy depends on the size of the investments in productive resources and duration of time required for those investments to generate financial returns (Lazonick 2011).
- Stock buybacks	Stock-based compensations to executives and employees are regularly exercised (Lazonick and Sakinç 2010).		**Neoclassical financial theory:** Short-term earnings per share and share price are the most important measures of corporate performance. Only shareholders are "residual claimants" as they receive returns only after all other stakeholders have received their "guaranteed contractual stakes" (Lazonick 2007). By giving managers stock-based compensation, shareholders mitigate the principal-agent problem – they ensure that managers have aligned interests with them and allocate resources efficiently (Jensen and Meckling 1976). **Theory of innovative enterprise**: Shareholders are not the only "residual claimants". State is one example of a "residual claimant" without guaranteed return on investment to taxpayers (Lazonick 2007). Strategic decision-makers allocate resources to financial interests using speculation and stock-based compensation, to increase stock price regardless of the effect on organizational learning that can result in a commercial product (Lazonick and Tulum 2011).
Other sources of funding: debt and venture capital	Companies are supported by public capital markets and financial institutions lending money secured only by stock (Ernst&Young 2011). Debt funding dominates the sector.	The industry is not mature enough to attract debt finance for growth-by-acquisition strategy of the US industry (EuropaBio 2006). Venture capital industry is fragmented, with weak specialization (EC 2009).	**Theory of innovative enterprise**: Productivity problems of the US biotechnology industry were not due to a shortage of funding, but due to the highly financialized business model which undermines innovation (Lazonick and Tulum 2011), as managers extract value; they don't create value by allocating resources to developing and utilizing productive resources (Lazonick 2011).
Other sources of funding: established pharma companies	In order to maximize shareholder value, companies typically become acquired by pharmaceutical companies, instead of pursuing high-risk R&D (Ernst&Young 2011).	Mature companies mostly license out their inventions to large pharmaceutical companies, get acquired by better funded US companies or move to the USA to access their product and financial markets and thus export value-creating R&D (EuropaBio 2006).	**Theory of innovative enterprise**: Pursuing acquisitions of small biotech companies by established pharmaceutical companies as a dominant business strategy prevents Europe from developing self-sustainable, larger biotech companies and endangers the extent of future innovation (Jonsson 2007). In both Europe and the USA, this trend negatively affects the investments in early stage research by pharma companies (Dorsey et al. 2010).

Appendix S: Summary in Slovenian language

Uvod

Prenos znanja med akademskim svetom in gospodarstvom v vedah o življenju, je bil v zadnjih 30 letih deležen precej pozornosti v literaturi o znanstveni politiki, inovacijah in podjetništvu. Za izraz "prenos znanja med akademskim svetom in gospodarstvom" splošno priznana definicija ne obstaja. V bistvu je najbolj poznan izraz, ki se uporablja v literaturi, "prenos tehnologije med akademskim svetom in gospodarstvom". Za potrebe pričujoče raziskave prenos znanja definiramo kot uporabo in deljenje znanstvenih dognanj, novih odkritij in inovacij med znanstveniki iz akademskih in drugih raziskovalnih ustanov na eni strani ter gospodarstvom na drugi. Neprofitne znanstvene ustanove, ki delajo raziskave v vedah o življenju, so univerze, državni laboratoriji, raziskovalni instituti in raziskovalne bolnišnice (Ewing Marion Kauffman Foundation 2003).

Proces prenosa znanja (ali tehnologije) se odvija med raziskovalnimi ustanovami ali posamičnimi raziskovalci (ki razvijajo ali iznajdejo nove tehnologije) na eni strani ter gospodarstvom (ki napravi tehnologije, nastale v univerzah, tržno zanimive) na drugi. V praksi se prenos znanja med akademskim svetom in gospodarstvom dogaja preko treh mehanizmov: 1) skupni raziskovalni projekti, vključujoč svetovanje in s strani gospodarstva financirane raziskave; 2) patentiranje ter licenčni sporazumi za uporabo invencij z obstoječimi podjetji (Henderson et al. 1998); in 3) ustanavljanje odcepljenih (spin-off) podjetij za trženje rezultatov akademskih raziskav (glej Bozeman 2000, Lockett et al. 2005). Vsakega od teh procesov olajša še tretji deležnik, in sicer pisarne za prenos tehnologije (TTO-ji) ali upravljalci pravic iz naslova intelektualne lastnine univerz (Siegel et al. 2004).

Globalna rast prenosa znanja se je začela v ZDA leta 1980 s sprejetjem Uredbe za patente in blagovne znamke (Patent Law 96-517), ki jo poznamo tudi kot Bayh-Doleov zakon. Bayh-Doleov zakon je dal univerzam (in drugim neprofitnim organizacijam ter malim podjetjem) pravico do ohranitve lastniške pravice nad invencijami, ki so jih razvili s pomočjo javnih sredstev. Poslej imajo univerze zelo široke pravice, da lahko izkoriščajo invencije, ki so jih razvili v svojih raziskavah - od zaračunavanja licenčnine za uporabo patenta in dodelitve patenta na tretjo osebo do določanja, kako naj bodo kakršnikoli dohodki razdeljeni med ustanovo, raziskovalcem in raziskovalnimi centri ali oddelki (Henderson et al. 1998). Opisana sprememba zakonodaje, najprej v ZDA, potem pa v večini Evropskih držav, kot tudi povečana odvisnost podjetij od univerzitetnih raziskav in razvoja (R&D), je omogočila univerzam širitev tradicionalnega poslanstva učenja in raziskav na še 'tretje akademsko poslanstvo', in sicer na prenos tehnologije na gospodarstvo (Kruecken 2003).

Evropska komisija je nedavno (2013) objavila poročilo, da je približno polovica evropskih držav dosegla cilje, opisane v priporočilu Komisije o upravljanju pravic iz naslova intelektualne lastnine pri dejavnostih prenosa znanja, v obdobju 2010-2012. Še več, ugotavlja tudi , da je prenos znanja zelo skoncentriran, saj predstavlja zgornjih deset odstotkov univerz devetdeset odstotkov vseh prihodkov. Veliko raziskav dokazuje, da povprečna ameriška univerza zaradi manj sistematičnega in strokovnega evropskega upravljanja znanja in pravic iz naslova intelektualne lastnine prekaša povprečno evropsko univerzo po številu invencij in patentov (European Commission 2007).

Ker je tema prenosa znanja med akademskim svetom in gospodarstvom s politične perspektive izjemno pomembna, so o njej opravili že zelo veliko raziskav, ki se med sabo zelo razlikujejo glede na vidik (gospodarstvo, država), strukturo (uradna, neuradna), raven analize (trg, organizacija, posameznik) in učinek (gospodarski, akademski, znanstvene zmogljivosti, institucionalen, kulturen, upravni) (Boardman and Ponomariov 2009). Te študije raziskujejo različne prednosti in izzive, ki izvirajo iz vpletenosti akademskih raziskovalcev in ustanov v dejavnosti prenosa znanja. Na eni strani imajo raziskovalci veliko dokazov, da imajo tesne vezi med akademskim svetom in gospodarstvom mnogo pozitivnih vidikov tako za akademskim svetom kot tudi za poslovnega partnerja v smislu dopolnjevanja med temeljnimi in uporabnimi raziskavami (Azoulay et al. 2006), ustvarjanju novih raziskovalnih idej (Rosenberg 1998) in preseganju dejstva, da zasebni sektor premalo financira temeljne raziskave (Agrawal and Henderson 2002, Czarnitzki et al. 2009). Na drugi strani pa obstaja bojazen, da bi lahko vključevanje raziskovalcev v dejavnosti prenosa znanja v gospodarstvo ogrozilo njihovo zavezanost k normam odprte znanosti in povzročilo omejevanje razkritja in zamude pri objavah (Geuna and Nesta 2006). Dasgupta & David (1994), Henderson in kolegi (1998), Kenney & Patton (2009) in mnogi drugi razpravljajo o neučinkovitosti prenosa znanja, kar deloma izvira iz stalnih trenj med akademskimi ustanovami, ki želijo objavljati in vzpostaviti prioritete, na eni strani ter korporativnimi sponzorji raziskav, ki želijo zavlačevati z objavami, dokler ne vzpostavijo patenta, s katerim bi zavarovali bodoče gospodarske donose na določeno inovacijo. Na ta način se morda pravila tržne konkurenčnosti ne skladajo z družbenimi pravili prioritete in prostega kroženja znanja (kar smatramo kot njihovo najbolj pomembno vrednoto) znotraj znanstvene skupnosti (Calderini et al. 2007).

Raziskovalni problem in namen

Disertacija analizira štiri glavne raziskovalne probleme. Prvič, mnoge raziskave, ki raziskujejo koristi in izzive prenosa znanja med akademskim svetom in gospodarstvom, dajejo bogate, a vendar nasprotujoče si in razdrobljene izsledke, brez jasnih priporočil in posledic za politiko. Bolj natančno, med avtorji empiričnih raziskav ni soglasja za to, kaj točno spodbuja prenos znanja med akademskim svetom in gospodarstvom, tako na individualnem nivoju kot tudi na nivoju organizacij. Poleg tega se različni avtorji, ko delajo primerjalne analize uspeha prenosa znanja med akademskimi ustanovami in gospodarstvom, osredotočajo na različna merila in determinante uspeha. Prvi raziskovalni problem izhaja iz potrebe po razvoju splošnega konceptualnega okvirja, s katerim bomo lahko ovrednotili učinkovitost prenosa znanja med akademskim svetom in gospodarstvom ter njegov učinek na javno znanost.

Drugič, čeprav interes za vpliv prenosa znanja med akademskim svetom in gospodarstvom na omejevanje izmenjave znanja med člani akademske bioznanstvene skupnosti narašča, se večina raziskav osredotoča na patentiranje, vplive ostalih oblik prenosa znanja pa pušča neraziskane (Larsen 2011). Ravno tako je pri ocenjevanju odnosa med prenosom ter izmenjavo znanja mnogo raziskav zanemarilo potencialno heterogenost različnih oblik akademske izmenjave znanja (Blumenthal et al. 1996, Louis et al. 2001, Campbell et al. 2002, Walsh et al. 2007). Poleg tega obstaja splošno pomanjkanje raziskav na tem področju, ki bi upoštevale vlogo različnih institucionalnih kontekstov (Haeussler 2011, Haeussler 2014, Walsh and Huang 2014). Zato je treba razviti konceptualni model determinant prenosa in širjenja znanja ter izpeljati njegovo empirično testiranje.

Tretjič, obstoječe raziskave, izvirajoč iz teorije socialnega kapitala, večinoma raziskujejo omejen razpon dejavnikov omejevanja izmenjave znanja znotraj bioznanstvene akademske skupnosti, kar povzroča omejeno poznavanje tega pomembnega pojava. Zato je potrebna identifikacija in empirična ocena individualnih in od konteksta odvisnih determinant, ki vplivajo na omejevanje izmenjave znanja. To bo prispevalo k obstoječi teoriji ter omogočilo porajanje specifičnih priporočil za znanstveno politiko.

Četrtič, malo je znanega o tem, kako financiranje raziskav v vedah o življenju ter sistem pravic iz naslova intelektualne lastnine omogočata uspeh inovacij v biotehnologiji zdravstvenega varstva. Identifikacija ključnih dejavnikov, ki spodbujajo uspeh inovacij v biotehnologiji, ima uporabno vrednost pri upravljanju podjetij, ki si konkurirajo v tem gospodarskem sektorju.

Za to raziskavo smo izbrali ta specifičen kontekst vedah o življenju in biotehnologije, ker je to najbolj pogosto raziskano področje dejavnosti prenosa znanja med akademskim svetom in gospodarstvom (Blumenthal et al. 1996, Powell and Owen-Smith 1998, McMillan et al. 2000, Owen-Smith et al. 2002, Stuart and Ding 2006).

Cilj doktorske disertacije

Cilj pričujoče disertacije je prispevati k boljšemu razumevanju procesa prenosa znanja med akademskim svetom in gospodarstvom v vedah o življenju. Cilji raziskave so:

1. Zagotoviti sistematični pregled (identifikacija, ovrednotenje, pridobivanje in povzemanje) zbranega znanja o prenosu znanja med akademskim svetom in gospodarstvom v vedah o življenju.
2. Razviti splošen konceptualni okvir za oceno učinkovitosti prenosa znanja med akademskim svetom in gospodarstvom ter njegovim učinkom na javno znanost.
3. Preiskati heterogenost prenosa znanja med akademskim svetom in gospodarstvom ter mehanizmov izmenjave znanja v bioznanstveni akademski skupnosti.
4. Preiskati vlogo institucionalnega konteksta pri razmerju med prenosom znanja in izmenjavo znanja med akademskim svetom in gospodarstvom.
5. Razviti celosten konceptualni model prenosa in izmenjave znanja na ravni posameznika.
6. Ugotoviti razmerje med različnimi oblikami prenosa znanja med akademskim svetom in gospodarstvom ter različnimi oblikami omejevana izmenjave znanja v vedah o življenju.
7. Zagotoviti dokaze za vlogo različnih posamičnih in vsebinskih determinant omejevanja izmenjave znanja v vedah o življenju.
8. Opisati vlogo pravic iz naslova intelektualne lastnine, nastale v univerzah, ter mehanizmov financiranja raziskav in razvoja pri uspehu inovacij v biotehnologiji zdravstvenega varstva.

Povzetek glavnih ugotovitev

Namen disertacije je prispevati k boljšemu razumevanju procesov prenosa znanja med akademskim svetom in gospodarstvom v vedah o življenju z (1) zagotavljanjem sistematičnega pregleda zbranega znanja o prenosu znanja med akademskim svetom in gospodarstvom ter razvojem vsebinskega okvirja za proučevanje prenosa znanja med akademskim svetom in gospodarstvom in ovrednotenja njegove učinkovitosti in učinka na javno znanost; (2) raziskovanjem, kako različni procesi prenosa znanja med akademskim svetom in gospodarstvom ovirajo formalno in neformalno sodelovanje v različnih institucionalnih kontekstih akademske skupnosti v vedah o življenju z namenom razvoja teoretskega okvirja za analizo interakcij med prenosom in izmenjavo znanja; (3) testiranje vloge dejavnosti prenosa znanja med akademskim svetom in gospodarstvom, osebnih in od konteksta odvisnih dejavnikov, v različnih oblikah omejevanja izmenjave znanja v akademskih skupnostih v vedah o življenju; (4) analiziranje dejavnikov uspeha inovacij v biotehnologiji zdravstvenega varstva.

V naslednjih odstavkih povzemamo najpomembnejše ugotovitve v povezavi s specifičnimi cilji disertacije.

Dejavniki in implikacije prenosa znanja med akademskim svetom in gospodarstvom v vedah o življenju na javni red: pregled in konceptualni okvir

Prvo poglavje doktorske disertacije vsebuje sistematičen pregled (identifikacija, ovrednotenje, pridobivanje in povzemanje) znanja o prenosu znanja med akademskim svetom in gospodarstvom s posebnim poudarkom na vedah o življenju. Sistematičen pregled vključuje 135 člankov, objavljenih med leti 1980 in 2014. Raziskave smo razvrstili v več kategorijah, osnovanih na pojavljajočih skupnih temah. Znotraj vsakega skupine smo analizirali vsebino člankov in jih primerjali med sabo glede na pridobljene rezultate in uporabljene raziskovalne metode, spremenljivke in empirične kontekste, na katere so se osredotočale. Potem smo rezultate povzeli in sprejeli sklepe za vsako od šestih prepoznanih osnovnih tem raziskav o akademskem svetu in gospodarstvu: determinante vključenosti v prenos znanja, vloga spodbud, dejavniki institucionalnega uspeha, institucionalizacija prenosa znanja, razmerje z raziskovalnim delom in vplivom na odprto znanost. Nastajajoče teme, ki smo jih identificirali v spremljanju sistematičnega pregleda literature, so se dotikale dejavnikov in posledic interakcij prenosa znanja med akademskim svetom in gospodarstvom za javne institucije. Na podlagi naših ugotovitev smo razvili konceptualni okvir za raziskovanje prenosa znanja med akademskim svetom in gospodarstvom ter ovrednotenje njegove učinkovitosti in vpliva na javno znanost. Pokazali smo, da morajo raziskovalci, menedžerji in oblikovalci vladnih politik, kadar ocenjujejo učinkovitost interakcij prenosa znanja med akademskim svetom in gospodarstvom, vzeti v obzir tako individualne dejavnike (znanstvena produktivnost raziskovalcev, profesionalni status, demografske značilnosti, socialni kapital, pogledi, motivacija ter predhodne izkušnje prenosa znanja) kot tudi zunanje dejavnike (viri raziskovalcev, značilnosti neposrednega delovnega okolja, okvir uradne politike, predhodno financiranje gospodarstva, tehnološke priložnosti in lokacija), vključno z značilnostmi tehnologije. Ti dejavniki vplivajo na vključevanje posamičnih raziskovalcev v prenos znanja med akademskim svetom in gospodarstvom kot tudi na splošni uspeh prenosa institucionalizirane tehnologije. Razviti konceptualni okvir turi prikaže posledice prenosa znanja med akademskim svetom in gospodarstvom na produktivnost raziskovalcev in na njihove interakcije z ostalimi člani akademske skupnosti.

Raziskovanje razmerja med prenosom in izmenjavo znanja v medkulturnem kontekstu: primer skupnosti v vedah o življenju

V drugem poglavju disertacije raziskujemo, kako različni procesi prenosa znanja med akademskim svetom in gospodarstvom zavirajo formalno in neformalno izmenjavo znanja na področju ved o življenju. Opravili smo obširen pregled obstoječe literature, zbrali kvalitativne podatke iz 38 poglobljenih intervjujev z akademiki, strokovnjaki in specialisti na področju prenosa tehnologije iz šestih držav. Cilj je bil pokazati njihove izkušnje in poglede o vlogi prenosa znanja iz akademskega sveta v gospodarstvo ki jih imajo v odnosih z drugimi člani – raziskovalci na področju ved o življenju. V zapisanih intervjujih smo najprej identificirali glavne analitične kategorije na podlagi glavnih raziskovalnih vprašanj ter vprašanj iz intervjuja, potem pa smo kodirali, uporabljajoč vnaprej razvito shemo kodiranja, in kategorizirali. Nato smo identificirali bolj primerne nastajajoče teme znotraj kategorij ter kategorizirali citate v skupne teme. S pomočjo programske opreme Atlas.ti (verzija 6.2) smo primerjali podatke iz različnih kategorij anketirancev in institucionalnih okvirjev. Analiza podatkov je pokazala, da je omejevanje prenosa znanja v akademskem svetu odvisno od vključenosti akademskih raziskovalcev v različne vrste dejavnosti prenosa znanja, ki segajo od sodelovanja z gospodarstvom in zaščito pravic iz naslova intelektualne lastnine do podjetništva in drugih poslovnih dejavnosti. Še več, pokazalo se je, da je prenos znanja med akademskim svetom in gospodarstvom povezan z naborom omejevanja izmenjave znanja v akademskem svetu: z direktno izmenjavo raziskovalnih podatkov, z informacijami in materiali (specifična izmenjava znanja), s predstavitvami na konferencah (izmenjava splošnega znanja), s skupnimi raziskovalnimi projekti (formalna izmenjava znanja), z uporabo sporazumov za izmenjavo materiala (MTA) (formalna izmenjava raziskovalnih materialov), z izmenjavo znanja skozi izmenjavo osebja, z izmenjavo znanja, povezano z objavami študentov na doktorskem študiju, z vsebino objav in s časovnim načrtom objavljanj (izmenjava znanja s širšo javnostjo).

Glede na to, da večina raziskav o prenosu znanja med akademskim svetom in gospodarstvom gradi na empiričnih podatkih, ki so jih raziskovalci pridobili od anketirancev iz ZDA (Baldini 2008), in da so raziskave, ki se osredotočajo na več kot le eno državo, precej omejene (Haeussler 2011, Haeussler 2014, Walsh and Huang 2014), smo bili pri naših pogovorih z intervjuvanci posebej pozorni na institucionalno okolje, v katerem delujejo. Z vključevanjem anketirancev iz šestih različnih institucionalnih okolij smo prispevali k razumevanju vloge profesionalnega okolja raziskovalcev v njihovo vključevanje v dejavnosti prenosa znanja med akademskim svetom in gospodarstvom. Pri ocenjevanju vpliva vladnih in institucionalnih politik o prenosu tehnologije smo se večinoma opirali na podatke, pridobljene neposredno od naših anketirancev, in le deloma na podatke, ki so dostopni v drugih virih (Escoffier et al. 2011, Geuna and Rossi 2011, 2013, Messer-Yaron 2014). Pokazali smo, da institucionalni normativi in politike, povezane z prenosom znanja med akademskim svetom in gospodarstvom, tudi vplivajo na obnašanje akademskih raziskovalcev pri izmenjavi znanja. Anketiranci iz ZDA so izrazili večjo zaskrbljenost nad možnim vplivom omejevalnih univerzitetnih politik prenosa tehnologije na normative odprte znanosti v akademskih institucijah kot anketiranci iz drugih raziskanih institucionalnih kontekstov.

Analiza rezultatov empirične študije nam je omogočila, da smo razvili teoretični okvir za ocenjevanje interakcije med prenosom in izmenjavo znanja. Ta model je zajel odnose med omejevanjem v določenih vrstah izmenjave znanja med akademskimi raziskovalci ter določenimi oblikami dejavnosti prenosa znanja. Čeprav so anketiranci navedli dejavnosti izmenjave znanja med akademskim svetom in gospodarstvom kot glavni razlog za omejevanje pri izmenjavi znanja, smo pri obširnem pregledu literature in pri analizi podatkov iz intervjujev identificirali mnoga druga pomembna omejevanja. Tako vsebuje model individualne in od konteksta odvisne dejavnike omejevanja izmenjave znanja v akademskih skupnostih in je primeren za uporabo glede na specifične demografske strokovne in poklicne značilnosti raziskovalcev. Prikazujemo tudi dokaze, ki podpirajo pogled na trenutni sistem znanosti/znanstveni sistem kot na hibrid med odprto znanostjo in omejevanjem razkritja (Mukherjee and Stern 2009), ne le zaradi vedno večjega pomeni komercialne uporabe rezultatov akademskih raziskav, pač pa tudi zaradi intenzivne tekmovalnosti v znanosti zaradi prvenstva pri razširjanju rezultatov, prestiža in financiranja raziskav.

Dejavniki omejevanja izmenjave znanja v vedah o življenju: testiranje vloge prenosa znanja med akademskim svetom in gospodarstvom, osebnih in od konteksta odvisnih dejavnikov

V tretjem poglavju disertacije smo empirično testirali razmerje med različnimi oblikami izmenjave znanja med akademskim svetom in gospodarstvom ter različnimi oblikami omejevanja izmenjave znanja v vedah o življenju. Raziskali smo dejavnike sedmih različnih vrst omejevanj izmenjave znanja v akademski skupnosti: omejevanje pri vsebini objav, času objav (zamude), omejevanje pri soavtorskih objavah, omejevanje pri vrstnem redu soavtorskih objav, omejevanje pri izmenjavi znanja med prezentacijami rezultatov raziskav, omejevanje izmenjave znanja pri izmenjavi neobjavljenega znanja (informacije, podatki ali materiali) in omejevanje izmenjave znanja pri izmenjavi objavljenega znanja. Kot svoje najpomembnejše neodvisne spremenljivke smo upoštevali tri različne vrste prenosa znanja med akademskim svetom in gospodarstvom: gospodarske dejavnosti, temelječ na sodelovanju, dejavnosti, povezane s pravicami iz naslova intelektualne lastnine, in akademske podjetništvo in s poslom povezane dejavnosti. Glede na predhodne raziskave smo domnevali, da bo imela vključenost v prenos znanja med akademskim svetom in gospodarstvom pozitivno povezavo z omejevanjem pri izmenjavi znanja, toda da bo intenzivnost te povezave odvisna od vrste dejavnosti prenosa znanja med akademskim svetom in gospodarstvom ter vrste izmenjave znanja. Za testiranje naše hipoteze smo razvili inštrument raziskave, ki je temeljil na pregledu literature, na predhodnih raziskavah in na polstrukturiranih intervjujih z 38 ključnimi informanti. Za preverjanje inštrumenta smo naredili pilotne intervjuje s petimi znanstveniki, ker smo želeli zaznati neprimerna ali nejasno zastavljena vprašanja. Vprašalnik smo najprej pripravili v angleškem jeziku, potem pa ga prevedli v hrvaški jezik, pri tem smo uporabili back-to-back prevajalsko metodo. Vprašalnik smo preko spletne platforme za anketiranje, LimeSurvey, po elektronski pošti poslali vsega 2,550 anketirancem, hrvaškim znanstvenikom ved o življenju, ki imajo doktorat in ki so bili aktivni raziskovalci v zadnjih petih letih. Stopnja odzivnosti je bila 20,05%, 212 odgovorov pa smo vključili v ekonometrično analizo. Rezultati binomske regresije so pokazali, da bolj ko se akademski raziskovalci vključujejo v prenos znanja med akademskim svetom in gospodarstvom, bolj bodo omejili izmenjavo znanja z ostalimi člani akademske skupnosti. Lastnosti tega odnosa pa so odvisne od vrste dejavnosti prenosa znanja med akademskim svetom in gospodarstvom in od oblike izmenjave znanja. Ko gre za sodelovanje z gospodarstvom, pa se je pri večini oblik izmenjave znanja pokazalo pozitivno razmerje z omejevanjem prenosa znanja. Odnos med dejavnostmi prenosa znanja med akademskim svetom in gospodarstvom, kjer je bila v igri pravica iz naslova intelektualne lastnine, in omejevanjem izmenjave znanja je bila značilna in pozitivna v primeru restrikcij časovnice soavtorskih objav in v primeru omejevanja izmenjave znanja med prezentacijami. Po drugi strani pa so imeli rezultati regresije za omejevanje objavljenega in neobjavljenega znanja značilne in negativne koeficiente. Pokazali smo tudi, da je sodelovanje v akademsko-podjetniških dejavnostih značilno povezano le z omejevanjem izmenjave objavljenih podatkov in materialov.

V našo empirično analizo smo vključili nabor predvidenih individualnih in od konteksta odvisnih determinant omejevanja izmenjave znanja v akademski skupnosti poleg prenosa znanja med akademskim svetom in gospodarstvom. Na vzorcu 212 znanstvenikov iz področja ved o življenju smo pokazali, da so pričakovanja izida na ravni posameznika značilno negativno povezana z večino raziskanih oblik omejevanja izmenjave znanja. Po drugi strani pa pričakovanje izida v skupnosti ni značilno povezano z nobeno obliko omejevanja izmenjave znanja. Nismo uspeli pokazati, da bi bilo zaupanje značilno povezano z omejevanjem izmenjave znanja pri neposredni neformalni izmenjavi neobjavljenih in objavljenih informacij, podatkov in materialov, čeprav smo predvidevali drugače. Se je pa pokazalo, da je zaupanje značilno povezano z restrikcijami v časovnici soavtorskih objav ter omejevanji pri javnih predstavitvah rezultatov. Na splošno se ugled med kolegi ni pokazal kot pomembna determinanta omejevanja izmenjave znanja v akademski skupnosti. Raziskava kaže na mešane rezultate pri odnosu med znanstvenimi vrednotami ter omejevanjem izmenjave znanja. V naši raziskavi smo tudi dokazali, da je tekmovalnost med znanstveniki pomembna determinanta omejevanja izmenjave znanje pri objavah, javnih predstavitvah rezultatov in neposredni izmenjavi objavljenih podatkov in materialov z drugimi raziskovalci. Pomembno razmerje z institucionalno klimo glede podpore izmenjave znanja smo dokazali samo pri restrikcijah v časovnici soavtorskih objav, kar pomeni, da obnašanje znanstvenikovih neposrednih nadzornikov in kolegov v oddelku večinoma ne igra značilne vloge pri njihovih odločitvah o izmenjavi znanja. Rezultati znanstveno produktivnosti, merjeni s številom objav v zadnjih petih letih, kažejo, da več ko raziskovalci objavljajo, bolj omejujejo izmenjavo znanja med javnimi prezentacijami in manj zavračajo neposredne neformalne zahteve drugih raziskovalcev za dostop do neobjavljenih in objavljenih podatkov in materialov. Leta delovnih izkušenj so značilno povezana samo z omejevanjem prenosa znanja pri javnih predstavitvah ter pri omejevanju vsebine pri soavtorskih objavah, pri čemer starejši znanstveniki manj omejujejo izmenjavo znanja. Sicer pa smo ugotovili, da so omejevanja pri vsaki vrsti izmenjave znanja na ravni posameznih akademskih raziskovalcev napovedane z različnimi osebnimi in kontekstualnimi dejavniki.

Kako vplivajo univerzitetni IPRji (pravice iz naslova intelektualne lastnine) in mehanizmi financiranja R&R na uspeh inovacij v biotehnologiji zdravstvenega varstva? Dokazi iz Evrope in ZDA

Četrto poglavje disertacije analizira vlogo na univerzi pridobljenih pravic iz naslova intelektualne lastnine ter mehanizmov financiranja raziskav in razvoja pri uspehu inovacij v biotehnologiji zdravstvenega varstva. Za prikaz specifičnih razlik med Evropo in ZDA smo uporabili teoretični model, razširjen s statističnimi podatki. Svojo raziskavo smo oprli na korpus literature, ki raziskuje zgodovinski razvoj biotehnologije zdravstvenega varstva, njeno širitev na nove subjekte in nova znanstvena področja ter na vlogo različnih virov financiranja procesa komercializacije biomedicine. Za osvetlitev dejavnikov uspeha inovacij v biotehnologiji smo uporabili teorijo inovativnega podjetja in koncept »doseganje maksimalne vrednosti za delničarja«. Pri na univerzi pridobljenih pravicah iz naslova intelektualne lastnine smo pokazali na mnoge pomanjkljivosti le-teh v vlogi gonil razvoja, in tu Evropa na splošno posnema model ZDA. S pomočjo teorije inovativnega podjetja smo argumentirali, da so patenti v primerjavi z inovativnimi sposobnostmi za pretvorbo novih tehnologij v inovativne produkte in procese šibkejši determinanti uspešnega razvoja inovativnih produktov. Pokazali smo tudi, kako teorija inovativnega podjetja in neoklasična teorija različno razlagata, zakaj so javne investicije v bazo znanja na univerzah nujne za razvoj inovacij. Analiza različnih mehanizmov financiranja procesa komercializacije biotehnologije je pokazala, da so trgi špekulativnih vrednostnih papirjev pritegnili precejšnje tokove finančnih sredstev v ta sektor v ZDA, manj pa v Evropi, primarno pri začetnih javnih ponudbah ter pri dajanju nadomestil v vrednostnih papirjih. Razpravljali smo, kako so bile zaradi priložnosti hitrih izstopov za investitorje prisotne visoke investicije, čeprav je pri večini podjetij šlo za razvojno naravnana podjetja, ki niso bila dobičkonosna in niso imela na trgu tako rekoč niti enega produkta. Ta poslovni model se je v veliki meri zanašal na neoklasično finančno teorijo in na njen poudarek na kratkoročno maksimiranje vrednosti za delničarja, čeprav gre za panogo, kjer velja dolgoročnost in visoka tveganja.

Povzetek priporočil

Doktorska disertacija prispeva k teoretičnim in empiričnim spoznanjem o prenosu znanja med akademskim svetom in gospodarstvom kot tudi k znanstveni politiki in poslovni praksi.

Priporočila za teorijo

Prva teoretično priporočilo se nanaša na razvoj novega konceptualnega okvirja za ocenjevanje učinkovitosti prenosa znanja med akademskim svetom in gospodarstvom ter učinka na javno znanost. Čeprav se številne raziskave ukvarjajo s prednostmi in izzivi procesov izmenjave znanja med akademskim svetom in gospodarstvom, splošni okvir za ovrednotenje učinkovitosti prenosa znanja med akademskim svetom in gospodarstvom in njegovega učinka na javno znanost še ni bil zasnovan. Z sistematičnim pregledom literature in predlaganim konceptualnim okvirjem smo pokazali, da morajo raziskovalci, menedžerji in oblikovalci vladne politike, kadar ocenjujejo učinkovitost prenosa znanja med akademskim svetom in gospodarstvom, vzeti v obzir tako individualne dejavnike (znanstvena produktivnost raziskovalcev, profesionalni status, demografske značilnosti, socialni kapital, pogledi, motivacije in predhoden prenos znanja) kot tudi zunanje dejavnike (raziskovalni viri, značilnosti neposrednega delovnega okolja, institucionalni okvir, predhodno financiranje gospodarstva, tehnološke priložnosti in lokacija), vključno z značilnostmi tehnologije. Ti dejavniki vplivajo tako na vključevanje posamičnih raziskovalcev v prenos znanja med akademskim svetom in gospodarstvom kot tudi na celoten uspeh institucionalnega prenosa tehnologije. Konceptualni okvir, ki smo ga razvili, vključuje tudi implikacije prenosa znanja med akademskim svetom in gospodarstvom na produktivnost raziskovalcev in na njihovo sodelovanje z drugimi člani akademske skupnosti.

Druga teoretična implikacija se nanaša na konceptualizacijo in empirično testiranje razmerja med prenosom znanja ter izmenjavo znanja med akademskim svetom in gospodarstvom, upoštevaje heterogenost različnih oblik akademskega prenosa znanja in izmenjave znanja. Kljub obilici člankov iz tega področja jih je le omejeno število dovolj poglobljeno obdelalo kompleksni problem omejevanja neformalne in formalne izmenjave znanja med člani akademske skupnosti v povezavi z vključenostjo znanstvenikov v prenos znanja med akademsko sfero in gospodarstvom in z dejavnostmi komercializacije. Večina raziskav na tem področju se osredotoča na splošni vpliv patentiranja ali dejavnosti prenosa znanja, brez da bi razlikovali med različnimi mehanizmi prenosa znanja med akademskim svetom in gospodarstvom. V nalogi predlagamo celovit model prenosa in izmenjave znanja na individualnem nivoju in pokažemo, da vse oblike prenosa znanja med akademskim svetom in gospodarstvom niso povezane z vsemi oblikami omejevanja izmenjave znanja. Naši rezultati kažejo, da je nujno upoštevati značilnosti določenih dejavnosti prenosa znanja med akademskim svetom in gospodarstvom, ko ocenjujemo njihov vpliv na omejevanje izmenjave znanja v akademskih skupnostih. V povezavi s tem smo z anketiranjem raziskovalcev iz šestih različnih institucionalnih okolij prispevali k razumevanju vloge profesionalnega okolja akademskih raziskovalcev. Dokazujemo, da institucionalni normativi in politike, ki so povezani s prenosom znanja med akademskim svetom in gospodarstvom, tudi vplivajo na obnašanje akademskih raziskovalcev pri izmenjavi znanja.

Tretja teoretična implikacija raziskave je, da prispeva k poznavanju dejavnikov omejevanja izmenjave znanja med znanstveniki na področju ved o življenju, ker upošteva širok nabor individualnih in od konteksta odvisnih determinant omejevanja izmenjave znanja. Obstoječe raziskave, ki izhajajo iz teorije socialnega kapitala, večinoma raziskujejo omejen nabor dejavnikov omejevanja izmenjave znanja v akademskih skupnostih na področju ved o življenju, kar naše znanje o tem pomembnem pojavu precej omejuje. Identificiramo in ocenimo različne individualne in od konteksta odvisne determinante omejevanja izmenjave znanja ter pokažemo, da lahko različni individualni in kontekstualni dejavniki napovedujejo različne oblike omejevanja izmenjave znanja.

Četrti teoretični prispevek raziskave je v razumevanju gonil uspeha inovacij v biotehnologiji zdravstvenega varstva. Analizirali smo vlogo na univerzah pridobljenih pravic iz naslova intelektualne lastnine, javnih investicij v bazo znanja ter mehanizmov financiranja komercializacije pri stimuliranju uspeha inovacij v biotehnologiji zdravstvenega varstva. Na te tri dejavnike uspeha inovacij smo se v naši raziskavi osredotočili po temeljitem pregledu literature, ki je opozorila na omejeno znanje o ključnih dejavnikih, ki poganjajo razvoj v tem sektorju. V naši raziskavi smo neposredno primerjali biotehnologijo zdravstvenega varstva v ZDA in Evropi, opirajoč se na teoretični model, razširjen s statističnimi podatki. Naš konceptualni okvir izhaja iz dveh temeljnih teoriji, neoklasične finančne teorije in teorije inovativnega podjetja, ki smo ju primerjali, pri čemer smo pri oceni dejavnikov vpliva na inovacije v biotehnologiji zdravstvenega varstva upoštevali teoretično in praktično prvenstvo prve in zgodovinski vidik druge.

Metodološke implikacije

V raziskavi prvi uvedemo številne ukrepe za zajemanje obsega tako formalnega kot tudi neformalnega omejevanja izmenjave znanja med člani akademske skupnosti na področju ved o življenju. To je pomembno, če upoštevamo, da obstoječe raziskave večinoma merijo zgolj obstoj (Blumenthal et al. 1997, Campbell et al. 2000) ali pogostost (Campbell et al. 2002, Walsh et al. 2007) zadrževanja podatkov in materialov, brez da bi sočasno skušale zajeti vpliv dejavnosti prenosa znanja na formalno izmenjavo znanja med znanstveniki.

Drugič, to je ena prvih raziskav, ki celovito razišče ključno vlogo institucionalnega konteksta pri interakcijah med prenosom in izmenjavo znanja. Z vključitvijo anketirancev iz šestih različnih okolij prispevamo k razumevanju vloge profesionalnega okolja akademskih raziskovalcev pri njihovem vključevanju v dejavnosti prenosa znanja med akademskih svetom in gospodarstvom. To je pomemben prispevek, saj se večina doslej objavljenih člankov iz tega področja osredotoča na le eno državo, prvenstveno na ZDA (Baldini 2008).

Tretjič, v štirih poglavjih disertacije smo kombinirali različne kvalitativne in kvantitativne raziskovalne metode, vključno s poglobljenim in sistematičnim pregledom literature, pol-strukturiranimi intervjuji, univariatno statistiko, bivariatno statistiko kot tudi multivariatno statistiko. Naredili smo sistematičen pregled (identifikacija, ovrednotenje, pridobivanje, povzemanje) 135 člankov, objavljenih med 1980 in 2014 z namenom razvoja konceptnega okvirja za ocenjevanje učinkovitosti prenosa znanja med akademskim svetom in gospodarstvom ter njegovega učinka na javno znanost. Poglobljen pregled literature smo kombinirali s pol-strukturiranimi intervjuji z 38 akademiki, strokovnjaki in specialisti za prenos tehnologije iz šestih držav, da smo lahko raziskali heterogenost mehanizmov prenosa ter izmenjave znanja v akademskih skupnostih na področju ved o življenju. Za testiranje odnosa med različnimi oblikami prenosa znanja med akademskim svetom in gospodarstvom, individualnimi in od konteksta odvisnimi dejavniki ter različnimi oblikami omejevanja izmenjave znanja v akademskih skupnostih na področju ved o življenju smo uporabili kvantitativne raziskovalne tehnike. Uporabili smo tehnike univariatne, bivariatne kot tudi multivariatne analize.

Praktične implikacije

Disertacija vsebuje številna priporočila za oblikovalce vladne politike in podjetnike. Prva skupina priporočil izhaja iz opravljenega sistematičnega pregleda predhodne literature, ki nam je omogočil razvoj novega konceptualnega okvirja za oceno učinkovitosti prenosa znanja med akademskim svetom in gospodarstvom ter njegovega vpliva na javno znanost. Ta okvir bi moral služiti kot uporabno orodje za praktike, vključene v dejavnosti prenosa znanja v akademskih ustanovah, ki jih zelo zanimajo dejavniki, ki poganjajo prenos znanja med akademskim svetom in gospodarstvom, ter posledice teh dejavnosti za javno znanost zaradi intenzivnih raziskav ter sprememb inovacijske politike v zadnjih nekaj letih.

Bolj specifično je glede motivatorjev prenosa znanj naša raziskava pokazala, da bi morali oblikovalci vladne politike razviti mehanizme, ki bi stimulirali vključevanje izrednih/ne rednih raziskovalcev v dejavnosti prenosa znanja, saj je bilo do sedaj njihovo vključevanje manj vidno kot vključevanje starejših raziskovalcev s stabilnimi položaji. Za izboljšanje menedžerskih in poslovnih veščin ne-rednih raziskovalcev lahko razvijemo posebej za njih prilagojene programe usposabljanj in financiranja, ker bi s tem ustvarili ugodne pogoje za njihovo vključevanje v projekte komercializacije. Isto velja za ženske raziskovalke, ki se manj vključujejo v različne oblike prenosa znanja kot njihovi moški kolegi.

S sistematičnim pregledom smo dokazali, da se bodo akademsko najbolj produktivni raziskovalci manj verjetno intenzivno vključili v prenos znanja z gospodarstvom kot pa manj produktivni raziskovalci. Na drugi strani pa empirične raziskave v številnih okoljih razkrivajo, da lahko znanstveno manj produktivni raziskovalci tudi pozitivno prispevajo k nivoju patentiranja v akademskih institucijah. Pri upoštevanju takšnih zaključkov moramo biti po našem mnenju previdni, saj bi morale institucije pri ocenjevanju uspeha prenosa znanja dati prednost kvaliteti pred kvantiteto. To priporočilo velja tudi za oblikovalce vladnih politik v EU, ki bi morali obstoječ seznam kazalnikov razširiti s tistimi, ki promovirajo kvaliteto, ne pa le število outputov, kot na primer število novih patentov, licenčnih sporazumov in ustvarjenih odcepljenih podjetij.

Akademske institucije bi morale pri definiranju spodbud za večje vključevanje raziskovalcev v prenos znanja upoštevati, da finančne spodbude niso edini mehanizmi, ki so na voljo, ker raziskovalci na področju ved o življenju včasih vrednotijo priložnost pridobivanja sredstev iz gospodarstva, ki podprejo razširitev aktivnosti njihovega laboratorija, višje kot le prejemanje finančnih nadomestil iz naslova licenčnin. Še več, institucionalni menedžerji ne bi smeli zanemariti dejstva, da se prenos znanja dogaja tudi izven formalnih institucionalnih struktur, kot so pisarne za prenos tehnologije. Namesto tega bi morali raziskati, v kakšnem obsegu in zakaj se njihovi predavatelji odmikajo od administratorjev za prenos tehnologije, čeprav obstajajo regulative in ostali formalni dokumenti, ki zahtevajo takšno pot prenosa znanja.

Poleg tega institucionalne politike podpirajo ustanavljanje akademskih odcepljenih podjetij, ki so delno ali povsem v njihovi lasti, obenem pa pogosto ne upoštevajo struktur njihovega menedžmenta in timskih struktur ter tržne privlačnosti spin-off tehnologij. Kot pokažemo v naši raziskavi, je posledično število propadlih akademskih odcepljenih podjetij zelo visoko. Tehnološki menedžerji na akademskih institucijah bi zato morali podrobno oceniti, koliko so akademske invencije sploh primerne za komercializacijo s pomočjo novoustanovljenih spin-off podjetij.

Pokažemo tudi, da dejavnosti prenosa znanja ne dajejo nujno le pozitivnih rezultatov, kot so povečana denarna sredstva za akademske institucije ter boljše izkoriščanje na univerzah pridobljenih rezultatov raziskav. Pozitivne rezultate beleži le manjšina institucij, posebej v Evropi. Politike akademskih institucij torej ne smejo promovirati brezpogojno komercializacijo; ravno nasprotno, zelo natančno bi morali upoštevati znanstvene interese akademskih raziskovalcev ter značilnosti invencij, preden stopijo v pogodbena razmerja z gospodarstvom.

Druga skupina praktičnih priporočil temelji na konceptualizaciji in empiričnem testiranju dejavnikov omejevanja izmenjave znanja v akademskih skupnostih na področju ved o življenju. Na prenos znanja in tehnologije se na splošno gleda kot na zaželene in ustrezne vire financiranja raziskovalnih dejavnosti (Colyvas and Powell 2006). Istočasno pa se pojavljajo tudi zadržki glede potencialnih negativnih vplivov teh dejavnosti na normative odprte znanosti. Največ polemik je o patentiranju raziskovalnih orodij oziroma *vložkov/inputa* za nadaljnje raziskave kot tudi za razširjanja pravic iz naslova intelektualne lastnine na življenjske oblike (Caulfield and Ogbogu 2008). Zaradi tega finančne agencije od znanstvenikov čedalje pogosteje zahtevajo, da se držijo politike odprte znanosti in da dovolijo drugim raziskovalcem ponovitve in nadaljnji razvoj njihovih rezultatov (Franzoni and Sauermann 2014). Naši rezultati kažejo, da bi morali menedžerji raziskovalnih organizacij in oblikovalci vladne politike upoštevati vlogo različnih oblik interakcij akademskih raziskovalcev s poslovnimi dejavnostmi gospodarstva, kadar proučujejo ovire pri odprti izmenjavi znanja v akademskih skupnostih. Morali bi upoštevati tudi druge dejavnike, kot so osebne značilnosti raziskovalcev, njihove motivacije in vrednote, kot tudi od konteksta odvisne dejavnike različnih oblik omejevanja izmenjave znanja. Takšen pristop bo olajšal oblikovanje znanstvenih politik, ki stimulirajo prenos znanja med akademskim svetom in gospodarstvom, in istočasno podpiral lastnosti sistema odprte znanosti. Dokazujemo, da je pogled na trenutni sistem znanosti kot na hibrid med odprto znanostjo in omejevanjem razkritja (Mukherjee and Stern 2009) pravilen, ne le zaradi vse večjega pomena komercialnega izkoriščanja rezultatov akademskih raziskav, pač pa tudi zaradi intenzivne tekmovalnosti med znanstveniki ter zaradi drugih individualnih in od konteksta odvisnih dejavnikov, ki značilno vplivajo na različne oblike omejevanja izmenjave znanja.

Tretja skupina praktičnih priporočil naše raziskave izhaja iz analize vloge na univerzah pridobljenih pravic iz naslova intelektualne lastnine in analize vloge mehanizmov financiranja raziskav in razvoja v uspehu inovacij biotehnologije zdravstvenega varstva. Naša raziskava je pokazala, da je poslovni model ameriške biotehnološke industrije močno odvisen od monetizacije na univerzah pridobljenih pravic iz naslova intelektualne lastnine, od vladnih investicij v raziskave z visokim tveganjem ter od javnih kapitalskih trgov in finančnih institucij. Evropska biotehnološka industrija se močno prizadeva ta model posnemati zaradi njegovega večjega uspeha v večini indikatorjev. Po drugi strani pa smo tudi dokazali, da v industrijskem sektorju, ki zahteva 'potrpežljivi kapital, finančno naravnani ameriški sektor zaradi osredotočanja na kratkoročne finančne koristi ovira uspeh inovacij, ki so vezane na fluktuacije cen vrednostnih papirjev in nadomestil v vrednostnih papirjih, kar pod vprašaj postavlja dolgoročno vzdržnost biotehnološke industrije.

Ker so opravljene empirične raziskave pokazale, da se število komercialno irelevantnih na univerzah pridobljenih patentov veča, predlagamo, da evropske akademske institucije razmislijo o svojih trenutnih politikah prenosa tehnologije: namesto siljenja svojih pisarn za prenos tehnologije v vlaganje čim večjega števila patentov na 'monoliten način' naj raje investirajo v razvoj učinkovitih izhodišč za kritično ovrednotenje invencij, ki jih potencialno lahko patentirajo. Na ta način bodo zmanjšali število irelevantnih dejavnosti v pisarnah za prenos tehnologije; zmanjšali pritisk na temeljne znanstvene raziskave in znižali stroške pravnih storitev, povezanih z zaščito pravic iz naslova intelektualne lastnine (npr. vlaganje patentov, uveljavljanje). V zadnjem času so se pojavili tudi predlogi za alternativno ureditev režimov pravic iz naslova intelektualne lastnine. Ti vključujejo vračanje k izumiteljevi lastnini in obveznemu neizključenemu licenciranju (Kenney and Patton 2009, Dorsey et al. 2010, Hoffenberg 2010). Obvezno licenciranje, ki so ga pred kratkim iniciirali v ZDA, v Nemčiji pa je že v uporabi, bi moralo inovativnim podjetjem omogočiti donosnost na njihove naložbe v raziskave. Istočasno bi imeli uporabniki dostop do tehnologije po primerni ceni.

Področje, kjer bi evropska industrija morala posnemati ameriško biotehnologijo, je v večji medsebojni povezanosti med temeljno znanostjo in kliničnim razvojem, kar so že predlagali Owen-Smith in kolegi (2002). Pokazali so, da ameriške javne raziskovalne ustanove in majhna biotehnološka podjetja istočasno izvajajo decentralizirane raziskave in razvoj na več področjih in stopnjah razvoja, medtem ko ima Evropa regionalno specializacijo z manj raznoliko skupino javnih raziskovalnih organizacij, ki delajo na manj področjih in imajo bistveno bolj centralizirano nacionalno financiranje. Evropa mora torej drugače razdeliti delo, če hoče podpreti inovacije.

Če hočemo podpreti stalen razvoj, mora evropska biotehnološka industrija usmeriti več naporov v strateško selekcijo manjšega števila prioritet financiranja in v dolgoročno usmerjenost v terapevtske in diagnostične produkte, ki so lahko resnično komercialno uspešni (Komisija 2007). Velika priložnost tiči v razvoju biološko podobnih zdravil (ki predvideva, drugače kot produkcija generičnih zdravil, intenzivne dejavnosti raziskav in razvoja), ker bo mnogim biotehnološkim zdravilom v prihodnjih letih potekla patentna zaščita. Razvoj načinov zdravljenja zelo redkih bolezni ali bolezni z zelo majhnimi populacijami pacientov predstavlja priložnost, ki so jo že prepoznali na obeh straneh Atlantika (Ernst&Young 2011) kot odziv na problem nevzdržnih »blockbuster« zdravil. Takšne strategije bi morale spremljati adekvatne politike, ki bi spodbujale večjo specializacijo in vlagateljem tveganega kapitala in drugim vrstam investitorjev večale potrebo po kapitalu »pacientov«.