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ENDOGENOUS ECONOMIC MECHANISMS OF UNEVEN DEVELOPMENT

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AUTHORSHIP STATEMENT

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Endogeni ekonomski mehanizmi neenakega razvoja - povzetek

V disertaciji preučujemo dva še neidentificirana endogena ekonomska mehanizma na strani ponudbe, ki prispevata k ohranjanju neenakega razvoja med državami. Postavimo dve glavni hipotezi, od katerih se vsaka nanaša na delovanje posameznega proučevanega mehanizma. Prva je, da so mednarodni relativni stroški proizvodnih dejavnikov odvisni od stopnje razvitosti, kar določa strukturne pogoje za privzemanje novih tehnologij na način, ki ohranja neenakomerno porazdelitev tehnologije in tako prispeva k ohranjanju in poglabljanju neenakega razvoja. Druga, da granularnost, ki odraža razlikovanje med proizvodnimi omejitvami komplementarnih sklopov produkcijskih opravil, dinamično součinkuje z mednarodno distribucijo relativnih stroškov proizvodnih dejavnikov in tako endogeno povzroča neenako funkcionalno specializacijo. Takšna mednarodna specializacija prispeva k ohranjanju neenakega razvoja, saj se manj razvite države specializirajo za tista produkcijska opravila, ki imajo manjši potencial za rast produktivnosti in tehnološki napredek.

Delovanje obeh mehanizmov temelji na hipotezi, da so mednarodni relativni stroški dejavnikov strukturno povezani s stopnjo razvoja. Razlike v mednarodnih relativnih stroških proizvodnih dejavnikov so bile empirično raziskane, pri čemer so relativni stroški kapitala, tehnologije in znanja sistematično nižji v bolj razvitih državah in obratno (Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997). Teoretična razlaga za to, v marksovskem okviru, je, da je splošna mobilnost dela bolj omejena kot mobilnost kapitala, tehnologije in spretnosti ter da so lokalni stroški akumulacije kapitala, tehnologije in spretnosti relativno višji v manj razvitih državah (Amin, 2010; Shaikh, 1979). Te izpeljave so neločljivo povezane z Marxovo teorijo mezd (Marx, 1992; Starosta & Fitzsimons, 2018).

Za razumevanje razmerja med neenakim razvojem in tehnološkim napredkom je ključna konceptualizacija tehnologije, ki povezuje pogoje tehnološkega napredka difuzije s cenami dejavnikov proizvodnje (Acemoglu, 2010; Acemoglu & Autor, 2011; Acemoglu & Restrepo, 2017a, 2017b, 2019; Sylos-Labini, 1984; Zeira, 1998). Ti pristopi temeljijo na ideji, da industrializacija pomeni kvalitativno razširitev opravil, ki jih lahko namesto dela profitabilno opravljajo stroji, kar vodi do neposredne povezave med ravnijo plač in procesom substitucije med stroji in delom. V literaturi na tem področju obstaja precejšnja vrzel. Po eni strani teorije endogene rasti, ki temeljijo na heterogenosti produkcijskih opravil, modelsko povezujejo endogeni tehnološki napredek z relativnimi cenami proizvodnih dejavnikov v zaprtem gospodarstvu, po drugi strani pa še ni konceptualne in teoretične posplošitve, ki bi preučevala endogeno tehnološko rast in dinamiko širjenja tehnologij ter upoštevala mednarodno razhajanje v relativnih stroških proizvodnih dejavnikov. Po drugi strani se raziskave, ki obravnavajo dejavnike privzemanja tehnologije in krivulje privzemanja tehnologije na bolj mikroekonomski ravni, zatekajo k predpostavki homogenosti na

makroekonomski ravni in tako tudi abstrahirajo od neenakega razvoja in mednarodnih relativnih stroškov dejavnikov (Comin & Hobijn, 2010; Griliches, 1957; Stokey, 2021). Nasprotno pa se v evolucijski ekonomski tradiciji enodimenzionalna tehnološka dinamika pogosto preučuje v nelinearnih modelih, ki pojasnjujejo ter modelsko izpeljejo zgodovinsko pogojene divergentne trajektorije razvoja, hkratna številna stacionarna stanja in tehnološke pasti (Fagerberg idr., 2010; Gomulka, 1990; Verspagen, 1991). Te teorije se sicer ne osredotočajo na mednarodne razlike v relativnih stroških proizvodnih dejavnikov, vendar ponujajo alternativne razlage neenakega tehnološkega napredka in splošnega razvoja, a ne izpeljejo determinant in trajektorij privzemanja tehnologij na mikroravni. V poglavju 3 to vrzel odpravljamo z novo konceptualizacijo modela tehnološke difuzije. Osnovno argumentacijo, ki jo je Verspagen (1991) uporabil za izpeljavo svojega modela tehnološke pasti, prenesemo v ekonofizikalni okvir (Chatterjee et al., 2005; Dimitrijević & Lovre, 2015) in vključimo mednarodne razlike v relativnih stroških proizvodnih dejavnikov kot glavno gonilo razhajanj pri privzemanju tehnologije. Tako ne le endogeniziramo vzorce mednarodnega privzemanja tehnologij v zveznem kontinuumu zgodovinsko pogojenih divergentnih trajektorij, temveč nam uspe izpeljati tudi povprečne krivulje privzemanja tehnologije za različno razvite države. Tako je naš predstavljeni model prvi, ki zapolnjuje vrzel med splošnejšimi spoznanji evolucijskega pristopa in bolj mikroekonomsko usmerjenimi pristopi k analizi privzemanju tehnologij, s tem da je v njem hkrati zajeta zgodovinsko pogojena tehnološka rast posameznih držav, kot tudi državno specifične krivulje privzemanja individualnih tehnologij.

Drugi preučevani domnevni mehanizem na strani ponudbe je povezan s funkcionalno specializacijo (Timmer et al., 2019), izbiro tehnike (Amin, 1976) in strukturnimi spremembami na strani ponudbe - dinamičnimi vzorci, ki jih ustvarjajo heterogene tehnične značilnosti različnih opravil proizvodnega procesa (Acemoglu & Guerrieri, 2008; Baumol, 1967; Ngai & Pissarides, 2007). Na tem področju obstaja raziskovalna vrzel, saj so modeli teorij strukturnih sprememb na strani ponudbe konceptualizirani v zaprtem gospodarstvu in umanjka analiza, ki bi preučila dinamično interakcijo med mednarodnimi relativnimi stroški dejavnikov proizvodnje in dinamiko strukturnih sprememb na strani ponudbe. Medtem ko je empirična pomembnost dinamike strukturnih sprememb na strani ponudbe obravnavana v poglavju 4, je dinamično delovanje tega mehanizma preučeno v poglavju 6. Neoklasični ponudbeni model strukturnih sprememb zaprtega gospodarstva (Acemoglu & Guerri, 2008) razširimo na večregionalno modelsko okolje in spremenimo nekatere predpostavke modela, da bi preučili dinamično interakcijo med relativnimi stroški dejavnikov in dinamiko strukturnih sprememb na mednarodni ravni. Rezultati potrjujejo našo hipotezo, saj se endogeno pojavijo vzorci funkcionalne specializacije, ki prispevajo k ohranjanju neenakega razvoja.

Ključne besede: Neenak razvoj, razlike v mezdah, prenos tehnologije, mednarodna teorija vrednosti, strukturne spremembe, nelinearni dinamični model.

Endogenous Economic Mechanisms of Uneven Development - Summary

In the thesis, we examine two as yet unidentified supply-side endogenous economic mechanisms that contribute to the perpetuation of uneven development across countries. There are two main hypotheses, each relating to the operation of a particular mechanism under study. First, we hypothesise that international relative factor costs depend on the level of development, which determines the structural conditions for the adoption of new technologies in ways that maintain the uneven distribution of technology and thus contribute to the maintenance of uneven development. Second, we hypothesise that granularity, reflecting differentiation among the productive constraints of complementary task sets, interacts dynamically with international relative factor costs and endogenously leads to uneven functional specialisation. Such international specialisation contributes to the persistence of uneven development, as less developed countries specialise in those tasks that have lower potential for productivity growth and technological progress.

The operation of both mechanisms depends on the hypothesis that international relative factor costs are structurally related to the level of development. Differences in international relative factor costs have been studied empirically, with the relative costs of capital, technology, and skills being systematically lower in more developed countries and *vice versa* (Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997). The theoretical explanation for this, in the Marxian framework, is that the general mobility of labour is more constrained than the mobility of capital, technology, and skills, and that the local costs of accumulating capital, technology, and skills are relatively higher in less developed countries (Amin, 2010; Shaikh, 1979). These derivations are inextricably linked with Marxian wage theory (Marx, 1992; Starosta & Fitzsimons, 2018).

Key to understanding the relationship between uneven development and technological progress is a conceptualization of technology that links the conditions of technological progress and the adoption of existing technology to the prices of technical factors of production (Acemoglu, 2010; Acemoglu & Autor, 2011; Acemoglu & Restrepo, 2017a, 2017b, 2019; Sylos-Labini, 1984; Zeira, 1998). These approaches are based on the idea that industrialization represents a qualitative expansion of tasks that can be profitably performed by machines instead of labour, leading to a direct link between wage levels and the process of substitution between machines and labour. There is a significant gap in the literature in this area. On the one hand, task-based endogenous growth theories link endogenous technological progress to the relative prices of factors of production in a closed economy, and there is not yet a conceptual and theoretical generalisation that examines endogenous technology growth and diffusion dynamics and accounts for international divergence in relative factor costs. On the other hand, research that addresses the determinants of technology adoption

and technology adoption curves at a more microeconomic level resorts to the assumption of homogeneity at the macroeconomic level and thus also abstracts from uneven development and international relative factor costs (Comin & Hobijn, 2010; Griliches, 1957; Stokey, 2021). Conversly, in the evolutionary tradition, one-dimensional technology dynamics are often studied in nonlinear models that feature path-dependent trajectories, multiple steady states, and technology traps (Fagerberg et al., 2010; Gomulka, 1990; Verspagen, 1991). While these theories do not focus on international differences in relative factor costs, they offer alternative explanations for uneven technological progress, diffusion, and overall development, but are unable to link micro-level technology adoption and technology adoption trajectories in the international setting. In chapter 3, we address this gap through a novel conceptualization of the technology diffusion model. We transfer the core argumentation used by Verspagen (1991) to derive his dual steady-state technology trap model into an econophysics framework (Chatterjee et al., 2005; Dimitrijević & Lovre, 2015) and incorporate international relative factor cost differences as the main driver of divergence in technology adoption. Thus, we not only endogenize the international technology adoption patterns in a continuum of path-dependent trajectories, but also succeed in deriving the average technology adoption curves. Thus, our presented model is the first to bridge the gap between the general insights of the evolutionary approach and the micro-oriented approaches to technology adoption by simultaneously endogenously deriving country-specific path-dependent adoption curves and country-level technological growth.

The second hypothesised mechanism on the supply side is related to functional specialization (Timmer et al., 2019), choice of technique (Amin, 1976), and supply-side structural change - the dynamic patterns created by the heterogeneous technical characteristics of the different parts of the production process (Acemoglu & Guerrieri, 2008; Baumol, 1967; Ngai & Pissarides, 2007). There is a research gap in this area, as supply-side structural change theories operate in closed-economy setting and no analysis has yet been conducted to examine the dynamic interaction between international relative factor costs and the dynamics of supply-side structural change. While the empirical relevance of the dynamics of supply-side structural change is established in chapter 4, the dynamic operation of the mechanism is examined in chapter 6. We extend the closed-economy neoclassical model of supply-side structural change (Acemoglu & Guerri, 2008) to a multiregional setting and modify some model assumptions to examine the dynamic interaction between relative factor costs and the dynamics of structural change at the international level. The results support our hypothesis, as endogenous patterns of functional specialization emerge that contribute to the persistence of uneven development.

Key words: Unequal development, wage differentials, technology transfer, international value theory, structural change, non-linear dynamic model.

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Introduction

The study of uneven development and the broader study of the determinants of growth and development is almost as old as the discipline of economics. Since Smith posed the question of the determinants of the wealth of nations, the question has been ubiquitous in almost all of the social sciences. Entire fields of research within economics are devoted to the study of the question of development within the international capitalist economy. From the early Marxist theories of imperialism to high development theory, dependency theory, world systems theory, heterodox and orthodox theories of growth and endogenous growth, economic geography, and the new trade theory, they all aim to explain the determinants of growth and development.

Various theories from different paradigmatic fields have attempted to understand the determinants of development from both an endogenous and exogenous perspective, as well as the intra- and extra-economic factors. Among the many determinants considered relevant to economic growth outcomes and uneven development are technology, investment, demography, institutions, history, geography, and political factors. The goal of the research presented in the dissertation is modest and does not claim to answer the most comprehensive questions about growth, development, and their determinants.

The main objective of the dissertation is to identify and explore two previously unidentified endogenous economic mechanism that shape the functioning of international and domestic markets at their core and contributes to the maintenance of uneven development and to develop a comprehensive understanding of the internal logic of their functioning. By endogenous economic mechanisms, we refer to a set of functional features of the operation of competitive markets that do not depend on exogenous structural or extra-economic differences.

The basic idea with respect to the object of our study - the two as yet unidentified economic mechanisms contributing to uneven development - is that there are two supply-driven economic endogenous determinants that contribute to uneven development. Both mechanisms are linked with the structural relationship between the level of development and international relative factor costs. Empirical research has consistently shown that the relative costs of capital, technology, and skills are lower in more developed countries and higher in less developed countries (Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997). In the Marxian framework, this can be explained by the fact that the mobility of labour is more constrained than the mobility of capital, technology, and skills, and the local relative costs of accumulating these factors of production are relatively higher in less developed countries.

The first explored mechanism in the dissertation relates to the link between uneven relative factor costs and technology diffusion. If technology is linked to the prices of technical factors of production, as explored by the approaches that study industrialization as expansion of the tasks that can be performed profitably by machines, leading to a direct relationship between wage levels and the substitution of machines for labour (Acemoglu, 2010; Acemoglu & Autor, 2011; Acemoglu & Restrepo, 2017a, 2017b, 2019; Sylos-Labini, 1984; Zeira, 1998), this can endogenously contribute to persistence of uneven development due to uneven distribution of relative factor costs and their effect on technology diffusion.

The second explored mechanism is linked with the endogenous patterns of international specialization in the globally interconnected economy, consistent with what Amin (1974) calls determinants of choice between "light" and "heavy" techniques, known in more current currents as "functional specialization." The main hypothesis of the dissertation is that relative factor costs are a major endogenous economic determinant of technology diffusion, functional specialization, structural change, and thus global patterns of uneven development. In this context, we are surprised that differences in relative factor costs have never been used in the contemporary growth and development literature as primary explanatory factors for functional specialization, intersectoral structural change, and technological growth patterns in the multiregional setting, despite ample evidence of their effect in the context of a closed economy (Sylos-Labini, 1984; Zeira, 1998). This dissertation aims to fill this yawning gap in supply-side economics.

There are 2 very broad groups of studies that aim to explain the persistence of uneven development endogenously. The first group focuses on endogenous dynamics primarily related to non-economic factors such as demography, education, institutions, or geography. The core of our dissertation (with the exception of the chapter 2) does not have the same object of study as these theories, since we focus our investigation on determinants primarily related to the functioning of the market. The second group is more relevant to our study because it focuses on endogenous economic explanations for uneven development. It includes various theories from different paradigmatic areas. In the first chapter, we provide a thorough overview of these approaches, which range from high development theory, various endogenous growth theories, evolutionary path-dependent approaches, the study of various transition dynamics, and the balance-of-payments constrained growth approach. These theories offer conceptual explanations for various endogenous mechanisms that contribute to

uneven development. We divide them into five broad groups:
1.) Dynamics of increasing returns to scale;
2.) Agglomeration dynamics;
3.) Multiple steady-state dynamics - development traps and path-dependent dynamics;
4.) North-South dynamics;
5.) Balance-of-payments constraint multiregional dynamics;

The increasing returns to scale are the most common form of functional inference of divergent economic dynamics in the growth and development literature. We can trace the analysis of increasing returns to scale back to Young (1928), high development theory frequently draws on increasing returns arguments and conceptualizations (Kaldor & Mirrlees, 1962; Myrdal, 1957; Rosenstein-Rodan, 1943), and a broad field of endogenous growth literature (Lucas, 1988; Romer, 1986, 1990) represents further attempts to study growth and development with increasing returns to scale as central assumptions. The main research object of this dissertation - the previously unidentified endogenous economic mechanism that contributes to the persistence of uneven development - does not operate because of increasing returns to scale and, to the best of our knowledge, has not been explored by the literature focusing on increasing return dynamics. There is a second major factor why the theories that focus on increasing returns are less relevant for exploring the functional features of our analysis. Theories of increasing returns focus predominantly on growth analysis in a closed economy and thus neglect crucial structural patterns and interdependencies that emerge in the context of globally connected and integrated countries in a multiregional context. Conversely, our research object (yet unidentified supply driven endogenous economic mechanism) functions in a multiregional setting, as its central patterns of functioning emerge in an international context.

Agglomeration dynamics are explored primarily in the fields of new economic geography, new trade theory, and urban and regional economics (Krugman, 1981, 1991; Krugman & Venables, 1995). Economies of scale and transportation costs drive various models of polarising dynamics that lead to industrial agglomeration. However, these dynamics do not apply to dynamics between large regional units. Some regional industrial agglomeration may contribute to dynamics within larger units, but it cannot explain long-term uneven development between countries and continents. The operation of the yet unidentified endogenous economic mechanism, which is the central research object of this dissertation, does not depend on the introduction of transportation costs and has nothing to do with the agglomeration dynamics studied in the above areas. In the research in these areas, we could not find any reference to the mechanism that we want to study and analyse.

Poverty trap thresholds are dynamic solutions to models that lead to multiple discrete steady states, typically a low (near zero) and a high steady state. The endogenous variables in these conceptualizations are often not primarily economic, such as endogenous fertility or education. Nevertheless, many poverty trap thresholds are derived from endogenous economic mechanisms, with the best examples being various conceptualizations of technology diffusion traps (Fagerberg, 1987; Frey, 2019; Gomulka, 1990). However, technology trap research has not identified and explored the relationship between relative factor cost dynamics and technology diffusion in the international setting, which is the focus of our study. The functional mechanisms used to derive the multiplicity of steady- states mostly rely on exogenous learning capacity (Fagerberg, 1987) or technological congruence defined by Abramovitz (1986). One of the contributions of this dissertation lies in the endogenization of uneven patterns of technology diffusion, which we present in a novel model that is the first to provide a functional derivation of technology adoption curves that are specific to the level of development and depend on relative factor costs. This is presented in chapter 3. Various elements of path-dependent technological development dynamics are explored primarily by neo-Schumpeterian evolutionary economics, but also by various fields that sometimes overlap with poverty trap dynamics, structural change dynamics, the dynamics of increasing returns to technology and innovation, and the dynamics of international trade (Araujo & Lima, 2007; Gabardo et al., 2020; Lorentz et al., 2016; Pasinetti, 1983, 1993).

North-South modelling (Darity, 1990; Dutt, 1989; Findlay, 1980, 1981, 1984), in contrast to the above approaches, is primarily concerned with international economics and trade. The researchers in this tradition assume a priori and exogenous differences in the structural characteristics of the economies of the North and South, from which they derive development outcomes. As a rule, growth regimes are assumed to have a different functional form for the North and the South. Choices include the neoclassical Solow-Swan model, the Lewis dual sector model, or modifications with some Kaleckian, post-Keynesian, or Marxian assumptions. For this reason, the divergent steady states they derive are neither truly endogenous nor purely economic, but arise from assumed structural differences among trading economies that are not only exogenous but could also be extra-economic in nature. Thus, at the level of conceptual analysis, their object of research does not correspond to the object of our study. However, some core insights into how structural differences, particularly differences in sectoral development, affect trade gains and development outcomes offer important insights for our goal to derive them endogenously and within the normal functioning of the market system.

Growth modelling with balance-of-payments constraints is a multiregional international trade framework that allows the analysis of trade and development in the context of international integration (Dutt, 2002; Spinola, 2020; Thirlwall, 1979; Vera, 2006). It is the field that deals with uneven development and its endogenous derivation in the multiregional international setting - thus it has a research object that is most similar to the research object of our dissertation. Structural change in terms of complex intersectoral dynamics, endogenous technology growth and diffusion, and complex international trade elasticities define a set of interrelationships and interdependencies that arise from the functioning of international markets and lead to uneven development (Araujo & Lima, 2007; Gabardo et al., 2020; Lorentz et al., 2016). However, there are some conceptual problems within this framework.

The balance-of-payments constraint approach to growth modelling focuses exclusively on demand-side processes and ignores fundamental supply-side factors such as endogenous technological progress, investment-driven progress and supply-driven structural change. This narrow focus on demand-side processes oversimplifies the complex issues of growth and uneven development. The development results of balance of payments constraint modelling rely exclusively on assumptions about international demand elasticities. While demand elasticities can explain some of the differences in output growth across regions, the underlying determinants of these elasticities are not fully understood and are likely related to both supply and demand factors, as international trade elasticities conceal the complex supply-side dynamics. In such models, it is therefore impossible to disentangle the supply-side effects hidden behind trade elasticities. Despite many similarities in the general approach, the object of our dissertation, unlike the balance of payments approach, lies entirely in supply-side economics and hasn't been identified in this field.

The object of our study are two endogenous economic mechanisms, driven solely by supply-side dynamics, that contributes to the perpetuation of uneven development, which, to our knowledge, has not yet been identified. The first relates to technology diffusion and its potential interaction and codetermination with the relative factor costs (Acemoglu & Restrepo, 2017a, 2017b, 2019, 2022; Zeira, 1998). The second relates to the operation consisting of several known and researched dynamic patterns and interactions, each of which has been described in isolated closed economy frameworks (Acemoglu & Guerri, 2008) or descriptively examined (Amin, 1974, 1976), as well as empirically evaluated (Timmer et al., 2019). The core idea behind the operation of the second studied supply-driven endogenous economic mechanism was expressed by Amin through the formulation of the question of the choice of technique in differently developed countries linked in the global capitalist economy:

It is the search for profit, and that alone, that leads central capital to establish light rather than heavy industries in the periphery. With the same productivity, wages are lower in the periphery than at the center. In a given branch of production, using the same techniques, the increase in profit resulting from emigration of capital from the center to the periphery will be the greater in proportion to the 'lightness' of this branch. It is this force that accounts for unequal specialization. (Amin, 1976, 233)

Amin's distinction between light and heavy techniques is not very clearly delineated. On the one hand, it supposedly reflects capital intensity, although it does not correspond to it. The distinction focuses on the relative potential for productivity growth within the given technological framework. Specialization in light or heavy techniques can be observed as functional specialization in specific sectors or, in a more globally integrated value-added economy, in specific tasks that produce intermediate goods. Relative capital or labour intensity is thus only the consequence of such specialization.

A more modern articulation of the distinction between 'light' and 'heavy' techniques is taken up by recent studies of international functional specialization (Timmer et al., 2019), in which the broad conceptual analogy to 'heavy' tasks might be capital-, skill-, or technology-intensive tasks. Studies of functional specialization empirically show that highly uneven functional specialization emerges when differently developed countries are subject to international economic integration. Such patterns lead to divergent development outcomes associated with path-dependent trajectories and technological lock-ins related to the middle-income development trap (Bárány & Siegel, 2018; Eichengreen et al., 2013; Hartmann et al., 2021; Krūminas et al., 2019; Myant, 2018; Timmer et al., 2019) or the club convergence hypothesis (Battisti et al., 2016; Quah, 1993). The theoretical understanding of how such uneven development is driven by autonomous, decentralized, market-driven processes is largely lacking in modern economics. Despite the empirical interest arising from the study of occupational data, functional specialization has not been studied as an endogenous, supply-driven economic phenomenon. We attempt to fill this gap by identifying and specifying the operation of the endogenous supply-side mechanism that economically generates uneven functional specialization patterns and thus contributes to the perpetuation of uneven development.

Our methodology for addressing the issue begins with the broadest possible identification of the elements that might endogenously contribute to such supply-side dynamics. Our broad structured survey, presented in chapter 1, identifies four main elements that appear to be fundamental to the operation of the object of our study:
1.) The nature of technological progress and the role of factor costs;
2.) The role of inter-sectoral heterogeneity and the dynamics it drives;
3.) The role of the law of value at the international level;
4.) The role of the international division of labour, as determined by relative factor costs.

Consistent with the identification of these elements, we set the following research hypotheses related to the endogenous mechanism that is the object of our study:

The first hypothesis states that in an environment of internationally integrated, differently developed countries, overall technological development and adoption of production technologies are structurally determined by the relative cost of production technology, which depends on the level of development.

Differences in technical composition reflect productivity differences and at the same time determine wage differentials across countries. On the other hand, heterogeneous capital goods flow back and forth between countries much more openly than labour power. This leads to different relative factor costs that depend directly on the stage of development (Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997). Since the relative costs of production technologies depend directly on relative factor prices, the relative costs of production technologies also depend on the initial level of development, which could be an important endogenous mechanism for maintaining uneven development because of the dependence of technology adoption on relative costs.

The second hypothesis states that sector- and task-specific development in the setting of internationally integrated differently developed countries is structurally determined by the differences in the level of development, due to the sector- and task-specific granularities and complementarities in the production constraint and the international difference in the relative factor costs. This endogenously leads to uneven functional specialization on sector- and task-specific level, which further perpetuates uneven technological development and adoption.

If the characteristic of each sector or functional task set is the unique impact of different technical compositions on labour productivity, then cross-country sectoral or functional specialisation could be endogenously determined by differences in relative factor costs as well as relative costs of production technology among differently developed countries. Such a development of uneven sectoral or functional specialisation of production could provide another dynamic endogenous mechanism for maintaining uneven development because of sectoral and task-specific functional differences in the potential for productivity growth.

The structure of the dissertation is as follows. In chapter 1, we undertake a comprehensive literature review in which we consider research and literature from different paradigmatic traditions that have addressed the issue of uneven development from both exogenous and endogenous perspectives, as well as from both intra- and extra-economic perspectives. This gives our research object a broad framework and relates it to various other endogenous mechanisms of uneven development that have been explored and may coexist alongside the main object of our dissertation.

The chapter 2 aims to further explore both economic and extra-economic endogenous mechanisms already identified in the literature in various paradigmatic areas, as summarised in detail in the first chapter. It provides a comprehensive empirical overview of various development trap threshold regimes that are empirically analysed using the logistic function to capture threshold and transition dynamics. The aim of the chapter is to delineate the relevance of the different development trap threshold regimes already studied for different levels of development. The main finding of this chapter is that the extra-economic threshold regimes studied explain a substantial part of the uneven development for low-income countries, while their explanatory power for middle-income dynamics is more limited. This establishes increased relevance to the study of the supply-driven endogenous economic mechanism, which is the main object of our study in the following chapters, as it could complement explanations of persistent uneven development examined by other intra- and extra-economic endogenous mechanisms, particularly in the context of persistent uneven development among industrially developed countries and regions.

Chapter 3 begins the core conceptual chapters of the dissertation. This chapter addresses the relationship between technological diffusion and uneven economic development across countries and aims to bridge the gap between theories of technology adoption (Comin & Hobijn, 2010; Griliches, 1957; Stokey, 2021), which focus on technology adoption curves but abstract from the macroeconomic dynamics of uneven development, and aggregate evolutionary approaches to technology and path-dependent uneven development (Fagerberg & Godinho, 2018; Verspagen, 1991) that focus on various technology traps and multiple steady-state dynamics, but with simplified and one-dimensional conceptualizations of technology that lack the explanatory power of individual country and technology adoption rates. We propose a novel dynamic conceptualization of technology adoption that draws on analogies to the physical process of heat or particle diffusion and incorporates the economic and social effects of uneven development as primary determinants of technology diffusion. We develop the concept of the space of relative costs of technology implementation to endogenously explain the emergence of technology adoption curves in the context of uneven development. Our main result is that relative wage levels significantly determine country-specific technology adoption curves and shape the socially uneven process of technology diffusion and overall development. We test the dynamic model and hypothesis using the CHAT and PENN databases and obtain robust results showing that technology diffusion is endogenously perpetuated by uneven development and that relative factor costs play a significant role in these dynamics. By bridging this gap in technology adoption research, we contribute to both streams of the literature - on the one hand, we succeed in reproducing the central evolutionary path-dependent dynamics, which in our case is even extended in comparison to discrete multiple steady-state dynamics and contains a whole continuum of different diverging steady-states, while on the other hand, we simultaneously endogenously derive the country-specific average technology adoption curves based on their level of development, which was never part of any technology adoption study before.

In chapter 4 we focus on the empirical assessment of the determinants of intersectoral structural change and its possible interaction with uneven development. We propose a novel multiregional structural input-output decomposition that decomposes the determinants of employment change into 19 distinct elements. The proposed structural decomposition contains several novel elements that contribute both methodologically to the field of input-output economics and empirically to the field of structural change and value chain research. Unlike most empirical input-output studies of structural change (Appelbaum & Schettkat, 1999; Raa & Schettkat, 2001; and Savona & Lorentz, 2005), our study focuses on both employment and output dynamics, which allows for a more detailed examination of supply-side effects than if only output changes were analysed. A novel protocol allows us to perform a series of simultaneous structural decompositions for all 44 countries in the WIOD dataset, enabling a new complex decomposition of trade and value chain dynamics simultaneously with the demand- and supply-driven dynamics of structural change. To the best of our knowledge, our study is the first to comprehensively combine all three elements. It evaluates stylized empirical indices that we develop to measure structural shifts in employment and output away from agriculture and from manufacturing toward services separately for each country in the sample. The key empirical contribution lies in the finding that the determinants of structural shifts from manufacturing to services are primarily supply-driven, which is at odds with input-output-based studies (Appelbaum & Schettkat, 1999; Raa & Schettkat, 2001; and Savona & Lorentz, 2005). The reasons why our study contradicts the empirical results could be multiple: first, most previous studies did not perform structural decomposition in real terms (with deflated values at the sectoral level for both final and intermediate output); second, because these studies do not look at the dynamics of structural change from the employment perspective but from the output perspective; and third, because the final demand component is not decomposed into its non-homothetic component, which theoretically drives the dynamics of structural change and various other final demand effects such as homothetic income effects, price effects, and changes in trade structure. Our main finding in this chapter is that the shift of jobs away from agriculture depends on different factors than from manufacturing to services. The shift of jobs from manufacturing to services is primarily due to supply-side effects, while the shift of jobs away from agriculture is primarily due to the non-homothetic preference structure of final demand. These results highlight the importance of studying the dynamics of supply-side structural change in the context of uneven development, especially in the context of uneven development among industrially developed countries that have already escaped the development trap of agricultural subsistence.

What follows is a conceptual chapter 5 that aims to examine the operation of the endogenous mechanism that is the object of our study within a Marxian framework. In chapter 5, the first objective is to analyze the dynamics of relative international factor costs that arise from differences in factor mobility across countries using a Marxian framework. This analysis will facilitate the integration of some Marxian assumptions with the neoclassical modelling framework used in the following chapter. The second objective is to expand upon

Amin's framework on functional specialization between light and heavy techniques and reframe it within an analytical Marxian framework. We propose a new conceptual reformulation of the international law of value, which is a price system in a Marxian framework. The approach incorporates both social and technical dimensions of the production process, arguing for a disaggregated production function while detaching the issue of social distribution from the technical aspects. In our framework, the distribution of income between the two classes is not determined by individual marginal productivity, but by the average national productivity of the tradable sector. While our wage theory is primarily Marxian and a generalization of the worldwide law of value, it also draws on the mainstream work of Samuelson and Balassa. While we acknowledge that individual marginal productivity and skill can influence wage levels within countries, our focus is on the social and economic effects of wage differentials between countries, especially those due to differences in national productivity rather than individual skill. The second main idea of this chapter is to try to extend Amin's descriptive framework and main arguments concerning functional specialisation to light and heavy techniques in the international economy. By reformulating the arguments presented in Amin's work only as descriptive arguments that often jump back and forth between different levels of abstraction (heavy/light, capital-intensive/labour-intensive, high productivity/low productivity) within a precise Marxian framework of analysis, we set the preconditions for further reformulation that would be suitable for introduction into multiregional dynamics modelling framework. The main conceptual discovery that allows us to finalise and bring together all the dynamic components of the functioning of our research object - the supply-driven endogenous economic mechanism that contributes to the persistence of uneven development - is that functional specialisation and the distinction between different groups of techniques are not directly related to their capital intensity or productivity, but to their medium-term differences in the production constraints that lead to these differences phenomenally. From this point, we develop an alternative aggregate production function that, unlike the smooth neoclassical production function, is granular: it consists of different complementary sets of tasks that exhibit medium-term differences in their production constraints. This reformulation represents a fundamental novelty that we use to endogenously derive the persistence of uneven development due to uneven functional specialisation, which is reinforced by the effects of structural change in the international multiregional modelling framework presented in the next chapter.

In the final chapter 6, we merge all the main findings from the analyses of the previous three chapters to explore the dynamic operation of our studied endogenous dynamic mechanism in the multiregional modelling framework. We begin our derivation using a neoclassical model for a closed economy from Acemoglu and Guerri (2008) as the basis, because a steady-state model allows an introduction of the granular supply constraint explored in the previous chapter. Modifying the neoclassical model and extending it into a multiregional setting, allows analysis of how the specific properties of the modified production constraint and its interaction with trade specialization leads to persistent uneven development. It is also easier to extract the effects of the modifications from the reference model if it is a convergent steady-state model than if the reference model already contains elements of other endogenous mechanisms that contribute to uneven development that have already been extensively explored in the literature. The main idea of this chapter is to capture the endogenous functioning of the supply-side functional specialization characterized by a granular production constraint, supply-driven dynamics of structural change, international trade, and global value chain integration. To this end, we attempt to model the object of our study under *ceteris paribus* conditions. We modify the neoclassical reference model with additional Marxist and evolutionary assumptions and modifications that represent the core dynamics explored in the previous chapters, extend the model to include several regions to account for trade- and value-chain-driven dynamics, and introduce tradable and nontradable sectors, to account for Balassa-Samuelson effect. The core model presented in chapter 6 is not a growth model and we do not interpret its results deterministically. Conversely, the purpose of the modelling is to focus on a narrow specific question - how does granular production constraint and its interaction with relative factor prices in the international setting of differently developed countries endogenously contribute to persistence of uneven development in competitive markets. The results reveal the complex functional patterns that emerge even under conditions of diminishing returns to investment. The granularity of the production constraint and its interaction with relative factor costs can endogenously lead to functional specialization that contributes to the persistence of uneven development across the whole distribution of development inequality and can lead to feedback loops in technology, technique and functional specialization that function as lock-ins in both low, middle, upper-middle, and even among high income countries.

Because we draw from different economic traditions, our overall contribution to the literature is different from each paradigmatic perspective. In the field of Marxian economics, we contribute by first transforming Amin's descriptive framework into Marxian analytical framework and then formulating his ideas in the final chapter in terms of granular production constraints and specific assumptions about factor markets. From the Marxian analytical perspective, steady-state economics and rationality have always been the starting point for various analytical derivations that reflect the core components of the Marxian paradigm (Roemer, 1982). While many current and earlier Marxian approaches rely on disequilibrium and agent-based analyses (Chiarella et al., 2005; Cogliano et al., 2018, 2022; Flaschel, 2008; Flaschel et al., 2012), our goal of deriving the previously unidentified endogenous supply-driven mechanism as a normal steady-state operation of the market mechanism led us in the direction of combining ideas and assumptions from the analytical foundations of Marx and Amin's choice of technology analysis and the basic neoclassical supply-driven structural change model (Acemoglu & Guerri, 2008).

The contribution to the mainstream supply-side literature lies in the exploration of the specific functional form of the production constraint that leads to the persistence of uneven development. The functional form of granularity is indirectly corroborated by the empirical chapter 4, where we find empirical evidence that supply-side productivity growth is not only highly uneven across sectors, but also has direct implications for employment patterns. While supply-side heterogeneities have been studied extensively theoretically (Alvarez-Cuadrado et al., 2017, 2018; Baumol, 1967; Ngai & Pissarides, 2007), this has always been in a macroeconomically homogeneous or even closed economy setting. How supply-side structural change dynamics and granular production constraint relates to relative factor prices, endogenous functional specialization in the context of integrated, differently developed economies or regions has never been studied. Our contribution within the mainstream literature can therefore be seen as extending the supply-side understanding of structural change to a multi-regional setting, where the interaction between supply-side dynamics and their heterogeneous granular structure and the dynamics of global value chain specialization contributes to persistently uneven development even under general conditions of diminishing returns to investment. The converging dynamics assumed by the neoclassical production function are systematically counteracted by the feedback loops and lock-ins driven by endogenous specialization patterns.

Our main contribution to the evolutionary tradition is presented in chapter 3. We reformulate the core ideas from Verspagen's (1991) evolutionary investigation of how technology diffusion leads to discrete multiple steady states, and combine them into a classical form of the diffusion equation drawn from the general econophysics tradition. With this novel conceptual reformulation, we reconcile two different approaches to the study of technological diffusion and uneven economic development across countries. The first approach focuses on technology adoption curves and ignores macroeconomic dynamics (Comin & Hobijn, 2010; Stokey, 2021), while the second approach explores path-dependent uneven development and technology traps but does not provide a comprehensive understanding of individual country and technology adoption rates (Fagerberg & Godinho, 2018; Verspagen, 1991). By bringing these two approaches together, we can better understand the interplay between technology diffusion and adoption and economic development. Our approach captures the full range of path-dependent dynamics and a continuum of multiple steady-state dynamics, while deriving country-specific curves of technology adoption based on their level of development. This synthesis contributes to both areas of study and provides a more nuanced and comprehensive understanding of the complex relationship between technology and economic development.

Aside from the specific contributions to various research paradigms, the most important contribution of this dissertation is the identification, exploration, and study of the operation of a supply-driven endogenous economic mechanism that has not been explored by any paradigmatic field. This discovery and its conceptual formulation represent an objective mechanism that we should better understand, and our investigation provides some evidence not only for its existence, but also for its concrete mode of operation. This could have significant implications for our understanding of the uneven development invariant to the paradigmatic field. It also complements the more demand-driven approaches within the balance-of-payments constraint framework by offering a fully supply-side explanation for the phenomena under study.

The extensive literature on uneven development and growth from various paradigmatic approaches has provided explanations for many endogenous mechanisms that contribute to the perpetuation of uneven development. Our discovery and investigation provides insight into previously unidentified complementary mechanism that is relevant to both the persistence of the developmental differences between industrialized countries as well as to subsistence trap economies, as it complements our understanding of uneven development in addition to other mechanisms that were already explored by the literature.

Chapter 1

The Endogenous Mechanisms of Uneven Development: Structured Survey

1.1 A broad overview of the research field

The research field of the dissertation is broad and draws from various approaches in international economics, development theory and macroeconomic growth theories.

Our work is not limited to a single theoretical tradition. We draw ideas, conceptualisations and insights from Marxist theory, high development theory, neoclassical endogenous growth theory, structural change theory and theory of technological change. Our structured review aims to present the broad contribution of each paradigmatic approach to understanding the mechanisms that contribute to the persistence of uneven development, while exploring the more specific literature in each of the chapters according to related topics.

While there is an extensive body of research and literature that examines various exogenous determinants of growth, from the broadest institutional factors to the political environment to geography and culture (Acemoglu et al., 2001, 2005; Acemoglu & Dell, 2010; Acemoglu & Johnson, 2005; Barro, 1996; North, 2005), in addition to the literature we have examined, our study focuses primarily on the literature that examines the endogenous determinants of uneven development. By endogenous factor, we mean that it is driven by the functioning of decentralised, market-based decision-making and is methodologically inferred as part of the functioning of the model interaction, rather than assumed or predetermined.

1.2 Historical materialist approach

The relationship between the theory of Marx and Engels and the question of development, especially uneven development, has been the subject of dispute and different interpretations. On the one hand, it has often been assumed that their theory of history is teleological in character, leading technically from one stage to the next (Avineri, 1968). One of Marx's main themes was his study of the characteristics and driving forces of the technological dynamics specific to the capitalist mode of production and the impact of capitalist social relations on the development of the productive forces (Marx, 1992, 1993a, 1993b, 1993c). This has led many scholars to call his approach "diffusionist" or even to assume he predicted long-term convergence (de Paula, 2015). This interpretation of Marx's work asserts that the functional logic of development is tied to the capitalist mode of production and that because of his prediction of the widespread diffusion of capitalist relations, the effects would eventually lead to the development of industrial capitalism with converging labour productivity throughout the world (Brenner, 1977; Brewer, 1990; Foster-Carter, 1978). For this interpretation, the role of noncapitalist social relations in explaining uneven development is essential.

The second interpretation claims that Marx developed a multi-linear theory of history that allows for various complex interactions between social formations and different modes of production. This interpretation focused on Marx's notion of internal contradictions in the development of productive forces and examined the processes of underdevelopment and uneven development as phenomena characterized by and driven to a large extent by the specific development of capitalist social relations. This established a link between Marx's approach and the early theory of dependency.

The main contribution of the early classical Marxist authors to the study and conceptualization of uneven development is mainly in the theories of imperialism. Rosa Luxemburg (2003) put forward two main theses in her attempt to expand the theory of capital accumulation. She claimed that all surplus value cannot be realised within the limits of a given scale of the capitalist mode of production and necessarily requires expansion - which can be internal (subsuming non-capitalist parts of the economy) or external (expanding markets abroad through imperial expansion). Thus, the expansive character of the capitalist mode of production implied that the imperialist form is a direct consequence of the internal laws of capitalist development, leading to a geographical expansion of the capitalist mode of production. What Marx called the process of primitive accumulation is for her not only a historical development of the preconditions for the emergence of capitalist social relations, but a permanent process in which pre-capitalist social relations are subsumed under the expanding capitalist mode of production. Hilferding (2007) formulated the main line of argumentation of the theory of imperialism, which was later popularised by Bukharin and Lenin (Lenin, 2004, 2018; Luxemburg & Bukharin, 1972). He claimed that capitalist competition tends to create monopolies in the form of conglomerates of financial, industrial and commercial capital in conjunction with banks. This form of monopoly capital relies heavily on state interference to protect it from outside competition, transforming market competition into an interstate struggle for the expansion of domestic markets, protectionist measures, and other extraction privileges, and inevitably turning it into a struggle for territories and colonies (Hilferding, 2007). Among the classical Marxist authors, Trotsky was the only one who directly addressed the issue of uneven development. He argued against the mechanistic understanding of the stages of development and claimed that the expansion of the capitalist mode of production produces uneven and combined development. With this concept, he aimed to capture the interlocking divergent and convergent tendencies in development, the ability of capitalist forms to subsume other country-specific social forms, and the discrete nature of social progress and development (Trotsky, 2008). The concept of uneven and combined development forms the basis for Mandel's (1995, 1999) specific approach to uneven development as well as contemporary Marxist economic geography (Harvey, 2005, 2011, 2017; Pavlínek, 2018).

The conceptualization of monopoly capitalism by the early Marxist authors had a great influence on the development of dependency theory, which was advanced by the research of the American Marxists (Baran, 1957; Baran & Sweezy, 1966; Frank, 1966). Technological progress was at the forefront of their investigations. Dependency and underdevelopment were analysed through the prism of the periphery's inability to develop and adopt technologies that would enable its autonomous development. Underdevelopment was conceptualised as not merely the absence of development, but a development of a special kind - a development driven by the interests of the developed regions (Frank, 1966). Later, this approach converged to the world-system approach, which conceptualises a single capitalist world-system with its core and periphery as its constituent parts (Wallerstein, 2011a, 2011b, 2011c).

The uneven division of labour and the unequal skill composition of labour between the centre and the periphery is a feature of a dependency maintained by the monopolistic structure at the centre and its monopoly over technology. Baran and Sweezy have departed from Marx's theory of value and developed their own, different conceptualization of surplus. In doing so, they seek to explain how the immense development of productive forces in developed regions increasingly expanded into ever increasing surplus consuming activities that further reinforced the non-equalising dimension of global capitalist development (Baran & Sweezy, 1966). In this tradition, Rodney (2018) examined the fundamental determinants of Africa's underdevelopment. He found that the effects of slavery, colonialism, and, in particular, the extractive nature of imperialist rule were the main factors underlying the development trajectory of the African continent.

Concurrent with the development of dependency theory by U.S. Marxists, similar theoretical streams emerged in Latin America, later referred to as Latin American structuralism (Cardoso & Faletto, 1979; Furtado, 1977, 2020; Prebisch, 1950, 1959). Beginning with the work of Prebisch and Singer and their famous study of how trade elasticities constrain the growth of the periphery, the tradition largely followed the ideas of dependency theory and later merged with the world-systems approach.

A different approach to uneven development was defined by Emmanuel's Unequal Exchange, in which he applied Marx's law of value to an analysis of differently developed regions and their interaction in international trade. His main idea is based on the enforcement of a uniform rate of profit between countries. Because of the assumption of the immobility of labour, this leads to two types of international transfer of value. The first is defined by the uneven organic composition of capital and the second arises from the uneven level of wages. The approach has been heavily criticised for its uncritical application of the functioning of the law of value to the international environment (Andersson 1976; Bettelheim 1972; Shaikh 1980; 1979).

Amin analyzed the uneven development in a similar context (Amin, 1974a, 1974b, 1979, 2010). On the one hand, he wanted to adapt the theory of value to take into account the criticism of Emmanuel's approach. For this reason, he focuses on wage differentials, which are larger than productivity differentials between countries, and finds these wage differentials as the main source of the imperialist rent that accrues to capitalists in developed countries. On the other hand, he conceptualized the world capitalist mode of production as a totality characterized by the division into core and periphery, in which the processes of capital accumulation, technological progress, productivity growth, and overall development is determined by the structural needs of the core countries. For him, the structural features that contribute to the persistence of uneven development are related to the development of monopoly power, differences in the organizational structure of the working class and the power to influence wages, and the different structures of social formations, with his characterizations of the periphery often exhibiting pre-capitalist elements and modes of production. The role of pre-capitalist forms in underdeveloped countries is particularly important in explaining differences in the utilization of surplus. Surplus value generated in a capitalist mode of production has an internal tendency to be utilized in the form of capital accumulation, while surplus generated in pre-capitalist forms tends to be consumed, especially in the form of conspicuous consumption by the elite. Research that addresses the question of capitalist and pre-capitalist social forms in the context of uneven development usually draws on the insights of social anthropology and is linked to the question of articulation (Berman, 1984; Foster-Carter, 1978). The concept comes from the structuralist Marxist tradition and the concept of social formation, which consists of several modes of production, one of which is dominant (Althusser, 2014; Balibar, 2016). These approaches emphasize that the existence of pre-capitalist modes of production not only persists, but must be treated as integral to the functioning of the global capitalist formation, and is sometimes even encouraged by developed capitalist countries (Foster-Carter, 1978; Hirst & Hindess, 1979; Meillassoux, 1972, 1981; Rey, 1979). The qualitative dimension of what in contemporary high classical development theory is usually regarded only as an assumed quantitative difference between differently developed countries - a difference in savings rate, demographic trends, and access to industrial economies of scale - has usually been studied in Marxist theories of uneven development as structural features of the social formation and its specific combinations of different modes of production with their internal laws of functioning.

1.3 High development theory

High development theory is a theory of growth and development developed in the 1940s and 1950s of the previous century. It is mainly concerned with the theory of industrialization and development under conditions of underdevelopment and predominantly agrarian production. The core arguments of this theory are based on the concept of external economies of scale, which lead to potential poverty traps that can endogenously perpetuate uneven development. Industrialization, modernization, and the structural changes that accompany them are seen as self-reinforcing processes. The high development theories have been used to reinforce government-driven industrial policies and modernization programmes that aimed to push underdeveloped countries out of the poverty trap. The main features of early development theory lie in the analysis of the duality and structural differences between subsistence-oriented agricultural production and modern industrial development.

Classical development theory begins with the approach of Rosenstein-Rodan (1943). His conceptualisation of external economies of scale is a combination of demand- and supply-driven factors. As is characteristic of all classical development theory, he conceptualises the duality between traditional (subsistence) and modern (industrial) techniques.

Production of the former is characterised by scale effects and can afford higher wages. His main idea, which captures the cumulative causation of the pre-industrial poverty trap, is that market size (demand effect) determines the profitability of large industrial firms that exhibit scale effects. Moreover, development is conditioned by discontinuities and discrete jumps. Therefore, industrialization in general cannot start slowly and gradually, but must reach a size that allows further industrialization due to the effect of market size. Consequently, this theory advocated a policy of so-called "big push" to industrialization, i.e., that entire sectors, as opposed to firms, should be the subject of a massive and coordinated investment programme to break with traditional techniques and achieve self-sustaining industrialization (Murphy et al., 1989).

The second important contribution to classical development theory is the two-sector model of Lewis (1954). In contrast to focusing on the increasing returns of industrialization, Lewis conceptually focuses on the structural dualism that characterises underdeveloped economies. On the one hand, there is a subsistence sector that includes not only subsistence agriculture, but also domestic services, a plethora of local barter and crafts, and unpaid domestic labour. The basic idea is that in this sector the marginal productivity of labour is zero and that there is hidden unemployment in this sector because employment in the subsistence sector is determined by communal social forces (prestige, local arrangements, customs, etc.) rather than market forces. All workers are paid subsistence wages. On the other hand, there is the capitalist industrial sector that coexists with the subsistence sector. It is dominated by market forces and marginal productivity determines income, with wages above subsistence levels. Capitalist investment and job displacement have positive externalities by reducing hidden unemployment in the subsistence sector and thus increasing aggregate productivity, reinforcing the virtuous cycle without direct assumptions about scale effects (constant returns are assumed in the industrial sector).

Myrdal (1957) approaches the development problem from a similar standpoint. He claims that there is a tendency for wealthier countries to become wealthier and poorer countries to become poorer. He conceptualises this process in terms of a theory of cumulative causation, which indirectly relies on the scale effects of growth and also incorporates elements of unequal exchange theory. It conceptualises two driving forces of polarisation, the spread effect, i.e., the element of increasing returns, and the backwash effect, i.e., the effect that reduces growth prospects in the periphery due to interaction and integration with more developed regions. The main conclusion of this theory is that neither international trade alone nor the market-oriented functioning of the capitalist economy based on the profit motive within a region can overcome the logic of cumulative causality. Instead, state intervention is a necessary element of development policy.

Demography has also been considered one of the most important factors in understanding the development process. Nelson (1956) examined a model of the demographic trap in which the subsistence economy is caught in a trap: increases in income due to savings and investment lead to increased population growth, which keeps relative per capita output in a steady state of the poverty trap. To break out of this trap, a larger increase in income relative to population growth is required.

An important discussion of the period dealt with the policy issue whether development toward industrialization should be balanced or concentrated in a few particularly productive sectors. Proponents of balanced growth (Nath, 1962; Nurkse, 1953; Rosenstein-Rodan) based their arguments on big-push theory, which focused on market size, while proponents of unbalanced growth, of whom Hirschman (1958) was the most prominent, argued for an unbalanced approach. His conceptualization included backward and forward linkages between firms (firms linked with intermediate demand) that generate external effects of scale within the economy. According to Hirschman, backward or forward value chain linkages between industries occur when at least some scale effects exist and the expansion of such linkages further increases the external scale effect associated with specialization.

Rostow's (1959, 1971) theory of stages of growth does not contribute much to understanding the specific mechanisms that drive or block development, but instead provides a comprehensive classification of the various stages of development. He conceptualises five stages of modernization, from traditional subsistence society, through the intermediate take-off (associated with escape from the development trap), to the final stage of maturity and mass consumption, to which he later added a final stage of the search for quality improvements. In a theoretical sense, the stages are presented as teleological sequences, without taking into account the structural specifics of development in the different stages and the complex effects of international interaction when countries in different stages of development compete and cooperate with each other.

Despite the lack of inclusion of the economies of scale in the formal models of early development theory, external economies of scale represented a fundamental aspect of the reasoning of the vast majority of classical development theorists. The most comprehensive conceptualizations of the effects of increasing returns can even be traced back to the early classics of political economy. Smith's (2018) views on the importance of market size, specialisation, and the effects of the increasing division of labour implicitly follow the form of the external effects with increasing returns. The arguments regarding the role of increasing returns are formulated directly in Young (1928) and implicitly in the arguments of Nurkse, Rosenstein-Rodan, and Myrdal, the latter of whom summarises the ideas in the concept of circular cumulative causality.

After the 1960s, developmental theory was in decline and gave way to more formal methodological approaches. The sheer complexity of the structural differences in the different stages of development made it difficult for developmental theorists to approach the problems in a mathematically exact way. There were two authors who paved the way for further formalizations of the study of the mechanisms of uneven development. Kaldor, who focused on the functioning of increasing returns to manufacturing, and Findlay, who attempted to translate the general ideas of high development theory into formal models, resulting in a series of North-South models.

1.4 Structural North-South models

In the 1970s and 1980s, the inability of neoclassical theory to adequately address uneven development and persistent international inequality among countries led to work on North-South structural models of growth and trade. This area lies at the intersection of development theory and international trade theory. The main difference between the neoclassical framework and the North-South models is that the latter take into account the structural and institutional differences between countries at different stages of development. The main objective of North-South models is to identify a fundamental asymmetry between the developed and developing regions that goes beyond mere factor endowments and fundamentally affects the development and distribution of benefits from international trade. This leads to models in which differently developed regions converge to different steady states, factor prices do not equalise as predicted by neoclassical trade theory (according to the factor price equalisation theorem - Lerner, 1952; Samuelson, 1948), and in some cases, involvement in international trade may contribute to even greater divergence between the North and the South and contribute to the perpetuation of uneven development.

The formal development of North-South models can be traced back to the attempt to incorporate trade into the neoclassical Solow-Swan growth model. Ruffin (1979) created a symmetric 2-country Solow-Swan model with a single good and differences in saving rates driving intertemporal optimization. Because of the assumed symmetry, the growth rates and incomes of the two countries are identical in steady state.

Starting with the idea of combining growth models and integrating them into an international trade framework, Findlay laid the foundation for stylized North-South modeling (1980, 1981, 1984). Essentially, his models are an examination of the terms of trade in dynamic equilibrium. His benchmark North-South model consists of two structurally distinct economies linked by international trade. The first is characterized by the Lewis's dual sector production structure with an unlimited supply of labour that produces primary goods, while the second has a neoclassical Solow-Swan production structure and produces an investment good for both regions. Due to international specialization, the South specializes in agricultural output produced by traditional techniques, while the North has its own steady state determined by its internal savings and investment rate. The growth rate of the developed region, characterized by the neoclassical production function, determines the growth rate for both regions, as the growth of the less developed region takes the form of a mere spillover of the development of the industrial region. The growth of the subsistence economy of the South depends on manufacturing imports from the North. Steady-state per capita output converges to different steady-states with a common steady-state growth rate, indicating a persistent and stable long-term output gap between the regions.

Many extensions of the benchmark North-South model were attempted in the 1980s and 1990s. Darity (1990) further extends Findlay's framework by changing the structure of the North from the neoclassical Solow-Swan structure to Keynesian and Kaleckian structures, first by dropping Findlay's assumptions of full employment and full natural long-term growth rate, and second by making an investment function conditional on the rate of profit and assuming profit equalization as opposed to the natural long-term growth rate. This leads to even greater divergence between regions with different levels of development, as even the relative gap between output in the North and South widens. Similar attempts to introduce capital mobility by assuming profit equalization lead to the same results-regional technology, savings, and demand shift in ways that negatively affect the terms of trade for the less developed region (Burgstaller & Saavedra-Rivano, 1984).

Wooton, (1985) examined a dynamic general equilibrium model of the North-South world economy with constrained labour mobility. His analysis shows that restricted labour migration has no effect on the terms of trade in the long run and can be beneficial to both the North and the South. However, this is under the assumption that there are no differences in wage rates between domestic and immigrant workers. Abe (2005) integrates restricted labour migration with free capital flows (Burgstaller & Saavedra-Rivano, 1984) into the North-South benchmark model and arrives at substantially different results than Wooton. He shows that allowing for labour migration is in the long-term interest of the developed region.

There are a number of similar variations of the benchmark North-South model (Taylor, 1983; Whalley, 1984). Taylor (1981) constructed a three-country model with three goods and complete specialization, with a separate oil-producing region, to study the effects of the oil shock on the terms of trade and uneven development. Most North-South models have the feature of general equilibrium under asymmetric structural growth conditions in different regions. The feature of North-South models is the study of multiregional growth in a context of complete specialization. The differences between the models are mainly at two levels. First, the assumed structural differences between regions. The options for structurally defining the differences in the functioning of the economic system in the North and South are limited. The most commonly used assumptions are either the neoclassical

Solow-Swan assumption with full employment, the Keynesian assumption of the dependence of investment on the desired rate of accumulation at the firm level, the vulgar Marxist assumption of a fixed subsistence wage level, or the Kaleckian framework of capacity utilization (Dutt, 1989).

Krugman's (1981) approach to international trade, which initiated a turn toward a new trade theory, makes similar assumptions to the North-South models. Manufacturing is assumed to have increasing returns to scale and agriculture is assumed to have diminishing returns to scale. His model not only explains why most trade occurs between countries with similar factor endowments (scale effects in manufacturing), but also provides a pattern of uneven specialisation. Initial differences in development lead one region to specialise entirely in manufacturing and take advantage of scale effects, while the other region restricts itself to agricultural production. The application of North-South modelling to international trade led to the development of the field of new economic geography (Krugman, 1991; Krugman & Venables, 1995). The main feature of these multiregional studies is the use of the Dixit-Stiglitz benchmark model (Dixit & Stiglitz, 1977) for production and the inclusion of over-the-top transportation costs to analyse how centrifugal and centripetal forces create agglomeration patterns - the concentration of industry clusters in just one region.

Because stylized North-South modelling is situated at the intersection of international trade, growth, and development economics, it simultaneously addresses issues of development, growth, production structure, institutional structure, and trade and distribution. The North-South models examined, in the tradition of Findlay (1981), focus primarily on the study of uneven development as a result of structural differences within the economic structure, including the determination of employment, wages, profits, capacity utilisation, rates of accumulation, etc. There are two similar traditions that focus on the examination of uneven development in the context of strict equilibrium models of trade. The first is Kaldorian growth modelling, which examines differences in returns of scale across the sectors in which countries specialise. Conversely, the second, closely related framework places greater emphasis on trade dynamics and growth under conditions of increasing returns, modelling the differences between North and South economies and emphasising demand-side factors. The second approach can be roughly labelled as the balance-of-payments constraint trade approach.

1.5 Kaldor's approach to growth and uneven development

Kaldor's approach to theory of growth differs markedly from the neoclassical approach followed by his contemporaries. His critique of the neoclassical Solow-Swan approach was formulated on two levels. The first criticism relates to the conceptualization of technological progress as separate from the exogenous part of technological change and the endogenous changes in factor shares. Thus, the main driving force of aggregate growth that drives the benchmark neoclassical model remains unexplained or, rather, is assumed. Second, Kaldor rejected the notion of capital as a homogeneous and linearly additive substance through which productivity growth is generated.

Kaldor's critique, and to some extent his solution, captured the core ideas of what would decades later become known as the endogenous growth approach. In his seminal article, he defined a function of technological progress by defining productivity growth as an increasing convex function of the difference between the capital stock and employment (Kaldor, 1957). The function of technical progress is an attempt to overcome the separation of growth attributable to technical change and that attributable to capital accumulation and to link them instead. In doing so, he captured the idea of growth driven by increasing returns. However, the technological progress function was still reducible to the neoclassical Cobb-Douglass production function as a linear approximation, and the long-term steady state was determined by exogenous technological growth, similar to neoclassical growth. The main difference was the nonlinear form, which led to path-dependent growth trajectories with stable differences in aggregate output, growth rates, and productivities (Black, 1962).

Because of stability problems, Kaldor and Mirrlees (1962) proposed a different function of technological progress, conceived as productivity progress driven by qualitative improvements in machinery. With this formulation, Kaldor and Mirrlees moved further away from the neoclassical conceptualizations of aggregate production functions with marginal productivities and derived aggregate growth without any reference to capital accumulation. However, similar to Kaldor (1957), the steady-state growth rate is reducible to the neoclassical steady-state values, leaving the same conceptual problem in a different form (Black, 1962).

Kaldor's assumptions are indirectly linked to Verdoorn's (1980) law, which states that long-term productivity growth is linearly related to long-term output growth. In its formulation, Verdoorn's law (often referred to as Kaldor-Verdoorn's law) essentially summarises the idea of increasing returns within manufacturing and not only represents one of the fundamental points of many Kaldorian growth models that are export driven, but is also an important conceptual building block within the balance-of-payments approach that examines the international implications of Verdoorn's law. However, the link between Verdoorn's law and Kaldorian growth due to increasing returns is overshadowed by the conceptual problems associated with the existence of the aggregate production function raised by the capital controversy, as well as the difficulties in empirically examining the technological progress function or Verdoorn's law due to accounting constraint problems (McCombie & Spreafico, 2016).

Kaldor's extensive research into development and modern growth led him to formulate his famous stylized facts of modern growth, which can be briefly summarized in the following points. The "share of wages and the share of profits in the national income has shown a remarkable constancy in "developed" capitalist economies...(1957: 591)." Also, "...the value of the capital equipment per worker (measured at constant prices) and the value of the annual output per worker (also in constant prices) are steadily rising, the trend rates of increase of both of these factors has tended to be the same, so as to leave the capital/ output ratio virtually unchanged over longer periods. Constancy in the share of profit and in the capital/output ratio also involves constancy in the rate of profit earned on investments (in the "marginal efficiency" of capital), and this again appears to be confirmed by empirical investigation.(1957: 592)"

Kaldor's (1970) research demonstrated that differently developed regions grow very unevenly and that relative differences increase over time. He uses the concept of circular and cumulative causation (Myrdal, 1957) to show that opening up of differently developed regions or countries leads to faster progress of the more developed at the expense of the underdeveloped region or country. He developed a world economy model of structural North-South full specialization (Kaldor, 1976, 1978, 1979). His main assumptions for the asymmetry are differences in returns to scale, with the North producing industrial output with modern technique with increasing returns and the South producing primary output with decreasing returns (Kaldor, 1978).

There are several extensions of Kaldor's model of uneven development. Conway and Darity (1991) use Kaldor's notion of asymmetric returns to scale to study uneven development in a model that has similar features and conclusions as Findlay's North-South model. Molana and Vines (1989) examine a North-South model with a surplus labour in both the North and South regions and with exogenously determined wages, taking into account the substitution of consumption between the outputs of each region. The model examines endogenous cycles driven by the low price elasticity of demand for primary products. Canning (1988) examines a model in which diminishing returns in agriculture and increasing returns in industrial sectors create complex effects on growth dynamics. He identifies a development trap at the phase of transition from predominantly agricultural production to industrial production due to low agricultural productivity. If a region manages to break out of the development trap, the increasing effects of the manufacturing sector prevail in the long run, allowing for increasingly cheaper investment in the agricultural sector, which enables long-run growth despite the assumed diminishing returns in agriculture. Thirlwall (1986) developed a model of export-led growth based on Verdoorn's law and the basic Kaldorian assumptions of uneven returns to scale between agricultural and industrial production. In the model, an expansion of the export sector leads to specialisation in the production of export products, which increases productivity due to effects of increasing returns. The productivity growth creates further potential for labour to shift from the traditional sector of primary goods production to the export-driven sector, creating a positive feedback loop of export-led growth due to increasing returns. These models have been the subject of various extensions and applications (Atesoglu, 1994).

1.6 Balance-of-payments constraint growth

The classical approach to political economy and Ricardo's assumptions about international trade and comparative advantage lead to a deterioration of the terms of trade for the country that has increasing returns and consequentialy falling prices (Ricardo, 2004). In terms of Kaldorian North-South models, this would imply a deterioration of the terms of trade for the North. To account for the actual distribution of gains from trade, structural differences in demand factors between the differently developed regions must be assumed. The field that studies the uneven development and distribution of gains from international trade by introducing structural differences between North and South on the demand side is commonly referred to as the balance-of-payments constraint growth approach.

The systematic inclusion of the demand factor in the examination of international trade can be traced back to the beginnings of the dependency theory that would later become known as the Prebisch-Singer hypothesis. The core idea of this approach is that manufactured goods produced by the North have a higher income elasticity of demand than primary goods produced by the South. Thus, global growth that raises income causes demand for manufacturing goods to rise faster than demand for primary output. Because of the balance of payments constraint, this leads both to a deterioration in the terms of trade for the South and to constrained lower growth rates that perpetuate uneven development in the long run (Prebisch, 1950, 1959; Seers, 1962; Singer, 1950).

The basic framework of the vast majority of balance-of-payments constraint growth approaches to trade is the mathematization of Kaldor's stylized North-South approach with export-driven growth, defined most clearly by Dixon and Thirlwall (1975). However, their approach still lacks the direct implementation of the balance of payments constraint, which allows for long-term unbalanced flows across regions and countries. The benchmark growth model with balance-of-payments constraint is presented by Thirlwall (1979). In his model, trade elasticities and foreign demand growth determine and constrain each country's long-run growth rate. Trade elasticities in this framework represent more than consumption preferences, but also capture technological capabilities and scale effects associated with specialization. Cross-country differences in trade elasticities can lead to multiple steady states of long-run growth rates. The main prediction of the model is that a country's output growth is approximately equal to the ratio between export growth and the income elasticity of import demand.

Several extensions of the models have been proposed. Araujo and Lima (2007) extended the model by disaggregating it into a multisector balance-of-payments constraint model. The approach is largely based on the sectoral and demand driven conceptualizations of Pasinetti (Pasinetti, 1983, 1993). Disaggregation across sectors allows for the study of demand-driven unequal specialization - not only do aggregate trade elasticities impose a constraint on growth, but also the sectoral composition of output. Therefore, less developed regions can reduce their growth constraint by structural cross-sectoral relocations of its output to sectors with higher income import elasticities of demand. This approach is one of the rare attempts to model international specialization taking into account explicit sectoral structures.

Another way to extend the basic model is to allow for capital flows and debt accumulation. Thirlwall and Hussain (1982) introduce a growth model with balance of payments constraint that allows capital inflows without debt accumulation restrictions. Moreno-Brid (1998) further modifies the model by incorporating a realistic constraint on the level of debt. To consistently close the balance of payments constraint, Elliott and Rhodd (1999) consider a flow of interest payments based on the foreign capital stock and implement debt service costs in the model. Another extension includes remittances from migrant workers and examines the dynamic feedbacks between the size of remittances, domestic income, and global aggregate income (Alleyne & Francis, 2008).

Various adaptations of the basic framework of the model, focusing on an open economy on the one hand and on the rest of the world on the other. Nell (2003) introduces a generalized multiregional model, as opposed to the core model with a single small open economy. Vera's (2006) adjustments go in a different direction - by introducing interdependence of all variables, the model is transformed into a North-South model with demand-driven uneven development and path-dependent trajectories, accounting for capital flows and debt accumulation. With similar intent, Dutt (2002) introduces North-South regions with typical structural assumptions about conditions for accumulation and growth. Business cycles were introduced in this model by Spinola (2020).

One of the most important criticisms against the demand driven balance-of-payments growth approach was formulated by Palley (2003). He claims that neither neoclassical growth theory nor only the demand-driven approaches can provide a consistent model for long-run growth because the demand and supply sides must be balanced at steady state. On the one hand, if supply capacity creation does not directly match demand dynamics, this leads to potential long-term overcapacity or undercapacity. His proposed solution introduces an endogenous determination of the income elasticity of demand and links it to a capacity utilization rate, thereby bringing supply-side considerations to the fore.

The various forms of balance-of-payment constraint growth models have been extensively tested on empirical data, with mixed results (Bagnai, 2010; Cimoli et al., 2010; Garcimartín et al., 2010; Gouvea & Lima, 2010; McCombie, 1997; Nell, 2003). Although the core idea of balance-of-payments constraint growth modelling is at least indirectly inspired by Kaldor's and Verdoorn's contributions to growth, the approach is entirely demand-driven and completely ignores all supply-driven determinants of technological progress, choice of technique, investment-driven progress, external economies of scale and their asymmetric distribution among differently developed regions. In this sense, the most essential criticism of the broadest framework of the balance-of-payments constraint approach to growth is that it reduces the complexity of growth to completely one-sided demand-driven processes. The problem of explaining complex issues of growth and uneven development exclusively on the demand side can be traced back to the beginning, when the approach was still in its embryonic form. Even the famous Prebish-Singer hypothesis relies in its entirety on assumptions about the elasticities of international trade. Further developments of the balance-of-payments constraint approach are mere formalizations of the Prebish-Singer assumptions and their integration into various dynamic demand-driven equilibrium models. It may be that phenomenal trade elasticities explain a large share of the differences in output growth between differently developed regions and thus explain at least part of the persistence of uneven development. What remains completely unknown, however, are the underlying determinants of trade elasticities and their endogenous determination, which must necessarily be related to supply-driven determinants of technological growth, intersectoral composition and specialisation, external effects with increasing returns to scale that might be unequally distributed across both sectors and countries, and many other factors linked with both supply and demand and their complex intersectoral interaction. In this sense, the post-Keynesian paradigm is reductionist to a similar degree as the neoclassical paradigm and represents a mere antithesis in which the results are largely the projections of the assumptions, regardless of the complexity of the modelling exercises.

1.7 Neoclassical growth theory and endogenous growth

Neoclassical growth theory predicts exponentially rapid income convergence unless international flows of technology and capital are proscribed or differences in saving rates across countries are unrealistically high and persistent. The benchmark neoclassical growth model is the Solow-Swan model with exogenous technology growth, exogenous saving rates, and an aggregate Cobb-Douglass production function with constant returns to scale and decreasing marginal productivities of factors of production. The diminishing marginal productivity of capital leads to a stable steady state in which investment equals the amortization of the existing capital stock (Solow, 1957; Swan, 1956). One of the most important implications of neoclassical growth theory is the convergence hypothesis. Barro and Sala-i-Martin (1992, 2004) and Mankiw et al. (1992) were among the main proponents of applying a neoclassical framework for closed economies or its extended versions to analyses of aggregate output levels across countries and even regional differences in output within a country.

The inability of the neoclassical approach to provide an explanation of the functioning of the key driver of productivity and development - technological progress - was the starting point for the development of endogenous growth theory. Although it shares many features and insights with earlier theoretical approaches that attached great importance to external scale effects, the main body of endogenous growth theory has a distinct neoclassical character and is based on the principles of methodological individualism.

One of the earliest accounts of endogenous growth goes back to Young (1928), who argued that increasing returns are the main characteristic elements of growth. This is consistent with Smith's (2018) view that market size, specialization, and increasing division of labour follow the form of increasing returns. Increasing returns are introduced in most models of endogenous growth in the form of positive externalities. In one of the early approaches, Arrow (1962) conceptualized a model of growth by learning-by-doing. Firm-level productivity is assumed to be an increasing function of sectoral investment, with increasing returns to investment viewed as externalities because accumulated knowledge and know-how are assumed to be freely available to all firms.

Romer (1986) presents a growth model in which knowledge is conceptualized as a factor of production with increasing marginal productivity. The main idea lies in technological spillover effects among producers with constant returns at the firm level but increasing returns to the economy as a whole. The closed economy model potentially predicts multiple long-term steady state growth rates and provides an endogenous explanation for long term divergence in cross-country outputs. In another paper, technological change is assumed to be driven by direct investment based on profit maximization in an environment of monopolistic competition (Romer, 1990). The main contribution of Lucas (1988) to the emergence of a modern endogenous growth approach involves two models. One is based on the accumulation of human capital and the other focuses on the specific process of learning-by-doing in the context of such accumulation. Human capital is distinct from physical capital, which is conceptualized with a standard neoclassical decreasing marginal productivity. Human capital is assumed to increase productivity and its rate of accumulation is proportional to effort, regardless of the size of the stock. This assumption leads to similar effects as the increasing returns assumption characteristic of the endogenous approach.

A qualitatively different attempt to endogenous development is the systematic introduction of new quality in the form of upgrading ladders (Grossman & Helpman, 1991). An approach similar to earlier approaches to poverty traps consists of a model with discrete change in technology after a certain threshold of human capital is reached (Azariadis & Drazen, 1990). This leads to several steady states based on initial conditions. The second major field of endogenous growth explanations comes from the Shcumpeterian tradition, which uses the concept of creative destruction to model the process of technological progress. Most neo-Schumpeterian models treat the interaction of innovation and lagged technology adoption as a function of the size of the technology gap (Aghion, 2004; Aghion et al., 2005, 2016; Aghion & Howitt, 1992; Hellwig & Irmen, 2001; Howitt & Aghion, 1998). Productivity differences arising from differences in technology are thought to be mostly determined by the capacity to innovate, which is determined by the political and institutional environment (Acemoglu, Aghion, and Zilibotti, 2002; Aghion et al., 2005, 2016; Howitt, 2000).

1.8 Task based approaches to growth and technology

In the last decade, the old questions about long-term technologically biased changes and the impact of automation on employment, wages, and income distribution have resurfaced, driven mainly by rapid changes in the development of robots and artificial intelligence. A new paradigmatic approach to technological change, distinctly different from neoclassical and heterodox approaches, focuses on the examination of tasks as opposed to aggregate production functions. In most models, a production function is examined as a disaggregated continuum of tasks that produce intermediate outputs that are eventually aggregated into a total output. The main idea of the task approach is to examine the effects of labour-saving technology changes and the role of the cost of factors of production, which are impossible to examine within the framework of current neoclassical production functions (Acemoglu, 2010).

The origins of the task-based framework can be traced back to Zeira (1998, 2005). He analysed a formal model in which firms face a choice between investing in labour-saving machinery or hiring labour power, which endogenously drives industrialization and productivity growth. From the results, a causal link between wages and productivity can be inferred. On the one hand, wages determine the incentives to replace labour with machines, which drives up wages. On the other hand, the rise in wages increases the set of tasks for which it is more profitable to do them with machines rather than with labour. This further increases automation and aggregate productivity, so that wages and productivity are linked in a positive feedback loop, similar to the external effects of manufacturing examined by high development theory. The model also shows diverging steady states and a potential low-level equilibrium of a poverty trap when the initial level of industry is too low to provide an incentive to begin industrialisation in a profitable way.

The main questions to be answered by the task-based approach are related to the functioning of endogenous technological progress, its effects on labour income and its distribution, and the feedback effects of the wage level on technological progress. In his seminal paper, Acemoglu (2010) examined the structures of technological progress in a broad abstract framework and concluded that most neoclassical and endogenous growth models cannot account for the productivity-driven technological changes that are labour saving. Since then, the task-based approach has been extensively used to explore labour market dynamics, the effects of biased endogenous technological changes and their impact on the polarisation of the income structure in the developed countries, and to answer broader prospects of the future, especially the impact of labour-saving changes brought about by rapid robotization and the introduction of artificial intelligence (Acemoglu & Autor, 2011; Acemoglu & Restrepo, 2017a, 2017b, 2019, 2022; Autor, 2013; Nakamura & Nakamura, 2019).

Although these approaches work in the context of a closed economy, they have implications for understanding the mechanisms of uneven development. If technological progress is assumed to be driven by the introduction of labour-saving machinery, it is not only endogenous but also associated with the relative costs of machinery and wages. These relative costs, which are highly unequal between differently developed countries due to differences in the relative mobility of labour and the relative mobility of capital goods, may thus be a driving force of an endogenous mechanism that contributes to the perpetuation of uneven development.

Not only does a task-based approach represent a completely distinct form of endogenous growth theory, it also offers possibilities for generalization to the multiregional model with international trade. Since production is already disaggregated, one can easily conceptualize both trade in aggregate final goods and trade in intermediate goods or tasks, which is related to global value chains and their increasing importance in international trade (Baldwin & Robert-Nicoud, 2014).

1.9 Uneven development and growth from the perspective of global value chains

The concept of spatially distant production sharing of a single commodity is rarely directly incorporated into the main body of theoretical literature on economic development, growth, and international trade. The phenomenon of production sharing, which existed even before the emergence of the capitalist mode of production, is considered indirectly in some theories and models in the form of trade in intermediate goods or through the conceptual inclusion of intersectoral linkages in the case of disaggregated model types. However, it is never the focus of their theoretical consideration. In response to this overarching gap, various approaches emerged from the 1980s onward that placed the network structure of global economic integration at the forefront of their examination and theorization. The initially heterogeneous conceptualizations of the global factory, commodity chains, and production networks were largely subsumed under the framework of global value chain analysis in the late 1990s. The theoretical approach evolved into an eclectic field combining elements of the world-system approach, analytical sociology, emerging business and management studies, theories of the firm, and globalisation studies and international trade. What all of the different approaches to value chains have in common is that they place the network structure of spatial inter-firm linkages at the forefront of conceptual examination and analyse the impact that the increasingly important network structure of global capitalism has on growth and development.

The first concept of the commodity chain can be traced back to world-system theory. Hopkins and Wallerstein (1977) defined the commodity chain as an interrelated series of processes and inputs that culminate in the production of a consumption good. With this definition, the authors sought to define a new field of research that was not limited to a developmental framework for analysing the interaction among relatively autonomous nations and countries, but rather analysed a unified world-system in which the division of labour within commodity chains is unequal in both the technical sense and the sense of unequal value captured by each of the elements in the commodity chain's production structure. Arrighi and Drangel (1986) explain that the core-periphery division primarily refers to the unequal distribution of rewards among the various production processes that constitute the global division of labour within the world economy. The commodity chain appeared as the basic unit of analysis of such a global division of labour. The commodity chain framework combined descriptive, historical, and empirical analyses of the emergence, role, and impact of commodity chains on key development issues, such as technological growth and development traps, persistent core-periphery division, uneven development, and its underlying determinants (Gereffi & Korzeniewicz, 1994; Hopkins & Wallerstein, 1986).

Despite the origins of commodity chain analyses in the field of critical theory, the development of the research programme in the 1990s split into two separate fields. The main issue of the division was the question of what should take the place of the main unit of analysis, as well as the broader research aims. On the one hand, world-system theorists argued that the world-system as a whole is the unit of analysis and that the commodity chain is a construct that helps explain the dynamics of capital accumulation, the acquisition of surplus along the value chain, and the methods of its distribution among the various agents in the commodity chain production process. They argued that the division of the world-system division is stable in the long run, partly due to commodity chain dynamics contributing to uneven development, although individual countries may be mobile within the division of the world-system (Wallerstein, 2011a, 2011b, 2011c). The second group of commodity chain researchers, on the other hand, placed the firm, especially the multinational firm, at the centre of their research and made it a fundamental unit of analysis in their approach to commodity chains (Appelbaum & Gereffi, 1994; Gereffi, 1996; Gereffi et al., 2001; Gereffi & Korzeniewicz, 1994). Their main objective was to understand both the process of value creation and value distribution within commodity chains, focusing on intra-firm dynamics and analysing the asymmetric relationships between firms in the production and distribution process within commodity chains (Appelbaum & Gereffi, 1994). One of the most important conceptualizations was that of the leading firm, which acts as the engine of the chain and can have complex organisational, technological, and distributional effects on the other participants in the commodity chain.

The general framework of the global value chain emerged at the turn of the century with the aim of unifying similar research conducted under different terminology (Gereffi et al., 2001). Gereffi identifies four dimensions of value chain analysis:
1.) an input-output structure;
2.) a spatial dimension;
3.) a governance structure;
4.) an institutional framework.

The aim of reformulating the global value chain framework was to standardise terminology and structure a coherent research programme that encompasses existing heterogeneous approaches ranging from global production networks (Coe et al., 2004; Henderson et al., 2002) and global factory (Buckley, 2009) to global production systems (Milberg, 2004).

The stream of research in the 1990s produced an extensive body of descriptive and empirical analysis of specific global value chains. Based on this work, one of the most important studies focused on the analysis of governance structures with the discovery of the main theoretical distinction between the producer- and consumer-driven commodity chain (Gereffi et al., 2005). The former is characterized by capital-intensive industries where technology and know-how are fundamental and the leading firms monopolize the technological and organizational aspects of the production process, often claiming a large share of the value and directly or indirectly controlling the vertically integrated supplier networks with strict quality controls and frequent interventions of the leading firm in the production process of its suppliers. The most typical case analyzed is the automotive industry (Brincks et al., 2018). On the other hand, commodity chains characterized by low technological and capital inputs, such as the apparel industry, are largely consumer driven. Marketing, retailing, and branding represent the entry points and capture most of the value, with a loose network of decentralized and interchangeable supplier networks subject to a high degree of market competition (Appelbaum & Gereffi, 1994; Bair & Gereffi, 2003; Gereffi, 1996, 2001b). Such heterogeneous and asymmetric governance structures may be a factor in persistent uneven development, as underdeveloped regions are pushed toward labour specialization in labour-intensive industries that are more closely linked to buyer-driven commodity chains (Bair, 2005).

At the turn of the century, on the one hand, the global value chain approach increased the focus on the firm level and merged with the literature from international business and management, combining it with the new institutional transaction cost approach. On the other hand, the emergence of the first fully integrated multi-regional international input-output tables led to a revival of the global macroeconomic approach to global value chains (Dietzenbacher & Romero, 2016; Los et al., 2015; Timmer et al., 2015). The international input-output structure represented the turning point away from the study of concrete governance structures towards macro-level changes in inter-firm linkages and their aggregate impact on growth and development. Global value chains became a measurable object of international economic trade and structure.

Early I-O measures of global value chains were simple upstream and downstream indicators corresponding to the distance to final demand measure (upstream) and the Leontief measure of backward linkage (downstream), often referred to as value chain length (Antràs et al., 2012; Zaclicever et al., 2017). Fally defined the downstream global value chain indicator as to "reflect how many plants (stages) are involved in production one after the other" up to the point observed and the upstream indicator to "measure how many plants this product will pass through (e.g. by assembly with other products) before it reaches final demand (Fally, 2011, 10)". Fally structured a measure of value chain integration as the number of vertical stages weighted by the value added at each stage, with the distance between each stage set to 1. Since then, average vertical distance has been the basic measure of value chain length in the international I-O framework. Miller and Temurshoev (2015) have further specified the existing measures by presenting upstream and downstream indicators in a matrix formulation using Ghosh's forward coefficient matrix and Leontief's backward coefficient matrix (Ghosh, 1958; Leontief, 1936). These upstream and downstream measures are simple measures of the upstream and downstream length of value chains, measured by average vertical distance. The conceptualisation of contemporary measures of GVC participation is largely based on the work of Johnson and Noguera (2012), who created a value-added export matrix that captures information on value flows in the economy between any two points (country- sectors) in the economy. This forms the basis for disaggregating value at the country- sector level depending on whether the value was produced domestically for domestic consumption or whether it involved cross-border transactions for final consumption or productive consumption (Koopman et al, 2014; Wang, 2020; Wang et al, 2017). Using this input-output conceptualisation, it is possible to disaggregate total international trade to the domestic part, classical 'Ricardian trade' in finished goods, simple GVC and complex GVC trade in multiple cross-border intermediate goods. Within this framework, further improvements have been introduced by separating the domestic production sharing from the global value chain measures, by integrating downstream and upstream measures, and by accounting for price movements separating real and nominal measures of global value chain changes (Arto et al., 2019; Borin & Mancini, 2019; Knez et al., 2021; Miroudot & Ye, 2021; Muradov, 2016; Stehrer, 2012; Timmer et al., 2021).

The intensification and rapid growth of value chain trade in recent decades is reflected in the shift of theoretical approaches away from North-South approaches based on the structural asymmetries between different regions and making the integration of value chains and multinational enterprises the object of study. The broader development issues are largely sidelined as the global value chain framework is promoted as a development opportunity that allows for increased technological upgrading, spillover effects and similar positive factors of value chain integration. Although increasing participation in global value chains is mostly presented as a positive prospect for both developed and less developed regions, the global and local impacts of such structural changes in the functioning of the national economies have been shown to have complex and non-linear effects that cannot be unilaterally reduced to simple aggregate benefits from trade (Baldwin & Robert-Nicoud, 2014). There is a considerable body of empirical and theoretical literature addressing the effects of specific structural changes brought about by increasing integration into global value chains, with a focus on the specific experiences of Central and Eastern European EU countries, accounting for both technological upgrading and downgrading, potential for increased technological spillovers, as well as dynamic technological lock-in, and specific way in which middle income development trap is connected with the structure of the global value chains (Blažek, 2016; Brincks et al., 2018; Castelli et al., 2011; Coe & Yeung, 2019; Drahokoupil & Fabo, 2020; Dyba et al., 2018; Freyssenet, 2003; Frigant & Layan, 2009; Grodzicki & Skrzypek, 2020; Krpec & Hodulák, 2018; Krūminas et al., 2019; Kuc-Czarnecka et al., 2021; Landesmann & Stöllinger, 2019; Maskell et al., 2007; Pavlínek, 2008, 2018, 2020; Pavlínek & Žížalová, 2016; Pleticha, 2021; Rodrik, 2018; Shields, 2009). Broadly speaking, a specific combination of activities associated with specialisation in manufacturing, the high or low skill content of exports and the distribution of labour-intensive processes in the global division of labour can enable and perpetuate a state in which the benefits of the global division of labour are highly disproportionately distributed (Arrighi, 1996; Arrighi & Silver, 2001; Martin et al., 1990).

1.10 Discussion and conclusion

We have provided a comprehensive overview of the conceptualisations of the endogenous (and exogenous) mechanisms that contribute to the perpetuation of uneven development. While the historical development of ideas makes them paradigmatically distinct from each other, many conceptualisations of different approaches overlap due to their focus on similar themes, albeit with different emphases.

In the comprehensive review we have shown that our object of study - a supply-driven mechanism that operates due to supply-side granularities in the production constraint and its interaction with relative factor costs in the international setting - has not yet been identified or explored by the literature, to our best knowledge. On the one hand, the literature that examines the supply-side endogenous technological growth and machine-labour task based substitution, which shares some core arguments regarding our object of study, is entirely focused on homogeneous closed economy setting. On the other hand, the conceptualizations of interaction between uneven development, relative factor costs and functional specialization is very limited and constrained to few descriptive remarks within the Marxian framework. This represents the core literature gap that we address by our exploration of the supply-side interactions that contribute to endogenous functional specialization and thus persistent uneven development.

The identification and deepening of the understanding of our object of study complements and deepens understanding of uneven development that is explained by various endogenous and exogenous mechanisms by the literature from different fields. Our two objects of study do not coincide with any category of the above examined endogenous mechanisms. They are neither driven by increasing return dynamics, agglomeration dynamics, nor a North-South structural pattern, but are unique supply-side relational functional endogenous mechanisms. If our study leads to identification and deeper functional understanding of how uneven development might be affected by the supply-side mechanism that operates due to granularities in the supply side constraint, uneven technology diffusion, and international specialization driven by relative factor costs, it will complement our understanding of other endogenous mechanisms in the overall knowledge of the determinants of uneven development.

In the next chapter, we show empirically that extra-economic poverty trap regimes are still the most relevant explanation for extreme underdevelopment even today. The chapter aims to explain the significance of these development trap regimes in various stages of development. If we show that non-economic threshold regimes are more important in explaining uneven development in low-income countries, whereas their impact is relatively limited in middle-income countries, this would highlight the need to examine the supply-driven endogenous economic mechanism of functional specialization in greater detail in subsequent chapters, which could complement existing explanations for persistent uneven development caused by other economic and non-economic factors, particularly in the context of industrially developed countries and regions.

Chapter 2

Examination of the Development Traps

2.1 Introduction

In this chapter[1], we explore empirically the functioning of the development traps in the form of threshold regimes. With this we examine the functioning mechanisms that are the main drivers of uneven development, when considering extremely underdeveloped countries and regions.

In general, we characterize a development trap as an endogenous, self-perpetuating mechanism that reproduces conditions of persistent underdevelopment. Although they function at completely different social and economic levels, the common feature of all development traps is their endogenous functioning, which determines multiple historical social and economic development paths based on countries' initial state. For this reason, development traps are theoretically described by dynamic models that lead to multiple equilibria and do not exhibit simple one-way linear causality between key determinants and development outcomes. Although no specific development trajectory can be reduced to a set of explanatory factors, dynamic conceptualizations of development traps can help us to understand better the various factors that make up the complex issue of a country's economic development as a whole.

First, in our approach, we distinguish between different development traps and characterize the empirical variables that best correspond to the main dynamic determinants of their functioning. We will assess the role of endogenously conditioned fertility and education dynamics (Azariadis, 1996; Cai, 2002; Grossman et al., 2021), the role of mechanisms of transition from subsistence to industrial economies described in early high development models (Lewis, 1954; Rostow, 1959) as well as more modern conceptualizations of uneven technological progress (Hidalgo et al., 2007; Zeira, 1998) and the role of technology transfer (Comin & Hobijn, 2010; Fagerberg & Verspagen, 2002; Gomulka, 1990).

[1]Some content of this chapter was published in different form in coauthorship with Tina G. Lokar in Regional Science Policy & Practice (Knez & Lokar, 2022).

Second, using country-level data for all available countries, we empirically link the variables corresponding to each development trap to a simple measure of economic development. For this measure, we use the purchasing power parity of the GDP at constant prices. Although it is not an ideal measure and does not capture every element of development, it is a good representation of productivity and total output. Because the dynamic functioning of development traps is highly nonlinear, we cannot use linear regression to evaluate the relationship. Instead, we use a nonlinear smooth transition regression that functionally corresponds to the dynamic process described by the theoretical models of development traps (Marquez-Ramos & Mourelle, 2019; Terasvirta, 1998, 2004).

Third, we use the results of the empirical model to assess empirically the conditions under which a country can be characterized as being in a corresponding development trap and characterize the results by distinguishing threshold regime dynamics for each of the empirical indicator.

Lastly, we conduct a case study of Afghanistan's level of development and its structural change in the last two to three decades. We assess the Afghanistan's position in the context of the examined poverty trap threshold regimes and model predictions to gain insight into the relative importance of various factors in Afghanistan's underdevelopment and evaluate its changing structure in this context. We link the empirical evaluation of Afghanistan's poverty traps with its specific historical and social development. Our hypothesis is that Afghanistan is caught in several development traps, the endogenous functioning of which mutually affect each other and Afghanistan's development. While the period of US occupation has led to relative improvements in some areas, the absolute state of the Afghan economy and institutions perpetuates its underdevelopment.

2.2 Determinants of development traps

2.2.1 Methodology

In this chapter, we do not aim to deepen the knowledge of the dynamic functioning of development traps, which have been extensively and sufficiently studied at the theoretical level. Our goal is to assess the functioning of development traps empirically by linking typical indicators, theoretically studied as the main determinants of specific development traps, to the country's level of development, measured with the GDP in constant 2015 US dollars, adjusted by purchasing power parity. An indicator that dynamically functions as part of a development trap has not a linear relationship with economic development but rather a continuous logistic relationship due to the dynamic functioning of the development trap.

Underdeveloped countries cluster at the lower-bound values of the indicator, while the vast majority of countries that have escaped the corresponding development trap have the upper values of the indicator. The model of the logistic relationship between the indicator and economic development provides information about the transition process, its shape, and the different stages of the development trap. Our general model takes the following form for each of the examined indicators.

$$i_{ct} = \frac{1 - b_3}{1 + exp(-b_1 G_{ct} + b_2)} + b_3 + u_{ct} \tag{2.2.1}$$

The panel variable G_{ct} represents country c's GDP per capita measured in purchasing power parity international dollars at time t, panel variable i_{ct} represents one of the analysed indicators listed below, and u_{ct} is the regression residual. We estimate parameters b_1, b_2, and b_3, which determine the shape of the development transitions for each indicator, separately.

Using a panel data set that includes 217 countries and covers the period from 1990 to 2020, we estimate the model for the following indicators: fertility rate, secondary school enrolment rate, average years of schooling, urbanization rate, share of agricultural employment, share of vulnerable employment, industry VA per capita, economic complexity index, technology density, and share of foreign aid in the GDP.[2]

The mathematical properties of the generalized logistic curve allow us to examine objectively the form of development traps as characterized empirically by various indicators. The first characterization of the development trap is the value of the horizontal shift of the logistic curve, which determines the inflection point of the S-curve. This determines the value of the "inflection point" of the transition from the state in the development trap to the breakout from it. The second characterization is determined by the intersection of the tangent slope from the "inflection point" and the upper bound for the "point of the end of the transition" and the lower bound for the "point of the beginning of the transition". With these empirical characterizations of the relationship between each indicator and economic development, we can distinguish between different phases of each development trap and evaluate Afghanistan's position regarding the studied indicator and the corresponding development trap.

[2]The source for the fertility rate, secondary school enrolment rate, urbanization rate, share of agricultural employment, share of vulnerable employment, industry VA per capita, and share of foreign aid in the GDP is the World Bank (2022); for the average years of schooling, the source is Barro and Lee (2013), available at http://www.barrolee.com/; the economic complexity index is defined by Hidalgo et al. (2007), available at https://oec.world/; and technology density is derived using the CHAT database (Comin & Hobijn, 2009), available at https://www.nber.org/papers/w15319.

Demography and education

A demographic trap occurs when fertility is high and, as a result, the population grows fast (Cai, 2002). This leads to difficulties in ensuring the conditions of prosperity as the demand for all material goods and services constantly increases due to the growing population. The additional young population puts pressure on the existing infrastructure while depending on the existing resources and labour of the adult labour force. This is reflected in access to material goods, health, education, and access to utilities such as water and electricity. All of these have implications for a country's standard and level of development (for a summary of the various approaches to the demographic trap: Ehrlich & Lui, 1997). A decline in the birth rate is also associated with a decline in the mortality rate, higher life expectancy at birth, greater urbanization, higher capital intensity, higher female labour force participation, and higher relative incomes (Ehrlich & Lui, 1997; Galor & Weil, 1996; Rostow, 1992; Schultz, 1985).

Moreover, the issues of individuals' participation in the educational process, the duration of that participation, changes in the educational composition of the labour force, and the resulting higher spending on education in the context of demographics have a significant impact on the broader social structure and development. These, in turn, affect the birth rate in a positive feedback loop. A high birth rate reduces the prospects for higher levels of education and investment and vice versa (Becker et al., 1990). The impact of changes in educational composition is uneven and varies with the country's development. In education, there is an upper bound that all developed countries eventually reach while underdeveloped countries do not. The potential impact of changes in educational composition is therefore greater for less developed countries than for more developed ones (Duflo, 2001; Kalaitzidakis et al., 2001; Marquez-Ramos & Mourelle, 2019). In the case of secondary education, the impact on growth is smaller for developed countries that already have high levels of secondary and tertiary education, while it is an important factor for underdeveloped countries where secondary education enrolment is low (Marquez-Ramos & Mourelle, 2019). This suggests the existence of a development trap related to education.

In this chapter, we measure the demographic trap using two World Bank (WB) indicators for 217 countries: fertility and secondary school enrolment rates. The data range from 1990 to 2020 for fertility and from 1990 to 2019 for secondary school enrolment rates. Primary school enrolment rates are no longer used as a measure of development as virtually all countries already have high enrolment rates, approaching 100 per cent. The irrelevance of primary school enrolment data for growth analysis was also confirmed by Barro (2001), who additionally noted that a large proportion of female primary school children indirectly reduces fertility. Tertiary enrolment is also not a determinant of the demographic trap as it is virtually absent in most underdeveloped countries, and differences in tertiary education characterize the middle-income trap rather than the demographic trap.

In addition, we use Barro and Lee's (2013) third indicator to measure the average years of schooling. Barro (2001) showed that an important determinant of economic growth is the average participation in education, especially at higher levels. Male participation in secondary and tertiary education has a significant impact on economic growth, while female participation does not show a significant relationship with economic growth because of discrimination against women entering the labour market. We will test the data on individual participation in education and its impact on economic development using the index of average years of schooling taken from the dataset of Barro and Lee (2013) with data from 1950 to 2015.

Transition from subsistence to industrial production

Economic development in a capitalist economy is based on capital accumulation and competition between firms, which lead to investment, constant improvements in technology, and higher labour productivity. Although much of the world has a purely capitalist economy, there are still countries that are in an intermediate position, with elements and relationships of two different forms of society – capitalist and pre-capitalist (Amin, 1974b; Berman, 1984; Foster-Carter, 1978; Meillassoux, 1981; Rey, 1979; Rey & Becker, 1982). In countries where pre-capitalist modes of production constitute an important part of the economy, agricultural subsistence production and domestic or dependent economic relations still predominate, the division of labour is limited, markets are poorly developed, and most of the population lives in rural areas. Production in pre-capitalist relations is geared towards meeting the basic needs of its members as opposed to developing production techniques and more efficient production driven by capitalist competition. While the pre-capitalist mode of production often creates a limited surplus, the form of the surplus and its role in the economy are also very different from capitalist profit – they are often not used for capital accumulation, investment, and productivity improvements. The subsistence development trap has been studied in detail by development theorists (Azariadis, 1996; Lewis, 1954; Rostow, 1959).

The main indicators by which we can judge the beginning of a country's significant integration into the capitalist economy are, above all, the shift from subsistence production to agricultural production for the market, the establishment of capitalist industrial production, market relations, and the growing importance of cities. To measure countries' integration into the capitalist economy and the conditions for their development and growth within the capitalist economy, we use World Bank data for 217 countries from 1990 to 2020. The first indicator that we use is the vulnerable employment indicator, with which we try to assess the country's entrapment in the pre-capitalist economy. The indicator measures the proportion of the population that is not involved in formal classical labour market relations. It indirectly indicates the scale of labour relations that are more informal and embedded in dependent relationships through direct subordination to others in the household, to the broader social network, or to influential leaders in the local community.

The second criterion is the proportion of people engaged in agricultural production. The third indicator is the degree of urbanization of the country, with which we can indirectly assess, on the one hand, the importance of cities and the presence of more formal relationships, and, on the other hand, the extent of rural settlements with potentially more communal relationships. Most industrial production takes place in cities, so the extent of industrial production is tied to urbanization. Services, which complement the urban industrial economy, are also an important sector and contribute to formal employment in cities. These factors attempt to capture the extent to which production relations are still embedded in municipal pre-capitalist relations. The fourth and final indicator that we examine is industrial value added per capita. Many developed countries are gradually reducing the share of employment in the industrial sector in the face of structural change driven by productivity gains and automation, leading to an increasing share of the tertiary sector. Hence, the share of employment in industry, while an important indicator for countries moving from subsistence to classical capitalist production, cannot be a general indicator of the scale and evolution of capitalist production. We have therefore developed an indicator of industrial value added per capita that captures the volume and value of industrial production in a given country independent of the number of people employed in that sector.

Transfer of technology and productivity

Technology, from the perspectives of both innovating new ways to produce and satisfy human needs more efficiently and technology adoption, is one of the most important determinants of productivity growth, global convergence or divergence, and overall economic development. Different economic traditions define technology in different broad frameworks. On the one hand, the traditional literature considers technology as a factor (or set of factors) that contributes to productivity or as a set of available production techniques (Dosi, 1982; Dosi & Nelson, 2016; Fagerberg et al., 2010; Gomulka, 1990). Broader definitions, on the other hand, view technology as human knowledge and the process of technological change, defined primarily by the process of learning and adopting knowledge and expertise that are often tacit (Arrow, 1962; Lundvall & Johnson, 1994; Pavitt, 1999; Stiglitz & Greenwald, 2014).

The process of technology adoption is rarely studied in isolation. While the technology gap and neo-Schumpeterian theory view the technology gap between developed and underdeveloped countries as having great potential for very high productivity growth and rapid catch-up, the process of technology adoption and implementation is largely determined by the social capabilities of the underdeveloped country (Abramovitz, 1986; Aghion & Howitt, 1992; Dosi et al., 1990; Fagerberg & Godinho, 2018; Fagerberg & Verspagen, 2002). Thus, technology adoption is directly related to the institutional structure, educational attainment, and political stability of an underdeveloped country. A broader understanding of technology as knowledge is often explored within the endogenous growth literature, which mostly works with the concept of increasing returns, leading to path-dependent development (Lucas, 1988; Romer, 1990; Young, 1928).

Empirically, we will evaluate two indicators. The first corresponds to the physical notion of technology, measurable through the use of concrete techniques and processes. We use the panel database CHAT (Comin & Hobijn, 2010), which, starting in 1960, records the use of 101 technologies in more than 170 countries, including agricultural technologies (such as the use of combine harvesters) and techniques in steel production, the textile industry, telecommunications, health care, tourism, and infrastructure. We define technology density as the use of each technology in relative per capita terms divided by the average use of that technology on a world scale. The second indicator aims to capture the knowledge and economic capabilities of countries through the economic complexity index (Hidalgo et al., 2007). Economic complexity is measure based on the product space determined by countries' revealed comparative advantages. It aims to measure the impact of increasing returns, in particular the mutual effects and spillover effects of the ability to produce different products and services. The product space shows a clear core–periphery divide, with core countries' specialization supporting each other with high spillovers, while the production structure of many peripheral countries does not show large knowledge spillovers. This reflects the technology and increasing returns productivity trap that we empirically investigate with the two indicators.

Dependence and the world market

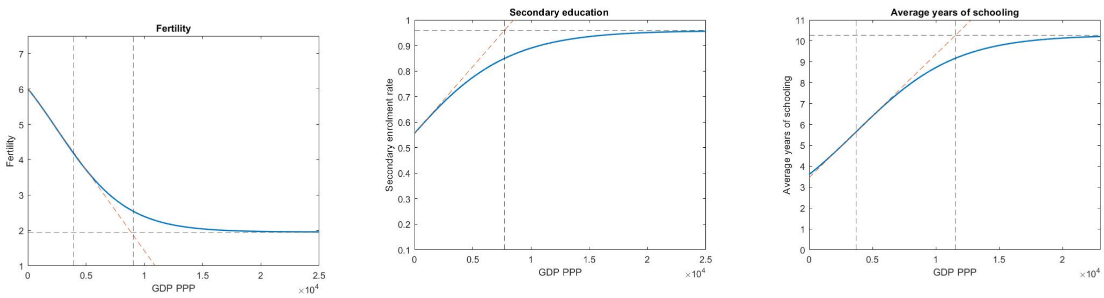
Dependence may be the result of high foreign inflows of FDI, debt, high foreign trade dependence, or a large share of foreign aid. Since foreign direct investment, debt, and foreign trade are very limited in most underdeveloped countries today, we focus on investigating whether a large proportion of foreign aid can be detrimental to development. The theoretical explanation of how foreign aid might negatively affect development is based on the concept of Dutch disease. The inflow of foreign aid indirectly leads to an increase in the price of local non-tradable goods through an increase in the aggregate demand. Since the real exchange rate is defined by the price ratio between tradable and non-tradable goods, this leads to an appreciation of the local currency, making exports less competitive. Some empirical studies have confirmed the functioning of such a mechanism, especially when foreign aid rates are high (Clemens et al., 2012; Elbadawi, 1999; White & Wignaraja, 1992). To assess the potential dependence on foreign aid empirically, we use data from the WB on foreign aid as a share of the GDP as an indicator.

2.3 Empirical results

The results of the nonlinear regression are presented in Table 2.1. All the regressions yield highly statistically significant results, except for parameter b_3 in the economic complexity, technology density, and foreign aid regressions. In these cases, the vertical shift in the logistic curve defined by this parameter appeared statistically insignificant and thus unnecessary because the lower and upper bounds of the indicator value were adequately represented by 0 and 1, respectively.

We explore the dynamics of the demography and education by separately examining the fertility and education. The overall results are presented in figure 2.1. The result for fertility shows an inverted S-curve, with predicted fertility values ranging from 6 for underdeveloped countries to 1.96 for developed countries. The inflection point of the logistic curve is at the fertility value of 4.18, while the characteristic value indicating the end of the transition is 2.54 (figure B.2a).

Figure 2.1: Demography and education poverty trap (Source: own work)



(a) Fertility threshold regime

(b) Secondary school enrolment threshold regime

(c) Average years of schooling threshold regime

The second part of the empirical examination consists of two education models that consider secondary school enrolment rate and average years of schooling. The two models produce similar results (figure B.2b and 2.1c). First, the secondary education model converges at 95.8 per cent for developed countries and shows transition dynamics of more than 55.6 per cent for underdeveloped countries, while the end of the transition is characterized by 84.9 per cent secondary education enrolment. However, the inferences regarding concrete phases of this development trap might not be precise because the robustness test shows indeterminacy of its shape.

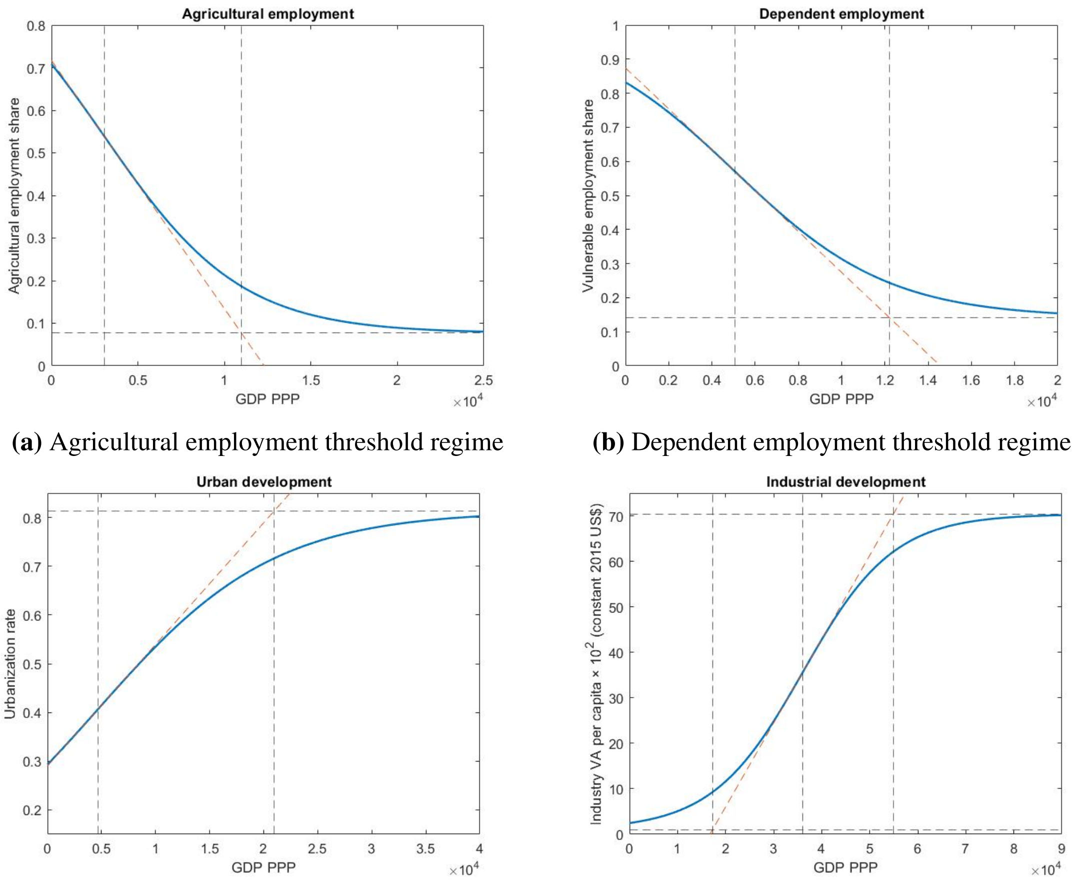
Second, the model predicts that the average years of schooling in underdeveloped countries below the inflection point range between only 3.16 years and 5.64 years and converges to 10.3 years for the developed countries, with the inflection point of the transition at 5.64 years and 9.17 years marking the end of the transition.

Table 2.1: Regression results - development traps (Source: own work)

Logistic relation to GDP PPP	b1	b2	b3	No. Obs.	R-squared
Fertility	-0.0003339 (8.40e-06) t = -39.77 $P > \|t\|$ 0.000	-0.8328674 (0.028572) t = -29.15 $P > \|t\|$ 0.000	0.1585881 (0.0030311) t = 52.32 $P > \|t\|$ 0.000	5,294	0.8812
Secondary education enrolment	-0.000224 (0.0000129) t = -17.34 $P > \|t\|$ 0.000	0.322507 (0.0410183) t = 7.86 $P > \|t\|$ 0.000	0.0415769 (0.004997) t = 8.32 $P > \|t\|$ 0.000	5,700	0.4624
Average years of schooling	-0.0002542 (0.0000178) t = -14.27 $P > \|t\|$ 0.000	-0.9388251 (0.0818368) t = -11.47 $P > \|t\|$ 0.000	10.27675 (0.1136346) t = 90.44 $P > \|t\|$ 0.000	705	0.9558
Industrial value added per capita	-0.0001063 (2.78e-06) t = -38.25 $P > \|t\|$ 0.000	-3.837327 (0.0792772) t = -48.40 $P > \|t\|$ 0.000	70.37734 (1.042725) t = t = 67.49 $P > \|t\|$ 0.000	4,599	0.7652
Economic complexity	0.000031 (7.09e-07) t = 43.78 $P > \|t\|$ 0.000	0.2002912 (0.0144033) t = 13.91 $P > \|t\|$ 0.000		2,782	0.962
Technology density	0.000342 (0.0000213) t = 16.07 $P > \|t\|$ 0.000	1.597529 (0.1053933) t = 15.16 $P > \|t\|$ 0.000		36,246	0.3551
Foreign aid	-0.0002256 (8.41e-06) t = -26.83 $P > \|t\|$ 0.000	1.43026 (0.0266965) t = 53.57 $P > \|t\|$ 0.000		5,405	0.5059

The examination of the subsistence trap is divided into four parts: agricultural employment, dependent and vulnerable employment, urbanization, and industrial development. The results are presented in figure 2.2. The model predicts that the agricultural employment share ranges from 70.8 per cent for underdeveloped countries and converges to 7.7 per cent for developed countries. The inflection point of the transition is 53.8 per cent, and the transition ends at 18.6 per cent agricultural employment (figure 2.2a).

Figure 2.2: Subsistence poverty trap (Source: own work)



(a) Agricultural employment threshold regime

(b) Dependent employment threshold regime

(c) Urbanization threshold regime

(d) Industrial development threshold regime

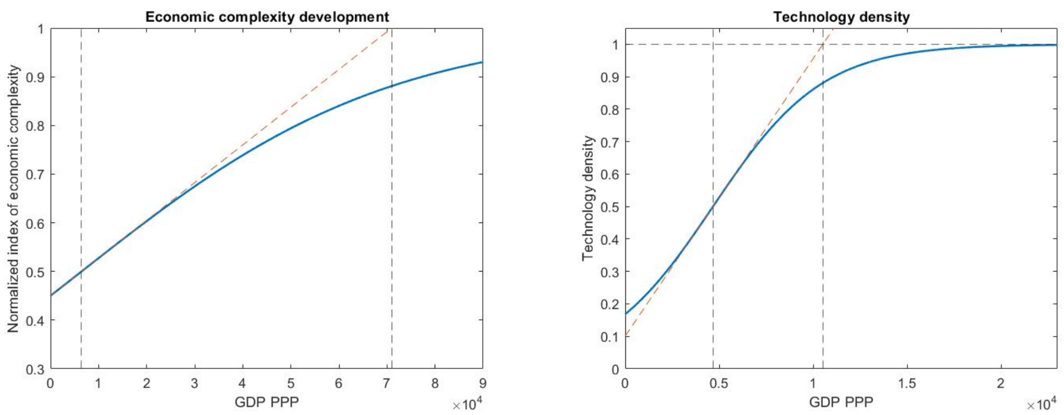
The communal structure of the underdeveloped countries is best estimated by the share of informal and dependent employment. The indicator that covers it is vulnerable employment share, collected and estimated by the World Bank. The model predictions for the share of vulnerable employment range from 83.2 per cent for underdeveloped countries and converges to 14.1 per cent for developed countries, with the inflection point of transition at 57.1 per cent and 24.4 per cent marking the end of the transition (figure 2.2b).

The urbanization rates predicted by the model assumes values from 29.3 per cent for the underdeveloped countries and converge to 81.3 per cent for the developed countries. The geometry of the transition is determined by the inflection point of the logistic curve at 40.6

per cent, and the urbanization rate of 71.6 per cent indicates the end of the urban transition (figure 2.2c).

Last but not least, we examine the relationship between industrial value added per capita and economic development. The model shows an S-shaped curve, with values of industrial VA ranging from as little as 246.4 US dollars per capita for underdeveloped countries to 7037.8 US dollars for most developed countries. This is the only case in which the logistic model exhibits three distinct phases, namely the beginning of the transition at 927 US dollars, the turning point of the transition at 3568.9 US dollars, and the end of the transition at 6210.7 US dollars (figure 2.2d). The distinct phases of the transition from low to high industrial value add per capita regime follow the logic of different structural changes. The dynamics of the extremely low values of industrial value added with concurrent low growth of industrial value added are characteristic of the subsistence and agricultural production poverty trap linked with most extremely underdeveloped regions. The above average growth of industrial value added in the phase before the inflection point is linked with rapid industrialization and structural shift from agriculture to industry, described extensively in various models linked with high development theory (Lewis, 1954, Nurkse, 1953; Rosenstein-Rodan, 1943). Lastly, the convergence in developed countries and limited growth of industrial value added per capita is linked with structural change that drives relocation of resources and employment from industry towards services.

Figure 2.3: Technology trap (Source: own work)



(a) Economic complexity threshold regime

(b) Technology density threshold regime

The technology trap is examined in terms of technology density and economic complexity. The results are presented in figure 2.3. Since the vertical transformation of the model is insignificant in both models, the model shape is determined by the properties of the logistic curve. Both models are constrained between 0 and 1 and have a transition point at the 0.5 value.

The predicted values of the model of relative technology density for the underdeveloped countries ranges from the values of 0.168 for the underdeveloped countries and reaches inflection point at 0.5. This means that the most underdeveloped countries and regions exhibit six times less intensive use of technology than the world average, while half the world average can be considered the threshold value indicating the inflection point in the model. The model prediction of normalized economic complexity range from a normalized value of 0.45, with developed countries converging towards 1.

The results linking the share of foreign aid in the GDP to development show a declining curve of 19.3 per cent and converge to 0 for developed countries, with the value of 6.5 per cent marking the end of the transition. Due to the fact that aid is highly dependent on political, historical, and military factors and does not necessarily relate to the level of development, the shape of the predicted model is not robust.

The theory of developmental traps suggests the existence of several complex dynamic economic feedback effects that lead to multiple steady states associated with different levels of development. Our empirical study contributes to our understanding of the specific form of each development trap in terms of the empirical indicators that best capture the underlying dynamics of each development trap. The model results inform us about the thresholds of the steady-state regimes and, most importantly, allow us to estimate the indicator value that represents the inflection point above and below which the endogenous dynamics converge to either a high or low steady state. Moreover, the shape of the transition, i.e., the steepness of the transition curve, informs us about how intense the feedback processes of the development trap are compared to other exogenous random forces. This contribution can help distinguish between country-specific development problems and help policymakers address the problems that generate the most persistent negative feedbacks.

Robustness tests

We conduct further robustness checks that test the robustness of the parameters that determine the threshold regimes. We test the robustness of the development trap's transitional shape by separately checking the robustness of the inflection point's position on the estimated logistic curve and its slope at the inflection point, as it is standard in the related literature (Teräsvirta, 2004, 1996, 1998). Both uniquely determine the transitional regime of the development trap.

The first modified model specifies arbitrary translation (c_1) of the inflection point:

$$L_1(b_1, b_2, b_3, G_{ct}, c_1) = \frac{1 - b_3}{1 + exp(-b_1 G_{ct} + b_2 + c_1)} + b_3 \quad (2.3.1)$$

β_1, β_2, and β_3 represent nonlinear estimates of our model parameters b_1, b_2, and b_3. We approximate the model at $c_1 = 0$ with the Taylor series and use our parameter estimates to

Table 2.2: Robustness check results (Source: own work)

	Hypothesis $^1H_0$		Hypothesis $^2H_0$	
Model	F	$Prob > F$	F	$Prob > F$
Urbanization	0.00	0.9682	0.27	0.6064
Agricultural employment	0.00	0.9571	0.10	0.7562
Fertility	0.00	0.9669	0.07	0.7965
Economic complexity	0.00	0.9729	0.00	0.9666
Secondary education enrolment	1314.64	0.00	3860.29	0.00
Average years of schooling	3.56	0.0595	5.45	0.0198
Vulnerable employment	0.00	0.9590	0.32	0.5709
Industry VA	1.44	0.2300	1.06	0.3043
Foreign aid	1565.71	0.00	3749.00	0.00
Technology density	0.00	0.9972	0.00	0.9966

derive a linearized model of the following form:

$$i_{ct} = L_1(\beta_1, \beta_2, \beta_3, G_{ct}, 0) - c_1 \frac{\partial L_1}{\partial c_1}(\beta_1, \beta_2, \beta_3, G_{ct}, 0) \tag{2.3.2}$$

The second modified model specifies arbitrary perturbation of the slope of the inflection point (c_2):

$$L_2(b_1, b_2, b_3, G_{ct}, c_2) = \frac{1 - b_3}{1 + exp(-b_1 G_{ct} + b_2 + c_2 G_{ct})} + b_3 \tag{2.3.3}$$

Similarly as with the first model, we approximate it at $c_2 = 0$ with the Taylor series and use our parameter estimates to derive a linearized model of the following form:

$$i_{ct} = L_2(\beta_1, \beta_2, \beta_3, G_{ct}, 0) - c_2 \frac{\partial L_1}{\partial c_2}(\beta_1, \beta_2, \beta_3, G_{ct}, 0) \tag{2.3.4}$$

We use a set of linear regressions to estimate the constants c_1 and c_2 and evaluate the following set of null hypotheses for every development trap:
Hypothesis $^1H_0$: The horizontal translation of the inflection point is zero $c_1 = 0$.
Hypothesis $^2H_0$: The derivative at the inflection point has a correction $c_2 = 0$.

We use the F statistic of the linear regression to decide whether we can reject each of the null hypotheses. The results are in a table 2.2.

A low value of the F statistic corresponds to the inability to refute the null hypothesis statistically, making the empirically estimated shapes of the development trap regimes robust to variations in the inflection point's location and slope, which determine the analysed threshold regimes. This makes the results robust to variations in transitional shapes.

We cannot reject most of the null hypotheses. The results defining the transition dynamics are robust to perturbation in cases of urbanization, agricultural employment, fertility, economic complexity, average years of schooling, share of vulnerable employment, and industry value added. The only perturbations of the shapes of development trap transition that do not pass the robustness tests are the secondary school enrolment and foreign aid. The inflection point location of the average years of schooling is robust to perturbation, while, for its slope, we could reject the null hypothesis at the 5% significance level, making it slightly indeterminate.

2.4 Case study - Afghanistan

2.4.1 Assessing Afghanistan's development

In this section, we attempt to describe the basic economic causes and key economic determinants of Afghanistan's economic development. We shift the focus from the military conflict perspective to the economic structure and its historical path dependence to explain Afghanistan's development path. To understand the economic impact of the US intervention and the economic development prospects under the new government after the withdrawal of NATO forces and the takeover of the Afghan government by the Taliban in 2021, we begin our analysis with the current economic situation in Afghanistan. Afghanistan remains a predominantly agrarian society, with the majority of the population (about three-quarters) living in rural areas. Much production is subsistence, markets are primarily local, and the state is highly decentralized, with limited authority in rural areas. The economic relationships in which production takes place are predominantly non-capitalist, and individuals are often tied to families, local communities, and clans through various forms of dependence and reciprocity. As of 2019, 42.5 per cent of the Afghan population is employed in agriculture, and approximately 80 per cent of all workers are employed through informal relationships rather than formal wage employment (World Bank, 2022). The state has limited authority in rural areas and is unable to enforce land ownership rights. Instead, the possession of land is determined by informal or customary arrangements (Roy, 2020, 14–15).

Ahistorical conceptualizations of the mainstream growth theory, such as neoclassical growth models driven by exogenous technological change and the savings rate, neglect the economic structural differences and fail to account for non-capitalist relationships. Thus, they cannot provide insights into the development trajectory of countries in the early stages of development (Amin, 1974a). Instead, we rely on early development theories, which consider that the use of surplus depends on its social and economic form and that investment comes predominantly from the profits of capitalist production and thus depends on its size and the ability of a capitalist sector to reproduce itself in an expanded form (Kaldor & Mirrlees, 1962; Lewis, 1954; Rostow, 1959). Because the capitalist sector in Afghanistan is small, there is little capital investment and industrial production and limited technological progress and productivity growth. Foreign trade and investment are also particularly constrained. The 20 years of US occupation had an impact on the economic structure and economic relations, especially in urban areas. Industrial employment has more than doubled from 9 per cent to 18.5 per cent and informal employment has declined from 93.3 per cent to 79.4 per cent of total employment (World Bank, 2022). Massive inflows of foreign aid, reaching nearly half of the GDP at its peak and consistently accounting for at least one-fifth of it, has contributed to government spending and the growth of public sector and service sector employment, which increased from 24.7 per cent of total employment in 2001 to 39 per cent in 2019 (World Bank, 2022). This raises questions about the extent to which changes in the employment structure have been driven by endogenous economic development and how persistent they will be under changing circumstances. The freezing of international aid after the Taliban took power has already drastically affected Afghanistan's economy. Many public employees are not receiving salaries, a situation that has far-reaching consequences for the urban economy. It is not only their conditions that are at stake but also the indirect demand effects on which a large part of the urban population relies (Landay & Shalal, 2021). Although these changes appear significant compared with the economic situation under the first Taliban government, Afghanistan remains among the world's least developed countries according to various indicators, which do not differ significantly from those of comparable underdeveloped African countries.

We approach the question of Afghanistan's development by examining its position in relation to the examined threshold regimes of various poverty traps. We discuss, evaluate, and empirically examine the role of various theoretically proposed development traps – endogenous mechanisms of the economic system that maintain uneven development and low productivity – in explaining Afghanistan's development path and its prospects for economic development.

Since there is virtually no foreign direct investment in Afghanistan, and public debt and trade represent only a small part of the economy, we will not investigate whether unequal exchange (Emmanuel, 1972), deteriorating terms of trade (Prebisch, 1950; Singer, 1950), or peripheral dependence on foreign capital (Amin, 1974a, 1974b; Mandel, 1999) are factors in Afghanistan's underdevelopment. The only element that we will examine in the context of the dependency development trap is the impact of foreign aid, which has accounted for a large share of the GDP over the past two decades.

2.4.2 Short summary of the main statistics for Afghanistan

Table 2.3 provides a brief summary of the main statistics that are analysed to establish the structure of the development traps in Afghanistan.

On the one hand, Afghanistan lags behind the world average in every indicator in absolute terms. On the other hand, the trends from 2002 to 2019 indicate some changes in most of the indicators that are more substantial than the changes in the world average. The only in-

Table 2.3: Summary statistics for Afghanistan and the World (Source: own work)

	Afghanistan 2002	Afghanistan 2019	World 2002	World 2019
GDP PPP	1190	2065	8012	11012
Fertility	7.272	4.321	2.644	2.402
Secondary education enrolment	12.5% (2003)	55.4% (2018)	62.3% (2003)	76% (2018)
Years of schooling	3.3 (2005)	4.8 (2015)	8.3 (2005)	9.2 (2015)
Agricultural employment	0.644	0.425	0.393	0.267
Vulnerable employment	0.925	0.794	0.518	0.436
Urbanization	0.223	0.258	0.476	0.557
Industrial VA per capita	US$65	US$90	US$1451	US$1756
Economic complexity	/	-3.555	0.007	-0.007
Foreign aid	49.4% (2009)	0.224	0.2% (2009)	0.002

dicator for which this does not hold true is urbanization, which is stagnating at low levels persistently. Although the comparative trends look promising for Afghanistan's development, we cannot evaluate whether they alone indicate enough substantial progress to enable it to escape from the development traps. For that reason, we continue with the empirical analysis of the development trap structures and transitional regimes.

2.4.3 Empirical results

Overall, Afghanistan appears to be caught in several development traps.

Afghanistan's fertility dropped dramatically from 7.27 to 4.32 between 2002 and 2019. While in 2002 it was actually higher than predicted by the model for the respective GDP PPP level, the decline in fertility during this period was so substantial that in 2019 it was lower than the model-predicted fertility. Despite the substantial improvement in fertility levels, the values are still high in absolute terms, close to the inflection point of the model curve, and may indicate that Afghanistan nevertheless remains caught in the demographic trap in terms of fertility.

Similar to fertility, secondary school enrolment in Afghanistan has also improved dramatically over the period 2003–2018, from only 12.5 per cent to 55.4 per cent. However, despite the positive trend, secondary school enrolment in Afghanistan remains below the model prediction for similar GDP PPPs.

Considering average years of schooling, Afghanistan has improved significantly on this indicator, from 3.32 years of schooling in 2005 to 4.83 in 2015. Although the data in this case are closer to the model prediction, they still do not reach the model's inflection point threshold.

Agriculture accounted for 64.4 per cent of employment in Afghanistan in 2002 and in 2019 declined to 42.5 per cent, which is lower than the model predicts for the GDP level. With the significant decline in agricultural employment, Afghanistan appears to have passed the inflection point of transition from a predominantly agricultural country. However, this appears to be linked with large increase in service employment in the urban areas, linked with the networks of the occupational forces or directly dependent on foreign aid financing.

The share of informal employment in Afghanistan declined from 92.5 per cent in 2002 to 79.4 per cent in 2019. Both values are above the model predictions for vulnerable employment at Afghanistan's GDP PPP values and far from the tipping point, suggesting that Afghanistan has above-average problems with informal and dependent employment, organized family labour and the influence of the communal and custom based social structures on the functioning of the economy compared with similarly developed countries.

Of the indicators examined for Afghanistan, the changes in urbanization are the least pronounced. The low urbanization rate is virtually stagnant, at 22.3 per cent in 2002 and 25.8 per cent in 2019. Afghanistan's urbanization rate is below the model's predictions and well below its inflection point, suggesting that the extremely rural character is an important issue for Afghanistan's development.

Afghanistan's industry VA per capita was only 65.16 US dollars in 2002 and 89.75 US dollars in 2019, both below the model's prediction and deep into the phase before the industrial transition even begins. This indicator indicates that Afghanistan is largely a pre-industrial society that has extremely limited industrial capacity. Thus it cannot benefit from any scale effects linked with manufacturing industries, neither on the supply nor demand level of the analysis.

The only data for Afghanistan's economic complexity is 0.39 in 2019, which is below the model prediction and lower than the threshold value at the inflection point. Afghanistan's mean technology density was 0.34 in 1981 and 0.32 in 2001, indicating technological stagnation during periods of ongoing conflict. The data for Afghanistan's technology density include many missing values and can be considered overvalued because the available data can exhibit above average values, while missing data corresponds to very limited technology use or even its complete absence. Both values are above the model predictions, albeit below the inflection point of the transition.

Despite the non-robust relationship between foreign aid and development, the size and dependence on foreign aid represents one of the fundamental characteristics of Afghanistan's development. Afghanistan is one of the countries with the highest dependence on foreign aid. Foreign aid as a share of the GDP was 49.4 per cent in 2009 and 22.4 per cent in 2019. Persistent high values of foreign aid can substantially affect developmental trajectory by altering the exchange rate and competitiveness of exports (Dutch disease), domestic consumption structure, as well as domestic production structure.

2.4.4 Discussion

Based on the theories of development traps and our analysis, we can conclude that several development traps function simultaneously in Afghanistan and that their negative effects reinforce each other. The core issue is the virtual absence of industry. The impact of industrial development extends beyond mere technology and productivity gains. Industrialization is associated with broader structural change in society that result in the formalization of legal relations, urbanization, and ultimately the inclusion of women in the labour market, all of which are indirectly linked with access to education and fertility. The absence of industry in Afghanistan corresponds to the extremely rural and informal character of the country's social structure and its weak state. Its functioning perpetuates itself and does not have the potential to develop industrial capacity endogenously.

The state of Afghanistan's development is highly path dependent and can be understood through its history and geographical position. Relative resource poverty, limited contacts and networks due to geographical isolation, the absence of European colonial rule, lack of sea access, and navigable rivers have created conditions that have contributed to the reproduction of the old social and institutional structures (Acemoglu et al., 2001). Consequentially, Afghanistan's state, throughout its history, has always been very weak, decentralized, unable to control its land or collect taxes, reliant on local communal elites, and often engulfed in conflict (Roy, 2020). Despite attempts to implement developmental modernization programmes in the past, first by Amanullah Khan after the First World War, then by Mohammed Zahir Shah, and later by Soviet-backed political forces, none succeeded in overcoming the old institutional and social structures. It seems that the US-backed state structure encountered similar problems when trying to further its developmental agenda.

There have been two important changes during the period of US intervention. The education enrolment rate increased dramatically and employment in the tertiary sector practically doubled in the period 2002–2019. These changes cannot be understood without the massive increase in foreign aid that has supported the changes in both education and the employment structure. With almost no industry and a weak state that is unable to collect taxes in rural areas, much of the public and tertiary sector employment has been at least partially dependent on foreign aid. As a result, there are now two very different and weakly connected social worlds – on the one hand, rural, communal, and agrarian and, on the other, urban, more formal, and service oriented. Usually, the development of extensive urban areas and public services is endogenously linked to the economies of scale of industrial development and their redistribution through increased demand and taxation – a crucial link that is missing in Afghanistan.

In this context, we can also understand the decades-long civil conflict in Afghanistan not only as a pure military conflict but also as a conflict between rural and urban social structures' functioning. Thus, the recent victory of the Taliban could be understood as a victory of rural, agrarian, conservative, and communal social forces. This further diminishes Afghanistan's prospects of escaping its development traps as the conservative government may compromise access to education, decline in fertility, and industrial development. The freeze on foreign aid primarily affects the urban, public, governmental, and non-governmental services that rely on it. If foreign aid remains beyond reach, the consequences will be devastating for the urban and more highly educated population – many have already emigrated, while those who remain will be pushed back into rural areas if the Taliban fails to create a nationwide tax system.

Chapter 3

Technology Diffusion

3.1 Role of Technology in Development

In this chapter, we focus on the technology and the process of technology diffusion as one of the factors affecting uneven development. Our contribution is threefold. First, we conceptualise technological diffusion as a process embedded in existing social relations, with existing levels of development and wage levels as the main determinants of technology adoption. Second, we present a simple dynamic mathematization of the technological diffusion process in the form of a macroeconomic technology diffusion model that incorporates the economic and social effects of uneven development as primary determinants of technology diffusion. Third, we test our main hypothesis with nonlinear and mixed effects regressions using the CHAT and PENN databases.

The concept of technology is central to most macroeconomic theories, and theories of growth and development. The long run growth of output per capita in the neoclassical growth theory is in its entirety driven by the assumed exogenous technological progress (Solow, 1957; Swan, 1956). The attempts to endogenize the technological progress of the Solow-Swan model, both neoclassical endogenous growth theories (Lucas, 1988; Romer, 1990), neo-Schumpeterian growth theories (Aghion & Howitt, 1992; Grossman & Helpman, 1991), theories focusing on the learning process (Arrow, 1962; Pasinetti, 1993; Young, 1991, 1993b, 1993a, 1998) and technology gap literature (Fagerberg, 1987, 1994) put the broadly conceptualised human knowledge, innovation and adoption of technology at the forefront of the dynamics of growth and development. Even the neoclassical theories of real business cycles rely on exogenous technological shocks to explain the cyclical movements in the economy (Kydland & Prescott, 1982).

The effect of unevenly distributed technology and broadly defined human knowledge on the cross-country income dispersion is one of the most well documented and examined issues in economics (Abramovitz, 1956; Comin et al., 2006; Comin & Hobijn, 2010; Comin & Mestieri, 2018; Fagerberg & Godinho, 2018; Gomulka, 1990; Hsieh & Klenow, 2009;

Klenow & Rodríguez-Clare, 1997, 2005). According to Comin and Hobijn (2010) the differences in technology adoption account for at least 25% of the differences and as much as 50% in the 19th century. However, despite the widespread empirical and theoretical understanding of the link between the technology diffusion and economic development, there exists very limited theoretical explanation that could provide an endogenous *economic* explanation for such patterns of technological progress and adoption in the context of differently developed countries. Our simple conceptualization of technology diffusion aims to address this issue both theoretically and empirically.

3.2 Conceptualisations of Technology and its Diffusion

3.2.1 Concept of Technology

Broad conceptualisations

There is no simple and strict definition of technology. The traditional economics literature views technology as a set of factors that contribute to productivity (Dosi, 1982; Dosi & Nelson, 2016). Broader definitions, on the other hand, view technology as information, human knowledge, and know-how, which often take complex and tacit forms (Arrow, 1962; Lundvall & Johnson, 1994; Pavitt, 1999). In either way, broader descriptive conceptions of technology are defined more strictly within theoretical models. While there exist wide heterogeneity in the concrete characterizations of technology, from short term to long term, from exogenous to endogenous, from firm based to society wide, the main conceptualisations of technology can be separated on two broad groups:
1.) A Technology defined as a factor of production;
2.) A Technology defined as a frontier of possible production techniques.

On the one hand, according to the first conceptualisation, technology coexists and develops independently of other production factors, offering explanations of productivity growth that cannot be explained solely by the changes in the observable factors of production. Changes in the proportions of production factors can happen independently of technological change, and *vice versa*, changes in technology can happen independently of factor proportions. On the other hand, according to the latter broadly defined group of conceptualisations, the technology is viewed as a set of possible production techniques (combinations of factors of production) and technological change is viewed as an extension of such a set (Comin et al. 2006; Fagerberg et al., 2010; Gomulka, 1990; Stoneman, 2010).

Technology as a Factor of Production

Most contemporary conceptualisations of technology define it as either one of the production factor directly or as a part of the production function which does not relate directly to production factor effects.

There are different levels of abstraction and different conceptualisations of the technology. These mainly differ with respect to whether technology is conceptualised endogenously or exogenously and include among others: technology as a production function residual (TFP), broadly defined costlessly accessed public knowledge, direct embodiment of R&D research stock and innovation capacities, quality ladder upgrading and replacing of the old technology through the process of creative destruction. While technology conceptualised as a production factor is characteristic of most of the neoclassical exogenous and endogenous growth theories, attempts were made to include technology in models featuring separate sector, function of which is only to produces technology (Gómułka, 1970, 1990; Nelson & Phelps, 1966; Oniki & Uzawa, 1965).

Much of the empirical and theoretical work concerning the economic growth uses the concept of the TFP to measure the progress and growth of technology. In the setting of the neoclassical Solow-Swan model with Cobb-Douglas production function consisting of labour and capital production factors, TFP is assumed to represent the contribution of the technology and general human knowledge towards output and productivity. The TFP was first explored by Abramovitz (1956), who famously argued that empirically TFP is "the measure of our ignorance about the causes of economic growth (Abramovitz, 1956, 11)". The early as well as more recent empirical studies conducted using the benchmark Solow-Swan model concluded that very little could be explained only by the changing factor proportions and their growth (Denison, 2012; Hall & Jones, 1999; Jerzmanowski, 2007; Kendrick, 1961; Klenow & Rodríguez-Clare, 1997; Solow, 1957). In other words, the majority of information explaining the productivity growth was hidden behind a TFP residual.

The conceptualisations of technology as a factor of production within any kind of aggregate production function has an appeal due to the simplicity of the modelling and relatively easily derived stylised results. It enables definition of the neutrality of technological change, which enables both theoretical analyses of different models with respect to the types of neutrality of technological progress, as well as empirical studies of the effect of the technologically non-neutral changes - defined as "biased" technological changes.

There exist two main definitions of neutrality of technology, which in some cases overlap, but mostly don't. On the one hand, Hicks (1963) defines neutral technology when it contributes to output increases while concurrently the factor shares remain stable *ceteris paribus*. Harrod (1951), on the other hand, defines neutral technological progress as the one which increases output and at the same time leaves capital and output ratio unchanged *ceteris paribus*. While in the past the issue with the two different neutralities of technological change was mainly due to the concern for the long run stability of macroeconomic models

(Acikgoz & Mert, 2015; Asimakopulos, 1963; Batra, 1970; Gomulka, 1990; Inada, 1969; Okuguchi, 1968; Uzawa, 1961), more contemporary debates focus on the explanation of long term changes in factor proportions and, more consequentially, incomes attributed to different factors as caused, among other reasons, by the non-neutral technological changes. An example of such a study is a task based model with disaggregated labour skill structure, where non-neutral technological change is the driver of the long term changes in the income distributions between groups of differently skilled labour (Acemoglu & Autor, 2010).

These approaches to the conceptualisation of technology have been extensively criticized on multiple levels (Fagerberg, 1994; Galor, 1988; Gomulka, 1990). The first, more technical critique, argues that the TFP, and more generally technology as a separate factor of production, must be questioned due to potential interrelationships between factors of production. On the one hand, the progress of technology in many cases requires substantial investment, as it is embodied in fixed capital. Domar (1946), Kaldor (1957) and Kaldor and Mirrlees (1962) argued for conceptualisation of technology that must be linked with investment and offered extensive critique of the conceptualisations of technology as independent of the machines in which it is embodied. Nelson and Phelps point out that traditional growth accounting cannot consistently separate the effects of capital accumulation and technological change due to such interdependencies. On the other hand, the non-neutral technological change can affect factor proportions, leading to indirect effects on the factor proportions that are directly caused by non-neutral technology changes, creating yet another endogenous interdependency, making it hard for researchers to adequately separate the effects of technology and other factors of production (Gomulka, 1990).

The second major critique came from the English Cambridge School of Economics within the discussion known as the Cambridge controversy. The issues raised by the post-Keynesian and Sraffian authors greatly surpass the issue of technical change, and can be understood as the last attempt to shake the neoclassical foundations within the mainstream economic theory. The critique extensively focused on the concept of the aggregate capital and the aggregate production function, especially in its Cobb-Douglas form characterized by diminishing marginal productivities of the production factors (Sylos-Labini, 1995). One of the main arguments against the aggregate production function was the fallacy of composition - the derivation of macroeconomic aggregate result based on the laws governing microeconomic interaction. Apart from more technical dimensions of the issue of capital deepening, the debate was highly political with respect to the question whether marginal productivities of the aggregate production function determine the distribution of income.

Marxist Conceptualisation of Technology

The Marxist conceptualisations of production and technology revolve around two main concepts. The first concept is the productive forces and their development. Productive forces comprise all the capacities that make the labour productive: labour itself and its various degrees of skill and knowledge, labour embodied in the means of production also with various degrees of sophistication and level of development and broader technological and organisational level of development. All the elements combined represent the underlying basis of the economic output and productivity.

The second concept that aims to relate production, productivity and technology is the organic composition of capital. Marx defines organic composition of capital as the unity of the value composition of capital and technical composition of capital (Marx, 1992). While the value composition of capital is defined as the ration between the value of the constant capital and the value of labour used in production, the technical aspect reflects the technical division between the use of material - dead and living labour within the production process. Many Marxist authors directly or indirectly assume some relationship between the aggregate capital intensity and the technological sophistication of the production. Such assumptions would lead to something similar to an exogenous growth model. However, as analysed extensively within the neoclassical framework, there is only a vague connection between the capital intensity (indirectly connected with organic composition of capital) and the productivity of labour. The productivity differences are not necessarily driven by the capital intensity, therefore, the organic composition of capital is not a relevant conceptualization of the technology as it cannot capture the technological progress that mostly happens without substantial changes in capital intensities or even by lowering it.

Our conceptualization

Our conceptualization of technology is multidimensional and draws from various traditions.

First, we refrain from conceptualizing technology as a separate factor of production. Since our aim throughout this dissertation is to explore the effects of a connection between factor costs and technological growth, the gravest mistake would be to conceptually separate technology from the functioning and effects of other technical factors of production. When individual technologies are considered, one can argue against conceptualizations of technology that would treat it as a separate factor of production. If we imagine a neoclassical production function, with land, capital and labour the question is: what could the smooth curves represent in the case of a single disaggregate technology. Does an alternative between simple farming tools and a tractor represent technological change or mare increase in capital intensity? If a farmer and a single combined harvester represent a given technology, what changes when farmer hires another labourer. Clearly labourer cannot join under conditions of the existing technology, his contribution being necessarily qualitatively different. With these examples we see that separation of the concept of technology and other factors of production within the production function is meaningless on the highly disaggregate level, as technology exhibits approximately Leontief structure in the short run and is inseparable from investment. In the longer run and in more broadly aggregate sense, smoothness of the curves could be more easily justified conceptually. However, as established by the Cambridge controversy, the aggregate production function is conceptually problematic precisely due to its aggregate assumptions that resemble microeconomic behaviour, as well as due to the important structural dynamics that remain hidden behind the aggregate form.

The alternative is to define technology as the production frontier (Denison, 2012; Jorgenson & Griliches, 1967; Maddison, 1987). Our conceptualization throughout this dissertations conforms to this approach. We define technology as a global production constraint linked to a specific period. This enables us to differentiate between short-term, medium-term and long-term technological changes. The short-term constraint allows only changes in employment as investment comes with a lag. The medium-term production constraint comprises changes in investment and employment under condition of a common global constraint. The changes in factor proportions and their potential scale effects represent the medium-term technological progress, which can be interpreted as a technologically driven medium-term cycle (Perez, 1983; Von Tunzelmann, 1995). The long-term technological progress is defined as a change and an extension of the medium-term global production constraint.

In this chapter, technology is treated only empirically and is measured by an intensive or extensive measure of its concrete use. Throughout the rest of the dissertation, however, we operationalize our definition of technology within a disaggregate production function, that aims to capture the medium-term global production constrain and enables us to study the dynamics of technological change conditioned by the development of productive forces and specific technical production factors. Despite the issues raised by the Cambridge controversy, we utilize the concept of the production function on a disaggregate level. However, as opposed to the neoclassical conception which derives income distribution based on the technical relations defined by the production constraint, we clearly separate the social and technical dimensions. While the production factors, broadly conceptualized as elements of the productive forces, can be, at least in the medium-term, meaningfully connected to represent the global medium-term production constraint, the technical factors carry no direct role in the distributional dimension of the economic system, which is determined through broader social determinants, aggregate productivity and class struggle.

3.2.2 Technology progress, diffusion, adoption

Evolutionary Approaches

Despite the differences in the definition of the object of study, there are no such differences in economic theory when it comes to the relevance and social and economic consequences of technological progress and diffusion. There is little dispute that continuous technological progress is the essential feature of the capitalist mode of production as opposed to pre-capitalist modes of production, and that patterns of technological innovation, diffusion, and adoption are fundamental determinants of productivity growth, global convergence or divergence, sectoral and broader structural change, and general social and economic development. The theoretical and empirical study of the process of technological diffusion thus appears to be fundamental to understanding the determinants of both uneven development and structural economic dynamics at the country level.

The majority of the evolutionary approaches to technology diffusion emerged due to the failure of the neoclassical theories to account for the role of the diffusion of technology in shaping the patters of the worldwide economic growth and its country specific paths. Either the complete absence of technology diffusion conceptualisation or simple assumptions of technology as a global commodity accessibly to everyone within the mainstream theory are the main reasons for the emergence of the modern evolutionary approaches to growth, which put innovation and diffusion of technology at the forefront of their explanation of cross country disparities in productivity and income.

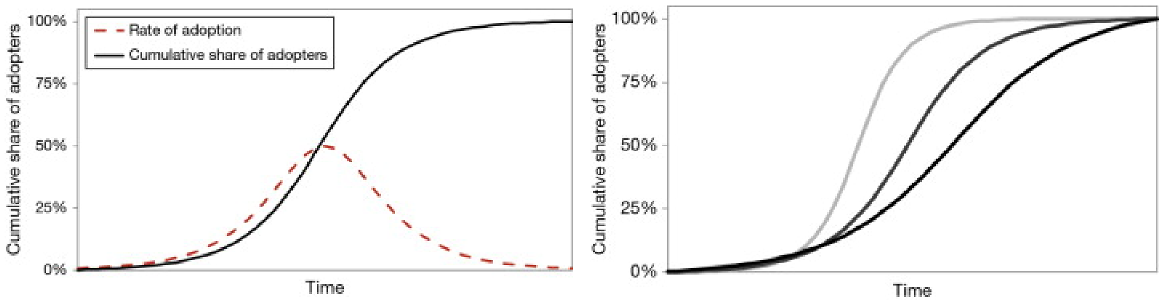
The technology gap theory aims to explain economic convergence and divergence processes and focuses on technology diffusion and adoption as primary factors determining uneven development (Abramovitz, 1986; Dosi, et al., 1990; Fagerberg & Godinho, 2018; Fagerberg & Verspagen, 2002; Fagerberg, et al., 2010, Nelson & Pack, 1999; Verspagen, 1991).

There are three central assumptions that are common to this theoretical approach. First, the technology is not assumed to be a global public good (Fagerberg & Verspagen, 2002). This has a consequence that technological differences are not simply or costlessly instantaneously overcome. The ability to overcome the technology gap significantly depends on the non-economic factors, mainly the institutional structure and its ability to adapt and structurally change in order to allow the absorbtion of the new technologies. Second, the technology gap approach tries to take into account the intertwinement of different social, technical and economic dimensions (discussed in the previous section) in the process of technology diffusion. The separation of technical and economic structures from the social and institutional structures is present in Perez's (1983) conceptual analyses of Kondratiev long waves and technology diffusion within them. Freeman and Louçã (2001) similarly conceptually ague in favour of inclusion of multiple social domains to offer explanation of technological change while taking into account the complex intertwinement of historical, scientific, political, technological and cultural dimension in explaining the technological development and its diffusion in their historical analysis spanning from industrial revolution onwards. Any approach that reduced the question of technology and its diffusion on only technical and economic factors (research spending, human capital, scientific innovation) fails to grasp the core of the mechanism which shapes the economic and technological growth. Third, the technology gap models produce neither balanced growth neither long term steady states. They function in the tradition of Schumpeter's (1934) analysis of disequilibrium caused by creative destruction and subsequent waves of development caused by the uneven distribution of innovation and adoption through time (Freeman & Louçã, 2001; Kondratieff, 1935; Schumpeter, 1934; van Duijn, 1977).

Conceptually the technology gap approach models the potential for high productivity growth and catch-up as growing linearly with the size of the technological gap. Its core explanation of why economic convergence is the exception rather than the rule in the global economy mostly draws on technological congruence (Abramovitz, 1986) and social capabilities (Ōkawa & Rosovsky, 1973) that supposedly determine the ability to implement and adopt technology (Rosenstein-Rodan & Bhagwati, 1973; Rostow, 1959). This social capacity for technology adoption is explained primarily in terms of extra-economic characteristics, such as educational attainment, institutional environment, political stability, labour market structure, financial market development, and effective demand. Verspagen (1991), for example, simply assumes that the capacity to learn drops exponentially with increasing technology gap to derive his model of catching up and falling behind. His model thus exhibits two steady state sinks: (1.) a technology trap of low development and low growth due to small spillovers (low learning capacity overcomes high potential for technological catch-up) and (2.) a classical convergence to the level of the developed country (initial learning capacity is high enough to overcome the technology gap and converge). The technology gap literature thus relies primarily on extra-economic factors in conceptualising and explaining the diverging trends in technology diffusion.

The majority of the contemporary neo-Schumpeterian models of creative destruction operate with similar assumptions. They model the interaction of innovation and lagged technology adoption as a function of the size of the technology gap. While the core model examines technological growth within a closed economy (Aghion, 2004; Aghion et al., 2005, 2016; Aghion & Howitt, 1992; Hellwig & Irmen, 2001; Howitt & Aghion, 1998), the approach focuses on explaining cross-country differences in capital accumulation as well as productivity differences. However, similar to the technology gap theory, productivity differences arising from innovation and spillover effects in cross-country setting are not explored endogenously, but are assumed to be determined exogenously, by parameters affecting the ability to adopt technology or the capacity to innovate, which are determined by political

Figure 3.1: Logistic curves representing technology adoption (Fleiter & Plötz, 2013)



(a) Share and rate of adoption

(b) Different slopes and inflection points

and institutional environment (Acemoglu, Aghion, and Zilibotti, 2002; Aghion et al., 2005, 2016; Howitt, 2000). In a similar fashion, Parente and Prescott (1994) analyse a model of growth, where exogenously growing worldwide technology is publicly available but there exist country specific barriers to adoption of new technology, which range from regulatory and legal constraints, to bribe requirements, violence and strikes.

The Logistic Curve of Technology Adoption and Microeconomic Models

With the broader macroeconomic patterns of technology change covered, we turn to the analyses which focus on the adoption of a single technology. Griliches (1957) was the first to introduce the logistic curve to describe an individual cumulative technology adoption curve. Logistic curves have some desirable features that make them appropriate for approximating the pattern of technology adoption. The logistic function exhibits nonlinear transitional dynamics between the two discrete values - zero and saturation level (Figure 3.1a). In the early phase only minority of early adopters use the new technology and adoption rates remain low. Near the inflection point the rate of adoption peaks and technology becomes predominant. In the late phases laggards are the last to adopt the new technology until it reaches the saturation point to be finally replaced by the new technology, repeating the cycle. The analysis of technology adoption with logistic curves enables cross-country or cross-region comparisons of the differences in the patterns of technology adoption (Figure 3.1b). The differences in the technology adoption rates can be due to translation of inflection point (lagged start of adoption), differences in the slope of logistic curves (different rates of adoption) and differences in the long run level of technology use (different steady state of technology intensity).

Since the introduction of the logistic curve to the analysis of technology adoption, it has been used in wide variety of both empirical analyses and theoretical models. Various microeconomic and game-theoretic approaches focus on modelling strategic decisions by firms to adopt a new technology under various conditions and attempt to explain the pattern of technology adoption characterised by the logistic S-curve.

Some of these approaches examine expectations of reductions in technology supplier's costs to explain technology adoption lags (Stoneman & Ireland, 1983; Ireland & Stoneman, 1986), some model rivalry in duopoly setting (Fudenberg & Tirole, 1985; Reinganum, 1981; Riordan, 1992), some focus on the uncertainty of the benefit brought by the new technology (Jensen, 1982; McCardle 1985; Thijssen et al., 2001), while some approaches combine both (Huisman & Kort, 2000; Jensen, 1992; Stenbacka & Tombak, 1994).

There are two common features of all microeconomic and game theory approaches. First, they clearly separate, on the one hand, the issue of innovation and research and, on the other hand, the adoption of technology in mass production. Second, they work by abstraction of firms' strategic behaviour from the macroeconomic environment. They may offer some insight into the functioning mechanisms for the delayed adoption of technologies in a country that is relatively homogeneous. In such cases, game theoretic models of duopoly rivalry, cost reduction expectations and uncertainty enable us to understand the pattern of technology adoption and dynamic mechanisms which produce early adopters and technologically lagging firms within a homogeneous country among similar firms. In other words, these models and conceptualisations deal primarily with dynamics *within* a homogeneous region not *between* them. Therefore, such approaches cannot provide a theoretical basis for explaining the dynamics of technology adoption in the context of differently developed countries, as much more fundamental disparities between regions and countries determine the relative patterns of technology adoption. Institutional differences, access to skilled labour and huge disparities in the relative costs of production factors determine the wide cross-country disparities in the costs and benefits of local technology implementation of already exiting technologies. Compared to the effect of these disparities, the effect of uncertainty of the benefits of the early upgrading of new technologies and short term expectations of their cost declines are minuscule and mostly concern the dynamics of innovation and adoption of technologies in the developed countries.

Stylised Empirical Facts and the Neoclassical Model of Technology Diffusion

Despite the wide uses of the logistic curve in explaining the process of innovation and the subsequent process of technology adoption, its utility as approximation of technology adoption was disputed empirically. In general, concrete technologies can have either extensive or intensive measure. The extensive measure of technology adoption captures the share of adoption among potential adopters and is individually a categorical variable 0 or 1. A share of steel produced with certain technology or a share of households with access to internet are examples of the extensive measure of technology adoption. The intensive measure, on the other hand, captures how many units representing certain technology are used in the economy (per capita). Quantity of combined harvesters, or length of the rail-roads are examples of intensive measure of technology adoption. Constructing and using Cross-country Historical Adoption of Technology (CHAT) database (Comin & Hobijn, 2009), the authors demonstrated that the logistic curve was a good approximation for the extensive margin of technology adoption, but failed to account for the intensive margin of technology adoption (Comin et al., 2006).

Using the collection of more than 100 technologies and their adoption across countries, with time span of more than a century for some of them, Comin et al. (2006) established four additional stylised facts empirically tested with the CHAT database:
1.) The dispersion in the adoption levels for certain technology is on average 5 times greater than cross-country income dispersion;
2.) Cross-country dispersion of technology adoption are highly correlated across technologies;
3.) For an average technology, an average convergence rate is 4%;
4.) The convergence in technology adoption is on average three times faster for technologies invented after 1925 than earlier technologies.

Aiming to offer a comprehensive theoretical explanation, on the one hand, for the patterns empirically observed on the level of concrete technologies and, on the other hand, the overall growth and stylised facts tied to growth theories, Comin and Hobjin (2004, 2010) introduced a theoretical model that merges neoclassical one sector growth model and process of technological diffusion to endogenously explain the growth of total factor productivity.

They introduce different firms that produce intermediate goods with various productivity levels. New intermediate goods can be produced more productively in the long run, but are more costly in the short run - they are produced within the framework of monopolistic competition with fixed entry costs. The endogenously determined production of intermediate goods exhibits a slow diffusion of new technologies (spread of new intermediate goods) captures the main theoretical and empirical findings of the microeconomic and game theoretic models - the technology adoption curves are logistic, providing an endogenous explanation of total factor productivity at the sectoral and aggregate level. The aggregate results of the model coincide with the neoclassical Solow-Swan model. Empirically calibrating the model with the CHAT database, the main result is that average lag of technology adoption is 45 years since invention, measured worldwide. (Comin & Hobijn, 2004, 2010)

The core theoretical explanation of the technology adoption lags within this model is in the introduction of monopoly capital goods producers with fixed entry costs. Therefore, this model, although its authors claim it to be a macroeconomic model, in fact relies on the microeconomic dynamics, similar to those examined in the previous sub-subsection. The core framework of the model is closed economy in general equilibrium. Thus, same considerations apply as with microeconomic and game theoretic approaches. It abstracts from all cross-country differences in institutions, education, labour skill, and most importantly, factor prices. Its explanation of technology lags rely on a monopoly, fixed cost entry barrier, which - similarly as with microeconomic approaches - can explain the dynamics of technology adoption *within* a country, but not *between* countries. Across countries disparities in factor prices as well as uneven specialisation in different tasks performed in the global economy (uneven global division of labour) determine highly unequal costs and benefits of technology adoption that cannot be explained by mere fixed cost barriers of monopoly producers. For this reason, cross-country differences in technology adoption remain theoretically unexplained or exogenous.

Relationship between factor costs and technological upgrading

Competition among capitalist firms remains the driving force that determines the choice of technology, the direction of investment, and the direction of research. Technology adoption depends greatly on the cost of its implementation, which depends strongly on the relative level of wages and relative costs of labour replacing machinery. The main assumption of most of the conceptualisations dealing with the choice of technique, technology and production factor costs is that technology does not exist as a separate factor, but is (partially) embodied in concrete capital investment as well as concrete factor proportions.

The early debates regarding the choice of technique in developing countries relate to this topic. Kahn (1951) and Chenery (1953) claim that the social marginal productivity is a guide to investment, leading to conclusion that less developed countries should specialise in less capital intensive industries and *vice versa*. On the other hand, Galenson and Leibenstein (1955) argued that static optimization (of either output or profit), while equal to the rule equating marginal productivity, does not necessarily lead to long term optimal investment choices of technique. Increasing the excess labour by investing into labour replacing capital can create greater output growth than the use of labour absorbing capital (Galenson & Leibenstein, 1955). Amin (1974) argues in favour of a developing country's strategy of investing in most productive techniques regardless of factor cost ratios and marginal productivities. He equates the most productive techniques with more heavy as opposed to light techniques in terms of their organic composition of capital.

Sylos-Labini (1984) was one of the first economists to analyse a formal model in which firms face a choice between investment into labour saving machinery or hiring labour power. Similarly Zeira (1998, 2005) analysed one of the first task based models of industrialisation. The model features a continuum of tasks which exhibit heterogeneous cost of machines which can replace labour. Under profit maximizing condition, the results demonstrate a link between wage levels and productivity growth - both are linked in a positive feedback loop. High wages create incentives to use more costly machines which leads to further industrialization, while industrialization contributes to further increases in wages. The model also features multiple steady states: the industrialisation cannot take off if the initial state of the economy is below a certain threshold.

Although all of these approaches work within the framework of a closed economy, they have explicit implications for all studies of technological development and technology adoption in the setting of differently developed countries. If the relationship between the relative prices of factors of production, primarily the relative price of labour power and the relative price of fixed capital, are determinants of technological progress, as studied by Sylos-Labini (1984) and Zeira (1998, 2005), then cross-country differences in relative factor prices determined by initial differences in productivity and technological development, could be a source of long-run structural differences in the relative costs of technology implementation and thus explain, at least in part, the long-run patterns of technology diffusion.

But what if aggregate technological change does not replace labour, but rather complements labour? The reasoning that distinguishes the effects of aggregate technological change lies, first, in the duality of technological change - one type represents the improvement of production efficiency (substitution of labour by machines, organisational improvements, etc.) and the other type represents a qualitative expansion of the consumption basket by expanding existing consumption possibilities (Frey, 2019; Vercherand, 2014). To obtain the aggregate technology effect, we also need to include the income effect that results from the improvement in production efficiency and drives the demand-side substitution effect, coupled with the demand changes due to qualitative changes in consumption markets (Acemoglu, 2010). For this reason, the distinction between whether the aggregate technology is a labour-substituting or a labour-complementary technology already involves complex interactions that go beyond the purely technical changes brought about by the technology and interact with factor markets and the dynamics of structural change (Acemoglu, 2010). Important to our main argument throughout the dissertation is that both types of technological change - improvements in production efficiency and qualitative extensions of consumption - are both permanent and constant features of capitalist dynamics that are not mutually exclusive but rather coexist. The technology dynamics that drive micro-level labour substitution endogenously and depend on factor costs are not negated by *post festum* income and substitution effects and complementary qualitative expansions in final demand. Both types of technological change permanently coexist and are two sides of the same coin. However, most of our arguments relate to the labour-substituting and efficiency-enhancing changes on the supply side, which are permanent feature of the capitalist economic system and exist regardless if the aggregate technology effect is labour-substituting or labour-complementary.

3.2.3 Conclusion and Research Gap Identification

According to the presented literature review on technology and technology diffusion, we detect a major duality in the current approaches and conceptualizations. On the one hand, we have the theories of technology diffusion that aim to capture the properties of concrete technology adoption through technology adoption curves that are detached from the broader macroeconomic determinants of uneven development and from the core-periphery heterogeneities that perpetuate uneven technology diffusion (Comin & Hobijn, 2010; Griliches, 1957; Stokey, 2021). On the other hand, macroeconomic and growth theories that focus on explaining uneven development, development traps, and conditions for convergence or divergence do not conceptualise and reproduce technology adoption curves that would correspond to the uneven development that is the subject of their study. Their conceptualization of technology is broad and often reduced to a one-dimensional parameter, conceptualised either as a set of possible production techniques (Fagerberg et al., 2010; Gomulka, 1990) or even as information, human knowledge, and know-how, which often take complex and tacit forms (Arrow, 1962; Pavitt, 1999).

The main aim of the following section is an attempt to bridge this gap by formulating a model of technology diffusion that both reproduces the pattern of technology adoption curves for individual technologies in individual countries and simultaneously endogenizes the persistence of uneven technology diffusion across differently developed countries.

3.3 Dynamic Model of Technology Diffusion

3.4 Introduction

In this section, we address the complex interdetermination of technological diffusion and uneven development, understood as persisting differences in economic development between countries. The main contribution is bridging the gap between theories of technology adoption that focus on the shape and pattern determining technology adoption curves (Comin & Hobijn, 2010; Griliches, 1957; Stokey, 2021) but abstract from uneven development, and more aggregate approaches to technology and path-dependent uneven development (Fagerberg & Godinho, 2018; Myrdal, 1957; Verspagen, 1991).

Our conceptualizations aims to endogenously explain the emergence of technology adoption curves in the setting of uneven development. We aim to analyse the endogenous economic differences across countries that are relevant for technology adoption in the single dimension of relative technology implementation costs. The main hypothesis is that the relative wage level is one of the most important endogenous socioeconomic determinants of the relative cost of technology implementation and thus significantly determines and shapes the socially uneven process of technology diffusion and overall development. Generalising the concept of spatial distance in diffusion processes, we conceptualise the space of technology adoption costs and use it to present a novel dynamic mathematization of the technological diffusion process in the form of a macroeconomic technology diffusion model that incorporates the economic and social effects of uneven development as primary determinants of technology diffusion. We test our model and our main hypothesis that relative wage levels are a determinant of relative technology adoption costs with nonlinear and mixed effects regressions using the CHAT and PENN databases.

The first main contribution of the chapter lies in the novel reconceptualization of technology diffusion in the international setting and its mathematical representation. Although the diffusion analogy is widely used in conceptualising and modelling technology adoption, the mathematical form of technological diffusion in both mainstream and heterodox theories, as well as in micro and macro approaches, does not take the form of the diffusion equation. The reason is that technology diffusion is a complex process determined by technical, economic, social, and institutional factors, and simple spatial distance has very little significance in this process. We aim to link the mathematical property of the diffusion equation and the broader social and economic constraints in a dynamic model that offers an endogenous explanation of technology diffusion in the international setting of uneven development. This requires a comprehensive reconceptualization.

Rather than focusing on the notion of spatial distance that determines physical and thermal diffusion, we create a concept of the space of relative costs of technology implementation. Within this space, there exists a generalized notion of distance that separates countries by the relative cost of technology adoption. With this generalized distance, we aim to account for both social and economic elements, such as the ratio between wage and capital costs, institutions, and the overall level of development. The central idea is that the disorderly and chaotic process that leads to diffusion in physical space also exists in the form of microeconomic interactions that lead to technology diffusion. However, the main dimension that determines the likelihood of the microeconomic interaction leading to technology adoption is distance in the relative cost of technology implementation, rather than simple geographic distance. Technology spreads very unevenly - flowing rapidly to countries with low relative costs of technology implementation and spreading only with considerable delay to countries with higher relative costs, leaving the most distant countries almost entirely behind.

The main hypothesis is that the generalized distance in the relative costs of technology implementation is primarily determined by differences in gross nominal wages. Since nominal wages are country-specific and the cost of technology adoption includes capital investment, for which the law of one global price is a more appropriate approximation, the relative cost of technology adoption might be approximated by relative wage levels. We test this hypothesis with nonlinear regressions and mixed effects regressions using the CHAT and PENN databases and obtain robust results showing that technology diffusion can be well represented by the diffusion equation and that there are global economic conditions that endogenously perpetuate uneven technology diffusion and hence uneven development.

3.5 Conceptualisation of the Diffusion Process and Model Derivation

In our conceptualisation of technology diffusion, we rely on the analogous derivation of the physical diffusion process as conceived in physics, namely Fick's law and the diffusion equation, which describe the processes of mass diffusion in liquid or gaseous matter and heat transfer (Fick, 1855).

The question arises why all discussions, conceptualisations, mathematisations, and models dealing with technology adoption only use the concept of diffusion as a broad descriptive analogy, while the technological diffusion process in the mathematical form never takes the form of the diffusion equation? The reason for this is the following. The physical process of heat or particle transfer is fundamentally characterised by the spatial dimension. In other words, an exogenous imbalance (heat or particle source) leads to an evolution of distribution (either heat or density), which is the parameter of time and space. In economic theory location and spatial dimension can play an important role. Transport costs can influence the pattern of urban and rural development as first proposed by von Thünen (2009) and later by new economic geography and urban economics (Krugman, 1991; Krugman & Venables, 1995). In these models spatial dimension plays a fundamental role and transport costs combined with scale effects in production create a diverging rural and urban patterns of industrialization. However, when it comes to the diffusion of technology on a global scale, such urban-rural agglomeration dynamics cannot be the core explanations of uneven diffusion of technology, as country-specific factor costs (Zeira, 1998), institutions (Freeman, 2019; North, 2005), labour power skills (Abramovitz, 1986; Stiglitz & Greenwald, 2014; Young, 1991) and overall development (Myrdal, 1957; Verspagen,1991) are more fundamental than mere spatial distance between technology users.

Instead of modifying spatial diffusion model to account for all the social and economic determinants of the technology diffusion, we generalise the spatial parameter to account for the trajectories across which technology diffusion unfolds. This is not the first attempt to generalize spatial parameter in economics, the most notable being the conceptualization of a generalized product space by Hidalgo et al. (2007), which serves as the basis for their empirical evaluation of the economic complexity.[1] Our spatial generalization aims to capture the conditions for the technology flow - we argue that the main dimension along which the process of technological diffusion takes place is the space of relative technology implementation costs. This generalized spatial dimension aims to endogenously grasp the differences in the condition for technological adoption, including not only direct economic costs, but also broader social and institutional preconditions for technology transfer. The central con-

[1]The distance in their generalized high-dimensional product space reflects the probability of a country having a comparative advantage in one product if it has it in another.

ceptual idea is that the analogy of the disorderly and chaotic process that leads to diffusion in physical space also exists in terms of microeconomic interactions that lead to technology diffusion. The main difference is that the microeconomic interaction that is relevant to technology diffusion does not occur on the basis of simple geographic distance, but is rather defined by distance in the relative cost of technology implementation. This derivation follows the logic of analogy between thermodynamics and economics proposed by various econophysicists (Chatterjee et al., 2005; Dimitrijević & Lovre, 2015), while being the first to treat diffusion of technology as an actual diffusion dynamics mathematically.

We begin our model derivation by defining the object of technology diffusion. Similar to physical diffusion, which works with density, we work with technology density, which is indirectly used in most contemporary empirical examinations of technology (Comin et al., 2006; Dosi & Nelson, 2016; Gomulka, 1990). Regardless if concrete technology is measured in intensive (for example number of combined harvester) or extensive form (share of population with access to internet) it can be defined as a technology density (Comin et al., 2006). While extensive measures of technology can already be interpreted as a measure of technology density, intensive measures of technology must be expressed in per capita form. We divide technology density of each technology by its world average to define a dimensionless quantity - relative technology density $\Phi(x,t)$.

Using the relative technology density as our main function of investigation is a novel way to address technology measurements in a cross-country setting and we argue for it due to its three main benefits:
1.) It can be the object of the diffusion equation in unmodified form.
2.) It reduces all different technologies, regardless if they are measured with intensive or extensive measure and regardless of the unit in which they are measured, to a dimensionless and comparable scale that represents each country's technology density in the units of the world average density.
3.) It avoids conceptual and modelling complications in introducing production as a source of technology. The production sources that lead to the global absolute increases in the same technology only contribute to the relative changes in technology density through their uneven distribution and adoption. Because of the relative definition of $\Phi(x,t)$, the function behaves like a probability density function and remains permanently standardised over time ($\int_0^\infty \Phi(x,t)dx = 1$), regardless of the absolute changes in technology use and potential production sources at the global level for each specific technology. Thus we can focus entirely on the process of diffusion.

The relative technology density $\Phi(x,t)$ describes the distribution of the relative technology density of each concrete technology along the time dimension (t) and the relative technology implementation cost dimension (x), which theoretically ranges from 0 to infinity on the real number scale. Equality $x = 1$ represents the world average of relative technology implementation costs, while higher or lower values represent deviations from the average.

As emphasised earlier, the dimension represented by x is not a standard spatial parameter but is a dimension representing relative country-specific technology implementation costs x. Countries are indirectly related to relative technology density through their country-specific relative technology implementation costs. We treat the space of relative technology implementation costs as continuous, conceptually representing the wide variety of countries, regions, and subregions with different technology implementation costs.

We begin our dynamic conceptualisation with an analogy to Fick's Law, which concerns mass diffusion (Fick, 1855). We define the flow of relative technology density $J(x,t)$ as determined by the gradient of relative technology density $\Phi(x,t)$ along dimension x and weighted by the diffusion constant D.

$$J(x,t) = -D\frac{\partial \Phi(x,t)}{\partial x} \tag{3.5.1}$$

The logic behind this is the following: the greater the difference in relative technology density and the smaller the difference in technology implementation costs (shorter the distance in x), the greater and faster will be the flow of technology density from a technologically denser to a technologically less dense country. We can see how the introduction of relative technology implementation costs affects the flow of technology in the context of the narrative of the technology gap theory, which defines two opposing forces that can either close or widen the technology gap. On the one hand, we have the potential that is determined with the size of the gap (the larger the gap, higher the catch-up potential). On the other hand, we have the learning capacity, conversely defined as having negative impact on technology adoption and increasing with the size of the gap (Verspagen, 1991). In the context of our equation, both forces are endogenised in the expression that flow of technology is proportional to $-\frac{\partial \Phi(x,t)}{\partial x} \approx -\frac{\Delta \Phi}{\Delta x}$. It is both the technology gap $\Delta\Phi(x,t)$ and the proximity of technology implementation costs Δx that constrain and determine technology flows. The main difference in the narrative is that we aim to treat technology implementation costs as economically endogenous, as opposed to exogenous and extra-economic learning capacity defined by Verspagen (1991).

From the perspective of a single infinitesimal point in the space of relative technology implementation costs, the difference between the relative inflow (from more developed countries) and outflow (to less developed countries) of technology density must lead to equal changes in relative technology density:

$$J(x) - J(x+dx) = \frac{\partial(\Phi dx)}{\partial t} \tag{3.5.2}$$

$$\frac{\partial\Phi(x,t)}{\partial t} = -\frac{\partial J(x,t)}{\partial x} \tag{3.5.3}$$

Using the continuity equation (equation 3.5.3), which simply establishes the predefined fact that relative technology density can only change relatively and cannot increase or decrease absolutely, we derive the classical diffusion equation (equation 3.5.4) for our main variable $\Phi(x,t)$:

$$\frac{\partial\Phi(x,t)}{\partial t} = D\frac{\partial^2\Phi(x,t)}{\partial x^2} \tag{3.5.4}$$

Equation 3.5.4 represents the final general solution of the proposed model, and any particular solution can be derived from the initial state of the relative technology density function by solving the partial differential equation.

Despite these general possibilities, we propose a comprehensive particular solution to the model. We claim that the initial implementation of each technology starts in the countries and regions with the lowest possible implementation costs ($x = 0$). Where the relative cost of technology implementation is lowest, there is not only the highest economic rationality for implementing the given technology (the benefit-cost ratio would be highest) but there are also the most economically fertile conditions for putting resources and human effort into solving the problem that leads to the invention and implementation of the given new technology.

Therefore, to solve the partial differential equation describing technology diffusion, we assume that the initial state of technology density at the time of invention is concentrated at $x = 0$.

$$\Phi(x, t = 0) = \delta(x) \tag{3.5.5}$$

$$\int_0^\infty \delta(x)dx = 1 \tag{3.5.6}$$

$$\int_\epsilon^\infty \delta(x)dx = 0 \qquad \forall\epsilon > 0 \tag{3.5.7}$$

Here $\delta(x)$ is a Dirac delta impulse function—a generalised function that has zero value everywhere except at $x = 0$ and whose integral over the entire set of real numbers is equal to one, corresponding to our predefined standardisation. The initial state of relative technology density is normalised and completely centered at the origin of our space of relative technology implementation costs. In this sense, it technically does not matter where the technology is invented because its spread is always determined from the origin of our space of relative technology implementation costs in the absence of additional economic barriers, such as patents[2]. Technology density then spreads according to the diffusion equation, initially

[2]While the location of invention is irrelevant from the perspective of our very general diffusion model, it is anything but irrelevant from the perspective of broader social consequences and the functioning of the competitive process, especially if the innovation can be legally protected by patents.

leading to implementation of the technology by early adopters (the most developed countries with the lowest relative costs of technology adoption), while slowly spreading over time to a broader and broader group of countries (figure 3.2).

The dynamic solution of our technology diffusion problem (equation 3.5.4) with initial condition (equation 3.5.5) is the fundamental solution of the diffusion equation, which is derived in detail in appendix A:

$$\Phi(x,t) = \frac{1}{\sqrt{\pi D t}} exp\left(- \frac{x^2}{4Dt} \right) \tag{3.5.8}$$

Equation 3.5.8 represents the dynamic solution of the technology diffusion process over time, characterised by the diffusion constant D and the dimension of relative technology implementation costs x specific to different countries or regions.

Up to this point we have treated our generalized spatial dimension of technology implementation costs as a broad indicator of the conditions for technology adoption. Our main hypothesis is that relative wage level is one of the most important determinants of this dimension, which shapes the uneven technology diffusion. We argue that there exists a direct first order economic relationship between relative wages and technology adoption costs.

There is a substantial amount of economic theory that links the technology diffusion with factor prices - primarily wage levels - which together endogenously determine productivity growth (Amin 1974; Sylos-Labini 1984; Zeira 1998). These theories attempt to explain the relationship between wage levels and productivity growth by examining and modelling the capital-labour relationship as a choice by firms between employing labour and purchasing labour-saving machinery. They derive the direct effect of the relationship between the relative costs of labour power and machinery on technical progress and productivity driven by the introduction of machinery. Acemoglu (2010) has analytically demonstrated that although the majority of canonical neoclassical and endogenous growth models conceptualise technology as labour-complementary, there also exists a plausible theoretical socioeconomic environment in which technology is strictly labour-saving. In such an environment, factor costs are one of the most important determinants of technology development and adoption. Our conceptualisation and subsequent empirical investigation aims to prove that in reality new technologies predominantly take the form of labour-saving improvements and that factor costs are important determinant of the technological diffusion process. Although these approaches work within the framework of a closed economy, they have explicit implications for all theories that attempt to study technological growth and diffusion in the setting of differently developed countries. If the relationship between the relative prices of factors of production - primarily the relative price of labour power and the relative price of fixed capital - are determinants of technological progress, as studied by Sylos-Labini (1984) and Zeira (1998), then the cross-country differences in relative factor prices that are determined by initial differences in productivity and technological development could be a source of long-run structural differences in the relative costs of technology implementation. Therefore, they may explain, at least in part, the long-run patterns of technology diffusion.

Given that a technology is adopted only if it is profitable, the adoption of new labour-saving technologies depends directly on the relationship between the nominal wage level and the fixed costs of adopting the technology (Kaldor & Mirrlees, 1962; Sylos-Labini 1984; Zeira 1998). Because nominal wage differentials are greater than differences in fixed costs of technology adoption, especially fixed capital costs, the countries with lower wages face higher relative costs of technology adoption and investment (Hsieh & Klenow, 2007; Jovanovic & Rob, 1997). Eaton and Kortum (2001) even find that prices of equipment and machinery are higher in countries with lower wages. Thus, the country-specific wage level and the global price of the technology that is embodied in the machines cause different countries to be more or less far apart in terms of the relative costs and benefits of technology adoption.

The relative costs of technology implementation are country and time specific. According to empirical analyses (Hsieh & Klenow, 2007; Jovanovic & Rob, 1997) we assume that the technology adoption depends on the fixed capital element of investment that has a single global price k and country-specific mean wage w_{ct}. This leads to the following relative factor cost ratio:

$$\frac{\frac{k}{w_{ct}}}{\frac{k}{\bar{w}}} = \frac{\bar{w}}{w_{ct}} \tag{3.5.9}$$

Our hypothesis translates to the proposition that the relative technology implementation costs are directly proportional to the ratio of global average and country-specific mean wage:

$$x = \alpha \frac{\bar{w}_t}{w_{ct}}; \qquad \bar{w}_t = \frac{\sum_{i \in c} w_{it}}{\sum_{i \in c} i} \tag{3.5.10}$$

3.6 Empirical Calibration

To empirically calibrate and evaluate the proposed model of technology diffusion, we use the CHAT panel data set, which describes the intensity of use of different technologies in different countries and time periods. CHAT is an unbalanced panel dataset with information on the adoption of technologies in more than 161 countries during the last 200 years. The technologies are measured either in intensive or extensive form, with country-specific use of technology reported in annual frequency of observation.[3] An empirical measure of labour costs w_{ct} is obtained from the PENN database and is used to measure the proposed relative

[3] A detailed description of the panel, countries and technologies included is provided by Comin and Hobijn (2009) and can be accessed at: https://www.nber.org/papers/w15319.

technology adoption costs x. Different technologies are denoted by the index T. Each technology has a specific relative technology density for each country c and each time period t, denoted by Φ_{ctT}. All of the technology data that is intensively measured is first expressed in per capita terms and then expressed as a ratio between country-specific per capita utilisation and global average per capita utilisation for each time period t separately.

Due to limited data for some of the available technologies that coincides with the data on labour costs (the cross section being zero or having small number of observations) and the relative country-specific asymmetry of some technologies[4], we used 36 technologies from the dataset for our empirical analysis. We conduct our empirical evaluation using a set of 36 technologies: four agricultural (number of combined harvesters, tractors, milking machines, and fertilisers), seven infrastructural (electricity generation, railroads, ship transportation), two steel (electric arc furnaces, oxygen blast furnaces), eight information technologies (cable TV, Internet, mail, newspaper, radio, telegram, telephone, TV), 12 health technologies (hospital beds, mammography, radiation, transplantation, dialysis), automobile use (2), and tourism capacity (2). Each technology has a corresponding specific time variable that measures the time since invention t_T. The time of invention is set as the first non-missing observation in the dataset, which is standard in similar studies of technology diffusion (Comin and Hobijn 2010).

Inserting relationship between relative technology adoption costs and wage levels (equation 3.5.10) into our model (equation 3.5.8) we obtain the following nonlinear model for empirical evaluation:

$$\Phi_{ctT} = \frac{1}{\sqrt{\pi D t_T}} exp\Bigg(- \frac{((\alpha \frac{\bar{w}_t}{w_{ct}})^2}{4Dt_T}\Bigg) \tag{3.6.1}$$

Using nonlinear least squares estimation, we obtain the results in Table 3.1. Highly significant results indicate a general relevance of the proposed conceptualisation of technology diffusion. To further analyse stability of the results, especially potential sensitivity to sample selection, we make additional random sampling robustness tests, which are presented in detail in appendix B. The bimodal normal distribution of the repeated sampling estimations of the diffusion constant show concealed heterogeneity in the technology diffusion process for different technologies and indicates that we should control for technology specific random effects in our estimations (figure B.1b).

For that reason we perform an additional estimation of nonlinear mixed effects based on maximum likelihood estimation. We modify our model to account for random effects at the level of the diffusion process of each technology. We define ϵ_T as a technology-specific random effect of the parameter α and δ_T as a technology-specific random effect of the

[4]For example, steel production as measured in tonnes, even when converted to per capita figures, still shows a large variability that has more to do with international specialisation than with the actual process of technology diffusion. Similarly, irrigation data are highly dependent on geographic and other country-specific conditions rather than pure technology intensity.

Table 3.1: Non-linear least squares regression results

Variables	(1) D	(2) α	R-squared	No. Obs.
Estimate	0.00202*** (2.83e-05)	0.329*** (0.00353)	0.474	32,552
t	71.49	93.14		
$P > \|t\|$	0.000	0.000		
95% int.	$(0.00196, 0.00208)$	$(0.322, 0.336)$		

diffusion constant D.

$$\Phi_{ctT} = \frac{1}{\sqrt{\pi(D+\delta_T)t_T}} exp\left(- \frac{((\alpha+\epsilon_T)\frac{\bar{w}_t}{w_{ct}})^2}{4(D+\delta_T)t_T} \right) + u_{ctT} \tag{3.6.2}$$

The technology implementation costs remain country and time specific, as defined in equation 3.5.10.

Table 3.2: Non-linear mixed effects regression results

Variables	(1) D	(2) α	(3) $var(\epsilon_T)$	(4) $var(\delta_T)$
Estimate	0.00318*** (0.00101)	0.477*** (0.00186)	0.105 (0.0268)	1,26e-05 (3.13e-06)
t	5.35	8.58	No. Obs.	
$P > \|t\|$	0.000	0.000	32,552	
95% int.	$(0.00201, 0.00434)$	$(0.368, 0.586)$		

The estimated mixed effects model yields quite similar results when compared to the non-linear least squares regression, but are much more stable and non-sensitive to random sample perturbation (appendix B). The additional information gained by introducing a technology-specific random distribution of diffusion constants is that the differences in diffusion constants are relatively small. The variance of the technology-specific random deviation from the general technology diffusion constant is relatively small when compared to the diffusion constant estimate. This means that our approach to technology diffusion is relatively universal for all tested technologies and that their diffusion process is very well described by the single diffusion constant and the distance based on relative nominal wage costs.

The calibrated model results that are shown in figure 3.2 describe the dynamic evolution of technology diffusion and are dynamic in two ways. First, the relative density of technology use spreads from developed countries to less developed countries depending on how close they are in terms of technology implementation costs. Second, countries can exogenously change their position in terms of their relative costs of technology implementation and with this improve the conditions for endogenous technology diffusion.

Figure 3.3 shows the evolution of technology density for countries with different wage levels. While the theory of technology adoption, which abstracts from uneven development, almost universally models technology adoption in the form of a logistic curves, our dynamic examination presents a generalisation. The main difference from most examinations of technology adoption is in the object of study. Our object of study is the relative technology density as opposed to either extensive or intensive technology measures, which are the subject of the majority of existing empirical work on innovation and technology adoption. In this sense, our results do not contradict existing research on technology adoption. In absolute terms, the technology adoption of each country can be approximated quite well by different logistic curves if measured in the extensive margin, as shown by Comin et al. (2006). The relative technology density adoption curves (figure 3.3) provide new information about the dynamics of technology adoption in the relative sense, which is the most important in the context of uneven development.

The most developed countries, with average productivity and wages above the world average, are the early adopters of new technologies and increase their relative technology density in the early period after invention. The relative technology density of the most developed early adopters only gradually begins to decline when the technology spreads to the majority of countries, even though it is still potentially increasing in absolute terms. The decline in the relative technology density adoption curve of the most developed countries represents a period of slower adoption rate when compared to new adopters from less developed countries. The countries with average productivity and wage levels close to the world average exhibit a technology adoption function that is quite similar to the logistic pattern described by the theory that abstracts from uneven development. The main differences between the technology adoption curves in the less developed countries is the much more gradual slope of technology adoption, and the longer period between the time of invention and the beginning of the economically relevant adoption rate. For example, the relative technology density for a country with twice the world average wage increases almost immediately after the invention; for a country with 50% of the world average wage level, it remains close to zero for more than 10 years since the invention; while for an underdeveloped country with wages equal to only 25% of the world average, it remains close to zero for many decades. Underdeveloped countries with wage levels close to subsistence level do not adopt new technologies at all and, according to our model, are practically technologically blocked. A general result can thus be summarised in the following statement: while each country in isolation experiences absolute technology adoption in the form of the logistic curve when measured intensively, both the horizontal translation and the slope of the

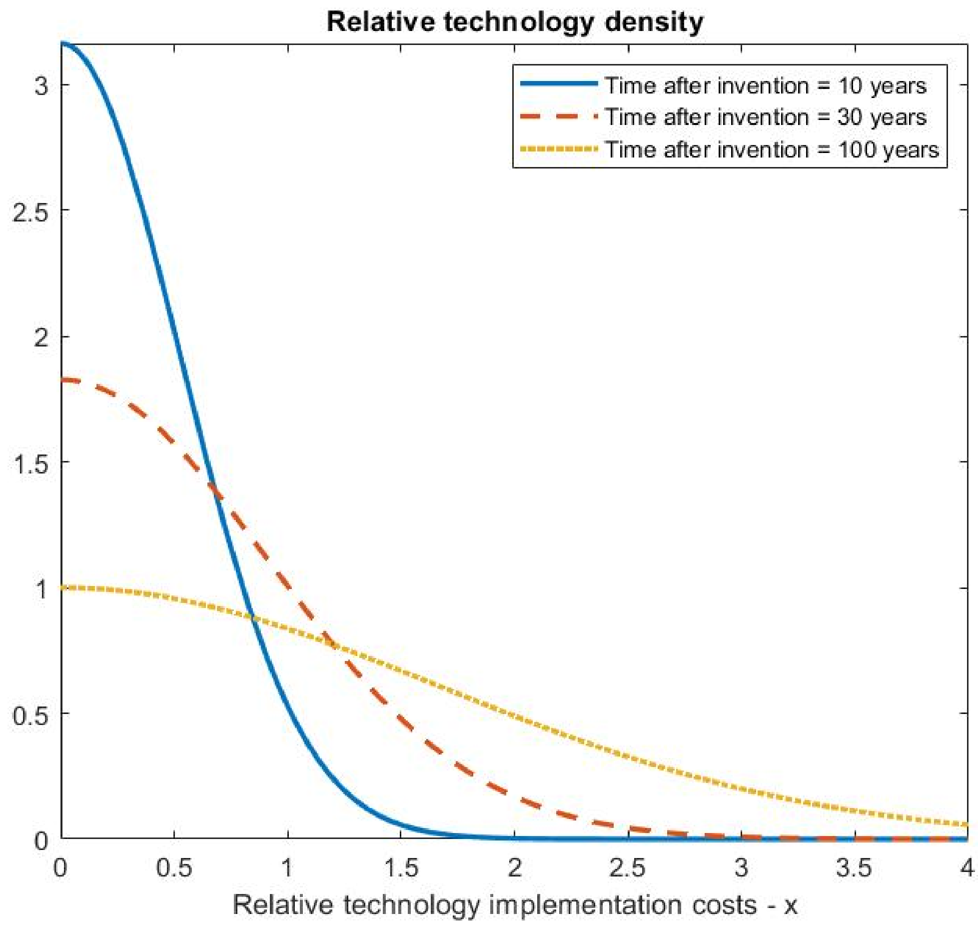
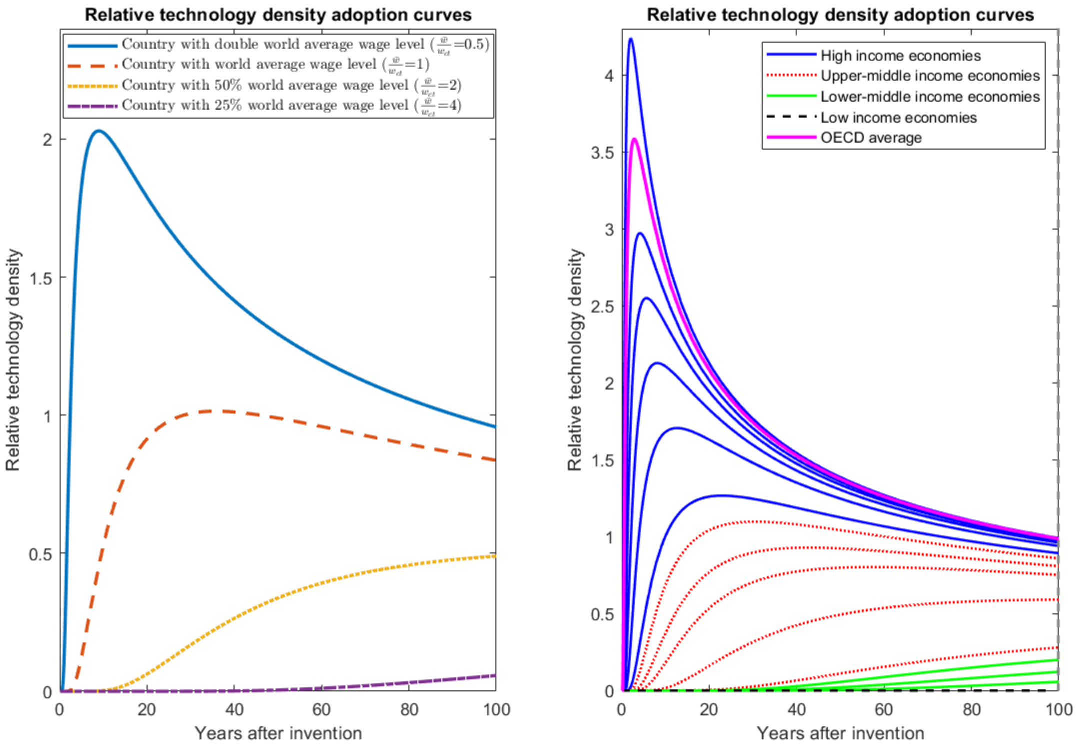


Figure 3.2: Diffusion of technology in relation to technology implementation costs
The diffusion of technology is represented by the relative technology density function at different stages of the diffusion process. Low values of x correspond to developed countries with high wage levels, while higher values of x correspond to underdevelopment, low wages, and (in the case of extremely high values) subsistence economies. The graph is plotted as the result of the diffusion equation 2 with parameters $D = 0.00318$ and $\alpha = 0.477$ taken from the results of the nonlinear regression, which takes into account the random effect deviations of different technologies (Table 3.2).



(a) Relative technology density adoption curves for countries with different wage levels

(b) Relative technology density adoption curves for different groups of countries depending on their GNI

Figure 3.3: Country-specific relative technology density adoption curves
Diffusion of technology through time from the perspective of differently developed countries. The graph is plotted as a result of the diffusion equation 3.5.8 with parameters $D = 0.00318$ and $\alpha = 0.477$ taken from the results of the nonlinear regression, which takes into account the random effect deviations of different technologies (Table 3.2). Linear relationship between wages and GNI per capita in 2021 is assumed to infer how country clusters defined by UN and WB methodology would correspond to relative technology adoption curves. The GNI per capita of high income economies is higher than 13.206$, for upper middle-income it is between 4.256$ and 13.205$, for lower middle-income it is between 4.256$ and 1.086$, with low income economies bellow that.

logistic curve are highly dependent on the relative costs of technology implementation, which are primarily determined by the wage level.

The relative technology density adoption curves of differently developed countries are thus highly uneven over time. Relative differences in technology use are largest initially (due to differences in the time between invention and the start of adoption for differently developed countries) and gradually decrease but still remain stable over long periods of time, indicating multiple steady states of the relative intensity in the technology use for differently developed countries. Even after long periods in which technology becomes obsolete and is replaced by a new innovation cycle, the relative density of the use of old technologies remains very unevenly distributed.

3.6.1 Discussion

The explanatory power of the proposed model bridges the gap between contemporary studies of technology adoption through the prism of technology adoption curves and broader macroeconomic theories of uneven development by linking technology adoption conditions to relative nominal wage levels. The empirical results can be seen as evidence that a broad conceptualization of technology needs to incorporate its predominantly labour-saving effect (Acemoglu, 2010) in order to adequately account for the dynamic effects of relative wage and investment costs on technology adoption and diffusion.

While we have based our derivation of endogenous technology diffusion on the direct relationship between the relative costs of technology adoption and wage levels, there are still many indirect relationships behind the link between wages, labour skills, productivity, overall development and institutional framework, all of which are endogenously intertwined.

There is ample literature on endogenous growth that emphasises the scale effects of learning and attempts to explain modern economic growth through the prism of human capital accumulation (Lucas, 1988; Romer, 1990), learning (Arrow, 1962; Stiglitz & Greenwald, 2014), and quality improvements (Grossman & Helpman, 1991). According to these approaches, wage levels reflect aggregate productivity and the scale effects of learning and skills. This would imply an indirect link between wage levels and the accumulation of human capital and skills, which in some cases are a prerequisite for effective technology adoption. The relationship between skills, wages, and endogenous technology growth has also been examined in a task-based framework. This has shown how endogenous technology growth can be influenced by skills and affect the distribution of income and, conversely, how the composition of skills endogenously determines technological upgrading and productivity growth (Acemoglu & Autor, 2010; Acemoglu & Restrepo, 2019). Institutional development, structural change, economic growth, and wages are inextricably linked (Acemoglu & Robinson, 2013; Freeman, 2019; North, 2005). Relative wages may thus indirectly signal and reflect also the institutional environment and other broader socioeconomic conditions for growth, providing another endogenous feedback loop through which relative wages indirectly influence technology adoption. Our finding that relative wages are a statistically significant and robust empirical equivalent of the relative costs of technology adoption can therefore be interpreted as reflecting both direct effects through the relative economic costs of investment and indirect effects of the broader social conditions for technology adoption that are indirectly signalled by relative wages.

Circularity and endogeneity within a conceptual model are not flaws, however, if circularity reflects the complex and non-linear dynamics of reality. In this context, our model aims to explain both technology adoption curves in the context of uneven development, as well as the broader aggregate results of cumulative causation models (Myrdal, 1957), industrialization approaches that use the demand-driven Kaldor-Veerdorn law and examine path-dependent uneven growth (McCombie & Spreafico, 2016), and evolutionary technology gap approaches (Fagerberg et al., 2010; Fagerberg & Godinho, 2018; Verspagen, 1991). Since wage levels are at least very roughly related to productivity and development that are largely determined by the available technology, this implies an indirect feedback loop through which wages can influence development outcomes both through their direct impact on the cost of technology adoption and as a mediator of aggregate demand, while being constrained by the given technology, which is a typical path-dependant evolutionary pattern.

Compared to Verspagen's (1991) study of the technology trap and the conditions for catching up and lagging behind, our model also exhibits nonlinear dynamic feedbacks that cause a path-dependent evolution of the technology gap between differently developed countries. The main differences are two. First, our model features an entire continuum in the scale of technology adoption states, rather than discrete, multiple steady states. This better reflects the complexity of technology adoption, in particular the fact that in addition to the near-zero technology trap, there are also states of medium and high industrial technology development that do not fully converge, indicating the phenomenon of the middle income trap. While various conceptual, modelling, and empirical analyses have proposed different factors that explain the emergence of a middle-income trap (Eichengreen et al., 2013; Hartmann et al., 2021; Krūminas et al., 2019; Myant, 2018), we differentiate from them by deriving it fully endogenously in the context of technology adoption. Second, the narratives describing the social and economic forces preventing catch-up and closing the technology gap are almost entirely extra-economic and exogenous (e.g., learning capacity, barriers to technology adoption, institutions) (Comin & Hobijn, 2010; Freeman, 2019; Parente & Prescott, 1994; Verspagen, 1991). Conversely, our model and its result show that uneven technology adoption can be understood endogenously, as an economic functioning of the global market-based economy, as there is no such endogenous force that would close a technology gap between highly unevenly developed countries. Our approach shows (both theoretically and empirically) that technology diffusion cannot be abstracted from relative production factor costs, especially relative wage levels, which put differently developed countries in a substantially different structural position when it comes to the process of adopting concrete technologies. Since local profitability is the endogenous driver of investment and technological change, differences in relative wage costs result in quite different amounts of feasible technology being available in different countries (Hsieh & Klenow, 2007; Jovanovic & Rob, 1997). Thus, the endogenous process that determines the closing of the technology gap is conditional. The technology gap closes quickly when differences in technology density are large and the relative costs of technology implementation are similar, while the technology gap may persist for decades and even centuries in cases where relative cost structures and wage levels differ widely.

Our approach to technology diffusion also sheds new light on the issue of development and industrial policy. While improving education, institutional stability, and research spending are fundamental preconditions for growth and catch-up, the pattern of technology diffusion under study requires more than passive creation of preconditions and letting the "invisible hand of the market" close the technology gap. Our results could indicate that, in addition to passive, broad-based societal prerequisites, closing the technology gap also requires active, deliberate intervention in the form of active industrial policy with a focus on technology transfer.

The relevance of technology transfer-oriented industrial policy in the context of our results can be briefly discussed in the example of China, which used its labour cost advantage and market size to attract administratively conditioned sector- and technology-specific FDI and used political and extra-economic means (such as conditioning domestic market entry with joint ventures and technology transfers) to promote and expand its own domestic capacity within state-owned or state-subsidised enterprises (Kenderdine, 2017; Mao et al., 2021). In contrast, the new Central and Eastern European EU member states also attracted a lot of FDI because of their labour cost advantage, but did not have a targeted industrial policy or influence on technology transfer to domestic producers because of the EU regulatory framework and the small size of their domestic market (Myant, 2018). Thus, on the one hand, China used targeted industrial policies, administratively mediated technology transfers, and subsidised domestic industrial champions to facilitate technology adoption, *despite* relatively unfavourable endogenous conditions related to their lower wages, positively affecting both wages and technology adoption in the long run. Conversely, the new CEE EU member states were and are caught in a typical middle-income trap, as technology diffusion is left to endogenous forces (Krūminas et al., 2019). This could indicate that a targeted exogenous and extra-economic push is needed to break out of path-dependent development explored by our model, and that relying solely on the labour cost advantage does not lead out of the technology trap and unfavourable functional specialisation.[5]

3.7 Conclusion

The proposed dynamic model of technology diffusion aims to address the two main drawbacks of the existing literature dealing with technology transfer and adoption. The first drawback is the abstraction from the uneven and highly asymmetrically developed world economy practised by the micro- and game-theoretic approaches that focus on technology adoption curves. The second major drawback is the almost exclusive reliance on extra-economic, exogenous and country-specific factors to explain the uneven distribution of technology in the world. In our approach, the process of technology diffusion is conceptualised as fundamentally dependent on the cost of technology implementation, which depends directly on relative wage levels. We derive the dynamic diffusion equations that describe the process of change in relative technology density that depends on the gradient of technology density with respect to distance in terms of the relative wage level.

There are 4 contributions of our approach:
1.) We provide a conceptual and modelling framework that describes the diffusion of technology in terms of a diffusion equation equivalent to physical and heat diffusion.
2.) We generalize the spatial parameter to account for endogeneities in the conditions of technology adoption and show that relative wages are the main determinant of this generalized spatial dimension.
3.) We derive relative technology adoption curves that reflect technology adoption in the context of uneven international development.
4.) The main aggregate results are consistent with the macroeconomic evolutionary and cumulative causation approaches to uneven development.

We thus close a gap between approaches that focus more on concrete technologies and their adoption curves and generally abstract from uneven development, and more macroeconomic approaches that reflect similar path-dependent dynamics at the aggregate level but lack more specific technology-related dynamics.

The endogenous process of technology diffusion and adoption can thus be understood as one of the endogenous structural mechanisms that contribute to the perpetuation of uneven development, dynamically acting in both directions. On the one hand, technology adoption is determined by the relative differences in wage levels and the different cost structures of

[5]This active intervention does not necessarily have to be done by the state, but could be implemented by a sufficiently large social structure that is able to make investment decisions that go beyond the issue of local and short-term profitability, that is able to redistribute surpluses from different sectors and tasks, and that has a very forward-looking horizon. The case of the South Korean and Japanese conglomerates would be a good example of such non-state actors.

technology implementation. On the other hand, the uneven distribution of technology determines uneven development and relative differences in wage levels. Although this may seem like a simplistic circular tautology, it is an alternative explanation for why the majority of middle-income countries remain middle-income, why the majority of high-income countries remain high-income, and why the majority of low-income countries remain low-income than the prevailing explanations that rely on country-specific exogenous capacity, institutional frameworks, culture, political stability, and similar extra-economic factors. While it is clear that institutions and other extra-economic factors are fundamental to the catch-up process, it is also clear that the long-term stability of global uneven development requires endogenous explanations.

The model also has some limitations and potential for further research and extension. The proposed model and its empirical calibration abstract from the specifics of each technology and cannot be used to explain technology adoption curves specific to each technology or country-specific patterns of adoption. Further research would be needed to combine the proposed framework with country- and technology-specific analyses and approaches that could potentially produce more detailed results and account for additional heterogeneities in both the characteristics of different technologies and country-specific institutions.

Chapter 4

Structural Change

4.1 Introduction

Structural change is defined as the reallocation of economic activity among a large group of sectors: agriculture, manufacturing, and services (Fisher, 1939). The most common empirical stylised fact of structural change is a long term decline of employment in agriculture, increase of employment in services and increase of employment in manufacturing in the early stages of development followed by a subsequent decline (Herrendorf et al., 2014). In this chapter we aim to empirically disaggregate the key determinants of the employment changes between these major sectors from the perspective of supply, demand, international trade, and domestic and global value chain structures.

The concept of structural change goes beyond mere redistribution of employment. In different stages of development, the structural re-employment between sectors is accompanied by long lasting cultural, political and institutional changes (Chenery, 1982). The research on structural change initially focused on the transition from the agricultural production to the manufacturing production - from low productivity to high productivity employment (Eberhardt & Vollrath, 2016). The benchmark approaches to this transition are the Lewis's (1954) dual sector model, expanded on different levels (Amano, 1980; Jorgenson, 1961; Ranis & Fei, 1961), and Kuznets' (1971) analysis which present basic theory that is often formulated as the stylised facts of the structural change and growth. Later research expanded and put extensive focus on the structural relocation of employment from manufacturing to services, characteristic for more developed countries (Baumol, 1967; Jorgenson & Timmer, 2011; Kuznets, 1967; Maddison, 1987).

Aggregate technological progress and productivity are not sufficient to define the economic system in a dynamic research. To go beyond the aggregate expressions, the framework must be formulated in disaggregate terms. Structural change, inter-sectoral dynamics and economic development are linked and must always be analysed concurrently (Amin, 1974, 1979; Pasinetti, 1983; Sylos-Labini, 1995). However, almost all the approaches of structural change analysis, both theoretical and empirical, operate within the closed country setting. While the vast research on structural change demonstrates that there exist fundamental inter-sectoral heterogeneities on many different levels, which induce important dynamics and complexities that shape the growth of individual economy, there are limited analyses that would apply the insights of this framework to the functioning of the globally integrated economy. The complex effects of inter-sectoral heterogeneities on the global division of labour, international specialisation and potential for technological upgrading remain largely unexplored, especially in the context of uneven development. The importance of understanding the effect of inter-sectoral heterogeneities on the uneven development is even further elevated with the increased fragmentation of the production process, which enables the inter-sectoral heterogeneities to function on an ever finer scale. Several paradigmatic approaches, not directly linked with structural change, deal with this phenomenon: global value chains, global production networks and task based model analyses.

This chapter focuses on the empirical facts of structural change. It aims to capture main determinants of structural change, while taking into account supply driven and demand driven factors, as well as changes in the international production fragmentation and trade. This empirical estimates will contribute to the broader understanding of the structural change in different stages of development and how it is affected by the rising value chain fragmentation. The results and insights will also contribute to the foundations of the theoretical model simulations conducted in latter chapter.

The two main research questions of this chapter are: What are the country specific supply-driven, demand-driven, trade-driven and value-chain-driven determinants of long-term employment changes (1.) from manufacturing to services and (2.) from agriculture to the rest of the economy. We conduct a comprehensive multi-regional input-output analysis using structural decomposition. We decompose annual employment changes in each country-sector into real changes in the labour productivity, real changes in the structure of supplier linkages, fabrication effects, and real changes in final demand. Using WIOD, WIOD in previous year prices, and SEA, we undertake a separate structural decomposition of employment changes for each of the 43 available countries. We construct two indices of structural change by summing the changes in employment from manufacturing to services and from agriculture to the rest of the economy over the entire period to identify a unique set of determinants of structural change for each country as well as for the world. The main novelty of the study is the systematic consideration of separate domestic and foreign real changes in supplier linkages and fabrication changes on the dynamics of structural change, which sheds new light on the country-specific determinants of structural change.

4.2 Theoretical Explanations of Structural Change

4.2.1 Supply Driven Theories

The theoretical explanations for the drivers of structural change are mostly either demand or supply driven. One of the earliest examination of supply side driven structural change is Baumol's (1967) two-sector model. The basic idea is that employment changes due to sector-specific productivity growth. In sectors with above-average productivity growth, employment declines and shifts to sectors with more stagnant productivity in the long run. The main assumptions are different technologies leading to different labour productivities. The first sector is stagnant in the long run and exhibits zero technology growth, while the second sector is progressive and exhibits exponential technological growth, similarly as in Solow-Swan model. Depending on the assumptions regarding the consumer preferences and substitutability of the commodities produced by the sectors, the employment and prices change. The most profound employment change happens if Leontief preferences are assumed, while if substitution between commodities is allowed, the effect is distributed between the price effect and the employment effect. In both cases either employment or relative price of the more stagnant part of the economy increases - the phenomenon labelled the Baumol's cost disease. Its main prediction is that structural change of this type, lead to increasing employment and costs of the services relative to the manufacturing, diminishing further prospects of high growth rates in developed countries.

The simplicity of the Baumol's dichotomy between services and manufacturing has been often disputed. This holds especially for the assumption of the zero technological growth of the service output. Empirical analyses confirm not only substantial heterogeneity within the service sector, but also very large effect of this heterogeneity on both domestic structural change effects as well as cross-country productivity differences (Buiatti et al., 2017; Duarte & Restuccia, 2017; Duernecker et al., 2021; Jorgenson & Timmer, 2011). Substitutability is also a major factor in determining the long term effects of structural change in services (Duernecker et al., 2017).

For that reason modern supply driven models of structural change conceptualise inter-sectoral heterogeneities without direct assumptions about production constraints for agriculture, manufacturing and service sectors, but rather either work in a completely abstract framework or with large number of sectors in a continuous framework. Ngai and Pissarides (2007) broaden the Baumol's framework by analysing m sectors charaterized by CES production functions with different TFP growth rates in a general equilibrium setting, arriving at similar results as Bauomol. Acemoglu and Guerrieri (2008) address the same issue with different type of differentiation between sectors. They assume that sectors differ with respect to sector-specific elasticities of capital productivity, which leads to sector-specific capital intensities and productivities. More capitally intense sectors are more productive, have lower employment and higher output and *vice versa*. Both intrasectoral heterogeneity in TFP and intrasectoral heterogeneity in factor marginal productivities affect structural change similarly. This result is in line with our discussion in the previous chapter regarding the impossibility of separating the effect of technology from the effect of the factor proportions. If we assume different sectoral production constraints, the same structural change is derived, regardless if the productivity differences are assumed to be given by technology or factor proportions. Both are inseparable and necessarily occur concurrently.

Further expanding the supply driven approach, Alvarez-Cuadrado et al. (2017, 2018) generalize the heterogeneity of production constraint by using CES production function as opposed to Cobb-Douglass production function used by previous approaches. This enables them to assume inter-sectoral heterogeneity in the elasticities of substitution between factors of production, not only to derive similar pattern of structural change as previous approaches, but also to derive the effect of the structural changes on the factor income shares under neoclassical assumptions.

Task based approaches to modelling production constraint often exhibit inter-sectoral or inter-task heterogeneities which resemble differences in previously discussed approaches (Acemoglu & Autor, 2010; Bárány & Siegel, 2018; Zeira, 1998). The focus is, however, less on the examination of inter-sectoral structural change itself, but mostly on the endogenous technological change and its bias in terms of its effect on the induced income distribution.

4.2.2 Demand Driven Theories

In contrast to the supply driven approaches, which derive the dynamics of the structural change as a consequence of the inter-sectoral heterogeneities of the production constraints, the demand driven approaches explore how sector specific consumption dynamics affect inter-sectoral changes in employment and output. The core idea is that the most common assumption of the non-homothetic preference function conceals the dynamics that might be driven due to the non-homothetic preferences. In other words, the consumers might that change the proportion of the demand with rising income *ceteris paribus* and this can be a factor in determining structural change.

The earlies examinations of non-homothetic behaviour can be attributed to Engel. His analysis demonstrated a relation between the consumption of the short term physical requirement goods (mostly food), other commodities and income. The main discovery, latter labelled as the Engel's law, was that the proportion of the income used for food is a good measure of the overall income. With income increases also the share of consumption for basic food declines (Zimmerman, 1932). The effect of Engel's law on the structural change and growth is crucial for explaining the long-term dynamics of economic growth according to the proponents of the demand driven explanations of structural change (Leon, 1967; Pasinetti, 1983).

One of the early approaches to demand driven structural change is Pasinetti's (1983, 1993) multi-sectoral macrodynamic analysis, where income elasticities for various goods are different and change with rising income. This creates unbalanced growth paths and different sectors expand based on the changing demand structure.

Laitner (2000) examines a two sector model of industrialisation with an endogenous savings and utility function based on Engel's law. It is used to analyse transition from subsistence agriculture to manufacturing. In this approach, the push creating employment relocation is driven indirectly by exogenous technology growth, which in turn rises incomes that are distributed more in favour of the manufacturing sector, due to the assumed preference structure. Gollin et al. (2002) present a similar variations of the Lewis' dual sector model. It conceptualises the early industrialisation as demand driven, with agricultural productivity as an essential feature in the early stages of development, while the model converges to the neoclassical exogenous growth model as the country develops and agricultural consumption becomes negligible.

An alternative way to implement Engel's law in the utility function is by using Stone-Geary utility function, which is a generalized Cobb-Douglass utility function that emerged as a solution to the linear expenditure system and allows for non-homothetic shape (Geary, 1950; Klein & Rubin, 1947; Stone, 1954). Park (1998) introduced a subsistence consumption parameter in the Stone-Geary function for the agricultural sector, to differentiate it from the manufacturing sector, to derive a three-factor, three good endogenous model of growth and structural change. Introducing the non-homothetic preferences into the general equilibrium model comprising three sectors yields similar results (Echevarria, 1997). Similarly, Kongsamut et al. (2001) derive a model of balanced growth that conforms to the Kaldor stylised facts and exhibits sectoral relocation of employment, which is driven by the differences in the income elasticity of demand for the different goods implemented in the Stone-Geary form of utility. However, balanced growth in this model is achieved by assuming constant relative prices, which establishes a questionable link between preferences and the production constraints (Foellmi & Zweimüller, 2006).

In contrast to other approaches, Foellmi and Zweimüller (2006, 2008) assume that the utility function has a hierarchical structure in terms of sequential consumption preference in the form of generalised hierarchical Engel's laws. The approach creates a theoretical dynamic structure of consumption similar to Shumpeterian approach to technological progress. New goods are constantly introduced. Initially they are perceived as luxury goods, while through time, as new goods are added to the consumption, their income elasticity declines. Overall, the main mechanism that drives the structural change in the model remain the inter-sectoral differences in the elasticities of demand.

Both supply and demand driven approaches and mechanisms are rarely integrated into a single theoretical model, which include both non-homothetic preferences and inter-sectoral heterogeneities in production constraints simultaneously (Boppart, 2014; Comin et al., 2021).

4.2.3 Empirical evidence

Because of the simultaneous operation of supply- and demand-related effects, it is relatively difficult to assess empirically the extent to which individual factors influence structural change. Moreover, structural change in different periods may be caused by different shares of supply- and demand-related dynamics. Relative demand elasticities and their non-homothetic form can indirectly explain supply-side dynamics arising from heterogeneous output constraints. However, such demand elasticities are abstractions that cannot be derived from pure consumer preferences, as they indirectly explain the processes driven by endogenous technological growth and sectoral unbalanced growth. The conceptual separation of pure demand- and supply-driven factors is therefore not trivial.

Due to the simultaneous operation of supply- and demand-related effects, it is relatively difficult to empirically assess the extent to which individual factors influence structural change. Moreover, structural change in different periods may be caused by different shares of supply- and demand-related dynamics. Appelbaum and Schettkat (1999), Raa and Schettkat (2001), and Savona and Lorentz (2005) emphasize the importance of demand factors in the transition from manufacturing to services in industrialized countries. They find empirical evidence that changes in consumer preferences and increased demand for services play an important role in shaping structural change. Supply factors, including technological progress, globalization, and the integration of the European economy, are also recognized as contributing to this transition. Liboreiro also notes that domestic demand, the price effect, and import substitution are the main drivers of deindustrialization, as opposed to technological change and other supply-related factors (Liboreiro et al., 2021). Other attempts to empirically measure the extent of supply- and demand-driven structural change mostly conclude that both factors are necessary to explain dynamic intersectoral redistributions of employment and output, but refrain from explicitly assessing the relative importance of each factor (Boppart, 2014; Buera & Kaboski, 2009; Herrendorf et al., 2013a, 2013b). Buera and Kaboski (2009) empirically fitted the model, which accounts for both demand and supply effects, with goodness of fit conditional on very low elasticities of substitution between goods. Herrendorf et al. (2013b) find two empirical approaches to study the demand- and supply-side effects of structural change. On the one hand, the approach based on final expenditures leads to demand-side effects being more pronounced, while on the other hand, the approach based on value-added trade leads to supply-side effects being more important of the two. Their empirical study concludes that only the inclusion of the input-output level of analysis can reconcile their results.

4.2.4 Theories and Models with Open Economy

The vast majority of the theoretical approaches to structural change are limited to conceptualisations and models of closed economy. A less theoretically explored dimension of structural change is the impact of international trade and the integration into global value chains.

Matsuyama (2009) analyses a model of small and open economy and derives that, while the world manufacturing is in decline due to supply driven factors, concrete open economy and its inclusion in the international trade can often offset this effect. This also puts under the question cross-country empirical approaches that theoretically rely on closed economy models. By integrating supply driven and demand driven conceptualisations of structural change with international trade, Uy et al. (2013) demonstrate on the case of Korea, that the role of trade is important in explaining structural change. Mao and Yao make a dynamic general equilibrium model that encompasses three sectors (agriculture, manufacturing and services), of which only agriculture and manufacturing are internationally tradable. With it they not only reproduce the stylized empirical facts regarding employment changes in these sectors, but are also the first to demonstrate importance of the Balassa-Samuelson effect[1] on the dynamics of the structural change in the international setting. The Balassa-Samuelson effect is shown to counteract the main supply driven effect due to productivity changes in a small and open economy (Mao & Yao, 2012). This stream of literature has shown that there exist direct effects of international trade on the patterns of structural change. *Vice versa*, the effects of structural change on trade have also been studied and are non-negligible, contributing to the global trade growth slowdown (Lewis et al., 2021).

A stream of Post-Keynesian literature that analyses the effects of structural change in an open economy, focuses on how international specialization across countries, as it is determined and determines structural change, impacts cross-country growth differences and uneven development. The approach is predominantly demand driven. Araujo and Lima (2007) merge, on the one hand, the balance-of-payments-constrained growth approach pioneered by Thirlwall (McCombie & Thirlwall, 2016; Thirlwall, 1979, 1983) and, on the other hand, the inter-sectoral analysis of structural change conducted by Pasinetti (1983, 1993). The main idea of the approach is that if the implication of the Pasinetti's analysis of structural change implies that changes in the structure of production lead to changes in growth rates, also the cross-country division of labour and differences in the structure of production can imply cross-country differences in the growth rates. Araujo (2013) introduces endogenous change into this framework by exploiting the broadest idea of increasing returns in the form of cumulative causation and Verdoorn's law. The main conclusion of this extended model is that differences between differently developed countries persist mainly due to demand driven effects. The country producing the commodity with high income elasticity exhibits high endogenously determined technological progress and productivity growth and *vice versa*.

4.3 Methodology

Our approach to identifying the relative contributions of the various determinants to employment changes is structural decomposition analysis (de Boer & Rodrigues, 2020; Rose & Casler, 1996). Using WIOD and SEA (Timmer et al., 2015), we perform a separate annual decomposition for each country available in the data. By analysing the annual changes in the variables, the impact of the inability to clearly separate mixed effects (Dietzenbacher & Los, 1998; Sonis et al., 1996) is minimised to second-order of importance because the annual changes are small relative to the values and the mixed effect terms consist of multiplying two such small annual changes. We approximate decomposition with mid-point

[1]The effect represents a tendency for the prices of the same quantity and quality to be systematically higher in more developed countries than in less developed countries. The effect, also called the PENN effect, is derived in a simple two country model with tradable and non-tradable sectors. While the relative productivities in the tradable sector set the overall anchor for the international prices, the prices differ in the non-tradable sector even if there are no productivity differences (Balassa, 1964; Samuelson, 1964).

weights, which was proven to minimise the errors (Muradov, 2021).

Decomposing employment changes into changes in the ratio of value added per worker (inverse productivity) for a given value added and into changes in value added for a given productivity is a common practice in structural decomposition analysis. The same applies to the decomposition of changes in final demand into different components - from the level of household, government and investment demand to the level of domestic and foreign final demand components.

The empirical and methodological novelty of our structural decomposition lies mainly in the decomposition of changes in the structure of production, which consists of changes in value added coefficients and the international Leontief inverse. We draw on two important contributions in this area. The first is a new framework for measuring cross-border supply chain fragmentation (Timmer et al., 2021). The main innovation is the derivation of annual changes in each variable using values expressed in prices of the previous year. This leads to an assessment of real changes in the structure of supplier linkages and other variables as opposed to nominal effects. The second important contribution is the examination of the decomposition of the dependent variables, primarily the value-added coefficients and the Leontief inverse (Dietzenbacher & Los, 2000). We generalise this approach and apply it to an extended international IO setting. Thus, we do not only decompose changes in value-added coefficients and the Leontief inverse on outsourcing propensity effects and the changes in the structure of supplier linkages, but additionally decompose them on several elements, similarly as proposed by Avelino et al. (2021). In the end, we obtain a decomposition that includes, on the one hand, the real changes in the structure of domestic supplier linkages, the real changes in the structure of intermediate import linkages, the real changes in intermediate import propensity as well as real changes in foreign intermediate linkage structures, and, on the other hand, the real domestic and foreign outsourcing propensity effects.
There are 3 main parts of the structural international input-output decomposition of employment changes:
1.) Real sectoral changes in labour productivity;
2.) Real changes in supplier linkage structures and real outsourcing propensity effects;
3.) Real changes in the final demand structure.

We use the standard international IO notation, which is explicitly defined in the Appendix A. We begin our decomposition by decomposing employment changes on the effect of real sector-specific productivity changes and the changes in value added due to other effects.

$$\Delta EMP_t = \left(\hat{v}_t + \frac{\Delta \hat{v}_t}{2}\right)\Delta\Psi_t + \Delta\hat{v}_t\left(\Psi_t + \frac{\Delta\Psi_t}{2}\right) \tag{4.3.1}$$

While the first element contains the main supply driven effects of employment changes, the remaining effects of changes in supplier linkages, outsourcing propensity effects, and final demand effects remain captured in $\Delta\hat{v}$. The main identity of equation 4.3.2 presents a basis for further decomposition.

$$v = \hat{c}(I - A)^{-1} f \tag{4.3.2}$$

The decomposition of real changes in value added follows the idea proposed by Dietzenbacher and Los (2000) to separate the real changes in the structure of supplier linkages and outsourcing propensity effects[2] by constructing a modified matrix of Leontief coefficients $\tilde{A}_t$. The basic idea is that each column of $\tilde{A}_t$ is defined to have the same distribution of coefficients as a column of $A_{t\,pyp}$, but is normalized to the column sum of A_{t-1}. This allows us to separate the effects of real changes, on the one hand, in the structure of supplier linkages and, on the other hand, in the value-added coefficients coupled with the changes in the column sums of A, which we call outsourcing propensity.

$$\Delta v_t = \hat{c}_t L_t f_t - \hat{c}_{t-1} L_{t-1} f_{t-1} \tag{4.3.3}$$

$$\Delta v_t = \hat{c}_t L_t f_t - \hat{c}_{t-1} L_{t-1} f_t + \hat{c}_{t-1} L_{t-1} \Delta f_t \tag{4.3.4}$$

$$\Delta v_t = \left(\hat{c}_t L_t - \hat{c}_{t-1} \tilde{L}_t\right) f_t + \hat{c}_{t-1}\left(\tilde{L}_t - L_{t-1}\right) f_t + \hat{c}_{t-1} L_{t-1} \Delta f_t \tag{4.3.5}$$

The first element of the equation 4.3.5 represents outsourcing propensity and the second element represents real changes in supplier linkages. Both can be further decomposed. The last element represents the effect of changes in final demand. This solution to the problem of interdependency in the structural decomposition was identified and proposed by Dietzenbacher and Los (2000) in the single-economy input-output framework. Our formulation extends their solution to the multi-regional input-output framework.

4.3.1 Real changes in intermediate supplier linkages

For each country, we separate the effect of real changes in supplier linkages ($\hat{c}_{t-1}\left(\tilde{L}_t - L_{t-1}\right) f_t$) on the following elements:

1.) Changes in the structure of domestic linkages;

2.) Changes in the structure of intermediate imports by domestic firms;

3.) Changes in the intermediate import propensity of domestic firms;

4.) Changes in the structure of foreign supplier linkages (including changes in domestic linkages of foreign countries).

Such a decomposition is necessarily specific to each country c. We focus on the difference of the two Leontief inverses contained in the second element of the equation 4.3.5. This step decomposes total change in the Leontief inverse into elements that are only by the change in

[2]They call them fabrication effects. We argue that outsourcing propensity would be a better label for this effect, since it captures the effect of changes in share of output produced within the firm.

the technical input-output coefficients. The choice of balanced weighs between the two polar decompositions was demonstrated by Muradov (2021) to be the most stable and precise way to decompose the changes of the Leontief inverse.

$$\tilde{L}_t - L_{t-1} = (I - \tilde{A}_t)^{-1} - (I - A_{t-1})^{-1} \tag{4.3.6}$$

$$\tilde{L}_t - L_{t-1} = \frac{1}{2}\tilde{L}_t \Delta A_t L_{t-1} + \frac{1}{2} L_{t-1} \Delta A_t \tilde{L}_t \tag{4.3.7}$$

The next step is to decompose the change in supplier linkages, captured within the ΔA. The following steps follow simple logic of differentiation between different elements in block matrix structure, as examined in a general multi-regional framework by Avelino et al. (2021).

$$\Delta A_t = \tilde{A}_t - A_{t-1} \tag{4.3.8}$$

Since we are working in a demand-driven Leontief model, the changes in the Leontief coefficient matrix ΔA_t represent real changes in downstream linkages that induce direct and indirect effects based on the given global final demand. From the perspective of a given country c, the matrix ΔA_t can be decomposed into two major parts. The first part ($\Delta_c A_t^D$) has all the columns that do not correspond to the country c equal to zero, and the second part ($\Delta_c A_t^F$) all columns corresponding to country c are equal to zero. A Leontief coefficient with indices (i, r, j, s) denotes the j-th sector and s-th country requirements for the production in sector i and country r. Note that each decomposition into country (c) is specific.

$$\Delta A_t = \Delta_c A_t^D + \Delta_c A_t^F \tag{4.3.9}$$

$$\Delta_c a_t^D(i, r, j, s) = \begin{cases} \Delta a_t(i, r, j, s) & \text{if } r = c \\ 0 & \text{otherwise} \end{cases} \tag{4.3.10}$$

$$\Delta_c a_t^F(i, r, j, s) = \begin{cases} \Delta a_t(i, r, j, s) & \text{if } r \neq c \\ 0 & \text{otherwise} \end{cases} \tag{4.3.11}$$

We want to further separate the effects of real changes in domestic intermediate linkages and real changes in the structure of domestic intermediate imports. To do so, we need to make additional definitions. Unlike the previous set of definitions, in this case we define total values as opposed to real changes, since further modifications are made by separate definitions of changes. In this way, we can separately assess the impact of changes in domestic supplier linkages, domestic intermediate import linkages, and domestic intermediate import propensity.

$${}_c a_t^{dom}(i, r, j, s) = \begin{cases} a_t(i, r, j, s) & \text{if } r = c \text{ and } s = c \\ 0 & \text{otherwise} \end{cases} \tag{4.3.12}$$

$$ {}_c a_t^{imp}(i,r,j,s) = \begin{cases} a_t(i,r,j,s) & \text{if } r = c \text{ and } s \neq c \\ 0 & \text{otherwise} \end{cases} \quad (4.3.13) $$

$$ {}_c a_{t\ pyp}^{dom}(i,r,j,s) = \begin{cases} a_{t\ pyp}(i,r,j,s) & \text{if } r = c \text{ and } s = c \\ 0 & \text{otherwise} \end{cases} \quad (4.3.14) $$

$$ {}_c a_{t\ pyp}^{imp}(i,r,j,s) = \begin{cases} a_{t\ pyp}(i,r,j,s) & \text{if } r = c \text{ and } s \neq c \\ 0 & \text{otherwise} \end{cases} \quad (4.3.15) $$

We define ${}_c\tilde{A}_t^{dom}$ as having the same distribution of coefficient as ${}_cA_{t\ pyp}^{dom}$, but having the column sum equal to the column sum of ${}_cA_{t-1}^{dom}$. Similarly, we define ${}_c\tilde{A}_t^{imp}$ with the same distribution of coefficient as ${}_cA_{t\ pyp}^{imp}$, but with the column sum equal to the column sum of ${}_cA_{t-1}^{imp}$. Using this, we define $\Delta_c A_t^{dom}$ in equation 4.3.16 and $\Delta_c A_t^{dom}$ in equation 4.3.17.

$$ \Delta_c A_t^{dom} = {}_c\tilde{A}_t^{dom} - {}_cA_{t-1}^{dom} \quad (4.3.16) $$

$$ \Delta_c A_t^{imp} = {}_c\tilde{A}_t^{imp} - {}_cA_{t-1}^{imp} \quad (4.3.17) $$

We can now further decompose the changes in supplier linkages and continue from equation 4.3.9.

$$ \Delta A_t = \underbrace{\Delta_c A_t^{dom}}_{(1.)} + \underbrace{\Delta_c A_t^{imp}}_{(2.)} + \underbrace{\left(\Delta_c A_t^{D} - \Delta_c A_t^{dom} - \Delta_c A_t^{imp}\right)}_{(3.)} + \underbrace{\Delta_c A_t^{F}}_{(4.)} \quad (4.3.18) $$

Since the ${}_c\tilde{A}_t^{dom}$ has the same column sum as ${}_cA_{t-1}^{dom}$, the first element (1.) represents real changes in the domestic supplier linkage structure. Similarly, the second element (2.) represents real changes in the import structure of domestic firms. The third element (3.) can be interpreted as the real changes in the intermediate import propensity. Since both ${}_c\tilde{A}_t^{dom}$ and ${}_c\tilde{A}_t^{imp}$ are defined with a column size predetermined by the previous year's domestic linkages and intermediate imports, the difference between the total effect of real changes in the structure of domestic firms' supplier linkages $\Delta_c A_t^D$ and the effect of changes in the structure of domestic linkages and the structure of intermediate imports includes exactly the isolated effect of changes in intermediate import propensity ${}_c\tilde{A}_t^{iip}$ - namely, the effect of substitution of domestic intermediate suppliers for intermediate imports or *vice versa*. The fourth element (4.) captures all the effects of changes in intermediate supplier linkages of foreign firms from the perspective of country c, i.e., changes in their domestic and global value chain structure and the foreign firm intermediate import propensities. Further decomposition of this element would not serve the purpose at this point, since the element from the perspective of country c captures only the overall effect of global changes in intermediate demand relevant to country c's sectors. Since we are working within demand-driven model, the fourth element captures the effect of changes in the inclusion of country c's domestic firms in global value chains due to changes in the structure of foreign intermediate supplier linkages, while the first three elements include the effects of changes in the structure of domestic firms' supplier linkages - namely, the effect of changes in domestic firms' domestic supplier structure (1.), international supplier structure of domestic firms (2.), or the relationship between outsourcing and domestic sourcing of domestic firms (3.).

To continue in more compact notation, we define changes in real domestic intermediate import propensity $\Delta_c A_t^{iip}$ with equation 4.3.19.

$$\Delta_c A_t^{iip} = \Delta_c A_t^{D} - \Delta_c A_t^{dom} - \Delta_c A_t^{imp} \tag{4.3.19}$$

The four elements of our decomposition can thus be written more compactly.

$$\Delta A_t = \Delta_c A_t^{dom} + \Delta_c A_t^{imp} + \Delta_c A_t^{iip} + \Delta_c A_t^{F} \tag{4.3.20}$$

Finally, we insert this result in the equation 4.3.7. Each decomposed element of ΔA_t accounts for both the direct and indirect effect of the real changes in the supplier linkages, when inserted in the equation 4.3.7.

$$\begin{gathered}\tilde{L}_t - L_{t-1} = \frac{1}{2}\tilde{L}_t \Delta_c A_t^{dom} L_{t-1} + \frac{1}{2} L_{t-1} \Delta_c A_t^{dom} \tilde{L}_t + \frac{1}{2}\tilde{L}_t \Delta_c A_t^{imp} L_{t-1} + \frac{1}{2} L_{t-1} \Delta_c A_t^{imp} \tilde{L}_t + \\ \frac{1}{2}\tilde{L}_t \Delta_c A_t^{iip} L_{t-1} + \frac{1}{2} L_{t-1} \Delta_c A_t^{iip} \tilde{L}_t + \frac{1}{2}\tilde{L}_t \Delta_c A_t^{F} L_{t-1} + \frac{1}{2} L_{t-1} \Delta_c A_t^{F} \tilde{L}_t + \end{gathered} \tag{4.3.21}$$

With this intermediate result (equation 4.3.21), we have decomposed both the direct and indirect effects of real changes in supplier linkage structures on changes in value added.

4.3.2 Outsourcing propensity effects

The first element $((\hat{c}_t L_t - \hat{c}_{t-1}\tilde{L}_t) f_t)$ of the equation 4.3.5, represents the outsourcing propensity effects. These include changes in the value added coefficients as well as the sums of the columns of the Leontief coefficient matrices. Thus, total outsourcing propensity effects account for changes in production procedures and techniques that alter the relationship between value added on the factory level and the use of intermediaries. One of the most important sources of outsourcing propensity effects at the international level is the changes in the share of outsourcing and insourcing of various tasks within the production process. Thus, this element of the decomposition helps us assess the impact of changes that primarily concern outsourcing. For each country c, we can decompose the whole element into the domestic outsourcing propensity effects ($\Delta_c FAB_t^{dom}$) and the foreign outsourcing propensity effects ($\Delta_c FAB_t^{for}$) as proposed by Avelino et al. (2021).

$$\Delta_c FAB_t = \hat{c}_t L_t - \hat{c}_{t-1}\tilde{L}_t = \Delta_c FAB_t^{dom} + \Delta_c FAB_t^{for} \tag{4.3.22}$$

$$\Delta_c fab_t^{dom}(i,r,j,s) = \begin{cases} \Delta fab_t(i,r,j,s) & \text{if } r = c \\ 0 & \text{otherwise} \end{cases} \tag{4.3.23}$$

$$\Delta_c fab_t^{for}(i,r,j,s) = \begin{cases} \Delta fab_t(i,r,j,s) & \text{if } r \neq c \\ 0 & \text{otherwise} \end{cases} \tag{4.3.24}$$

This decomposition allows us to consider the impact of changes in the outsourcing of domestic firms and the impact of changes in the outsourcing of foreign firms.

Having first separated real productivity effects from the remaining changes in value added (equation 4.3.1) continued with the decomposition of value added changes on outsourcing propensity effects, real supplier linkages changes, and final demand effects (equation 4.3.5), the remaining element that can be further decomposed is the effect of changes in final demand.

4.3.3 Final demand effects decomposition

In Leontief's demand-led international input-output model, final demand has a direct impact on the structure of production and employment. However, according to the demand-led approaches to structural change, it is not demand as such but the non-homothetic structure of preferences that determines the structural shift in employment. To enable the confrontation of demand-led theories of structural change with empirical facts, we decompose the change in final demand into a set of elements representing different economic phenomena related to final demand. These elements are: the price effect, the homothetic income effect, the non-homothetic income effect, and the effects of uneven income growth across countries.

The demand decomposition is based on basic microeconomic foundations. Homothetic income effect is defined as if the microeconomic preference structure were homothetic - thus it is proportionally distributed between all sectors. The price effect is evaluated using CES preference function and by a standard regression equation. The import propensity is defined as a share of final demand that directly results in imports. There are also some demand effects that we are the first to introduce in the multi-regional input-output analysis. We separately track changes in the import structure (from whom a country imports) and separate this element from non-homothetic changes of demand due to preference structure (orientation of demand towards products of specific sectors, regardless of country of origin).

In WIOD final demand is comprised of final demand for each country f_t^i and its foreign ${}^{for}f_t^i$ and domestic origin ${}^{dom}f_t^i$:

$$f_t = \sum f_t^i \qquad\qquad f_t^i =^{dom} f_t^i +^{for} f_t^i \quad \forall i \tag{4.3.25}$$

It is further broken down on 5 elements: final demand of households and non-profits serving households ${}^{dom}_{ho}f_t^i$, government ${}^{dom}_{go}f_t^i$, investment final demand ${}^{dom}_{in}f_t^i$, and inventory changes ${}^{dom}_{invent}f_t^i$. Because inventory changes represent an accounting residual that cannot be meaningfully decomposed further, we treat it as a separate component of our decomposition. We also merge the final demand of households and non-profits serving households ${}^{dom}_{ho}f^{i}_{t}$, as the latter is quantitatively insignificant in comparison and serves similar purpose of household final consumption.

$$ {}^{dom}f^{i}_{t} = {}^{dom}_{ho}f^{i}_{t} + {}^{dom}_{go}f^{i}_{t} + {}^{dom}_{in}f^{i}_{t} + {}^{dom}_{invent}f^{i}_{t} \tag{4.3.26} $$

The homothetic income effects

The homothetic income effect, by definition, represents a proportional increase in each consumption element and thus has no effect on the sectoral change. However, analysis of the international economy brings some additional considerations. There are 43 different national income effects based on the average real increase in final demand in each country. These national income effects affect both the domestic and foreign production structure (through imports and intermediate linkages). Since countries generally differ in the structure of their final demand and the size of the income effect, this can affect each country's sectoral production structure through nationally heterogeneous income changes in foreign final demand that affect its production structure. Thus, the simple fact that the homothetic income effect does not cause a structural relocation between sectors, which is true for the closed economy, is no longer true in the international environment where income growth and consumption structure are uneven across countries.

At the global level, only the global homothetic income effect is truly neutral to any structural shift, since it affects all consumption in all sectors in all countries equally. We define it as global average income growth r_G distributed equally across all consumption.

$$ r^{G}_{t} = \frac{\sum_{\forall i,j} \Delta f_t(i,j)}{\sum_{\forall i,j} f_{t-1}(i,j)} \tag{4.3.27} $$

The global homothetic income effect $\Delta^{HI} f_t$ is:

$$ \Delta^{HI} f_t = r^{G}_{t} f_{t-1} \tag{4.3.28} $$

However, the national income effects represent the real country-specific income effects that form the basis for estimating the price effect and the non-homothetic income effect. The national income effect $\Delta^{HI} f^{i}_{t}$ is defined for each country i by its average income growth r^{i}_{t}:

$$ r^{i}_{t} = \frac{\sum_{\forall j} \Delta f_t(i,j)}{\sum_{\forall j} f_{t-1}(i,j)} \tag{4.3.29} $$

$$ \Delta^{HI} f^{i}_{t} = \sum_{\forall i} r^{i}_{t} f^{i}_{t-1} \tag{4.3.30} $$

To introduce the national income effect as a basis for further decomposition, we need to consider the difference between the global homothetic income effect and the sum of all national income effects. We refer to this component of the decomposition as the uneven homothetic income growth effect $\Delta^{UHI} f_t$.

$$\Delta^{UHI} f_t = \sum_{\forall i} r_t^i f_{t-1}^i - r_t^G f_{t-1} \tag{4.3.31}$$

This difference represents the effect of structural change due to uneven growth between differently developed countries and their structural differences. The structure of production is affected by both the homothetic income effects of domestic demand and the different homothetic income effects of foreign demand, which shape the structure of foreign demand. In addition to these heterogeneities, there are also structural differences between domestic and import demand (e.g., domestic demand is more service-oriented compared to import demand). Together with differences in income growth across countries, these can affect the shares between domestic and import demand in different countries, which in turn can affect sectoral structural change, although all consumption changes are homothetic at the national level. These structural effects arising from these phenomena alone are captured by the uneven homothetic income growth component $\Delta^{UHI} f_t$.

The price effect

The price effect represents the substitution between the consumption of value added produced by different sectors due to relative price changes. To evaluate the substitution effect, we assume homothetic CES preferences and estimate a single elasticity of substitution ϵ for all countries and sectors.

$\Delta \mathring{X}$ represents the real change in household demand adjusted for the homothetic income effects expressed in relative terms. Thus, this element represents the real income-adjusted relative change in final demand.

$$\Delta \mathring{X} = \frac{\Delta f_t - \sum_{\forall i} r_t^i f_{t-1}^i}{f_t} \tag{4.3.32}$$

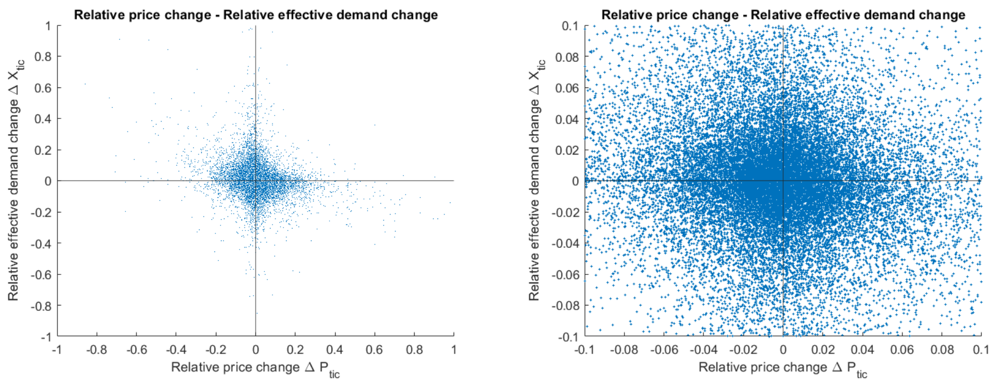
$\Delta \mathring{P}$ represents relative price changes. PI_{tic} represents a price index for value added produced in sector i in country c in year t. A relative price change is a price change adjusted for the effect of income change due to all price changes, expressed in relative terms.

$$\Delta P_t(i,j) = \frac{PI_t(i,j) - PI_{t-1}(i,j)}{PI_{t-1}(i,j)} \tag{4.3.33}$$

$$\Delta \mathring{P}_t(i,j) = \Delta P_t(i,j) - \frac{\sum_{i=j}^{56} \Delta P_t(i,j)\, f_t(i,j)}{\sum_{i=j}^{56} f_t(i,j)} \tag{4.3.34}$$

We assume that there is a single elasticity of substitution ϵ that describes the changes in demand between the value added of different sectors due to price effects. This elasticity of substitution is not a microeconomic object because it refers to consumption alternatives between the value added of different sectors. In the figure 4.1, we can see that there is no clear pattern linking price changes to real demand changes, suggesting that substitutability between consumption of value added of different sectors may be relatively limited.

Figure 4.1: Substitutability due to price effects



We estimate ϵ with a simple linear regression:

$$\Delta \overset{\circ}{X}_i(i,j) = \epsilon \Delta \overset{\circ}{P}_i(i,j) + c + u_i(i,j) \tag{4.3.35}$$

The results are presented in table 4.1. Despite the fact that a very small part of the variability is explained by the substitution effect ($R^2 = 0.032$), we use the estimated elasticity of substitution $\epsilon = -0.18$ as the basis for estimating the price effect. While this is a relatively crude approximation, it is nevertheless more empirically sound than the alternative Leontief demand preference structure assumption, which assumes zero substitutability between the consumption of value added by different sectors. Later, however, we will show that even the inclusion of price effects does not significantly change the results of our analysis, since the price effect has a very limited impact on the dynamics of structural change. The low substitutability reflects the fact that the consumption of value added in a given sector represents the purchase of a large quantity of different goods that can be more substitutable for each other at the micro level, but such substitution does not necessarily change the distribution of the consumption of value added at the sectoral level significantly. We define the price effect component of our decomposition as:

$$\Delta\ ^{PR} f_t = \epsilon \Delta \overset{\circ}{P} f_t \tag{4.3.36}$$

The nonhomothetic income effect and import propensity

After accounting for the effect of homothetic income changes and the substitution effect, the residual of changes in final demand, expressed in equations 4.3.37 to 4.3.41 , includes

Table 4.1: Regression results

VARIABLES	$\Delta\overset{\circ}{X}$
$\Delta\overset{\circ}{P}$	-0.179***
	(0.00533)
Constant	0.00165***
	(0.00038)
Observations	31,845
R-squared	0.032

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

two effects. The first is related to the changes in the import propensity of final demand and the changes in the import structure (from which country value is imported). The second is related to the non-homothetic changes in the preference structure of final demand, which affect the sectoral changes in consumption, regardless of the country targeted by the demand.

We decompose the two effects by expressing the average percentage change $APC(i,j)$ in non-homothetic demand for each sector, regardless of whether demand targets domestic value added or imports from different countries (we average over i). The average growth rate of non-homothetic demand for each sector j is then multiplied by each component of the previous year's actual demand. The results presented in equations 4.3.46 to 4.3.49 thus capture the effects of changes in the preference structure that drive the redistribution of sectoral consumption (hereafter referred to as the non-homothetic effect - Δ^{NH}). The partial residual, represented by equations 4.3.50 to 4.3.53, captures the effects caused by changes in import propensity and country composition of import demand. The residual captures the changes in import propensity and country composition of imports because, by definition, it represents the deviation of final demand changes from the changes caused by average non-homothetic sectoral redistribution of consumption across countries. We therefore refer to the residual as the effect of changes in import propensity and structure (Δ^{IPS}).

$$\Delta^{NHIPSfor}f_t^i = \Delta^{for}f_t - \sum_{\forall ii \neq i} r_t^{ii\,for}f_{t-1}^i - \sum_{\forall ii \neq i} \epsilon\Delta\overset{\circ}{P}_i{}^{for}f_{t-1}^i \tag{4.3.37}$$

$$\Delta_{ho}^{NHIPSdom}f_t^i = \Delta_{ho}^{dom}f_t - r_{t\,ho}^{i\,dom}f_{t-1}^i - \epsilon\Delta\overset{\circ}{P}_i{}_{ho}^{dom}f_{t-1}^i \tag{4.3.38}$$

$$\Delta_{gov}^{NHIPSdom}f_t^i = \Delta_{gov}^{dom}f_t - r_{t\,gov}^{i\,dom}f_{t-1}^i - \epsilon\Delta\overset{\circ}{P}_i{}_{gov}^{dom}f_{t-1}^i \tag{4.3.39}$$

$$\Delta_{in}^{NHIPSdom}f_t^i = \Delta_{in}^{dom}f_t - r_{t\,in}^{i\,dom}f_{t-1}^i - \epsilon\Delta\overset{\circ}{P}_i{}_{in}^{dom}f_{t-1}^i \tag{4.3.40}$$

$$\Delta_{invent}^{NHIPSdom}f_t^i = \Delta_{invent}^{dom}f_t - r_{t\,invent}^{i\,dom}f_{t-1}^i - \epsilon\Delta\overset{\circ}{P}_i{}_{invent}^{dom}f_{t-1}^i \tag{4.3.41}$$

$$APC(i,j) = \frac{\sum_{\forall i}\sum_{\forall ii} \Delta^{NHIPTSfor} f_t^i(ii,j)}{\sum_{\forall i}\sum_{\forall ii} {}^{for} f_t^i(ii,j)} \qquad \forall i,j \tag{4.3.42}$$

$$APC(i,j) = \frac{\sum_{\forall ii} \Delta^{NHIPTS} {}^{dom}_{ho} f_t^i(ii,j)}{\sum_{\forall ii} {}^{dom}_{ho} f_t^i(ii,j)} \qquad \forall i,j \tag{4.3.43}$$

$$APC(i,j) = \frac{\sum_{\forall ii} \Delta^{NHIPTS} {}^{dom}_{go} f_t^i(ii,j)}{\sum_{\forall ii} {}^{dom}_{go} f_t^i(ii,j)} \qquad \forall i,j \tag{4.3.44}$$

$$APC(i,j) = \frac{\sum_{\forall ii} \Delta^{NHIPTS} {}^{dom}_{in} f_t^i(ii,j)}{\sum_{\forall ii} {}^{dom}_{in} f_t^i(ii,j)} \qquad \forall i,j \tag{4.3.45}$$

$$\Delta^{NHfor} f_t^i(ii,j) = APC(i,j)^{for} f_{t-1}^i(ii,j) \tag{4.3.46}$$

$$\Delta^{NH} {}^{dom}_{ho} f_t^i(ii,j) = APC(i,j)^{dom}_{ho} f_{t-1}^i(ii,j) \tag{4.3.47}$$

$$\Delta^{NH} {}^{dom}_{go} f_t^i(ii,j) = APC(i,j)^{dom}_{go} f_{t-1}^i(ii,j) \tag{4.3.48}$$

$$\Delta^{NH} {}^{dom}_{in} f_t^i(ii,j) = APC(i,j)^{dom}_{in} f_{t-1}^i(ii,j) \tag{4.3.49}$$

$$\Delta^{IPSfor} f_t^i(ii,j) = \Delta^{NHIPSfor} f_t^i(ii,j) - \Delta^{NHfor} f_t^i(ii,j) \tag{4.3.50}$$

$$\Delta^{IPS} {}^{dom}_{ho} f_t^i(ii,j) = \Delta^{NHIPS} {}^{dom}_{ho} f_t^i(ii,j) - \Delta^{NH} {}^{dom}_{ho} f_t^i(ii,j) \tag{4.3.51}$$

$$\Delta^{IPS} {}^{dom}_{go} f_t^i(ii,j) = \Delta^{NHIPS} {}^{dom}_{go} f_t^i(ii,j) - \Delta^{NH} {}^{dom}_{go} f_t^i(ii,j) \tag{4.3.52}$$

$$\Delta^{IPS} {}^{dom}_{in} f_t^i(ii,j) = \Delta^{NHIPS} {}^{dom}_{in} f_t^i(ii,j) - \Delta^{NH} {}^{dom}_{in} f_t^i(ii,j) \tag{4.3.53}$$

Complete decomposition of final demand

This results in 43 final decompositions for every country. Elements of every decomposition sum up to the total final demand changes in every period.

$$\Delta f_t = \Delta^{HI} f_t + \Delta^{UHI} f_t + \Delta^{PR} f_t + \Delta^{NHfor} f_t^i + \Delta^{NH} {}^{dom}_{ho} f_t^i + \Delta^{NH} {}^{dom}_{go} f_t^i + \Delta^{NH} {}^{dom}_{in} f_t^i + \Delta^{IPSfor} f_t^i + \Delta^{IPS} {}^{dom}_{ho} f_t^i + \Delta^{IPS} {}^{dom}_{go} f_t^i + \Delta^{IPS} {}^{dom}_{in} f_t^i + \Delta^{NHIPS} {}^{dom}_{invent} f_t^i \tag{4.3.54}$$

4.3.4 The complete structural decomposition of employment changes on the country and sector level

We combine all our elements of structural decomposition into a single equation. We start by combining equations 4.3.1 and 4.3.5, continue by inserting equation 4.3.21 and 4.3.22, and finally the final demand decomposition equation 4.3.54. The full structural decomposition, done separately for each country c, consists of the real effects presented in a hierarchical tree in the figure 4.2. Each element in the final equation of our structural decomposition represents a structural change determinant presented in the figure 4.2 in the order of their occurrence:

$$
\begin{aligned}
\Delta_c EMP_t = & \left(\hat{v}_t + \frac{\Delta \hat{v}_t}{2}\right)\Delta\Psi_t + \\
& diag\Big(\Delta_c FAB_t^{dom} f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\Delta_c FAB_t^{for} f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1}\left(\frac{1}{2}\tilde{L}_t \Delta_c A_t^{dom} L_{t-1} + \frac{1}{2} L_{t-1}\Delta_c A_t^{dom}\tilde{L}_t\right) f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1}\left(\frac{1}{2}\tilde{L}_t \Delta_c A_t^{imp} L_{t-1} + \frac{1}{2} L_{t-1}\Delta_c A_t^{imp}\tilde{L}_t\right) f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1}\left(\frac{1}{2}\tilde{L}_t \Delta_c A_t^{iip} L_{t-1} + \frac{1}{2} L_{t-1}\Delta_c A_t^{iip}\tilde{L}_t\right) f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1}\left(\frac{1}{2}\tilde{L}_t \Delta_c A_t^{F} L_{t-1} + \frac{1}{2} L_{t-1}\Delta_c A_t^{F}\tilde{L}_t\right) f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{HI} f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{UHI} f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \qquad (4.3.55)\\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{PR} f_t\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{NH}{}^{dom}_{ho} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{IPS}{}^{dom}_{ho} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{NH}{}^{dom}_{go} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{IPS}{}^{dom}_{go} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{NH}{}^{dom}_{in} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{IPS}{}^{dom}_{in} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{NHfor} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{IPSfor} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big) + \\
& diag\Big(\hat{c}_{t-1} L_{t-1}\Delta^{NHIPS}{}^{dom}_{invent} f_t^i\Big)\Big(\Psi_t + \frac{\Delta\Psi_t}{2}\Big)
\end{aligned}
$$

Figure 4.2: Hierarchy of the structural decomposition

EMPLOYMENT CHANGE

- **Productivity effects** (1)
- **Outsourcing propensity effects**
  - ***Domestic outsourcing propensity effects*** (2)
  - ***Foreign outsourcing propensity effects*** (3)
- **Supplier linkage effects**
  - ***Domestic supplier linkage effects***
    - Structure of domestic supplier linkages (4)
    - Domestic structure of intermediate import linkages (5)
    - Domestic intermediate import propensity (6)
  - ***Foreign supplier linkage effects*** (7)
- **Final demand effects**
  - ***Global final demand effects***
    - Global homothetic income effects (8)
    - Uneven growth of income effect (9)
    - Price effect (10)
  - ***Non-homothetic effects***
    - Domestic household non-homothetic effects (11)
    - Domestic government non-homothetic effects (13)
    - Domestic investment non-homothetic effects (15)
    - Foreign demand non-homothetic effects (17)
  - ***Import propensity and structure effects***
    - Domestic household import propensity and structure (12)
    - Domestic government import propensity and structure (14)
    - Domestic investment import propensity and structure (16)
    - Foreign demand import propensity and structure (18)
  - Inventory changes (19)

4.4 Results

The decomposition breaks down the determinants of employment changes for each country and sector for each year. With the WIOD data, this covers 43 countries, 56 sectors, and 14 years (2000-2014). To analyse the impact of each decomposed element on the structural shift of employment from manufacturing to services and from agriculture to nonagriculture, we construct two indices of structural change. The MtS_{ct} index for the transition from manufacturing to services measures the annual contributions to the relative decline in manufacturing employment and the relative increase in services employment. The AtN_{ct} (agriculture to nonagriculture) index measures the annual contributions to the relative decline in agriculture employment and the relative increase in nonagriculture employment. Labelling S as a set of service sectors, M as a set of manufacturing sectors and A as a set of agricultural sectors, we define:

$$MtS_{ct} = \frac{\sum_{i \in S} \Delta EMP_{ict}}{\sum_{i \in S} EMP_{ict}} - \frac{\sum_{i \in M} \Delta EMP_{ict}}{\sum_{i \in M} EMP_{ict}} \tag{4.4.1}$$

$$AtN_{ct} = \frac{\sum_{i \in N} \Delta EMP_{ict}}{\sum_{i \in N} EMP_{ict}} - \frac{\sum_{i \in A} \Delta EMP_{ict}}{\sum_{i \in A} EMP_{ict}} \tag{4.4.2}$$

These indexes measure not only the direct shift of jobs from manufacturing to services or from agriculture to nonagriculture, but also the relative changes corresponding to faster employment growth in either sector during periods of growth or faster employment decline during periods of crisis. In general, the higher the index, the greater the relative shift in employment from manufacturing to services or away from agriculture in that year, and *vice versa*.

For each country and period, a structural decomposition of employment change provides an estimate of the country-specific determinants of structural change – both from manufacturing to services and from agriculture to non-agriculture. This allows us to perform our analysis at several levels. First, we analyse the annual relationship between the decomposed determinants and annual structural change, where we have a $14 \times 43 = 602$ observations. This is shown in figures 4.5a, 4.5c, and 4.8a. Second, we analyse the cumulative total effect of our determinants, their mutual relationship, and their relationship to cumulative structural change. The cumulative totals are obtained by simply summing the determinants of structural change over the time dimension. This approach results in only 43 observations (number of countries) and is presented in figures 4.5b, 4.5d, and 4.8b. Third, we plot the evolution of cumulative structural change and its determinants over the period studied, which allows us to observe and analyse the trend and changes in the impact of the different determinants over time. This approach is illustrated in figures 4.3, 4.4, 4.6, 4.7, 4.9, 4.10 and 4.11.

To link our empirical practice to theory, we group our effects into three broad categories and link them to the determinants already explored theoretically - supply-side effects, demand-side effects, and international trade effects. While there are numerous ways in which the supply mechanism operates, the common idea across all theories of supply-driven structural change is that intersectoral heterogeneities (which may be reflected in TFP, marginal productivity of capital, elasticities of substitution, etc.) lead to differential productivity growth across sectors, which in turn causes a long-run shift in employment. Thus, our measure of the effect of productivity (productivity differences across sectors) on structural change adequately captures all of the effects proposed by the various supply-side theories. The second major determinant studied theoretically is the non-homothetic preference structure, which is captured by combining the non-homothetic effect of domestic household, government, investment and foreign final demand. The third main group corresponds to all effects of international trade dynamics and includes changes in the import propensity and structure of final demand, changes in the real structure of international supplier linkages, and changes in the outsourcing propensity.

To better understand the logic behind the variability in cross-country determinants, we calculate the determinants of structural change for the 3 major country groups: developing Countries[3], developed Countries[4] and the EU countries of Central and Eastern Europe [5]. In this way, we can capture some measure of cross-country features of structural change variability that might be related to the level of development or the specific nature of international integration of these large groups. First, the developed countries represent the core of the world economy, with the highest technological development of their production base and a substantial orientation toward service sector employment as early as 2000. The group of Central and Eastern European countries (CEECs) represents highly internationally integrated, comparatively small EU member states that have developed above-average integration into the global value chain over the period studied and have experienced extensive growth fueled by foreign direct investment and labour cost advantages. Developing countries are characterised by the highest manufacturing productivity growth and exhibit classic autocentric growth through the economies of scale of industrial expansion, with international demand and value chain integration being important factors in their development.

4.4.1 Relocation from manufacturing to services

Main structural change drivers

In figure 4.3 we see the cumulative structural change from manufacturing employment to services employment and its main determinants at the global level. We see that among the three major groups of determinants, the demand-related effects play a very limited role, while the supply and international trade factors are the most important. On the one hand, faster productivity growth in manufacturing is pushing relative employment into the more stagnant service sectors. On the other hand, the international shift of labour-intensive manufacturing jobs to developing regions, either through an increase in traditional final goods trade or through an increase in global trade in the value chain, has created more manufacturing jobs worldwide than in services. International trade and value chain dynamics thus counteract the displacement effect of growing productivity by increasing the participation of cheaper labour power from developing countries in global manufacturing.

The price effects are slightly negative, reflecting the faster price decline in manufacturing relative to services. Nevertheless, the substitution effect due to price changes is almost negligible compared to other determinants. In this context, structural change does not take the

[3] China, Indonesia, India, Mexico, Turkey, Brazil, Russia.

[4] Austria, Belgium, Canada, Switzerland, Germany, Denmark, Finland, France, Greece, UK, Ireland, Italy, Japan, Malta, South Korea, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Taiwan, USA. Although the countries of CEE are also considered either developed or developing countries, we include them only in the group of CEE countries because they have significant specificities.

[5] Czech Republic, Estonia, Hungary, Lithuania, Latvia, Poland, Slovakia, Slovenia.

Figure 4.3: Global cumulative structural change drivers of relocation from manufacturing to services

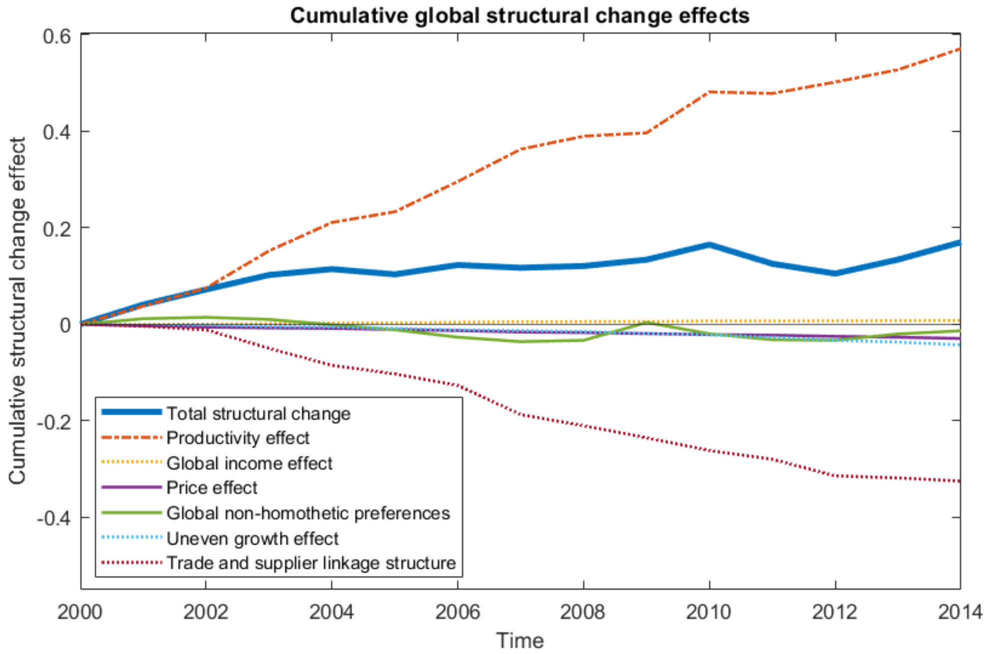
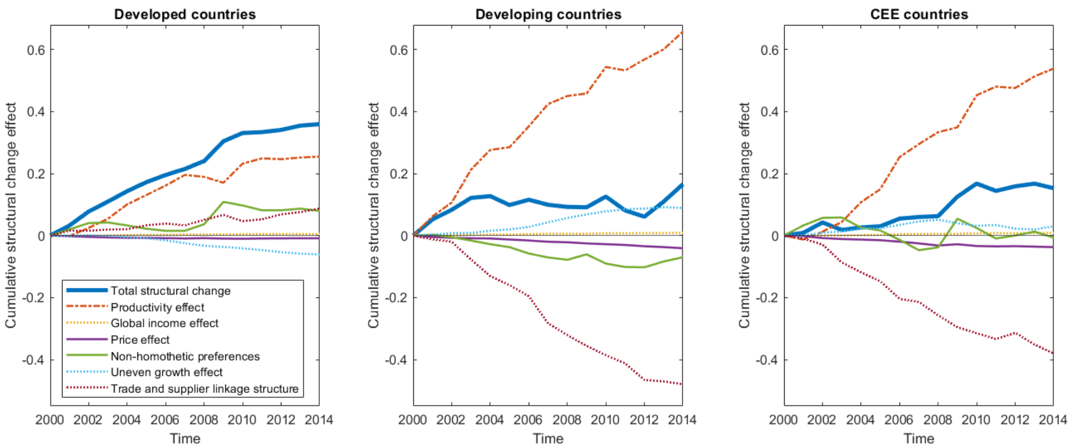
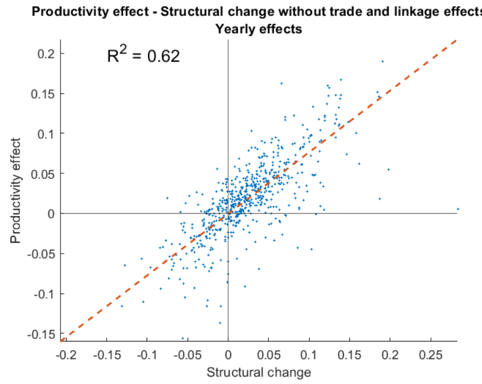


Figure 4.4: Cumulative structural change drivers - manufacturing to services

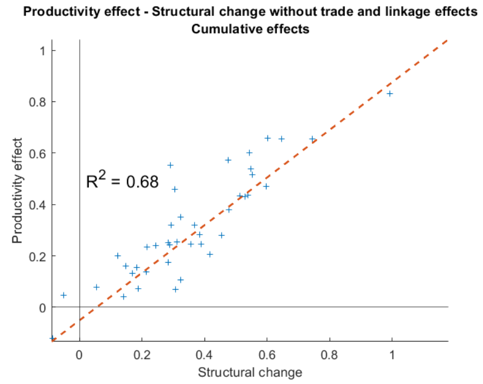


(a) Developed **(b)** Developing **(c)** CEEC

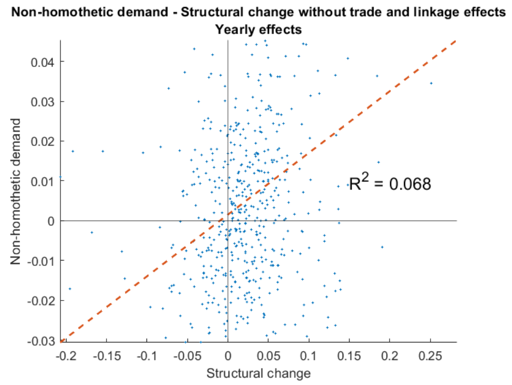
Figure 4.5: Supply and demand driven factors of domestic structural change



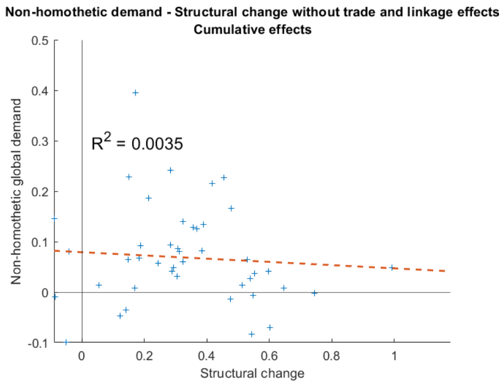
(a) Supply driven effects - domestic structural change
Yearly effects



(b) Supply driven effects - domestic structural change
Cumulative effects



(c) Demand driven effects - domestic structural change
Yearly effects



(d) Demand driven effects - domestic structural change
Cumulative effects

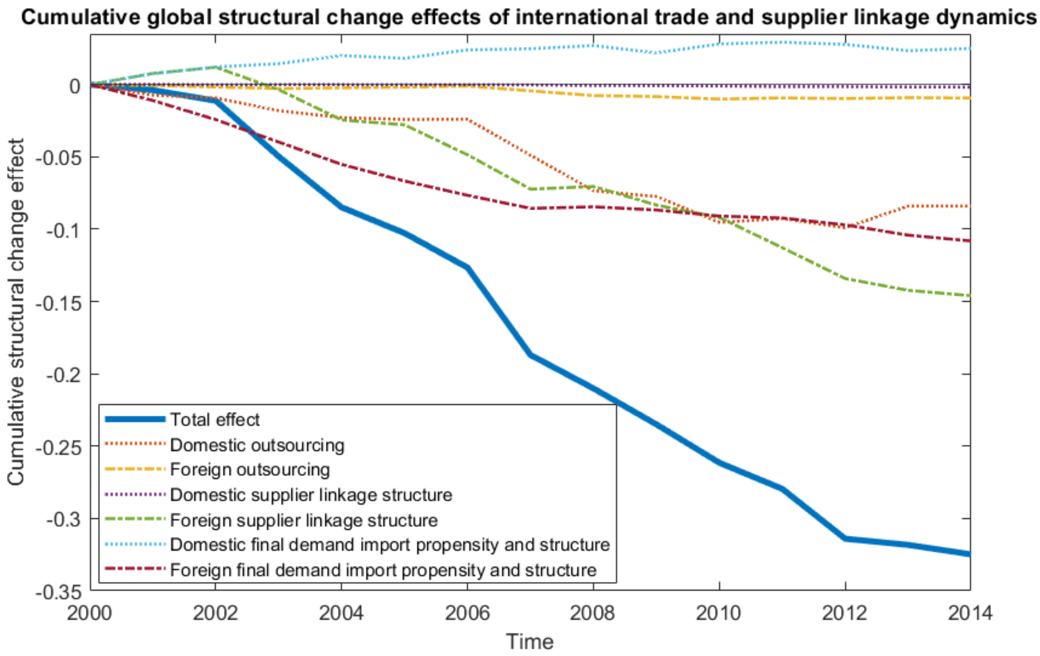
form of Baumol's (1967) cost disease. As expected from the definition, the global homothetic income effect does not affect structural change. The uneven homothetic growth effect is slightly biased in favor of manufacturing employment, as less developed regions grow faster and account for a larger share of manufacturing demand.

In the developed countries (figure 4.4a), the structural shift toward services is more pronounced than in the developing countries. Productivity-driven dynamics are the main driver, with demand and international factors accounting for less than one-third of the productivity effect. In developing countries and CEEC (figure 4.4b and 4.4c), demand-related factors tend to be negligible, with productivity and international effects almost completely cancelling each other out. The dynamics of international trade and supplier linkages have the most different impact on structural change in individual countries.

Domestic drivers of structural change - supply or demand driven?

The two main groups of theories of structural change in a closed economy derive it from either the supply or the demand side. To confront these theories with empirical data, we first

Figure 4.6: Global international structural change drivers - manufacturing to services



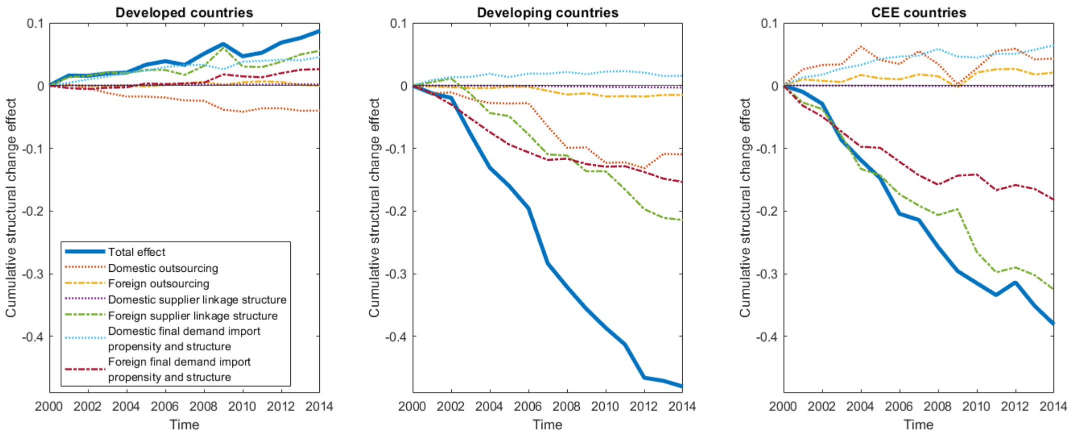
examine the effects of demand- and supply-driven factors while controlling for the effects of the real dynamics of international trade and linkages. Our empirical investigation shows that supply-side factors are the most important domestic determinant of the shift of jobs from manufacturing to services during the period under study. Demand factors driven by non-homothetic demand preferences have a negligible impact on structural change.

In figures 4.5a and 4.5b, we see that supply-related factors and total domestic structural change exhibit a robust linear relationship at both the annual effects level ($R^2 = 0.62$) and at the cumulative level of the entire 2000-2014 period ($R^2 = 0.68$). Conversely, figures 4.5c and 4.5d show that there is very little empirical evidence to support the claim that a non-homothetic preference structure is a relevant driver of structural shifts from manufacturing to services. A linear relationship explains only a very small part of the variability in the data, with $R^2 = 0.068$ at the annual effects level and an even smaller $R^2 = 0.0035$ at the cumulative effects level, and is furthermore not statistically significant. Regression results can be found in the Appendix E (table E.1).

International trade and supplier linkage structure effects on structural change

The international determinants of structural change contribute more to relative employment in manufacturing than in services worldwide (figure 4.6). There are three main factors for this. The rising import propensity of foreign final demand increases the export potential of final goods. Changes in domestic outsourcing reinforce the economies of scale of production fragmentation and domestic value chain development (Hirschman, 1958). Finally, the restructuring of foreign supplier linkages creates the opportunity to increase export of intermediate products. All three factors associated with the expansion of global value chains and

Figure 4.7: Cumulative international structural change drivers - manufacturing to services



(a) Developed **(b)** Developing **(c)** CEEC

an increase in world trade create more jobs in manufacturing than in services. A slightly offsetting element is the increasing propensity of domestic final demand to import, which creates a slight effect in favour of service sector employment by substituting imports for manufacturing jobs.

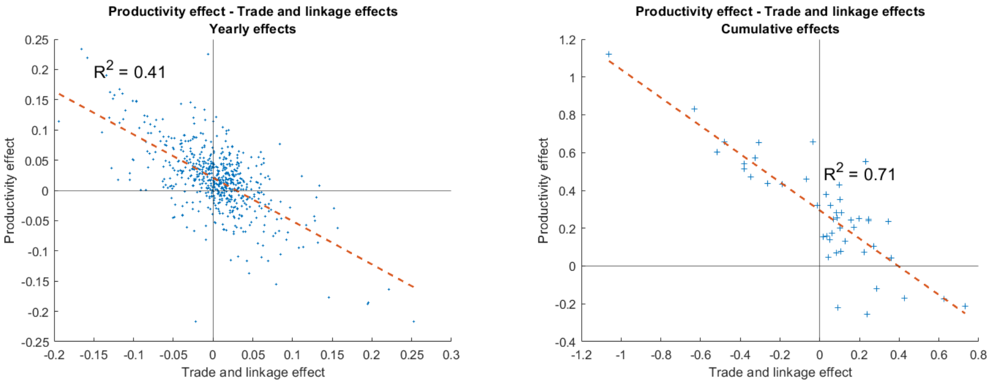
International job displacement and trade do not have a zero-sum effect on the dynamics of global structural change. While the dynamics of international trade and supplier linkages have a slight structural change effect in favour of services employment in developed countries (figure 4.7a), they have a much stronger effect in favour of manufacturing employment in developing countries and CEEC (figure 4.7b and 4.7c).[6] The simplest explanation is that international trade and value chain development still primarily affect manufacturing, as opposed to services, and that there are real economies of scale in global and domestic fragmentation and the international division of labour, creating more manufacturing jobs.

There is a correlation between supply-side and international determinants of structural change (figure 4.8). We can observe a highly significant negative correlation between the supply-side and the international determinants of structural change. In figures 4.8a and 4.8b, we present a relationship between domestic and international effects at the annual and cumulative levels, with linear regression results reported in table E.2 in Appendix E. Both estimates are significant and negatively related, with $R^2 = 0.41$ for annual effects and $R^2 = 0.71$ for cumulative effects.

Rapid and uneven productivity growth in manufacturing in an internationally integrated

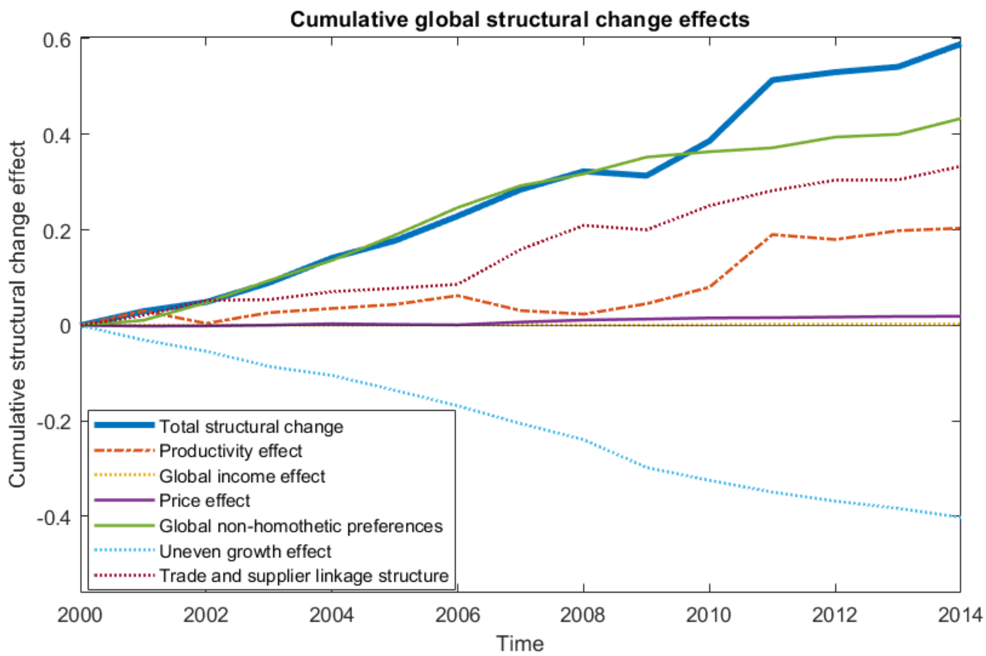
[6]The different effects of domestic outsourcing between developing countries and CEEC also reveal two different patterns of internationalisation. On the one hand, domestic outsourcing contributes more to manufacturing employment in developing countries, indicating development of domestic supplier linkages and economies of scale. On the other hand, due to their proximity to developed markets, CEE countries rely heavily on imports of intermediate goods, which limits the prospects for developing domestic value chains

Figure 4.8: International structural change effects - domestic structural change effects



(a) Yearly effects **(b)** Cumulative effects

Figure 4.9: Global cumulative structural change drivers - transition from agriculture

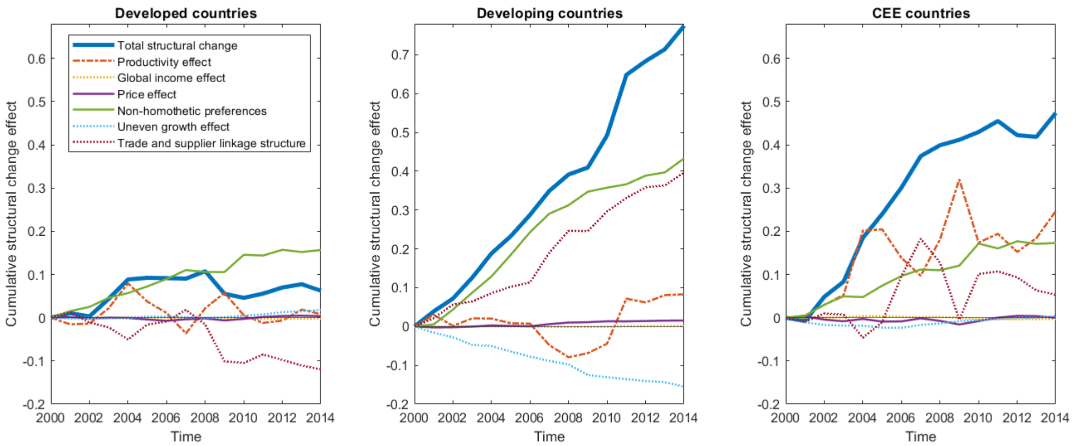


country does not necessarily lead to a structural shift of employment to services, as would be the case under the constraint of a closed economy. Instead, disproportionately rapid productivity growth can hurt international competitiveness in both final and intermediate markets. *Vice versa*, successful integration into international markets and value chains offers opportunities for faster productivity growth.

4.4.2 Relocation from agriculture to non-agriculture

In figure 4.9 we present the cumulative structural change in agricultural employment and its main determinants at the global level. The determinants differ substantially from the determinants of the shift from manufacturing to services. Of the three broad groups of determinants, the non-homothetic preference structure that pushes domestic demand away

Figure 4.10: Cumulative structural change drivers - transition from agriculture

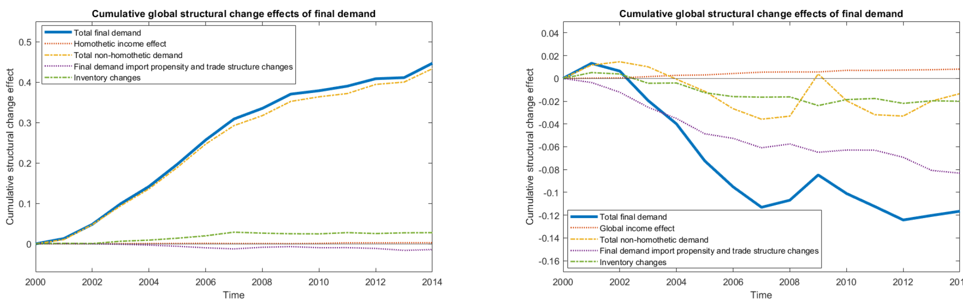


(a) Developed **(b)** Developing **(c)** CEEC

from consumption of agricultural output is by far the most important, while the productivity effect is less than half as important. International trade allows an even faster shift away from agriculture with increasing food imports, characteristic of developing countries and CEEC. Supply-side effects play only a marginal role in this case. The uneven homothetic growth effect is biased in favor of agricultural employment, as income grows faster in less developed regions that account for a larger share of agricultural consumption. In developing countries and CEEC (figure 4.10b and 4.10c), the structural transition from agriculture is more pronounced than in developed countries (figure 4.10a).

Compared to structural change from manufacturing to services, transition from agriculture is driven by the final demand, of which non-homothetic preferences of households play the most important role (figure 4.11).

Figure 4.11: Final demand effects of structural change



(a) Agriculture to Non-agriculture **(b)** Manufacturing to Services

4.5 Discussion

The theoretical implications of our empirical investigation are considerable. The first important result is the confirmation of the primacy of supply-side dynamics of structural change (Acemoglu & Guerrieri, 2008; Alvarez-Cuadrado et al., 2017, 2018; Ngai & Pissarides, 2007) from manufacturing to services in the period under study, which contradicts the claims and empirical analyses conducted for the previous periods, mainly 1960-1990 (Appelbaum & Schettkat, 1999; Raa & Schettkat, 2001; Savona & Lorentz, 2005). The differences in empirical results may be partly due to the fact that the earlier analyses did not account for the real demand dynamics, did not consider trade and value chain dynamics, and did not analyse employment dynamics, but only output dynamics. In the period we studied, above-average productivity growth in manufacturing leads to a shift of employment to the service sectors, which tend to be less dynamic. The results thus refute theoretical attempts to explain modern structural change primarily in terms of demand-driven factors (Echevarria, 1997; Foellmi & Zweimüller, 2006, 2008; Kongsamut et al., 2001; Laitner, 2000; Pasinetti, 1983, 1993), at least in the period we studied.

The Engel curve concept was originally developed and used to explain non-homothetic demand preference for agricultural output. Our analysis of structural change from agriculture to nonagriculture confirms the hypothesis that non-homothetic preferences for agricultural goods exist and are one of the most important drivers of the structural shift of jobs away from agriculture. Thus, the structural shifts from agriculture to nonagriculture and from manufacturing to services are completely different processes, and we cannot generalise the functional logic from one to the other. Therefore, generalising the Engel curve to the relationships between modern sectors is highly questionable according to our results. The empirical results do not support the hypothesis of a "demand hierarchy" between manufacturing and services, according to which households would increasingly redirect their demand to services as their income rises. At the global level, we could not even detect a non-homothetic shift toward services, as global demand, especially foreign demand, increases faster in real terms in manufacturing than in services. Even if the non-homothetic effect is present in the industrialised countries, it is an order of magnitude less important than the supply-driven dynamics.

The second important result is the limited substitutability between the value added of the different sectors. This is consistent with the approach of Buera and Kaboski (2009), whose model results are conditioned by very low elasticities of substitution between goods. While they find low substitutability implausible, we find that it is a persistent feature of final demand dynamics. Since the object of structural change analysis is always a fairly large group of goods or even tasks aggregated at the sectoral level or even at a larger cumulative sectoral level (agriculture, manufacturing, and services), price substitutability between the value added of these large groups of sectors could plausibly be very low, since the consumption of each product or service necessarily involves a broad distribution of tasks produced by different sectors. A necessary diversity in consumption then leads, by the law of large numbers, to a fairly stable distribution of consumption of the various sectoral value added. Therefore, the price elasticities between different products and services do not significantly affect the price elasticities between the value added of different sectors, since they do not overlap. The sectoral distribution of demand between sectors is thus close to the Leontief function, since it is governed by a very low elasticity of substitution (our estimate $\epsilon = -0.18$). Consequently, price dynamics play an insignificant role in structural change.

The third major result lies in the exploration of the significant impact of the real value chain dynamics and international trade on structural change. Supply- and demand-driven theories of structural change have mostly focused on dynamics within a closed economy. However, the international economy brings new heterogeneous dynamics due to uneven development, uneven growth, uneven technological distribution, uneven sectoral composition, and uneven wage levels. Even completely homothetic income growth, which is uneven across countries, leads to a structural change effect because of the different sectoral compositions of demand in differently developed countries. Even more important are the effects of the increasing international division of labour due to global value chains and the expansion of trade in final goods. The increasing international division of labour is not a zero-sum game, as can be seen in its effects on structural change. On the one hand, there are economies of scale of global fragmentation and division of labour, which create more jobs in manufacturing than in services worldwide. On the other hand, the international division of labour is driven in part by differences in wage levels. As new workers from developing countries with lower wages enter the global labour market, they are often employed in more labour-intensive manufacturing tasks, counteracting technology- and productivity-driven structural change in industrialised countries. Thus, classical international specialisation significantly alters the effects of structural change, which conceptually and theoretically have mostly been studied within a closed economy. This confirms the theoretical position of authors who emphasise the international dimension of the dynamics of structural change (Mao & Yao, 2012; Matsuyama, 2009; Pasinetti, 1983, 1993; Uy et al., 2013).

4.6 Conclusion

In this chapter, we address the question of the drivers of the long-term structural shift of jobs between agriculture, manufacturing, and services. We conduct 43 separate multiregional structural input-output decompositions to disaggregate the country-specific determinants of structural change. Our analysis provides new evidence that the shift of jobs from manufacturing to services is primarily due to supply-side effects, while the impact of non-homothetic preferences on this shift turns out to be insignificant. In contrast, the transition from agricultural employment is primarily driven by demand-side effects. In addition, international trade and value chain dynamics have a significant impact and tend to favour a shift of jobs to manufacturing at the global level. However, these effects are very heterogeneous and exhibit country-specific differences. The main conclusion is that studying structural change in closed economies may lead to wrong conclusions. Therefore, it is crucial to incorporate international open economy models to fully capture the relevant drivers of structural change. Fragmentation of global production not only leads to neutral job displacement, but also directly affects the dynamics of global structural change through economies of scale and the incorporation of cheaper labour power.

More generally, these results could not only provide evidence for more empirically grounded theories and modelling frameworks, but also contribute to our understanding of real economic dynamics and their drivers, and improve our ability to better respond to economic shocks and disruptive technological changes, as well as to better assess the impact of economic policies.

In summary, the results highlight the importance of analysing supply-side structure associated with uneven development. This is particularly crucial for industrialized countries that have already overcome the development trap of agricultural subsistence, as supply-driven dynamics appear to be more relevant to dynamics within industrialized regions that have already transitioned away from agricultural employment and are experiencing fundamental structural change dynamics in terms of manufacturing and service sector.

Supply-side dynamics are not limited to the intersectoral dynamics empirically demonstrated in this chapter, but also include intra-firm occupational level dynamics and task-related changes hidden behind the more aggregate sectoral data. Granular supply-side dynamics might therefore be relevant not only for dynamics within homogeneous closed economies, but especially in the context of economic integration of unevenly developed countries.

Chapter 5

Marxian Approach to Uneven Development and the International Law of Value

5.1 Introduction

In this chapter we explore the second object of our study - the endogenous mechanism of uneven functional specialization - within a Marxian framework. The main objectives of this chapter are two. First, we aim to provide a Marxian theoretical reasoning for the uneven international relative factor costs that are hypothesised to drive both endogenous supply-side mechanisms under study. Second, we aim to expand Amin's descriptive distinction between light and heavy techniques and reframe it more concisely within an analytical Marxian framework. Both goals provide theoretical and conceptual justification for some of the modifications of model assumptions used in the next chapter.

The first goal is linked with a theoretical concept of international value. While mainstream economics has abandoned the distinction between price and value (by abandoning the concept of value), this distinction remains a fundamental feature of all Marxian economics, not only because the value reveals the social relations and processes that lie behind the facade of the phenomenal forms of prices, profits, and wages, but also because value dynamics, unlike price dynamics, can offer a theoretical explanation for certain dynamic processes characteristic of the capitalist mode of production, especially those processes that have a functional logic based on the intertwining of the aggregate social dimension and the concrete individual functioning within the production process.

The main feature of the law of value in contrast to the Ricardian labour theory of value is its social character, captured by the conceptualization of the *socially* necessary labour time. This social character not only captures the essence of the competitive process at the microeconomic level, the dynamic process of technological improvement and creative destruction, and in this sense represents one of the first endogenous conceptualizations of economic growth under capitalism, but also captures the social character of the production process, the division of labour, and ultimately the distribution of the social product between classes.

The concept of value, then, can be an essential starting point for any conceptualization of the mechanisms that sustain unequal development at two levels. First, it can reveal the social relations that lie behind international exchange. Second, it has the potential to capture the dynamics of international economic interaction. International trade and the international division of labour are conditioned by the general social processes that operate at both the national and global levels, while operating at the concrete level of the individual that simultaneously drives and advances the social, national, and international levels of dynamics.

In the existing Marxian literature, there are two major traditions dealing with the law of value in an international framework. The first assumes that value is still nationally determined and infers transfers of concrete labour between differently developed countries (Amin, 1974; Emmanuel, 1972). The second assumes that value is internationally determined and that there are worldwide differences in the concrete international value produced per unit of labour by differently developed countries. This is due to the operation of the international law of value and international competition with countries that have different technological and technical conditions and different labour intensities (Dashkovskij, 1927a, 1927b; Matsui, 1970).

In this chapter we follow the ideas of the second tradition, for the reduction of analysis to concrete labour and concrete transfers of value undertaken by the various versions of the theory of unequal exchange not only mystifies the relationship between differently developed regions, but also abandons the elements of the theory of value (its social form and its social determination) that embody its potential to capture the dynamic operating mechanisms of capitalist competition.

However, the attempt to transfer the unmodified theory of value directly into the global framework also requires conceptual changes. The main problem arises in cases where the international division of labour is uneven and takes the form of almost complete specialisation of particular sectors, goods, or tasks. In these cases, the simple application of the unmodified value theory leads to misleading results and does not adequately capture the actual dynamic process in the international economy.

For this reason, we introduce a generalized law of value that contributes to the understanding of the functioning of international competition, the international division of labour, and uneven development. The core idea is to combine the logic of social determination of wages at the national level that correspond not to the specific productivity in the sector or task, but to the national level of relative productivity within the entire tradable sector. Coupled with the equalization of world price levels of international goods, this leads to a specific functioning of the international law of value based on socially necessary labour time weighted by aggregate national productivities in the tradable sector. Such a concept allows us to capture the dynamic functioning of international competition, where the rate of exploitation is constant in differentially developed countries and the generalized theory of worldwide value endogenously drives not only technological progress but also the international division of labour which is sector- and task-specific when sectors and tasks have unequal potential for productivity increases and technological improvements. The main results of endogenous international specialization driven by generalized worldwide theory are that sectors and tasks that have lower potential for productivity improvements and growth tend to be produced in less developed regions and, conversely, sectors and tasks with high potential for productivity improvements are mainly produced in developed regions. Moreover, the benefits of international trade are very unevenly distributed.

To derive a generalised law of worldwide value, we must also conceptualise the determination of the value of labour power in differently developed countries and address the issue of technology as an independent determinant of the development of productive forces and productivity, which, together with the skill of the labour force skill and organic composition, allows for a theoretical examination of the choice of technique in the context of unequal development.

The chapter is organised as follows. In section 5.2, we give a brief overview of the related discussions, research, and theoretical issues. In section 5.3, we present the generalised law of worldwide value. First, we discuss the determinants of international nominal wage determination, both from the perspective of concrete use values, which are the geographically and historically specific minimum required for the reproduction of labour power, and from the perspective of the formation of international nominal wage differences based on this set of use values. The main idea is based on the logic that country-specific productivity differences in the production of globally tradable goods are the primary determinants of international nominal wage differences. Second, we generalise Marx's law of value in a way that explains both national and international commodity prices, wage levels, and trade. The most important conceptual change in Marx's law of value lies in the definition of value by the socially necessary labour time required for production, as opposed to the concrete labour time of the Ricardian labour theory of value. The essence of the capitalist social relation is the difference between the value of labour power and the value of labour, which enables the derivation of exploitation in the form of the appropriation of surplus value as the sole source of capitalist profits. Moreover, the law of value enables both static and dynamic analyses of the functioning of the capitalist competitive process.

However, if we simply apply the law of value to the international setting, its symmetric assumptions about homogeneous value-creating labour lead to problems in theoretically understanding how competition works at the international level. Our generalisation aims to retain the explanatory power of Marx's law of value that it possesses for the analysis of the closed economy and, in particular, of exploitation and the objective conditions of its reproduction, while the generalisation aims to extend the explanatory power of the law of value in the international setting. We argue that the international formation of price levels depends, on the one hand, on nationally specific productivities in the globally traded sector, on the shares of labour employed nationally in the production of globally tradable sectors, and, indirectly, on average national wage levels.

In section 5.4, we use the proposed generalised law of worldwide value to examine the static and dynamic functioning of the capitalist mode of production in the international setting. We use it to examine the determinants of one of the most important theoretical issues of the uneven development - the choice of techniques and the global division of labour and their effects on the perpetuation of uneven development.

5.2 Background

Since Marx's formulation of the law of value (Marx, 1992), there have been numerous discussions on the application of this law to the international level and to the study of uneven development. Early classical Marxist authors focused on the conceptualization of imperialism and the inherent tendency of the capitalist mode of production to expand geographically (Hilferding, 2007; Lenin, 1969; Luxemburg, 2003). The first attempt to formulate a Marxist theory of international trade was made by Grossman (1929), who believed that all the necessary elements of such a theory were already present in Marx's own work. One of the seminal contributions that followed Grossman's approach to conceptualizing value and value transfers on a global scale is Emmanuel's (1972) unequal exchange theory, which sparked extensive discussion. Emmanuel's main argument was based on the assumption that capital is mobile and creates a uniform rate of profit across countries and industries, while labour is assumed to be immobile, which is a prerequisite for country-specific wage levels. According to Emmanuel, under such conditions, there are two types of non-equivalence in the application of Marx's law of value and the transformation of values into prices: transfers of value due to the unevenly distributed organic composition of capital and transfers of value due to differences in wage levels.

The theory of unequal exchange has been strongly criticized at various levels. Andersson (1976) pointed out that the transfers of value and unequal relations between countries derived by Emmanuel do not even depend on the existence of trade but exist because of the unequal development of productive forces and differences in productivity. Bettelheim criticized Emmanuel's focus on unequal exchange at three levels. According to him, the weakness of Emmanuel's derivation lies in the focus on the sphere of circulation as opposed to production, in the assumption that wages are independent and exogenous variables, and in the uncritical application of the law of value to the world market, wrongly assuming that the law of value functions internationally in the same way as it does in a closed economy (Bettelheim, 1972). The assumption of the exogeneity of wages and their treatment as a fixed minimum necessary for worker reproduction as opposed to a historically adjusted variable is a common misinterpretation of Marx's notion of the value of labour power (Amin, 1979; Baumol, 1983; Bettelheim, 1972; Evans, 1976). Moreover, the concept of exploitation, which is used to explain the social relations between classes that result from relations of production, cannot be used to explain the relations between countries and nations that extend beyond the distribution between classes. Even if there are relations of exploitation between classes of different countries, the exploitation is conceptually necessarily derived from the relations of production and not from the relations of exchange. In this sense, the transfer of surplus value between the working classes of differently developed countries cannot be understood as exploitation because the workers are not in a direct production relationship with each other.

The second tradition of application of the law of value on the international setting is presented by the work of Dashkovskij (1927a, 1927b). He claims that the international law of value is determined by the socially necessary labour time and that relative productivities determined by various factors (relative intensities of labour, differences in skill composition and technology) can lead to different concrete national labour amounts to yield different international values. Similar arguments were put forward by Matsui (1970). According to such conceptualizations, the individual transfers of concrete labour are inherent part of the functioning of the capitalist competition, as shown by Houston and Paus (1987). Both nationally and internationally, competition leads to unequal transfers of concrete labour, which means that the object of the study of unequal exchange theories only reflects the functioning of the competitive system.

In this context, difference between concrete labour used in production and abstract socially necessary labour reqired for production is fundamental, as extensively discussed by Rubin (2019). Marx's theory defines value as abstract, socially necessary labour-time required to produce a commodity, thus giving it a primarily social dimension. Therefore, of the two concepts - concrete and socially necessary labour time - the latter is primary for social and economic analysis. Any research of individual concrete labour time expended in production and transfers of such "labour time content" is misleading, since they are inherent in the dynamic functioning of competition at many different levels and, unlike the social values that indirectly determine exchange and social relations between classes, have no corresponding manifestations.

Nevertheless, the possibility of a direct application of the law of value to the international framework remains controversial. While the law of value governs prices and exchange within a closed economy, it cannot be simply be applied in to the international setting because it does not govern prices and exchange between countries (Baran & Sweezy, 1966; Shaikh, 1980; 1979; Sweezy, 1942). De Janvry and F. Kramer (1979) claimed that the transfer of surplus value from the periphery to the center cannot occur if the goods traded are not country- specific. They raised the question of how the law of value functions when certain countries are the only producers of internationally traded goods. Mandel (1999) has tried to find a solution to this problem by defining value as the global socially necessary time that would hypothetically be required to produce the good worldwide, even though it is produced in only one country. Such a solution, however, is inconsistent and indeterminate on many levels. In such a case, the question of international formation of prices and exchange remains unanswered within the framework of the law of value.

Bryan (1995) argued that cross-national differences in the productivities and intensities of labour are a fundamental aspect of international value formation. Marx (1992) pointed out that different productivities and different intensities of labour create different international values that are not equal to the socially average working time because of the unequal distribution of the technology and skills, despite the same labour time requirements:

But the law of value is yet more modified in its international application by the fact that, on the world market, national labour which is more productive also counts as more intensive, as long as the more productive nation is not compelled by competition to lower the selling price of its commodities to the level of their value. In proportion as capitalist production is developed in a country, so, in the same proportion, do the national intensity and productivity of labour there rise above the international level. The different quantities of commodities of the same kind, produced in different countries in the same working time, have, therefore, unequal international values, which are expressed in different prices, i.e. in sums of money varying according to international values. (Marx, 1992, 630)

This represents a starting point for the generalisation of the law of value on the worldwide level.

5.3 Generalized Law of Value

The purpose of the law of value is neither to explain the formation of individual prices nor to examine in detail the phenomenal forms that determine the mechanisms and the functioning of the economy. The main purpose of the law of value is to uncover the social relations hidden behind the phenomenal forms. Our aim, to generalize the law of value and give it an international dimension, follows the same purpose. Our primary aim is not to construct an approximation of the international price formation process (although it is a necessary side result) but to uncover the social relations of production in the international capitalist mode of production. The international relations of production do not only comprise of the production relations between classes within and between countries but also shape the uneven global division of labour, and the uneven potential for economic growth and prosperity.

Our attempt to conceptualize the law of worldwide value follows three main principles: (1) the worldwide value must provide a good and reasonable approximation of international prices; (2) the generalized law of value, when applied to the homogeneous and closed capitalist mode of production, must reproduce the dynamic and theoretical discoveries of the unmodified law of value; and (3) its dynamic functioning must reflect the objective processes of capitalist competition. The main questions are the following: Why cannot Marx's law of value in its unmodified form be used to represent the dynamic functioning of capitalist competition in the global framework? Which assumptions that are fundamental to the functioning of the law of value at the national level change in the setting of internationally connected capitalist countries with different levels of development?

The main goal of the production process in the capitalist mode of production is the extraction of surplus value and the accumulation of capital. The self-expansion of capital is a concrete manifestation of exploitation, the result of the functioning of capitalist relations of production. The circuit of capital, analysed in detail by Marx (1993a), presents the reproduction of capital as a social relation that includes the reproduction of labour power, the capitalist class, and the accumulation of capital (Palloix, 1977). The reproduction of the capitalist mode of production depends essentially on the reproduction of the conditions of its functioning, which include the distribution aspect: the freedom and separation of the working class from the ownership of the means of production and their centralization in the hands of the capitalist class (Balibar, 2016). In the international setting, the reproduction of the capitalist mode of production is no longer homogeneous with respect to either the preconditions or the resulting social relations and international exchange. The main difference is the persistent heterogeneity both in the average national productivity and in the average wage levels. Differences in wage levels do not exogenously determine distributional relations post festum, as Shaikh claimed (1980: 39–40), but directly affect the formation of the international price level. Since local conditions for the reproduction of local labour power lead to large differences in the use values required to reproduce labour power in different countries, the internationalization of the capitalist mode of production directly alters the link between the globally socially necessary labour time required for production and the international prices.

The link between prices and values in the homogeneous closed economy is based on hidden assumptions about a homogeneous value of labour power (distributed only along the skill dimension) and either uniform rates of profit or uniform rates of exploitation. Under these assumptions, the structural functioning of the agents of both classes creates a link between values and prices. On the one hand, a higher-than-average rate of profit in a given sector leads to more investment flowing into that sector and vice versa so that the profit rates converge in the long run. On the other hand, higher wages (for a given skill structure) in a given sector lead to an increased supply of labour in that sector, which in turn leads to the initial assumption of a homogeneous value of labour for a given skill structure. All this links the socially necessary labour time — value — with social costs expressed on the phenomenal level as direct and indirect expenditures for labour power, which, together with the profit, forms the prices.

However, because of the segmentation of the capitalist world economy into national economies, where labour mobility is severely limited and capital mobility is at least partially limited, these dynamic processes do not exist on a global scale. When a capitalist firm in a less developed country produces an internationally traded commodity with a less productive technology than the average technology, there is no bankruptcy pressure as in a homogeneous environment because lower wages compensate for lower productivity and still allow for average or above-average profits. When a capitalist firm in an underdeveloped country produces an internationally traded commodity with productivity similar to the world average, additional profits are generated (due to lower wages) and the prices of the good are driven down in the long run, making capitalist firms in developed countries less competitive and causing them to increase their productivity further, relocate abroad, or go bankrupt.

If two countries at different levels of development specialize in the production of two different goods, the international price relationship between the two commodities is affected by the relative aggregate productivities, not just by the socially necessary labour time required to produce each commodity. The reason is that the local economic competition process produces a tendency to make the value of labour power uniform within a country (given a certain qualification), while the global competition creates the tendency to adopt a global uniform rate of surplus value or profit, depending on the level of analysis. Massive differences in the global socially necessary labour time required to reproduce the local labour power thus directly affect (in the long run) the global international prices in addition to the main determinant of the socially necessary labour required to produce the concrete commodity. These differences must be understood as long-term country-wide differences in the aggregate productivity, which is phenomenally observed as wage differentials at a given rate of surplus value. The unchanged law of value is thus unable to explain the dynamic functioning of the segmented international capitalist mode of production.

While the vast majority of discussions of the functioning of the worldwide law of value focus on the transformation of values and prices of production, assumptions about uniform rates of profit, and perfect or imperfect mobility of capital, the adjustment of the law of value that we propose is at a more fundamental level and is independent of the transformation issue. A concept has only as much meaning in economic analysis as it reveals the underlying social processes and social dynamics of economic competition. Unchanged values transferred between countries and firms without regard to their phenomenal counterparts explain very little about the formation of international prices, international competition, and, more importantly, the global division of labour. Our modification of the law of value follows the principle that the generation of value in each local production process contributes on average to the generation of surplus value and that the modified law of value explains the average international price relations in the long run. To accomplish this, the concept of the worldwide value must be modified before any discussion of different organic compositions of capital and the transformation of value into prices.

5.3.1 International Wage Determination

The value of labour power, as a manifestation of the country-wide productivity differences, is an essential factor of price formation. This is because, in the world of manifestations, wages represent a large part of the costs that affect prices. Even if we do not argue for a cost approach to prices — characteristic of classical political economy — we cannot escape the fact that values and prices converge in a capitalist economy primarily because labour costs are assumed to be homogeneous. The phenomenal form is the primary determining force that shapes the functioning of competition, while the value form represents the broad underlying social processes of the division of labour, in this case the global division of labour. In the international setting, the process that affects price ratios is no longer just related to labour time since the country-specific wages also affect the long-term international price formation, given the distribution of concrete rates of exploitation and organic compositions. For this reason, we begin our approach with the international determination of wages.

The value of labour power is determined by the time required to produce a historically and culturally specific minimum necessary for the reproduction of labour power. This minimum must be treated as a variable that assigns, to each historically and geographically specific society, a concrete set of use values deemed to be socially necessary for its reproduction and assigned to the working class in the form of wages.

What determines this set of use values? While there are many factors with complex effects, the most important determinants are:
1.) The level of development of productive forces and productivity of labour;
2.) The intensity of the class struggle and its political achievements, which determine the

rate of exploitation;
3.) The proportion of use values required for reproduction that are obtained in commodity form as opposed to communally or domestically produced use values.

First, the level of development of productive forces includes changes in the composition of the labour force, the capital intensity, and the use of technology. The most important consequence of the overall development of the productive forces is the increase in labour productivity. The development of productive forces and labour productivity sets the upper limit of use values that can be assigned to the working class as a whole, and the productive forces of a country as a whole, as opposed to specific sectoral productive forces, determine the value of the local labour power (Starosta & Fitzsimons 2018).
Second, the objective situation in the labour power market (the size of the reserve army of labour and the demand for labour) and the objective limit of the productivity of labour constitute the framework in which the class struggle, in a more or less institutionalized framework, influences the dynamic changes in the rate of exploitation. The class struggle directly affects, at least in the short run, the use values required for the reproduction of labour power through direct negotiations on the level of wages, taxation, indirect labour rights, and institutionalized frameworks that are politically determined, such as administratively determined spillover effects of productivity increases into wage increases and the size of social reproduction funds.

Third, the use values required for the reproduction of labour power include not only short-term direct consumption needs, which include both tangible and intangible services, but also indirect consumption needs, which serve to reproduce the non-productive parts of the generation: children, students, and the elderly as well as the unemployed and the disabled. Whether the use values required for this indirect reproduction are produced as commodities (goods purchased for the direct consumption of the unproductive parts of society) or as public services financed by taxes or unpaid domestic or communal labour affects the quantity of use values obtained through wages. Only the portion of use values required for the reproduction of labour power, monetized in the form of either goods or public services, is formally included in the wage, first as part of the nominal family wage and second usually as part of the gross wage. In underdeveloped countries, often even a substantial part of material reproduction takes place in communal, domestic, or other non-capitalist production relations and is not mediated by the monetary wage. This has a strong impact on the quantity of use values obtained through the monetary wage.

The transformation of the historically determined set of use values required for the reproduction of labour power into money wages that are comparable between differently developed countries is not trivial. This is mainly due to the different proportions of use values that can be traded on either the local or the global market. Above all, the general level of development of productive forces on a global scale, as well as transportation costs, economic and extra-economic barriers to international trade, and the organization of public services, determine whether a given use value is traded globally or only locally. While most manufactured goods are traded globally, many services, public goods, and some material goods (e.g., simple building materials) are produced and consumed predominantly locally and cannot be profitably traded globally. The difference is that goods that are predominantly locally produced and traded have locally determined prices that vary from country to country, whereas goods in the global market have a single global market price. When all prices and wages are expressed in a single currency, local goods and services in underdeveloped countries are cheaper than local goods and services in developed countries because of lower wages. A globally comparable price level exists only for globally traded goods.

Thus, a global nominal wage ratio between differently developed countries reflects not only the sheer difference between the magnitude of the historical quantity of use values required to reproduce the labour power but also the fact that there is always a share of consumption that is not traded globally, the costs of which are locally specific — lower in underdeveloped countries and higher in developed countries (Balassa, 1964; Samuelson, 1964). This effect exacerbates the initial differences in the historically and geographically specific sets of use values required to reproduce the labour power and makes the nominal wage differentials even larger than the differentials in the consumption sets of use values.

What specifically determines the nominal wage in the international environment? It is still the value of labour power — the time required to produce what we have called the set of historically determined use values. While this is again a central Marxist proposition in the case of a homogeneous environment, it becomes more complex in the global environment of differently developed countries. Only the globally traded commodities serve as an anchor for the global price system, and the international nominal wage relations are consequently tied to the aggregate relative productivity in the globally traded part of economy.[1] Thus, international nominal wage relations are determined by the time required to produce the historical and country-specific quantity of use values comprising the historical minimum for reproduction that are traded globally. However, it is not the locally specific time required to produce this set of use values but the global socially necessary time required to produce them that explains international nominal wage relations and their high dispersion. It does not matter whether the goods in question are actually produced for export or for local consumption as long as they belong to a set of use values that can be traded globally. Nor does it matter with what level of productivity they were concretely produced. The globally

[1] Amin (1974, 1979) and Kollmeyer (2009) claimed that productivity differences cannot account for wage differentials. The mistake is comparing the productivity of concrete sectors as opposed to identifying productivity differences in the aggregate tradable sector. While the internationalized part of the economy, especially multinationals, seek the lowest wages providing the most modern techniques, large shares of economies with differences in real productivity that surpass the nominal wage differences between differently developed countries nevertheless exist.

socially necessary labour time required to produce the globally traded portion of the historically and country-specific wage basket primarily captures the productivity differences in the global traded sectors that determine the international nominal wage relations.

An extreme example is that of colonial primitive accumulation: proletarianization in underdeveloped countries coincided only with the gradual dissolution of communal and other pre-capitalist social relations, and capitalist wage labour coexisted with communal semi-subsistence agriculture, which still provided wage workers with a large part of the use values necessary for their reproduction (Meillassoux, 1981). Since the wage covers only a minimum of use values, this explains nominal wages, which are close to zero under these conditions. Since much reproduction is communally organized, the small amount of goods (food and clothing) generated by the money wage corresponds to a relatively small amount of global socially necessary time required for their production, even though local alternatives leading to similar levels of consumption require large amounts of concrete social labour time. On the other hand, the comparatively large quantity of use values that constitute reproduction in most industrialized countries, which includes access to a wide range of industrially produced goods, including indirect access to public services and commodities in the unproductive parts of the life cycle through child benefits, pension systems, and other social transfers that are part of the nominal gross wage, corresponds to their relatively higher wages. The international nominal wage ratio is thus indirectly determined by the productivity differences in the sectors producing globally tradable commodities.

5.3.2 Productivity Determination

Within the historical materialist paradigm, the central assumption regarding technical progress lies in the concept of the organic composition of capital. The organic composition of capital supposedly represents the unity between the value composition and the technical composition of capital (Marx 1992). This has led many authors to equate the value composition of capital with productivity and the overall development of the productive forces. In reality, however, there is no unity between the value composition of capital and its technical characteristics. The vast majority of productivity differences across countries are not reflected in the value composition of capital but are due to differences in the use of technology, organization, and skill composition. These do not necessarily have a unilateral impact on the value composition of capital. Therefore, labour productivity cannot be explained by changes in the organic composition of capital alone, especially because productivity gains in both machine production and consumer goods production occur simultaneously and productivity in output per worker can grow independently of changes in the value composition of capital. What contributes even more to the lack of a direct relationship between the value composition of capital and productivity are the long-term structural change—employment declines in sectors in which the productivity improvements are the greatest, while employment in new sectors with more stagnant productivity and lower organic composition of capital increases (Acemoglu & Guerrieri, 2008; Alvarez-Cuadrado et al., 2018; Baumol, 1967). Thus, even if there is a relationship between the increasing value composition of capital associated with technological improvements and machines replacing labour in certain sectors, such changes lead to the growth of sectors with lower value composition of capital. This leads to an indeterminate relationship between the value composition of aggregate capital and productivity at the country level.

Since the organic composition of capital and labour productivity do not have a trivial relationship, we deliberately omit the role of the organic composition of capital and the transformation of values into prices of production from our analysis. Our analysis of the functioning of the generalized law of worldwide value is thus carried out at the level of the abstraction of values and normal prices described by Marx in the first book of Capital, as opposed to the level of the abstraction of prices of production examined in the third book of Capital. There are four arguments for why the assumption of uniform rates of surplus value, as opposed to the assumption of uniform rates of profit, is sufficient for our analysis.

First, the probabilistic formulation of the law of value, which treats the main concepts as random variables and distributions, succeeds in reproducing all the main results of the central historical materialist theory with less stringent assumptions (Machover & Farjoun 1983). Values and prices are statistically related and profit rates have a tendency to converge toward steady-state distribution of profits as opposed to a single uniform profit rate. For a given distribution of the organic composition of capital and wages, the theory still reproduces the central functioning of capitalist competition and the development of the productive forces, and it infers exploitation as the source of all profits and thus of capital accumulation. Organic composition in this sense only artificially adds complexity since the most important social relations and proportions function at the level of the rate of surplus value — the aggregate class relations within both production and distribution are determined by the rate of surplus value, not by organic composition.

Second, profits, as currently measured by most firms, compare surplus value not with the total invested capital but with the total annual expenditures, which include only annual depreciation of fixed assets. Thus, even in the phenomenal form, capitalists maximize not the classical rate of profit (which is difficult to measure and observe) but a modified rate of profit in which investment in fixed capital plays a much smaller role and differences in the value composition of capital are greatly attenuated due to the prevalence of circulating costs in the calculation. Finger (2020) falsely claimed that the social rate of exploitation, unlike the rate of profit, is unobservable to capitalists. On the one hand, the uniform rate of profit is equally unobservable as the social rate of exploitation because it exists only as a uniform distribution of profit rates (Machover & Farjoun, 1983). On the other hand, individual surplus value and individual rates of surplus value (profits over wages) are equally observable to capitalists, as are individual (modified) profit rates. Thus, the structural behaviour of capitalists can be guided by any of these forms, from maximizing the phenomenal rate of surplus value (profits over wage expenses) or the absolute profits to the profit rate measured as profits over annual expenditures.

Third, the increasing importance of value chains (global division of labour and trade in intermediate goods) and their lengthening directly affect the classical rates of profit as the circulating capital increases and the same intermediate value added enters multiple production processes. The classical profit rate can change as a result of legal and formal accounting changes without any real economic changes. The same production process, organized either within one firm or within several cooperating firms under completely identical social and economic conditions, leads to lower classical profit rates in the latter case due to the multiple inclusion of intermediate value added in the case of value chain fragmentation. As a result, classical profit maximization becomes less important for capitalists when value chains' fragmentation is substantial, and analysis based on the uniform profit rate becomes less relevant. In these cases, extracting the maximum possible surplus value from each of the integrated parts of the production process while maintaining the lowest possible prices is a more fundamental tendency.

All these processes are associated with competitive tendencies that lead to a uniform rate of surplus value rather than a uniform classical rate of profit. Despite our assumption that the rate of exploitation is uniform in equilibrium, we do not claim that there are no exogenous country-specific factors and the evolution of the class struggle that can potentially lead to different rates of exploitation. Similarly, we do not assume that cross-country differences in the organic composition of capital do not matter. Analysis of the effects of organic composition is widespread in the field, and its results can easily be superimposed onto our central generalization of value theory without losing generality in our approach.

5.3.3 International Price Determination

Based on our discussion of the role of the value of labour power in the formation of international prices, we make the following modification to generalise the law of value. If we assume that exploitation rates are similar around the world in the long run, international differences in nominal wages arise primarily from average productivity differences in sectors of globally tradable goods. Thus, productivity differences in the sectors of globally tradable goods are fundamental determinants of worldwide value, which affect international prices in the phenomenal form through the wage level. $V(A)$ is the international value of commodity A, $P(i)$ is the productivity of the globally tradable part of country i's economy, and $Q(A(i))$ is the quantity of A produced in country i, while t(i) is the labour time spent in producing $A(i)$.

$$V(A) = \sum_{i=1}^{n} \left(\frac{nP(i)}{\sum_{i=1}^{n} P(i)} \right) t(i) \frac{1}{\sum_{i=1}^{n} Q(A(i))} \tag{5.3.1}$$

The generalized worldwide value of a commodity is the global socially necessary labour time required to produce it, modified by the country-specific labour productivity of the globally tradable part of the economy. The modified socially necessary labour time is no longer conceptualized as a simple average of each concrete individual labour time spent on production. Instead, we define the worldwide value as the weighted average of each individual labour time spent on production, weighted by the labour productivity of the globally tradable part of the economy. This formulation is consistent with our goal of providing a generalized version of the theory of value. It represents a generalized law of value because, if we apply it to the homogeneous capitalist mode of production, with no national differences in wages, it reduces to the classical law of value. All the dynamic and static results of the analysis carried out by Marx in his late works are thus preserved by this generalization, most fundamentally the difference between the value of labour power and the value of labour, while preserving the fundamental relationship between the phenomenal form of profit and the exploitation in production through the appropriation of surplus value.

Thus, our generalized formulation encompasses the entire proposition of classical Marxist theory within itself. Moreover, it not only offers an explanation of international and national price levels but also allows for both static and dynamic analyses of the international division of labour and its functioning, enabling an explanation of uneven development from the perspective of production relations as opposed to unequal exchange relations or Ricardian transfers of concrete embodied labour.

5.4 Choice of technique and uneven development

In this section, we will examine the argument frequently used by dependency theorists. Chenery (1953) and Kahn (1951) claimed that the social marginal productivity is a guide to investment, leading to the conclusion that less developed countries should specialize in less capital-intensive industries and vice versa. On the other hand, Galenson and Leibenstein (1955) argued that static optimization (of either output or profit), while equal to the rule equating marginal productivity, does not necessarily lead to long-term optimal investment choices of technique. Increasing the excess labour by investing in labour-replacing capital can create greater output growth than the use of labour-absorbing capital (Galenson & Leibenstein, 1955). Amin distinguished between light and heavy techniques, associating greater organic composition with higher productivity, and argued that the choice of technique under competitive pressure depends on the relative costs of the factors of production and may block the development of underdeveloped countries because of the limited potential for technological improvement of lighter techniques (Amin, 1974). Our approach,

Table 5.1: Proportional division of labour and international trade (Source: own work)

	Country 1	Country 2
Real productivity of globally tradable commodities	P_0	$4P_0$
Global value of labour power	$w_1 = 0,25h$	$w_2 = 1h$
Total output	$A_1 = 100\,000$ $B_1 = 100\,000$	$A_2 = 200\,000$ $B_2 = 500\,000$
Labour spent in production	$t_{1A} = 10h$ $t_{1B} = 10h$	$t_{2A} = 10h$ $t_{2B} = 10h$
International value	$V(A) = 2/30\,000$ $V(B) = 1/30\,000$	$V(A) = 2/30\,000$ $V(B) = 1/30\,000$
Absolute surplus value	$s_{1A} = 4,17h$ $s_{1B} = 0,83h$	$s_{2A} = 3,3h$ $s_{2B} = 6,67h$
Rate of surplus value	$e_{1A} = 167\%$ $e_{1B} = 33\%$	$e_{2A} = 33\%$ $e_{2B} = 66,7\%$
Consumption of A and B	$A_1 = 75\,000$ $B_1 = 150\,000$	$A_2 = 225\,000$ $B_2 = 450\,000$
Consumption of A and B per total labour hours used in production	$A_1 = 3\,750$ $B_1 = 7\,500$	$A_2 = 11\,250$ $B_2 = 22\,500$

focusing on the general productivity differentials as opposed to organic composition, sheds new light on the issue, showing that the structural functioning of international competition leads to a technological blockade of underdeveloped countries, forcing them to specialize in techniques that have lower potential for technological improvement.

Our example focuses on two countries that have a 1:4 ratio of aggregate productivity within globally traded sectors, leading to long-run differences in the value of labour power in the same ratio. We analyse the production of two commodities, A and B, that are complementary and consumed at a ratio of 1:2. The production technology of developed countries is more productive in both cases, although to different degrees. The production of commodity B is five times more efficient, while that of commodity A is only two times more efficient. We begin by examining an international economy in which both countries distribute labour equally between the production of the two commodities (table 5.1).

According to the generalized law of value, the international price of commodity B is half that of commodity A, which allows trade to achieve consumption at an assumed fixed ratio for both countries. We can see that the differences in the rates of surplus value lead to dynamic changes in both economies. On the one hand, the relative surplus value of the production of commodity A in country 1 is higher than the surplus value in the sector producing commodity B in the same country as well as being higher than that in the sector producing the same commodity in the other country. This leads to a Nash equilibrium in which both the alternatives, on the one hand, from the point of view of national capital investment (the choice between producing good A or producing good B in country 1) and, on the other hand, from the point of view of international capital (the choice between producing good A in country 1 or producing good A in country 2) lead to a tendency that increases the share of production of A in country 1. The same tendency at both levels applies to the production of the commodity B in country 2.

A more general conclusion from this example is the following: when aggregate productivity differences and other additional economic factors lead to persistent differences in wage levels, the relative difference in wage levels determines the tendency to specialize as a function of the relative productivity of the technique used in production. If the relative productivity difference in performing a particular task is higher than the relative average productivity difference in the globally tradable part of the economy (which also corresponds to the wage difference under certain assumptions), then such a task tends to be performed in a more developed country. If the relative productivity difference is lower than the relative average productivity difference of the globally tradable part of the economy, then such a commodity or production task tends to be produced in a less developed country.

In the long run, the tendencies lead to complete specialization of both countries in terms of products (or tasks) A and B. The steady state of international specialization driven by the dynamic generalized law of value is presented in the table 5.2. The final rate of surplus value is equalized to the normal level for both production processes. The biggest change after specialization is the relative change in the concrete labour hours invested in the production of A or B. On the one hand, the additional labour input for the developed country to produce the quantity of B that was previously produced by the underdeveloped country is only 2 labour hours (20% more in the sector producing B). On the other hand, specialization eliminates the 10 labour hours previously required to produce A. For the developed country, specialization results in a release of labour: of the total 20 hours previously expended, only 12 hours are required after specialization. Conversely, the labour requirement of the underdeveloped country increases from 20 hours previously spent on the production of A and B to 30 hours spent on the production of the total social requirement of A. Thus, the inner law of capitalist development creates such a pattern of specialization that reduces the total labour time in the developed country and increases the labour requirements in the underdeveloped country to produce similar total international output.

Table 5.2: Complete specialization in international trade (Source: own work)

	Country 1	Country 2
Real productivity of globally tradable commodities	P_0	$4P_0$
Global value of labour power	$w_1 = 0,25h$	$w_2 = 1h$
Total output	$A_1 = 300\,000$ $B_1 = 0$	$A_2 = 0$ $B_2 = 600\,000$
Labour spent in production	$t_{1A} = 30h$ $t_{1B} = 0h$	$t_{2A} = 0h$ $t_{2B} = 12h$
International value	$V(A) = 40/1\,000\,000$ $V(B) = 32/1\,000\,000$	$V(A) = 40/1\,000\,000$ $V(B) = 32/1\,000\,000$
Absolute surplus value	$s_{1A} = 4,5h$ $s_{1B} = /$	$s_{2A} = /$ $s_{2B} = 7,2h$
Rate of surplus value	$e_{1A} = 60\%$ $e_{1B}/$	$e_{2A} = /$ $e_{2B} = 60\%$
Consumption of A and B	$A_1 = 115\,385$ $B_1 = 230\,770$	$A_2 = 184\,615$ $B_2 = 369\,230$
Consumption of A and B per total labour hours used in production	$A_1 = 3\,846$ $B_1 = 7\,692$	$A_2 = 15\,384$ $B_2 = 30\,769$
Relative improvement in consumption level per labour hour spent on production	$2,6\%$	$36,7\%$

The aggregate final consumption of an underdeveloped country increases, while the aggregate final consumption of a developed country decreases, due to the asymmetric redistribution of the global division of labour. What is most relevant in such a comparison is the relative change in consumption per hour of labour devoted to production in each country. In Tables 1 and 2, we can see that the relative consumption per labour hour in production has increased in both underdeveloped and developed countries. Phenomenally, both countries have benefited from specialization. However, the increase in relative consumption per labour hour in this example is distributed highly disproportionately, amounting to only 2.6% in the underdeveloped country and 36.7% in the developed country.

Absolute productivity differences between countries in a specific sector or task indicate potential for cost-effective technological improvements. Since higher wages in industrialized countries create significant pressure for innovation and technological change that would replace labour with advanced machinery, the lower productivity gap in sector A implies lower potential for productivity improvements in that specific task at the given level of general technological and scientific development. Conversely, product- or task-specific productivity gaps that are larger than the wage differentials, and thus larger on average than the average nationwide productivity gap, indicate greater potential for technological improvements and productivity growth. Thus, not only are specialization gains highly unevenly distributed in the asymmetric environment of heterogeneous productivity gaps but the dynamic future prospects for productivity growth and technological progress within production are also highly asymmetric. The pattern of international specialization and global division of labour, continuously created and reinforced by the functioning of the internal laws of capitalist development and the generalized worldwide law of value thus leads to a global division of labour that perpetuates uneven development. This perpetuation is not the result of value transfers or inequalities in exchange but of the international competition, the international price formation, and the determinants of local and global productivity. The trend toward increasing fragmentation of the production process is only the most far-reaching aspect of such a process of global specialization as the increasing fragmentation of the production process leads to a fragmentation of the production process that was previously carried out within a single firm. This allows for even more detailed global division of labour that exploits very heterogeneous productivity differences as well as differing potential for technological improvement between specific tasks.

5.5 Conclusion

In this chapter we presented the Marxian reasoning for the establishment of the uneven international relative factor costs that are highly linearly related to development level. We presented the generalised law of worldwide value, which aims to better capture the static and dynamic effects of the functioning of the competitive process in the international capitalist mode of production, while retaining the explanatory power of its unmodified version when applied to a homogeneous closed economy. On the one hand, we retain the main theoretical link between the socially necessary labour time required for production and price formation. On the other hand, we introduce the impact of country-specific productivity differences on the worldwide value, functioning of international competition, and price formation. The novel approach treats the value of labour power as a variable endogenously determined by the functioning of international competition and assumes that differences in the productivity cannot be derived from differences in the organic composition of capital.

Using the proposed generalised law of worldwide value, we examine one of the main topics of research on uneven development - the choice of technique determination within the international capitalist mode of production. The main result is that international competition between countries with substantially different aggregate productivities and average wage levels leads to a specific division of labour - tasks and production processes for which the productivity differential is larger than the nationwide productivity differential tend to be produced in more developed countries and vice versa. Statically, such specialisation is consistent with the principle of relative comparative advantage, since both countries benefit from specialisation and exchange, but the distribution of gains is heavily skewed in favour of the more developed country. In addition, the distribution of the dynamic potential for technological improvement and productivity gains associated with such specialisation in the global division of labour perpetuates uneven development and blocks technological progress in underdeveloped countries.

What follows in the next chapter is a systematic examination of task based international trade and specialization under conditions of heterogeneous sectoral and task based production constraints and the international competition driven by the profit motive and international values and relative factor costs influenced the generalized law of world-wide value.

Chapter 6

Endogenous Complex Dynamics of International Development and Specialisation

6.1 Introduction

In the preceding chapters, we have both demonstrated the need for a dynamic, cross-sectoral, multiregional approach to international economics, growth, and uneven development and provided a solid foundation for conducting such an analysis.

In chapter 3, we explored how factor cost dynamics, which have been studied to affect endogenous technology growth and industrialization in closed economy task-based setting (Acemoglu & Restrepo, 2017a, 2017b, 2019; Zeira, 1998), also affect technology diffusion in a cross-country setting. The link is that relative factor costs depend on the level of development - due to generally lower labour mobility and higher capital and technology mobility, relative factor costs for capital and technology are lower in more developed countries and higher in less developed countries (Amin, 1974, 1976; Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997). The same structural differences in relative factor costs could be an endogenous source of uneven functional specialization. Since we explored in chapter 4 the relevance of supply-side granularity in the production constraint as most relevant for understanding the dynamics of intersectoral structural change in manufacturing and service sectors, this led us to hypothesise that the interaction between the endogenous processes, driven by the structural relative cost differences studied in chapter 3, and the supply-side driven dynamics of structural change studied by various supply-side approaches in the context of a closed economy (Acemoglu & Guerri, 2008; Baumol, 1967; Ngai & Pissarides, 2007; Alvarez-Cuadrado et al., 2017), could potentially provide an endogenous explanation for the patterns of international functional specialization.

The core idea of this chapter is to merge these dynamic features together in a novel multi-regional model and examine how they interact and whether, as asserted in our second main hypothesis, they endogenously drive functional specialization and constitute a functioning mechanism that contributes to the perpetuation of uneven development.

Methodologically, we will examine the interaction of these dynamic features in a dynamic multi-regional model. We begin our derivation from a neoclassical reference model for supply-side structural change (Acemoglu & Guerri, 2008) and modify it step by step to introduce all the features that have been explored in the previous three chapters and have proven to be important for the object of our study. These include extending the model by introducing a more granular production constraint that allows the study of functional specialization and the differentiation between various levels of 'light' and 'heavy' task-based techniques, introducing a Marxian price system that takes into account wage differentials and sets relative factor costs, and extending the closed economy model to the multiregional framework by introducing tradable and nontradable sectors to account for the Balassa-Samuelson effect.

The results of the modified model will allow us to interpret how the introduced dynamics interact and whether, as hypothesised, they contribute to the persistence of uneven development. Since the reference model is a neoclassical model whose core assumption is diminishing returns dynamic that normally leads to convergence, the absence of convergence in the modified model would suggest that the introduced dynamics and their complex interaction contribute to the persistence of uneven development.

The dynamic approach of this chapter is presented step by step. First, we explain the choice of the benchmark growth model that we modify. Second, we present the general assumptions of the modified model. Third, we present and discuss the general features of the model. Fourth, we develop a framework for a closed economy model and conduct a comprehensive analysis with model results and discussion and compare the results to the reference model. Fifth, we extend the model to include multiple regions, trade, and international specialization. We present a dynamic model with 2 regions based on the functioning of the closed economy model but including international specialization and trade. No structural differences between regions are assumed except for the difference in the initial stage of development. Sixth, a multiregional model with 3 regions is presented and discussed. In the last part of the chapter, additional modifications are made to the dynamic model, changing some of the assumptions made earlier.

6.2 The choice of the benchmark model for the derivation of the multiregional model

We use a model by Acemoglu and Guerri (2008) as a starting point for our derivation. The model is a neoclassical study of supply-side structural change in a closed economy. It uses two Solow-Swan production functions of intermediate goods that are combined into a final good that is used for both consumption and investment. The two Solow-Swan production functions have different marginal capital productivities, which allows exploration of the dynamics of supply-side structural change.

While the model itself serves only as the basis for our further derivation, in which we extend and modify the model to include additional evolutionary and Marxist assumptions, the choice of the neoclassical model as the starting point for our derivation nevertheless has certain limitations that are embedded in the neoclassical framework and therefore need to be explained conceptually. The choice of the neoclassical structural change model as the starting point for our dynamic multiregional analysis is made for several reasons.

First, the main argument is that our main hypothesis relates to the supply-side mechanism that perpetuates uneven development driven by the core functioning of the market. Deriving such a mechanism and exploring its functional pattern should therefore be done in an economic model that operates in steady-state, as opposed to agent-based models that are prone to path-dependency or disequilibrium dynamic models that study growth processes far from steady-state. In these models and analyses, it is not the core functioning of the market but its permanent disequilibrium that determines the main outcomes. The functional analysis of the supply-side mechanism that we seek to separate from other mechanisms and provide an explanation for its functioning would be very opaque if embedded in a model operating far from steady-state, as it would be difficult to separate the other disequilibrium effects from our hypothesised purely supply-side mechanism.

Second, the central result of the neoclassical Solow-Swan model (which is the core element of the nested production function in the benchmark model of Acemoglu and Guerri (2008)) is that, by assuming a homogeneous production constraint, all endogenous dynamics of the model lead to convergence due to diminishing returns to investment (conditional on the uniformity of exogenous parameters such as technology growth and the saving rate). Modifying the model, whose fundamental core is endogenous convergence dynamics, allows us to study in relative isolation the specific properties of the modified production constraint that leads to persistent uneven development, even under conditions of purely neoclassical markets. Should we study the supply-side mechanisms leading to persistent uneven development not in a general converging macroeconomic model, but in a model in which divergence is already implemented as a core aspect (such as disequlibrium markets, many classes of agent-based models, long-run increasing return dynamics), it would be much more difficult to disentangle the effects introduced by modifying the model from its benchmark, which already contains a divergent aspect. Therefore, using a convergent neoclassical steady-state model sets us the benchmark for conditional convergence. By examining the precise modifications to the production constraint and its interaction with factor markets, we can disentangle the effects of our modifications to the supply-side constraint from the benchmark model and thus examine, in relative isolation, the operation of the supply-side mechanism that perpetuates uneven development and leads to a stable distribution of uneven development under the mainstream assumptions.

Third, it is more difficult to theoretically derive a model with a stable solution that leads to uneven non-converging steady states if diminishing returns to investment are generally assumed in the model. By examining the supply-side mechanisms that we conceptually implement as modifications of the neoclassical model, it is possible to extrapolate that these same mechanisms would also contribute to uneven development if diminishing returns were not assumed in the same constraining manner. In most heterodox and evolutionary approaches, which use agent-based modelling as opposed to analysis of a representative agent and its rational behaviour, the assumptions regarding production are less restrictive than in the case of the neoclassical production function. This allows for the greatest possible generality of the supply-side mechanism under study, which can be assumed to operate without loss of generality under conditions with less converging core assumptions. If the functional structure of the production constraint under study produces a pattern of uneven development in a model in which diminishing returns to investment are the general assumption, then the same functional structure would similarly contribute to greater divergence under general conditions that normally lead to divergence.

Although it might seem that by adopting the neoclassical model as a starting point we are departing from our other, more heterodox derivations in the dissertation and our general exposition, this is not the case. There are three reasons for this:
a) We have already argued in the chapter 5 that the neoclassical production constraint is not conceptually inconsistent with the Marxist conceptualization as long as it is understood only as an objective technical constraint and not as a basis for social distribution. Analytical Marxian tradition works entirely within a steady-state equilibrium framework (Roemer, 1982, 1989).
b) We modify the benchmark model with additional Marxist and evolutionary assumptions and modifications, as explained in the following section.
c) We limit our exploration of growth dynamics to the medium term. In this way, we refrain from exploring the growth process in the long run, which is conditioned by diverging and increasing returns to scale and potential Kondratieff cycles. By limiting ourselves to the medium term, we restrict ourselves to the single technological cycle, which plausibly can

take the general form of the neoclassical production function, in particular diminishing returns to investment.

6.3 The main model assumptions

The model is derived using a combination of neoclassical, Marxian and evolutionary assumptions that best capture our conceptual hypothesis of the supply side dynamic mechanism that contributes to the perpetuation of uneven development. As explained in the previous subsection, for the core framework, Acemoglu and Guerri (2008) model of supply driven structural change is used and further modified and extended. The model is one of the benchmark models that deal with supply driven structural change dynamics and operates with 2 Solow-Swan production functions that have different marginal returns to capital investment.

Our first major modification of the framework is to define production constraint of intermediate goods as more granular. As opposed to 2 Solow-Swan functions for intermediate goods in a model by Acemoglu and Guerri (2008) we define 10 Solow-Swan production functions that each sequentially exhibit slightly greater marginal return to investment in the intermediate goods sectors, which are combined into final good with a Leontief production function, as opposed to CES production function. This enables us to analyse how such granularity in production constraint and limited substitutability between larger task groups, which we have empirically explored in the chapter 4 and shown to be crucial for understanding modern structural change dynamics, affects and determines persistence of uneven development.

Granularity and complementarity in intermediate production is a novel way of mathematical and theoretical examination of what Amin (1974) differentiates as light and heavy industries. In the medium turn, the granular differentiation between different task groups required in the production process represents different capital and labour intensive tasks that are constrained by the medium turn technological development. In the context of free international capitalist competition, Amin (1974, 1984) argued that technological lock-in could happened due to endogenous specialization of less developed regions for more light, labour intensive industries. However, his conceptual argument was never formulated in a theoretical modelling setting. We aim to represent his conceptual argument by our proposed formulation of the granular and complementary production constraint in the medium run within the neoclassical supply-side structural change model. Amin's arguments and distinction between light and heavy industries has neither a conceptual equivalence in modern mainstream economics nor in heterodox fields. A closest modern articulation of the dynamics behind his ideas of light and heavy industries are formulated in discussions and examinations of functional specialization that arose with increasing fragmentation of the production process in global value chain research. Introduction of granularity and complementarity in the production constraint also enables us to address the endogenous processes of functional specialization, in so far as they are reflected by the distribution of various task groups that reflect their medium term returns to investment by being more labour or capital, skill, or technology intensive.

To explore the dynamic that could be generated by the interaction between the differences in the relative factor costs and the granular production constraint, our model must also contain endogenous factor price dynamics. We implement this by introduction of a series of Marxian assumptions in the sphere of labour market and capital market (Amin, 1974, 1976). We introduce the empirically corroborated idea that relative mobility of labour is lower than relative mobility of technology and capital, due to which relative factor prices vary with development, by imposing more strict assumption of absolute immobility of labour and complete mobility of capital and technology. These assumptions are used as rough simplification of more nuanced relations, which by expressing the main point of differentiation explore how relative factor costs emerge endogenously in a stylised model. With introduction of the Marxian pricing system, the international law of value that links price levels with wage levels, with wages being determined on a homogeneous national level, and price of capital and technology determined on the global level, these assumptions lead to endogenous emergence of the relative factor costs for differently developed countries that are empirically corroborated (Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997).

We express the modified model in a discrete time framework, to enable derivation of a numerical solution. The discrete framework demands additional assumptions regarding its dynamics. We use the evolutionary elements to close the discrete framework: the prices and wages remain fixed throughout one period and change only at the end of the period after new information is taken into account. The market optimization process is driven by adjustments of real output, employment and investment at fixed wages and prices (Bénassy, 1982; Lorentz et al., 2016).

An extension of the closed economy model is conducted by introduction of multiple regions - first 2 and an additional model with 3 regions. The regions are introduced without any differentiation with respect to their production structure, as it is characteristic of North-South modelling, as well as without any non-homothetic or otherwise hierarchical demand driven dynamics, as is the characteristic of the balance-of-payments constraint framework. We introduce new regions in a completely symmetric manner, with only the initial state of output being different and with all the production structure properties being derived from the trajectory of the closed economy model structural change model derived and solved before an extension to the multi-regional setting. The extension to multiple regions is introduced stock-flow consistently and trade is assumed to be strictly balanced.

In order to summarize the paradigmatic origin of our assumptions, we group them in the sets of neoclassical, Marxian, and evolutionary assumptions.

Neoclassical assumptions:
1.) Neoclassical supply-side structural change model as a starting point of derivation;
2.) Neoclassical variation of the production constraint and exogenous savings rate;
3.) Full market clearance;
4.) No unemployment dynamics (focus on the medium term);
5.) Strict balance of payments constraint trade;
6.) Balassa (1964) and Samuelson's (1948) assumptions regarding non-tradable sector productivity and wage homogeneity within a country regardless of the sector of employment;
7.) Nominal wage ratios are determined by the productivity differences in the tradable sectors (Balassa, 1964; Samuelson, 1948).

Marxian assumptions:
1.) Wage/profit shares are exogenous claims on the aggregate product and are not determined by the technical properties of the production constraint (marginal productivities of individual technical factors of production);
2.) Workers and capitalists saving/investment rates are different and exogenous;
3.) Granularity and complementarity in the production constraint corresponding to the functional specialization options for differently light or heavy techniques;
4.) Assumption of cross-country immobility of labour and homogeneity of wages within a country;
5.) Uniform rate of exploitation.

Evolutionary assumptions:
1.) Wages and prices are fixed within discrete periods and change only at the end of the period with new information taken into account;
2.) Model is driven by the maximization of expected profits (expected surplus value) at given prices.
3.) Finite horizon of the capitalist agents when determining investment and employment to maximize profits (as opposed to neoclassical unbounded inter-temporal rationality).

6.4 Broad Model Characteristics

6.4.1 Technology as a Production Constraint

Although technology and technology diffusion are one of the central aspects of our study, we do not explicitly examine technology as a direct model variable.

We explain the argument, already briefly discussed in the chapter 3, in more detail. First, we define the measure of aggregate output $Q(t)$, which includes the quantity as well as the quality and variety of a set of products and services. The aggregate output is used for consumption and investment. Thus, it is a very abstract measure of consumption, on the one hand, and of the quality, quantity, and variety of productive capabilities, on the other hand, when used as investments in the means of production. The broadest concept of production constraint determines the ability to produce both variety, quality and quantity of goods. However, there are differences in how production constraint operates in terms of the time dimension and how the effects of technological change are operationalized.

First, the short-run production constraint only allows for changes in employment. Both investment and more extensive technological changes take time to implement and involve at least some time lag. Thus, the short-run output constraint allows the economy to be in a state of underutilised capacity, and the short-run dynamic determines the core logic of periodic business cycle fluctuations. In this chapter, we leave short-term dynamics aside to avoid unnecessary complexity.

Second, the medium-term output constraint allows for changes in both investment and employment. It is conceptualised as a global output constraint for a specific limited period of time. In technological terms, the medium-term period can be interpreted as the time frame of a specific technological paradigm, similar to a technologically determined medium-term cycle (Perez, 1983; Von Tunzelmann, 1995). Within such a medium-term cycle, there is a single global production constraint, and all technological change occurs within that constraint. Both investment and job displacement contribute to technological change in the medium run because technological change involves investment in new and modified capacity. Our interpretation of the medium-term properties of technological progress borrows from similar attempts to explain technological change solely in terms of changes in various factors of production, without explicitly accounting for any technology factor (Denison, 2012; Jorgenson & Griliches, 1967).

Since aggregate composite total output measures both quantity and quality, productivity improvements in the production of $Q(t)$ include both the mere expansion of the ability to produce more quantity with given labour and the expansion of varieties and new forms of use values. In the medium run, innovations, both in the form of new forms of consumption and production, and technical progress in the sense of quantitative productivity growth shape the overall productivity growth of aggregate $Q(t)$. The main assumption of our approach is that each medium-term technological paradigm has a corresponding global production constraint that encompasses all potential production possibilities within that time frame.

Third, technological progress is limited within a medium-term output constraint because it leads to saturation on the consumption side and the marginal technological opportunities for productivity growth diminish, leading to a necessary decline in aggregate growth (Freeman, 1982). Thus, by definition, long-run growth exceeds the medium-run output constraint as conceptualised in approaches that focus on long-run technological cycles (Freeman & Louçã, 2001; Perez, 1983; van Duijn, 1977; Von Tunzelmann, 1995). The long-term changes can never be represented by an ordered linear progress. Instead, they should be viewed as random periodic perturbations of the global production constraint. Similar to a paradigm shift in science, a shift between different technological paradigms represents a long-term technological cycle. In such a long-term switch, the global production constraint changes completely, reshuffling previously stable relationships and established patterns, resulting in a restructuring of the economy. In this chapter, we are not concerned with long-term technological change, but focus on the functioning of economic dynamics within a given global technological medium-term constraint. We believe that it is the medium-term period that hides the core of dynamics that sustains uneven development. Long-term changes in production constraints, however, are an interesting area of research. Questions about the future impact of technological change on income, employment, and general welfare are relevant, especially given the current changes in biomedicine, health care, neuroscience, robotics, and AI that may point to a new long-term technological cycle. The final pages of this chapter provide some dynamic analysis in terms of potential long-term changes and their implications.

The models we present in this chapter focus on medium-term dynamics. This helps us to narrow down the short-term issues and avoid the issues of long technological cycles. Technology and investment are assumed to be coupled in the medium term, and the overall potential for productivity growth is determined by the global output constraint. Productivity growth within the medium-term framework is investment-driven - where investment is understood as a broad concept of embodied past labour effort used to increase future potential output. Investment is assumed to have heterogeneous effects on labour productivity. To achieve this, we have divided production into several major sets of tasks that complement each other in producing total output and have different production constraints.

6.4.2 Task Groups and Heterogeneous Production Constraint

In each period, the general developments of science, existing technology, and knowledge determine heterogeneous objective barriers to productivity growth of different tasks required to produce the composite $Q(t)$. Our main assumption is that, regardless of the specific period and the specific level of technological development in a given time frame, there are broad groups of tasks that are complementary and have substantially different production constraints. The key supply-driven mechanism of inter-task dynamics is that there are different groups of tasks that differ substantially in their medium-term output constraints and are necessary to satisfy final demand - one group of tasks might have low potential for productivity growth, another high, and the third somewhere in between.

The concept of a task is understood from the perspective of the outcome, even if the outcome is not an entire product or service. Many specific tasks can be substituted in two ways. There can be substitution *between* tasks by completely changing the way the same or similar result is achieved, and there can be a change in the way work is done *within* a particular task. An example of the former would be the substitution of an electric car for a diesel vehicle. In this case, a number of tasks become redundant and new tasks take their place, which can change the concrete production constraint of car production. An example of the latter would be the concrete task of creating a rotational force that is used in the production of almost all goods. This can be done in a variety of ways, using a different set of production factors in different technological forms. A similar example would be agricultural food production, which always takes place on the land, but with infinite possibilities of combining capital in its more or less sophisticated forms and labour with different skills.

Regardless of the two possibilities for task substitution, we can always group them in such a way that, from the perspective of contribution to final aggregate output, there are groups of tasks with different production constraints that account for both within and between task substitution. In other words, the medium-term production constraints that determine the effects of changes in the factor shares used to produce a given task account for both within-task substitution and between-task substitution. Following this conceptualization, we construct a discrete set of task groups that exhibit heterogeneous production constraints that differ in the amount of potential for productivity gains within the described medium-term framework.

In our models, we assume that the heterogeneous production constraints have the Cobb-Douglass form. We use this form because of its simplicity and ease of use. Despite its simplicity, implementing the heterogeneous potential for productivity growth within this form allows us to capture the supply-driven dynamics and effects of structural change in sufficient detail and to reproduce all the key results of the supply-driven theories of structural change already within the closed economy model. Our conceptual separation of the technical and social dimensions, by separating the issue of distribution and production, also allows us to dispense with the concept of marginal productivities of the various factors of production in the process of income determination. The production constraint acts only as a technical constraint, determining investment and employment through the process of profit maximization, while the social distribution is determined by broader social and economic processes.

6.4.3 Investment Constraint

To determine aggregate capital accumulation, an exogenous investment rate is assumed. One way to operationalize the separation of the distributional issue from the technical properties of the production function is to simply assume an exogenous investment rate. The exogenous investment rate is determined primarily by the class-based distribution, with a high propensity to invest from profit income and a low propensity to invest from wages. The assumption of an exogenous investment rate thus reduces to the assumption of a fixed measure of surplus value - a medium-term fixed share of the value produced accruing to the working class and the capitalist class. Although the exogenous investment rate is identical in its mathematical form to the exogenous savings rate in the neoclassical benchmark growth model, both the reformulation of its name (investment rate) and its reconceptualization on the basis of a class-based distribution that is independent of the concrete technical constraints on production are intentional and of theoretical importance. On the one hand, savings themselves are not a sufficient condition for investment; on the other hand, the logic of economic activity, which is to a large extent conditioned by the class-based form of income flow, is a much more essential determinant of investment flows. While the short-term savings and financial investments of the working class are rarely aimed at long-term investment, but only at postponing consumption, which often leads to medium-term disinvestment, using the retirement fund for consumption in old age or buying a property to be used by family members in the long term. On the other hand, the large part of the profit income that is not distributed in the form of dividends remains in the accounting of the company, mainly with the aim of quantitative or qualitative expansion of its production cycle. The use of the income of workers and capitalists is determined by different internal logics.

6.4.4 Profit Maximization

The core mechanism of economic and social dynamics in a capitalist mode of production is the internal logic of capital accumulation driven by profit maximization.

The standard neoclassical approach to determining investment has long been to derive investment as a rational consumer decision process - the intertemporal optimization of consumption. Investment functions in this framework as intertemporal adjustments to consumption. However, the concepts, phenomenal forms, and their functioning are turned on their head in the neoclassical framework with respect to investment determination, which has generated many substantive criticisms (for a review, see Cesaratto, 1999, 2020) and may rarely be empirically plausible (Mankiw et al., 1982).

We need not assume rationality to derive the process of capital accumulation, let alone consumer rationality, because rationality is not a prerequisite for optimization. Investment is never a choice between consumption now or later, but an operating logic that defines the functioning of the capitalist mode of production and distinguishes it from pre-capitalist modes of production.

The accumulation of surplus value in the phenomenal form of profit is an exploitation concealed by the phenomenal forms of individual freedom and the rule of law. The concealment of exploitation is of greater importance to the functioning of the economic system than its direct social consequences (Balibar, 2016). For it is because of the concealment of exploitation that the capital fetish emerges as the dominant ideological conception of capital - a conception that capital is not an exploitative social relation, but an object with the inherent property that it creates more value through the process of its own internal circulation.

The process of capital circulation lacks any rationality. The logic of value creating more value, the logic of maximizing surplus value and repeating the cycle, is a logic that goes far beyond the actual future horizon of the limited individual. The process of capital accumulation thus takes on the appearance of an independent social force to which not only is the individual functioning of the capital owner or manager subordinated, but also robust, broader institutional frameworks emerge that primarily serve the process of capital accumulation (for example, financial markets). One might say that, contrary to the neoclassical approach, profit maximization is the central logic of the capitalist mode of production, while its effects on investment, real productivity growth, and consumption are the spillover effects. Our immediate assumption of profit maximization accounts for this logic of operation.

In our model, we assume that profit maximization is the main determinant of the distribution of employment and investment. However, profit maximization is constrained by limited information. Thus, it functions as maximization of expected profits given information about values. The changes in value caused by the profit-maximizing decisions are not directly predictable and observable by the individual capitalist making a profit-maximizing decision, since the changes in value are caused by the social effect of all the decisions of the profit-maximizing subjects and become observable only *post festum* after the profit-maximizing decisions have been made. In addition to the information limitation, the forward-looking horizon for profit maximization is constrained by the short-term period.

6.4.5 International Trade and Mobility

First, we assume that both labour and investment are immobile and cannot cross borders. Thus, investment is driven by domestic accumulation. With later adjustments, capital immobility is relaxed and foreign direct investment is possible, and capital flows are directly included in the account.

The use of the task-based framework rather than sectoral disaggregation also provides a basis for the international trade framework. International trade is conceptualized as task-based trade, which is consistent with the conceptualization of value-added trade. This eliminates the input-output complexity of specific final goods and services for our analysis, as all final goods are broken down into a variety of tasks subject to the production constraints discussed earlier and potentially performed by any region.

Task groups are divided into tradable and non-tradable to properly account for the Balassa-Samuelson effect. On the one hand, the output of each tradable task can smoothly cross borders, which explicitly enables value chain integration and intermediate trade. On the other hand, the output of the non-tradable tasks cannot cross the border between regions and is assumed to be produced domestically. Task-based disaggregation, in contrast to sectoral disaggregation, is even better at providing a clear separation between tradable and nontradable tasks because various inputs (which may be tradable) and new value added produced locally can be separated. For example, the direct value added of labour in services such as hairdressing or health care is mostly non-tradable and produced domestically, while the intermediate components of such services (equipment) can be produced as outputs of the tradable task groups. While all sectoral-level assumptions may be in a gray area, the task-based decomposition minimizes such conceptual problems.

We assume that market clearing takes place in international markets at all stages. The generalized worldwide law of value provides a basis for the international determination of value. In the absence of capital mobility, international exchange sets the balance of payments constraint for each region. In contrast to the critical approaches that also worked with the application of the balance of payments constraint and are associated with the post-Keynesian school, our analysis is entirely supply-side oriented. Thus, we show that reliance on demand-side assumptions is not necessary to derive complex international dynamics that create a pattern of persistent uneven development only because of the inner functioning of capitalist competition and complex production constraints.

6.5 Closed Economy Model

6.5.1 Model Equations

Main definitions

We define two different sets of sectors - a tradable and non-tradable. The difference and effect on model results will only be seen in models with multiple countries and trade. However, to properly link the closed economy results with multi-regional model, distinction is made at this point. Variables that are specific for each task group are labelled with index j throughout this chapter, while a whole set of available values of index j is defined by the set S_j.

$$S_j = (1, 2, \ldots, 9, 10, NT) \tag{6.5.1}$$

A full set of tasks required by the economy to produce a final composite good $Q(t)$ consists of 10 tradable tasks with variable effects of investment on productivity, signified by $j = 1, 2, \ldots 9, 10$, and 1 non-tradable task with labour as the only technical production factor, signified by $j = NT$.

Granular production constraint

A set of tradable task groups has heterogeneous production constraint with respect to the effects of investment. We assume the marginal technical productivity of capital to take range from 0.1 to 1 in steps of 0.1 for each group of tasks j. The parameter α is assumed to be 0.67 throughout the chapter. As in our reference model, the intermediate goods are produced by different Solow-Swan production functions with different marginal productivity of capital (Acemoglu & Guerri, 2008). The main difference is extending the granularity to 10 sets of task groups, as opposed to only 2 in the reference model.

$$q_j(t) = l_j(t)^{\alpha} k_j(t)^{j/10} \quad \forall j \in S_j \tag{6.5.2}$$

The non-tradable task is produced using labour only and labour productivity cannot be improved in the medium run. This form is assumed when Balassa-Samuelson effect is explored in a modelling framework (Balassa, 1964; Samuelson, 1948). The constant A_{NT} is assumed to be equal to 2 throughout this chapter unless otherwise specified. A subsection 6.6.3 is be dedicated to the analysis of the effect of the size of the non-tradable sector on the international specialization and development.

$$q_{NT}(t) = A_{NT} l_{NT}(t) \tag{6.5.3}$$

The total output is a composite aggregate defined by the Leontief production function. The composite aggregate output is an abstract measure of the capacity to produce use values for consumption and productive consumption in the form of investment into fixed capital. With this assumption granularity and complementarity between larger sets of tasks is imposed, as opposed to more general analysis with CES production function (Acemoglu & Guerri, 2008). We have shown in the chapter 4 that there exists substantial complementarity between larger sets of value added by different sectors, which fundamentally shapes the supply-side structural change.

$$Q(t) = \min_{\forall j \in S_j} q_j(t) \tag{6.5.4}$$

Aggregates

Full employment is assumed, as in most of the supply-side mainstream approaches (Acemoglu & Guerri, 2008). Because we are not interested in the complexities of the short-term business cycles, this simplification does not limit the generality of the approach. The full employment can be treated as an average employment participation in the medium-run period. We assume L to be fixed and equal to 100 throughout the chapter.

$$\sum_{j \in S_j} l_j(t) = L \tag{6.5.5}$$

We define aggregated variables for capital and investment as in the benchmark model (Acemoglu & Guerri, 2008).

$$K(t) = \sum_{i \in S_j} k_j(t) \tag{6.5.6}$$

$$I(t) = \sum_{j \in S_j} i_j(t) \tag{6.5.7}$$

Value and profit

One unit of the aggregate output has a value $v_Q(t)$, which is defined by labour spent for its production directly (L) and indirectly ($\delta K v_Q(t)$), as defined by the basic Marxian conceptual system (Amin, 1974, 1976; Cogliano et al., 2022; Marx, 1992, 1993).

$$v_Q(t) = \frac{L + \delta K(t) v_Q(t)}{Q(t)} \tag{6.5.8}$$

$$v_Q(t) = \frac{L}{Q(t) - \delta K(t)} \tag{6.5.9}$$

Values for the unit output of each set of tasks is defined similarly.

$$v_j(t) = \frac{l_j(t) + \delta k_j(t) v_Q(t)}{q_j(t)} \tag{6.5.10}$$

As discussed in the chapter 5, we use the core derivations from the first book of Capital, and a modified international law of value to close the international price system (Marx, 1992, 1993). Profits are equal to the surplus value. The surplus value is defined as the value of the total output minus the value of labour power used in production (w represents the unit-value of labour power) and the transfer of the previously created value (δ represents the depreciation of the fixed capital). The value of labour power is defined by the exogenous class based distribution and is defined by the assumed measure of surplus value $msr = 0.5$, which is an exogenous variable in the Marxian approach (Cogliano et al., 2022). The transfer of value previously created in the form of fixed capital or other types of investment equals the value of the depreciated capital goods (Cogliano et al., 2022; Marx, 1992, 1993).

$$\pi_j(t) = q_j(t)v_j(t) - wl_j(t) - \delta k_j(t)v_Q(t) \tag{6.5.11}$$

Expected profits are equal to the expected surplus value at given value levels.

$$\pi_j^e(t+1) = q_j(t+1)v_j(t) - wl_j(t+1) - \delta k_j(t+1)v_Q(t) \tag{6.5.12}$$

The capital accumulation equation

The dynamics in the model is driven by the two dynamic equations. The first is the capital accumulation equation that takes the standard form and the second is the main optimization equation - the profit maximization under a series of constraints (Acemoglu & Guerri, 2008).

Through this chapter we assume that the measure of surplus value is $msv = 0.5$, propensity to invest from profits is $p_I = 0.9$ and propensity to invest from wages $w_I = 0.1$. This makes the total propensity to invest new value added equal to $s = 0.5$. The aggregate investment $I(t)$ is defined by the share of total output that is invested. The assumed exogenous investment rates are similar to assumptions within the mainstream neoclassical growth modelling (Solow, 1957; Swan, 1956).

$$I(t) = sQ(t-1) \tag{6.5.13}$$

The aggregate investment represents a constraint for the investment in the production process corresponding to each task group - i_j (Acemoglu & Guerri, 2008).

$$\sum_{j \in S_j} i_j(t) = I(t) \tag{6.5.14}$$

The capital accumulation equation for each task group is defined by capital appreciation and new investment specific for each task group (Acemoglu & Guerri, 2008).

$$k_j(t) = (1-\delta)k_j(t-1) + i_j(t) \quad \forall j \in S_j \tag{6.5.15}$$

The Main Optimization Equation

The main driver of the dynamics in the model is the process of profit maximization. The expected profits are maximized under a series of constraints. The horizon of profit maximization is assumed to be limited by the short run time period. The core idea behind the values having lagged terms in the equation is the inability of the individual capitalist firm to influence the aggregate values. The values are formed as a social effect of the multitude of individual decisions only *post festum*. Due to discrete nature of numerical solving the model, we borrow from evolutionary approaches that any imbalances in supply and demand are rectified through quantity adjustments rather than price and wage changes, with prices only adjusting between discrete periods. This is achieved analytically by assuming that wages and prices remain fixed within each period, and any necessary adjustments occur only between periods (Benassy, 1982; Lorentz et al., 2016). With discrete time-points sufficiently short, this should not create substantial differences when compared to analytical continuous solutions of the reference model (Acemoglu & Guerri, 2008).

$$\max_{i_j(t),\, l_j(t)\ \forall j \in S_j} \sum_{j \in S_j} \pi_j^e(t) \tag{6.5.16}$$

We express the maximization problem in detail.

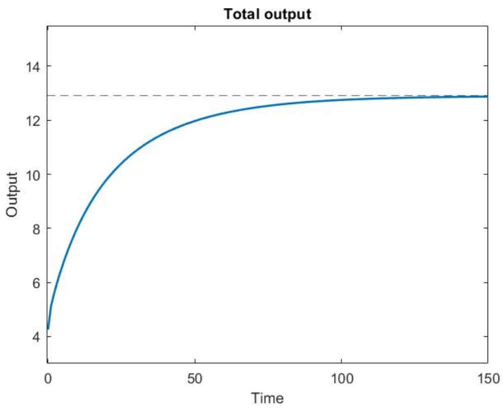
$$\begin{aligned}
&\max_{i_j(t),\, l_j(t)\ \forall j \in S_j} \left\{ \sum_{j \in S_j} \Big(l_j(t)^{\alpha} k_j(t)^{j/10} v_j(t-1) - w l_j(t) - \delta k_j(t) v_Q(t-1) \Big) \right\} s.t.\\
&1.) \qquad I(t) = sQ(t-1)\\
&2.) \qquad \sum_{j \in S_j} i_j(t) = I(t)\\
&3.) \qquad \sum_{j \in S_j} l_j(t) = L\\
&4.) \qquad k_j(t) = (1-\delta)k_j(t-1) + i_j(t) \quad \forall j, i \in S_j\\
&5.) \qquad q_j(t) = q_i(t) \quad \forall j, i \in S_j
\end{aligned} \tag{6.5.17}$$

The maximization of profits is reduced to choices of distribution of employment and aggregate investment among the tasks. The aggregate investment is determined by the previous year's output and its exogenous distribution between capitalist and working class. The second constraint states the identity of the aggregate investment with the sum of investments in particular task groups. Similarly the third constraint arises out of our simplifying assumption of full employment - all the labour is distributed to some productive activity. Capital accumulation equation determines the capacity and capital intensity of the production process associated with each task. The last production constraint follows from the complementarity of the task groups in producing the final total output.

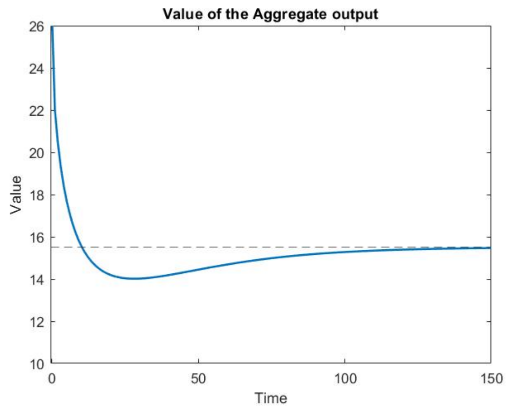
6.5.2 Results and discussion

The results of the model are obtained with numerical solution of the model. For each discrete step a separate interior-point algorithm for constrained non-linear optimization is used to determine the distribution of employment and investment that maximizes the profits (Byrd et al., 1999, 2000; Waltz et al., 2006). The initial condition is defined by $k_j(0) = 1 \quad \forall j \in S_j$ and employment distributed evenly across the task groups $l_j(0) = L/11 \quad \forall j \in S_j$.

Figure 6.1: Total output and its value - the closed economy model (Source: own work)

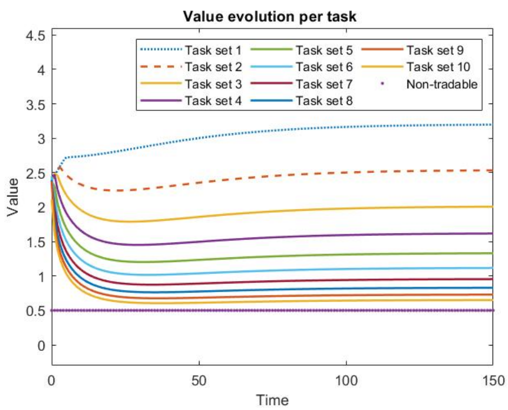


(a) Aggregate output medium-term evolution

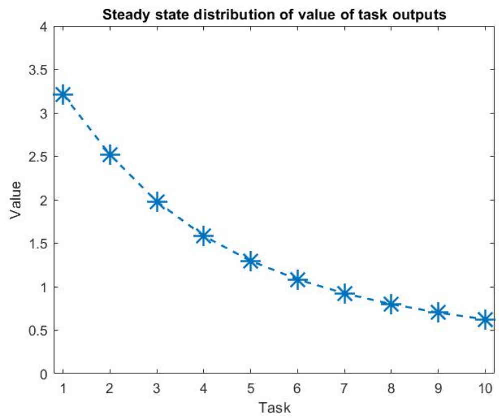


(b) The evolution of the value of aggregate output

Figure 6.2: The disaggregate evolution of value - the closed economy model (Source: own work)



(a) The disaggregate evolution of value



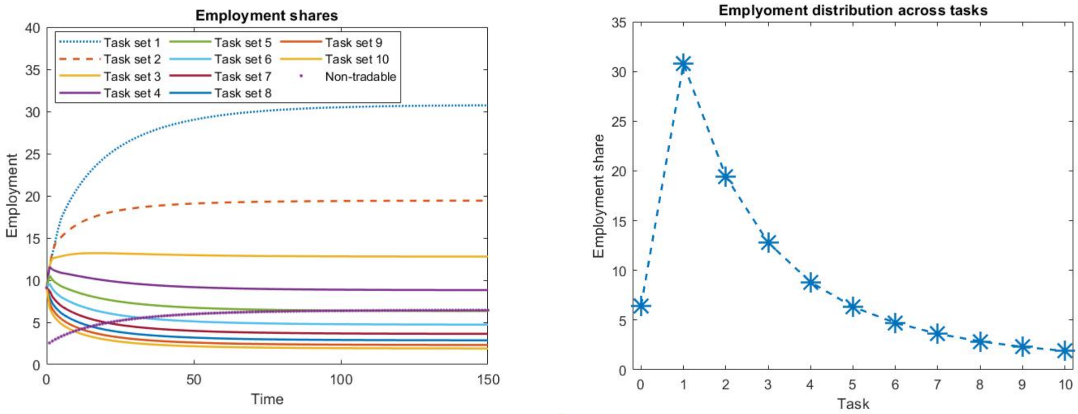
(b) The steady state distribution of value

The overall dynamics of aggregate output $Q(t)$ and its value $v_Q(t)$ can be seen in figure 6.1. Both aggregate output and its value enter a medium-term steady state, which is an overall result analogous to the Solow-Swan benchmark model that is use as a basis for our reference Acemoglu and Guerri (2008) model. Since the size of the labour force is fixed (L is a constant) and a fixed share of the population in the labour force is assumed, total output and growth in total output are equal to total output per capita and its growth. The growth in total output represents the increase in quantity, quality, and variety caused by the investment-driven medium-term technological changes within the global production constraint. The value of total output declines substantially due to the technology- and investment-driven productivity increases, indicating that greater quantity, quality, and variety can be produced with lower direct and indirect labour inputs. There is a slight upward correction in the value before it reaches its steady-state value and the next long-term technological cycle begins. The slight upward correction after the initial decline in the value of aggregate output is driven by two moments. The first is the increase in indirect labour input in the production of total output. The second is the effect of structural change - namely, Baumol's cost disease (Baumol, 1967). Because of the assumption of full employment, as productivity develops in the higher-value task groups, labour is increasingly used in the lower-value task groups, where productivity gains are more limited. This drives up the value of these lower task groups, causing the value of total output to reach its steady state from below.

The more detailed disaggregated value dynamics for each task group output $v_j(t)$ and its distribution at steady state can be seen in figure 6.2. The evolution of the value for each task group shows both Baumol's cost disease discussed earlier and an increase in indirect labour demand. All task groups experience an immediate decrease in their value due to technologically driven improvements, with the exception of task group 1, which experiences an increase in value throughout the period. The higher level task groups experience a larger decline in value, indicating larger labour-saving changes in the production process, while the lower level task groups experience less pronounced declines in value. After the initial decline, all values experience a slight upward correction due to the increase in indirect labour demand. However, the dynamics of structural change are the more important driver of the upward adjustment, so that most of the upward adjustment is accounted for by the lower level task groups, while the values of the upper level task groups remain stable and low. The steady state distribution of the value among the task groups reflects the effects of the changes in labour savings on the different tasks. It has a concave shape. The differences in direct and indirect labour required to produce a unit of output among the different task groups range from more than 3 for the lowest task group to less than 0.6 for the highest task group.

The dynamic changes in employment structure and the final steady state distribution of employment among different task groups is presented in figure 6.3. In the figure 6.3b, the results for task 0 represent the non-tradable task group employment in the steady state, while the integers from 1 to 10 rest represent the steady state employment within tradable task groups. The employment structure between tasks changes even more drastically than their values. The lowest three task group tiers experience an immediate increase in employ-

Figure 6.3: Employment evolution and steady state distribution of employment across tasks - the closed economy model (Source: own work)



(a) Evolution of employment shares

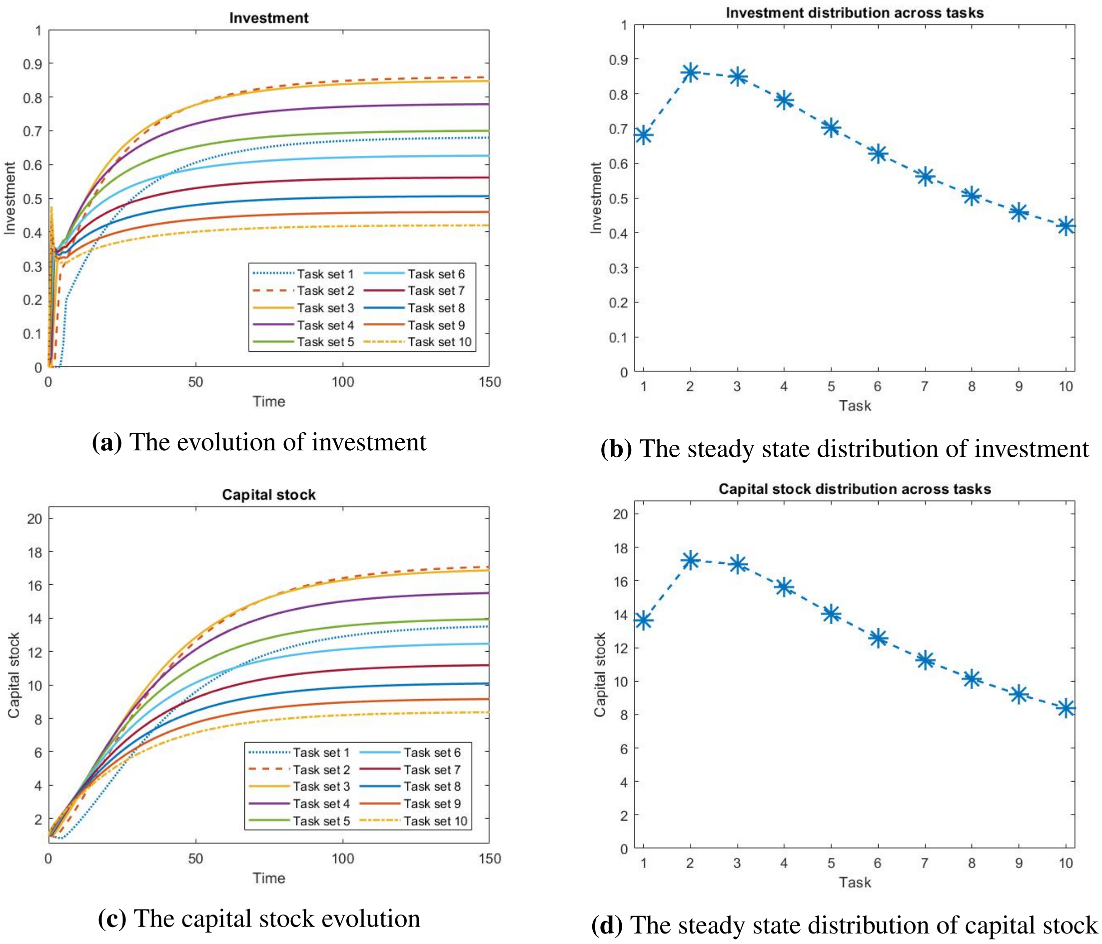
(b) Steady state distribution of employment

ment while employment declines in higher task group tiers correspondingly with the productivity improvements. The employment distribution converges to a steady state, which has an even more pronounced concave shape - the total employment in the task groups from tier 4 to 10 is lower that the total employment in the task group 1. The presented employment dynamics correspond to the previously discussed value dynamics, especially the the Baumol's cost disease, as the productivity growth of the lower tier task groups is significantly lower than their employment increases, leading to upward adjustments in their value.

The investment and capital stock evolution and steady state distribution are presented in figure 6.4. Both investment and capital stock converge to the same steady state structure of distribution across task groups, which is a condition for the existence of a stable steady state. The initial period exhibits some transitional process dynamics that does not correspond to the final steady state distribution. The investment is initially focused exclusively on the highest tier task groups, with investment starting in the lower tier groups with substantial lag that is largest for the lowest tier task group. In the later periods the investment and capital stock of the lower tier task groups surpasses the higher tier task group. The steady state distribution has an asymmetric bell shape. The capital stock is the highest in the task groups 2 and 3, with higher tier task groups having gradually lower capital stock in the steady state due to the more substantial effect of technology and investment on their productivity growth. To better understand the dynamics of capital accumulation we further explore the dynamics of capital intensity.

We define capital intensity as the ratio of the capital stock to labour used in production. The measure is directly linked with Marxian concept of the organic composition of capital, measured as a ratio of capital c divided by total value produced by labour $s + v$. Throughout this chapter we use the terms capital intensity, value composition of capital and organic composition of capital interchangeably. In all the cases we refer to the definition in the

Figure 6.4: Investment and capital stock - the closed economy model (Source: own work)



(a) The evolution of investment

(b) The steady state distribution of investment

(c) The capital stock evolution

(d) The steady state distribution of capital stock

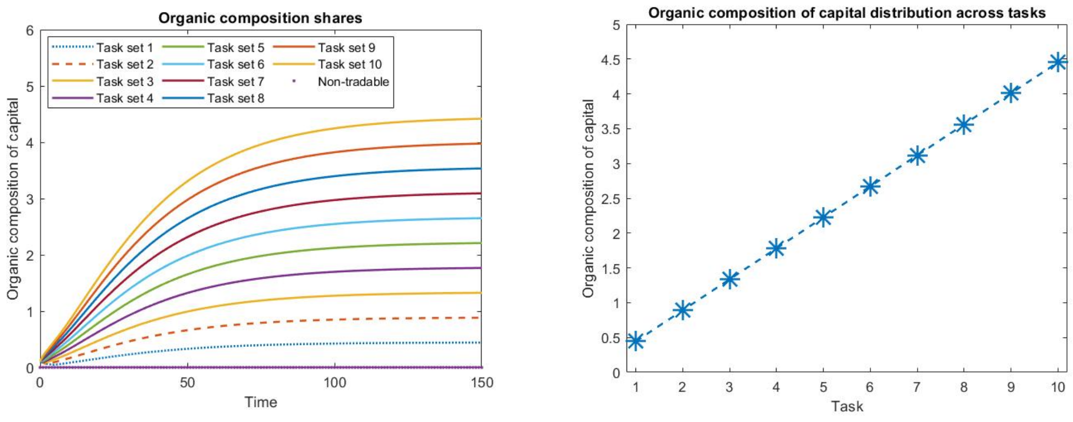
equation 6.5.18.

$$CI_j(t) = \frac{k_j(t)}{l_j(t)} \tag{6.5.18}$$

The disaggregate evolution of capital intensity and its steady state distribution between different task groups can be seen in figure 6.5. We can see that, as opposed to the evolution of value, employment, investment and capital stock, the capital intensity evolution exhibits no specific transitional process dynamics. The distribution of capital intensity between task groups is stable throughout the whole period. The distribution is linear with respect to task order, reflecting the differences of the effect of capital on technological productivity growth between different task groups, which is defined in linear steps.

The results of the closed economy model indicate that it represents a good starting point for our investigation of the medium-term open economy dynamics. On the one hand, it reproduces the reference model results of the supply driven structural change (Acemoglu & Guerri, 2008). The employment dynamics, productivity dynamics as well as price dynamics corresponds to the reference model results, with the main difference that instead of 2 different sector/task groups we analysed the effect of more granular, 10 different sector/task

Figure 6.5: Capital intensity - the closed economy model (Source: own work)



(a) Evolution of the capital intensity

(b) Steady state distribution of the capital intensity

groups that are characterized by the differences in the supply-side constraint. On the other hand, it also reproduces the main aggregate dynamics of the Solow-Swan growth model, which is a basic element of our reference model and represents a medium-term technological cycle in our broader conceptualization of the technological change and technological growth. The non-tradable sector, of course, in the dynamics of the closed economy does not contribute to anything worth mentioning. It is included only to enable easier generalization and implementation within the model with 2 regions and international trade.

The choice of 10 discrete task group structure makes a model numerically solvable and enables fine enough granularity to analyse the effect of granular and heterogeneous structure of production on the international trade and uneven development. The models exhibiting 2 or 3 discrete sectors simply do not offer large enough granularity with respect to their effect on both closed economy structural change dynamics, as well as global dynamic patterns explored in the following section. With relatively fine discrete disaggregation we also avoid working with too simplifying assumptions regarding the major sectors (primary, manufacturing and service) that can be subjected to severe critique. Instead, disaggregation on level of large task groups is made, that is easier to justify and also corresponds to the developments in the international economy in the last decades, with increasing share of production being conducted in value chains, drastically increasing the share of traded intermediaries. In the next section we structure the model of global trade with 2 regions.

The medium-term steady state should not be interpreted as a long term stagnation. Our focus on the medium-term limits our exploration mainly on the dynamic part, while the slowdown of the growth when it approaches the steady state is just an intermediate period before a next wave of medium-term dynamics begin with changes happening in the global production constraint. By focusing on the medium-term we focus on the bounded dynamics within a certain global technological paradigmatic framework, which cannot represent a realistic conceptualization of the long-term growth. Nevertheless important structural dynamics can be analysed within the assumed medium-term framework.

6.6 Model of international specialisation with 2 regions

6.6.1 Model Equations

Main definitions

We define two regions. Index $c \in (1, 2)$ indicates regions 1 and region 2. Since our aim is to identify and examine the supply-side endogenous mechanisms, which contributes to the perpetuation of uneven development, and do not depend on the exogenous differences between regions, we assume that all the structural characteristics of the regions are the same. The only difference that remains is the difference in the initial state of output.

Our definition of task groups remains the same as in the closed economy model, defined by the equation 6.5.1. Every disaggregate variable is thus characterized by the index $c \in (1, 2)$ indicating a region and index $j \in S_j$ indicating a task group.

Production constraint

The production constraints for tradable and non-tradable task groups are the same as in the closed economy model, defined by the equations 6.5.2 and 6.5.3. The only difference is that the task group outputs, labour and capital stock are all specific for the region. $A_{NT} = 2$ as in the closed economy model.

$$q_{cj}(t) = l_{cj}(t)^{\alpha} k_{cj}(t)^{j/10} \quad \forall j \in S_j \ \wedge \ \forall c \in (1, 2) \tag{6.6.1}$$

$$q_{NTc}(t) = A_{NT} l_{NTc}(t) \tag{6.6.2}$$

The global total output is a composite aggregate that is defined by the Leontief production function, similarly as in the closed economy model (equation 6.5.4). However, because we allow trade in tasks, the output of specific tasks can cross border between the regions. This means that the global output is not defined on the regional level, but on the global level. Since we assume market clearing, the global total output is defined by the Leontief production function, which has as its arguments the sums of each task group output from both regios.

$$Q(t) = \min_{\forall j \in S_j} \left(\sum_{\forall c \in (1,2)} q_{cj}(t) \right) \tag{6.6.3}$$

Aggregates

We assume full employment in both regions similarly as in the closed economy model. In addition to that, the size of the labour force is assumed to be the same in both regions, eliminating any differences due to the sheer size of the regions.

$$\sum_{j \in S_j} l_{cj}(t) = L_c \quad \forall c \in (1,2) \qquad L_1 = L_2 = L = 100 \tag{6.6.4}$$

The aggregate variables for the investment and capital stock are naturally specific for the region.

$$K_c(t) = \sum_{i \in S_j} k_{cj}(t) \quad \forall c \in (1,2) \tag{6.6.5}$$

$$I_c(t) = \sum_{j \in S_j} i_{cj}(t) \quad \forall c \in (1,2) \tag{6.6.6}$$

International value and profit

The global value of the aggregate output $v_Q(t)$ is defined in the same manner as in the closed economy model (equations 6.5.8 and 6.5.9), by summing the direct and indirect labour required for the production of one unit of global aggregate output.

$$v_Q(t) = \frac{L_1 + L_2 + \delta(K_1(t) + K_2(t))v_Q(t)}{Q(t)} \tag{6.6.7}$$

$$v_Q(t) = \frac{L_1 + L_2}{Q(t) - \delta(K_1(t) + K_2(t))} \tag{6.6.8}$$

The global value of output is crucial for the dynamics of international trade and specialization, as it determines the cost of capital investment, for which the law of one price is assumed.

In contrast to the closed economy model, in which we used the unmodified law of value to define the value of the output of each task group, we use our modified worldwide law of value to derive the international values. With this we account for the region-wide differences in productivity, which lead to region-wide differences in the value of labour power *ceteris paribus*. This affects relative factor costs and thus not only medium-run technological progress driven by investment, but also medium-run specialization patterns between the regions, as extensively discussed in the chapter 5. International value for the output of each task group is define by $v_j(t)$.

The distribution of the global output between the regions is based on the proportion of international value that was produced on aggregate in each region. This proportion represents a basis for the nominal wage ratios between regions, which correspond to the differences in the productivity of the tradable sectors as a whole. We define the region specific productivity of the tradable group of tasks $P_c(t)$ as the share of all of the international value produced in all of the tradable sectors of the region c, divided by the labour spent in production in all the tradable sectors of that region.

$$P_c(t) = \frac{\sum\limits_{\forall j \in S_j \setminus NT} q_{cj} v_{cj}}{\sum\limits_{\forall j \in S_j \setminus NT} (q_{1j} v_{1j} + q_{2j} v_{2j})} \frac{1}{\sum\limits_{\forall j \in S_j \setminus NT} l_{cj}} \tag{6.6.9}$$

$P_c(t)$ is not a region specific measure of real productivity, but instead a measure of international competitiveness in nominal terms that determines both nominal wage ratios and also represents the weights with which the labour spent on production of each region is weighted in the main definition of the worldwide value - as discussed in chapter 5.

With the effect of region wide productivity differences taken into account in the variable $P_c(t)$ we can define the international value for each task group, as defined by the equation 5.3.1 in chapter 5. The relative productivities in the tradable groups of tasks represent long term differences in the economies international capacities and their competitiveness. The effect of $P_c(t)$ on wages and international prices is lagged. Tradable groups of tasks of course have only one international value, defined by $v_j(t)$ as discussed in the chapter 5.

$$v_j(t) = \frac{l_{1j}(t)\frac{2P_1(t-1)}{P_1(t-1)+P_2(t-1)} + l_{2j}(t)\frac{2P_2(t-1)}{P_1(t-1)+P_2(t-1)} + \delta(k_{1j}(t) + k_{2j}(t))v_Q(t)}{q_{1j}(t) + q_{2j}(t)} \tag{6.6.10}$$

The value of the non-tradable sector remains the same as before, as there is no difference between the generalized law of value and unmodified law of value in cases where there exist no international trade. Similarly, as in the closed economy model (equations 6.5.11 and 6.5.12), the profits and expected profits are defined as the surplus value and expected surplus value of each task group separately. The value of the labour power is defined similarly as in the closed economy model, with the measure of surplus value being the same in both regions $msv = 0.5$. In other words, cross-regional ratio of the aggregate mass of wages corresponds with the cross-regional ratio of the aggregate outputs.

$$\pi_{cj}(t) = q_{cj}(t)v_j(t) - wl_{cj}(t) - \delta k_{cj}(t)v_Q(t) \quad \forall j \in S_j \wedge \forall c \in (1, 2) \tag{6.6.11}$$

Expected profits are equal to the expected surplus value at given value levels.

$$\pi^e_{cj}(t+1) = q_{cj}(t+1)v_j(t) - wl_{cj}(t+1) - \delta k_{cj}(t+1)v_Q(t) \tag{6.6.12}$$

International trade

Since specific task outputs from the tradable groups of tasks can cross borders, each region's aggregate output is conditioned by trade. International trade assures that markets clear and that each region obtains the same shares of output of all task groups, regardless of its specialization in production. The share of the aggregate output that is available to a region $Q_c(t)$ equals the share of international value it produces on the international markets.

$$Q_c(t) = \frac{\sum\limits_{\forall j \in S_j \setminus NT} q_{cj} v_{cj}}{\sum\limits_{\forall j \in S_j \setminus NT} (q_{1j} v_{1j} + q_{2j} v_{2j})} Q(t) \tag{6.6.13}$$

The trade variable T_{cj} describes the quantity of trade in output of the task group j from the perspective of the region c. A positive value of $T_{cj}(t)$ represents a quantity of exports and a negative value represents a quantity of imports respectively.

$$T_{cj}(t) = q_{cj}(t) - Q_c(t) \quad \forall j \in S_j \setminus NT \tag{6.6.14}$$

Throughout this chapter we assume a strict balance of payments constraint. We assume that trade must be balanced at any point and do not allow for any surpluses or deficits.

$$\sum_{\forall j \in S_j \setminus NT} \Big(T_{cj}(t) v_j(t) \Big) = 0 \quad \forall c \in (1,2) \ \wedge \ \forall t \tag{6.6.15}$$

The equation 6.6.15 captures the assumption of our balance of payments constraint.

The capital accumulation equation

Both regions are assumed to have the same exogenous investment rate ($s = 0.5$) in the similar manner as in the closed economy setting. Analogous to the equation 6.5.13 from the closed economy model, we define the aggregate investment for each of the regions separately. At this stage, we assume that all the capital accumulation is domestically driven and that capital cannot cross borders. Later we will abandon this assumption and adjust the model accordingly. For now, the investment is determined by the equation 6.6.16.

$$I_c(t) = sQ_c(t-1) \tag{6.6.16}$$

The aggregate investment represents a constraint for the investment in the production process corresponding to each task group - i_{cj} for each region, as in the closed economy setting (equation 6.5.14). The capital depreciation rate is universal and the same for both regions and all task groups ($\delta = 0.05$).

$$\sum_{j \in S_j} i_{cj}(t) = I_c(t) \quad \forall c \in (1,2) \tag{6.6.17}$$

Analogous to the equation 6.5.15 of the closed economy model, the capital accumulation is defined by the capital appreciation and new investment specific for each task group and each region.

$$k_{cj}(t) = (1-\delta)k_{cj}(t-1) + i_{cj}(t) \quad \forall j \in S_j \;\wedge\; \forall c \in (1,2) \tag{6.6.18}$$

The Main Optimization Equation

The profit maximization equation follows the same principles as discussed in the closed economy model section. The object of maximization are the total expected profits under a series of domestic and international constraints.

$$\max_{i_{cj}(t),\, l_{cj}(t)\; \forall j \in S_j \,\wedge\, \forall c \in (1,2)} \Big(\sum_{j \in S_j} \sum_{c \in (1,2)} \pi^e_{cj}(t) \Big) \tag{6.6.19}$$

The maximization of expected profits is again reduced to the alternative distributions of employment and aggregate investment among the tasks in each region. The maximization problem with all the constraints is expressed in the equation 6.6.20.

$$\begin{aligned}
&\max_{i_{cj}(t),\, l_{cj}(t)\; \forall j \in S_j \,\wedge\, \forall c \in (1,2)} \left\{ \sum_{j \in S_j} \sum_{c \in (1,2)} \Big(\pi^e_{cj}(t) \Big) \right\} s.t. \\
&1.) \quad \pi^e_{cj}(t) = q_{cj}(t)v_j(t-1) - wl_{cj}(t) - \delta k_{cj}(t) v_Q(t-1) \\
&\qquad\; \forall j \in S_j \;\wedge\; \forall c \in (1,2) \\
&2.) \quad I_c(t) = sQ_c(t-1) \quad \forall c \in (1,2) \\
&3.) \quad \sum_{j \in S_j} i_{cj}(t) = I_c(t) \quad \forall c \in (1,2) \\
&4.) \quad \sum_{j \in S_j} l_{cj}(t) = L \quad \forall c \in (1,2) \\
&5.) \quad k_{cj}(t) = (1-\delta)k_{cj}(t-1) + i_{cj}(t) \quad \forall j \in S_j \;\wedge\; \forall c \in (1,2) \\
&6.) \quad \sum_{c \in (1,2)} q_{cj}(t) = \sum_{c \in (1,2)} q_{ci}(t) \quad \forall j, i \in S_j
\end{aligned} \tag{6.6.20}$$

The main differences when compared to the equation 6.5.17 of the closed economy model are the double expressions for each of the regional constraints and the modification of the equality between output of each of the task groups, which is defined globally as opposed to regionally, since international trade in tasks is allowed. Each region's aggregate investment is determined by the previous year's region-wide output and the exogenous investment rate determined by the distribution between capitalist and working class. Both regions are constrained by the full employment assumption and have the same size of the workforce. The difference in the development between the regions is captured by the differences in their capital stock. Capital accumulation equation is defined for each region separately and determines the productivity of the production process associated with each task group.

6.6.2 Results

Initial conditions

While there is no difference between the assumed structural characteristics of both regions, the only and the main point in which regions differ within the analysed medium-term technological cycle are their initial conditions. The initial conditions for the model are set in the following way.

The initial condition for the region 1 is the same as the initial condition explored in the closed economy setting and is defined by $k_{1j}(0) = 1 \; \forall j \in S_j \backslash NT$. The initial condition for the region 2 is assumed to have the same distribution of capital stock and labour as the analysed region in the closed economy setting at time $t = 100$. If $k_j(100)$ and $l_j(100)$ denote capital stock and labour values at $t = 100$ within the closed economy model, then initial condition for region 2 can be expressed as $k_{2j}(0) = k_j(100)$ and $l_{2j}(0) = l_j(100)$.

Such initial conditions are chosen for multiple reasons. First, with such initial conditions we achieve the internal consistency of the resources spent within the country. If we treat each region in isolation, both initial conditions satisfy the fact that they are on the trajectory of growth characteristic for the closed economy model. Second, the difference between the regions is reduced to a time lag on the trajectory of growth defined by the closed economy model. In other words, region 1 is lagging behind region 2 in its investment into technological capabilities of the medium-term technological cycle. If both regions would be examined in isolation, the time lag would be the only difference between the regional economies, while the closed economy growth trajectory would still have the same shape. This contributes to the analysis of the effects of international integration and trade, with respect to its effect on the structure of the economies and its divergence from the closed economy structural growth trajectory. Third, the lag in the technological development leads to the overall differences in total output, which is the primary concern of our analysis. The initial total output that each region produces, and is derived out of the assumed time lag of the closed economy growth trajectory, is $Q_1(0) = 4.39$ and $Q_2(t) = 12.74$ respectively.

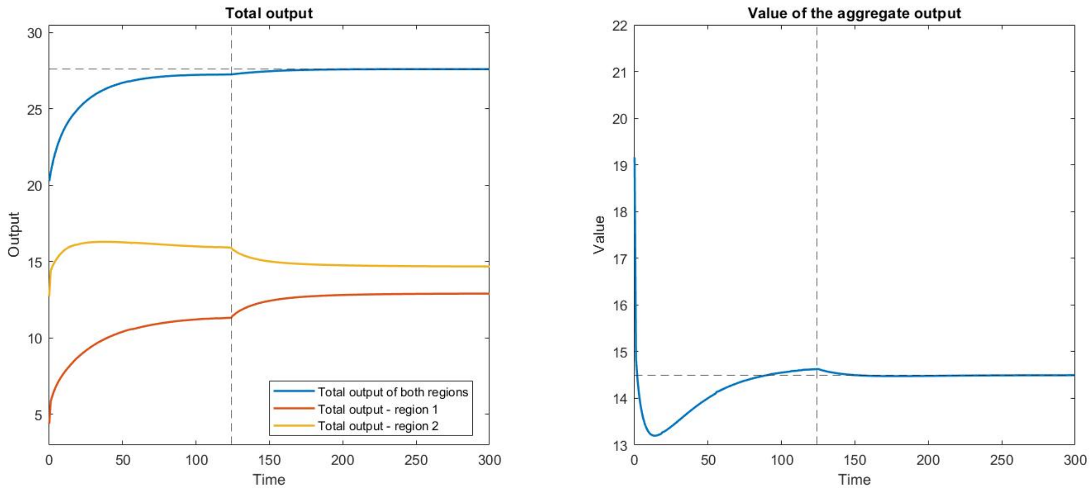
Total output and the diverging steady states

Similarly as with the closed economy model, we obtain the results with numerical interior-point algorithm for constrained non-linear optimization for each discrete step.

The results for global output as well as total output of the each region can be seen in the figure 6.6. When comparing with the evolution of total output of the closed economy model (figure 6.1) many differences can be observed.

One of the most relevant results is the absence of fast convergence to a common steady state

Figure 6.6: The evolution of aggregate output in the 2 region model (Source: own work)



(a) The evolution of aggregate output

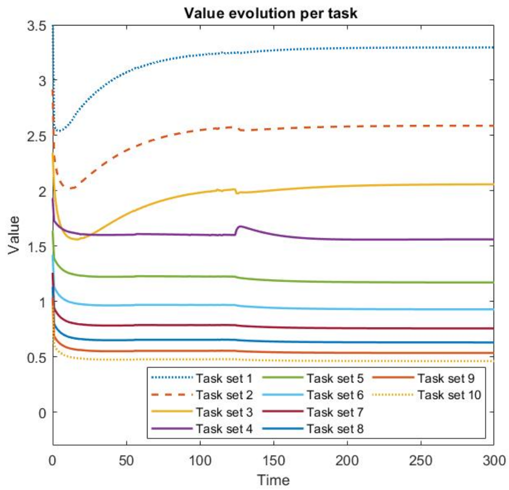
(b) The value of aggregate output

for both regions. If a closed economy model predicted convergence to a stable steady state in a period of less than 100 time units, we can observe a stable difference between the regional aggregate output still after 300 time units, with relative stability of regional difference that surpasses the medium-term period.

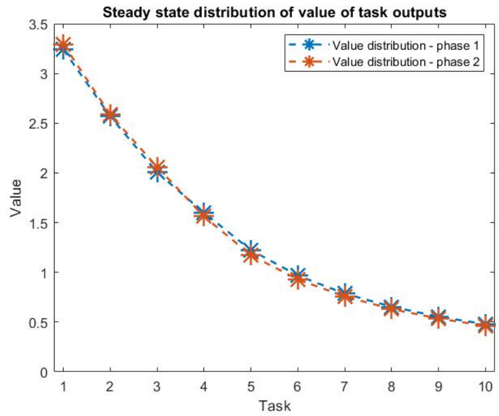
The second important results relates to the benefits of international trade and specialization. We can see that, despite the same size of the regions in the 2-region model and the region in the closed economy model, the aggregate global output of the 2 regions combined in an international cooperation and trade significantly surpasses the output of the 2 regions of the same size, that would develop as closed economies. While the output of a closed economy region in steady state amounts to $Q_{SS} = 12.87$, the global output of combined regions surpasses that amount by more than 2-fold as it equals $Q_{SS} = 27.25$. The scale effects induced by specialization contribute significant part of this differences and conform to the conceptualizations of the new trade theory regarding the overall benefits of international specialization driven by the increasing return effects. However, benefits of the international specialization are distributed unevenly between differently developed regions. While in the closed economy model rapid convergence to steady state is achieved, in the multi-regional model the regions have diverging long term steady states and reaching the final steady state involves substantial structural change and a phase transition.

Despite the fact that the two regions diverge to different steady states, both steady states are characterized by higher regional aggregate outputs than the aggregate output of the closed economy setting. This characteristic of the model conforms to the idea of the relative comparative advantage. Despite the fact that international trade and specialization creates different steady states for different regions, each of them benefits from specialization in terms of the aggregate output. However, the benefit is nevertheless distributed highly unevenly. On the one hand, the final steady state aggregate output of the less developed region amounts to $Q_{1SS} = 12.91$, which is less then 1% larger than the closed economy steady state. On the other hand, the initially more developed region exhibits a steady state of $Q_{2SS} = 14.69$, which is more than 14% higher than the closed economy steady state.

Figure 6.7: The evolution of the international value in the 2 region model (Source: own work)



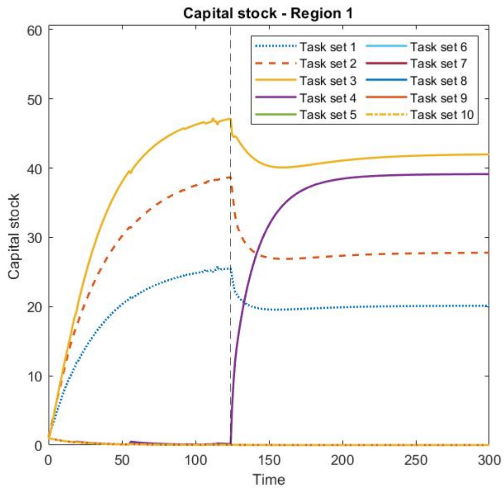
(a) The international value evolution



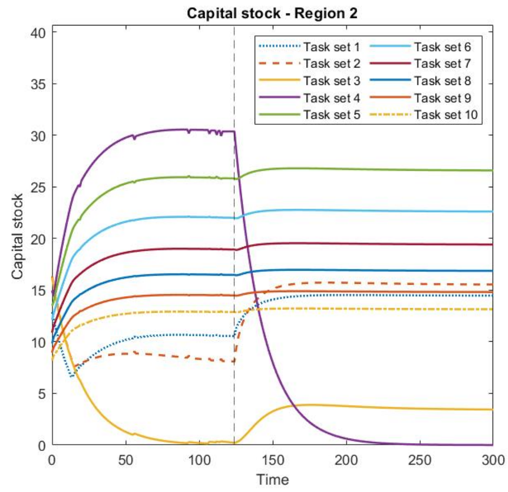
(b) The international value distribution

The dynamics of the value of the aggregate output are quite similar when compared to the value evolution in the closed economy setting (figure 6.2). Similarly, we can see the initial drop in the value of the aggregate output not only due to the technology and investment driven productivity improvements, but also due to scale effects linked to specialization and cross-regional distribution of labour and investment. The steady state value is lower than in the closed economy, indicating that larger quantity, quality and variety can be produced with lower amounts of direct and indirect labour when international cooperation, specialization and trade is allowed, as opposed to the development within closed economy. The upward adjustment of value is a bit more pronounced as in the closed economy setting. The core of explanation for the upward adjustment remains the same as in the closed economy setting, linked primarily to the increases in the indirect labour spent in production and the structural change linked with Baumol's cost disease. The additional factor that contributes additional adjustments in the model with international trade is the Samuelson-Balassa effect, which has a complex non-linear effect on the value dynamics, as it drives the costs of non-tradable sectors even further up, making the upward adjustment slightly more pronounced. Disaggregated value dynamics and distribution is presented in figure 6.7. We can see dynamics similar to the closed economy model, albeit value increases of the lower task group tiers are more pronounced not only due to the reasons analysed within the closed economy setting, but also due to the effects of international specialization and indirect effects of over-investment of the less developed country in the production of the lower task group tiers.

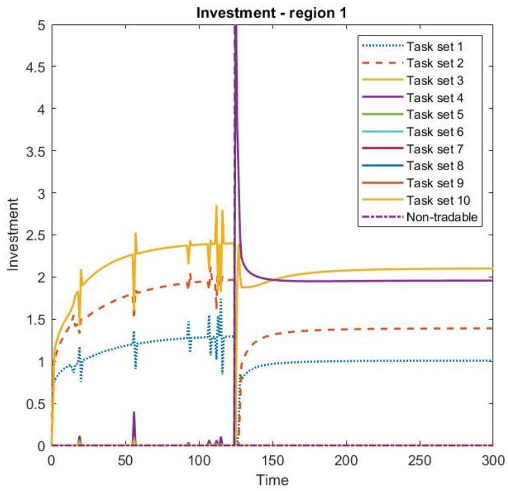
Figure 6.8: The evolution of capital stock in the 2 region model (Source: own work)



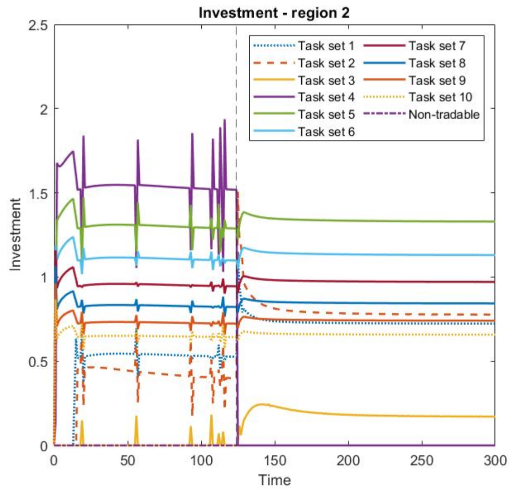
(a) The capital stock in the region 1



(b) The capital stock in the region 2



(c) The investment in the region 1



(d) The investment in the region 2

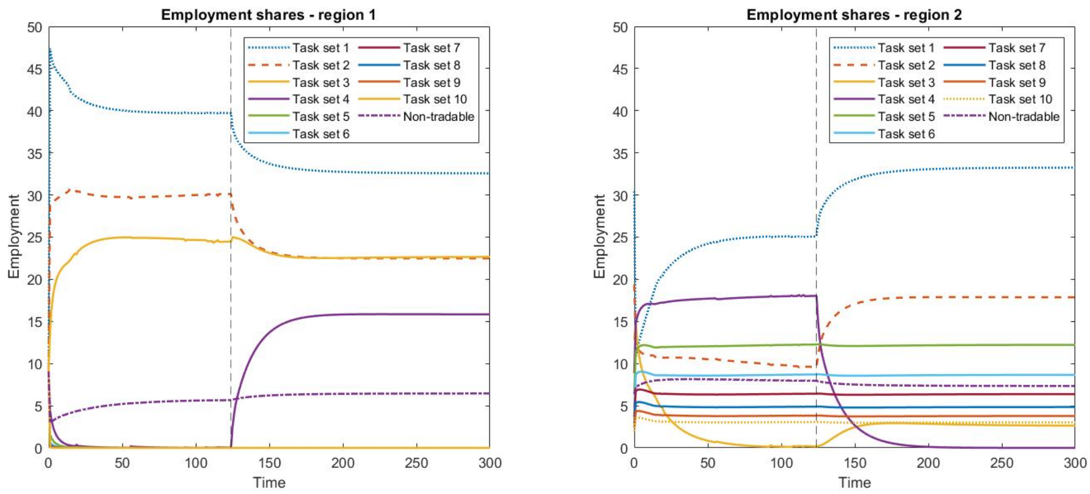
Endogenous phase transition

The most surprising result of the 2-region model is the endogenous phase transition that can be clearly observed in all the main variables of the model. Generally, a phase transition is a discontinuous change in the properties of the system. In out model, an apparent convergence of all model variables towards a certain steady state is abruptly disrupted at the $t = 124$. The abrupt change affects all the main model variables and pushes them eventually to a new, different steady state. For that reason, we call this phenomenon an endogenously driven phase transition, with a phase prior to it labelled as phase 1 and phase post the transition point labelled as phase 2. The properties and the underlying mechanisms driving the phase transition are discussed in detail by analysing every variable of the model separately.

International specialization and trade

A main characteristic that differs the model with 2 regions with a model of closed economy is the ability to internationally trade individual task group outputs. This creates a specialisation pattern driven by the relative comparative advantage. Since the region 1 lags behind the region 2 in the medium-term technological cycle it also lags behind in the aggregate output, aggregate wages and consumption. Since the global aggregate output and its value determine the cost of investment, while the wages are determined by the local region-wide development, it is an intuitive and expected result that profit maximization leads to heterogeneous specialization across task groups.

Figure 6.9: The evolution of the employment in the 2 region model (Source: own work)



(a) The employment in the region 1

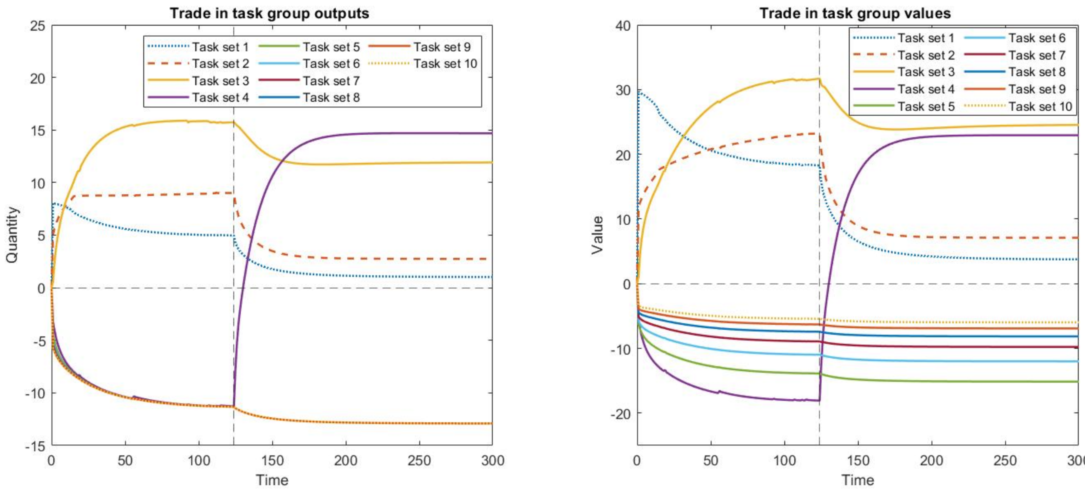
(b) The employment in the region 2

As can be seen on the figure 6.8 and figure 6.9, in the first phase the capital stock, investment and employment of the less developed region are entirely limited to the first three tier task groups only. On the other hand, the resources of the more developed region are more evenly spread, consisting both employment, investment and capital stock in the higher tier task groups, as well as some capital and employment in some of the lower tier task groups, albeit significantly lower amounts when compared to the less developed region.

In the phase 2 similar international specialization pattern emerge, with the resources of the less developed region, consisting of investment, capital stock and employment, limited to the first four tier task groups and the more developed region again having resources spread more evenly.

The international trade in quantities and international values can be seen in the figure 6.10. The results are presented from the viewpoint of the less developed region - positive values represent exports and negative values imports. We can see that the comparative advantage drives international trade and specialization. The less developed country exports output from more labour intensive task groups and imports the outputs from more capital and technology intensive task groups. It is interesting that the most labour intensive task groups exhibit limited international trade both in terms of quantity and value. The less developed region exports predominantly the output of task group 3 before the phase transition and output of the task group 4 after it.

Figure 6.10: The trade from the perspective of the less developed region (Source: own work)



(a) The trade in quantities of task outputs **(b)** The trade in international values of task outputs

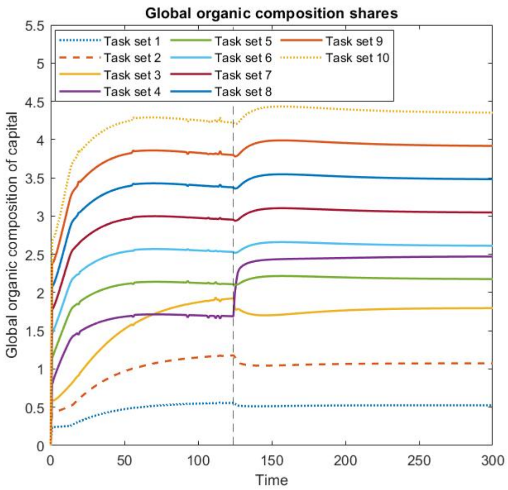
The analysed pattern of international specialization, driven by the profit maximization, conforms to our idea that international specialization pushes less developed countries into specialization of those task groups that have the least potential for productivity growth. No only that, the international specialization prevents the less developed countries from participation in the production of higher tier task groups that have high potential for technological productivity growth and exhibit the greatest effects of scale and can contribute to the most substantial labour saving improvements in the production process. The less developed country is thus stuck with the above average production of highly labour intensive tasks that do not have the potential to be technologically substantially upgraded within the medium-term technological cycle.

Conversely, the developed region does not specialize only in the higher tier task groups. Due to the great scale effect of the task groups that have the greatest potential for the productivity growth, these higher tier task groups tend to employ limited amount of labour force, allowing the developed region to increase its participation in the non-tradable production as well as in the lower tier task groups. This makes the production structure of the developed region much more balanced when compared to the lagging region, which has resources invested and employed only in the lowest tier section of the tradable task groups. These differences in the production structure, driven by the profit maximization, appear to be the main underlying reason for the long term persistence in the uneven development, in this case observed in the form of diverging aggregate steady states.

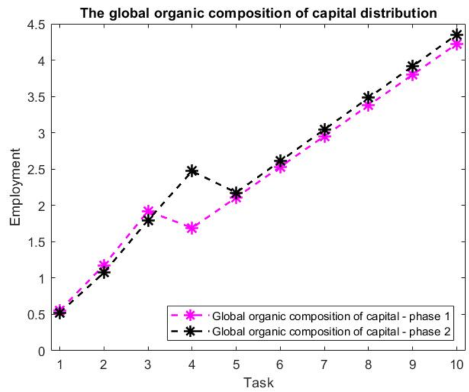
Pivoting point of the phase transition - complete specialization

The lagging region specialization structure appears to be the driving force behind the phase transition. It is the lack of profitability that limits its production structure to only the first three task group tiers, and it is the endogenous change in its social region-wide characteristics that enable it to shift and extend the set of task groups it specializes in to include also the fourth task group tier. For that reason, we examine in detail the characteristics of phase transition and differences between the steady states in the period before and after the phase transition, as well as discuss the broader social characteristics and endogenous drivers of such transition.

Figure 6.11: The evolution of global capital intensity in the 2 region model (Source: own work)



(a) The global capital intensity evolution



(b) The global capital intensity distribution in each steady state

The main regularity observed in the closed economy model is presented in the figure 6.5. There we can see, that in the conditions of closed economy, profit maximization creates a condition for stable and balanced growth, with capital intensities having fixed proportions throughout the whole dynamic evolution. Not only are capital intensities exhibiting no disorderly transnational dynamics, also their proportions are fixed and linear, corresponding to the assumed linear differences in the technical marginal productivity of capital in different task groups.

When comparing the evolution and steady state distribution of capital intensity obtained for the closed economy model with the results of the model with 2 regions, we can immediately see that the growth of capital intensity no longer happens in fixed proportions, but is unbalanced. In figure 6.11 we can see that both the evolution of capital intensity is not growing in fixed proportions and its distribution both in the steady state before and after the phase transition is not in a strict linear function, albeit it roughly resembles it. What drives these differences in the development?

The irregularities appear due to the international specialization. In the closed economy setting, capital investment could be proportionally distributed between task groups based on the effect of capital on the productivity. In the case of international specialization between the two regions, however, the initial development of productive forces sets a constraint to the less developed region in terms of which task groups are potentially profitable and into which it can invest resources into under the given assumptions of profit maximization. The fact that less developed region is endogenously constrained to production of only first three task group tiers distorts the linear development of the global capital intensities.

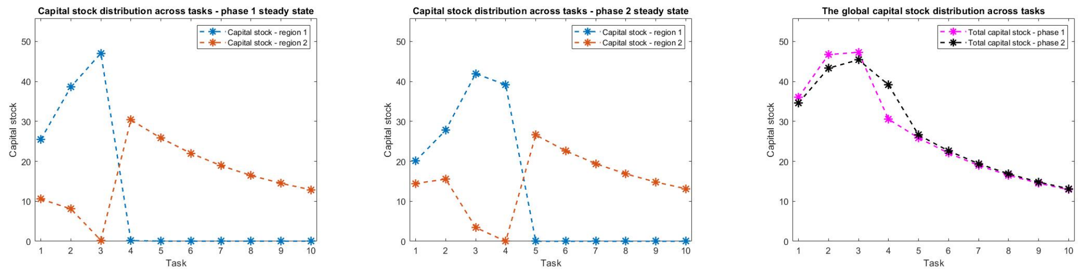
From the perspective of the less developed region in the phase 1, the task group 3 is the task group with the most potential for the productivity growth among the task groups that can be profitably undertaken in the region. For that reason, the less developed region puts major share of its resources into the production process of task group 3, in order to make them as productively as possible. This leads to the complete specialization of the task group 3, with all the global output being produced by the less developed region. In addition to that, the less developed country invests unproportionally into the task group it fully specializes in, which exhibits a higher capital intensity than what would be expected under the trajectory of the closed economy. In our model of international trade with two regions only one task group exhibits complete international specialization at any point in time. The task group that exhibits complete specialization is always the highest task group tier that is still profitable for the less developed region. We call that task group - the pivoting point of specialization.

Endogenous technological upgrading of the developing region

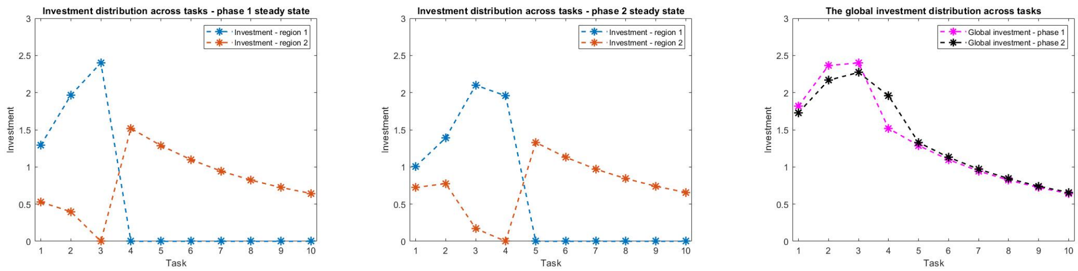
In figure 6.11 we can observe that discussed patterns of specialization lead to global capital intensity steady state to be distributed differently as in the closed economy model. The fact that less developed region is investing above proportionately (in comparison to the closed economy trajectory) into the lower task group tiers creates a break in the linearity. The capital intensity of the pivoting point task group 3 also gradually surpasses not only its linear proportion characterized by the closed economy trajectory, but even the capital intensity of the task group 4.

Therefore, albeit structural differences inhibit the full potential of the initially less developed region to reach the output levels of the developed region, the resources are spent among the profitable task group tiers in such a way, to slowly and gradually increase the share of the international output that is realized by the less developed region. The push to-

Figure 6.12: The distribution of the capital stock and investment in the 2 region model (Source: own work)



(a) The capital stock distribution in phase 1 steady state **(b)** The capital stock distribution in phase 2 steady state **(c)** The global capital stock distribution in each steady state

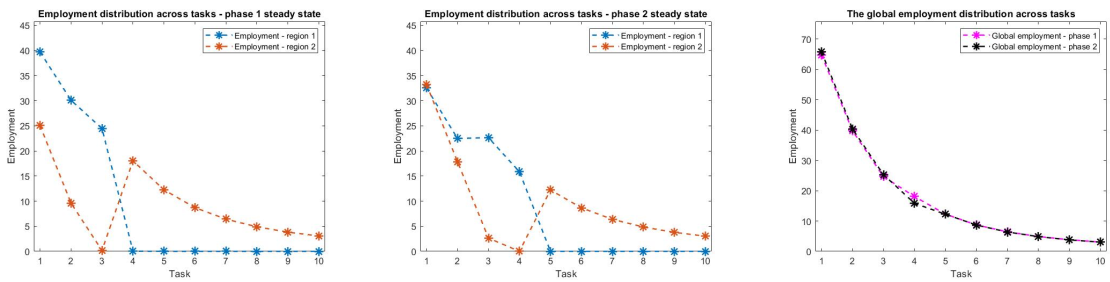


(d) The investment distribution in phase 1 steady state **(e)** The investment distribution in phase 2 steady state **(f)** The global investment distribution in each steady state

wards complete specialization of the highest task group tier that remains profitable and the relative over-investment in it (as well as other lower task group tiers) enables gradual and incremental increases in the size of value captured on the international markets, which indirectly leads to improvements of its nationwide productivity and wage levels.

These endogenous incremental improvements, however, reach a threshold that changes the profitability of the location of the task group 4, making it more profitable to be produced by the less developed country as opposed to the developed country, where it was produced in the phase 1. This creates a chain of events that initiate a phase transition to a new stable steady state in the medium-term.

Figure 6.13: The distribution of the employment in the 2 region model (Source: own work)



(a) The employment distribution in phase 1 steady state **(b)** The employment distribution in phase 2 steady state **(c)** The global employment distribution in each steady state

This transition can be interpreted as technological upgrading of the less developed region, which takes the form of a discontinuous break and can be seen globally and regionally as a phase transition. In figures 6.12 and 6.13 we can see the distributions of investment, capital stock and employment in the phase 1 steady state and phase 2 steady state. The main change during the phase transition is the change in the pivoting point of specialization - from the task group tier 3 to 4. This extends the opportunities for the capital driven technology improvements in the lagging region and substantially decreases the difference in the produced regional aggregate outputs. This can be seen in the figure 6.6. Prior to the phase transition, the steady state exhibits larger cross-regional difference in output than post transitional steady state, which marks substantial decline in the cross-regional difference in total output. In addition to that, the technological upgrading of the less developed region further increase the steady state global aggregate output.

Looking at the dynamic of investment, capital stock and employment around the timeframe of the phase transition in the figures 6.8 and 6.9 we can see that broad incremental improvements in the overall global and regional productivities changed local regional conditions of capital accumulation and profitability drastically. After a point when pivoting point changes and new task group becomes more profitable in the less developed country a quick reallocation of the productive activities of tier group 4 commences. The investment in the less developed region is subjected to an endogenous shock and its structure changes drastically. The investment into the pivoting task group of the next phase greatly increases, while the existing investment rates into lower task group tiers are substantially reduced. In the short-term time-frame of the phase transition, almost all of the resources are spent on achieving the new stable structure of both investment, capital stock and employment. This leads to a decline in the capital stock of the task groups of lower tiers and gradual establishment of a new steady state with stable investment and capital stock structure.

Polarization effect in the developed region

On the one hand, the phase transition and its structural adjustment represent the technological upgrading of the developing country. On the other side of the coin, the phase transition represents inter-sectoral changes that can explain the polarization process in the developed country. With polarization we refer to the widely analysed process of the changes in production structure, that favour the high and low extremes in terms of labour skill or capital complexity and the gradual disappearance (or lowering of the income) of the middle skill and medium complexity based production processes (Acemoglu & Restrepo, 2019, 2022; Autor, 2013). Polarization was predominantly examined as being driven by the specific form of technological changes, that were supposedly biased in favour of the increased demand for the lower and higher skilled jobs. While we do not explicitly examine skill structure of the labour power in our model, we can nevertheless interpret the task group tiers as indirectly characteristic of the complexities and skill within the production process. If investment is (as should be) interpreted broadly, as any expenditure of use values today, which increase productivity potential in the long run, the differences between employment in lower tier task groups and employment in higher task groups can be linked with not only different productivity of labour and different increasing return effects, but also with different skill and knowledge of the workforce required for a certain task, that can be accumulated through education and training. Tasks that are inherently labour intensive and have limited potential (within the medium-term framework) to have enhanced productivity growth with any kind of investment often correspond to low class employment, while tasks that have high increasing return effects on investment are linked with high skill, knowledge intensive production techniques.

In this context, polarization can be seen most easily on the figure 6.13, which depicts the distribution of employment in both phases. In the figure 6.13a we can see that even prior to the phase transition the steady state employment distribution in the developed country is somewhat polarized. This must of course be the effect of the less developed country specializing in the more labour intensive tasks. However, as we can see in the figure 6.13a and have extensively discussed earlier, the less developed country pushes its resources primarily into the task that is its pivoting point, leaving the lower task groups to competition with the production form the developed country. In the developed region this results in the employment distribution that is fairly balanced in the higher task group tiers but also includes some employment in the lower task group tiers. Before the phase transition the employment in task group 1 and 2 consist of roughly a third of the total employment in the developed region.

In the figure 6.13b we can see the steady state employment distribution after the phase transition. The phase transition creates a polarising effect on the employment distribution across tasks performed in the developed country. On the one hand, the phase effect changes the pivoting task group, for which complete specialisation is characteristic. While in the phase 1 the task group characterized by complete specialisation was of tier 3, in the second phase the task group that is exclusively produced by the developing country becomes tier 4. This leads to task group 4 employment in developed region to decline to zero, which relocates existing employment mostly between lower tier task groups, greatly increasing employment of task group 1, 2, and 3, as seen in the figure 6.9.

After the phase transition more than half of the employment of the developed region comprises employment of the task group 1 and 2 as opposed to mere third prior to the phase transition. While the overall increases of the employment in the higher tier are also present, the productivity and scale effects, as well as importance of large capital investments and technology, are so large that the additional employment and output cannot absorb the loss of the medium tier 4 capacity. In this sense the shock of phase transition between the steady states in our 2 region model exhibits a polarization effect on the employment opportunities within the developed region, increasing employment in most labour intensive task groups. This leads not only to the slight lowering of the overall standard of living in the developed country, but also explains the so called polarization effect - which we demonstrated is not driven by the form of the technological change, but by the specific form of international specialization driven by its disaggregate structural characteristics.

Endogenous drivers of production relocation

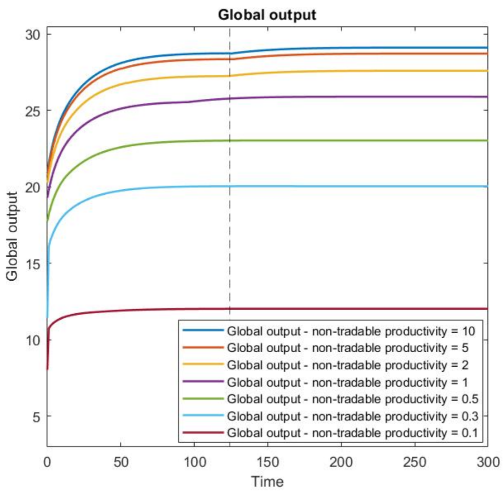
On of the most surprising results of the dynamics of the phase transition is linked with the interpretation of the abrupt complete relocation of the productive activities linked with the task group tier 4. While it is a common knowledge that the process of international integration and global value chain development is driven primarily politically, by the removal of the tariff and non-tariff barriers to trade and establishment of free-trade agreements, the model also offers an endogenous economic explanation, as to why the push towards outsourcing could be more pronounced in certain time periods. It might be that the actual development of the developing regions not only condition increases in production relocation but also endogenously drive them, as the capacity of the developing region increases with development and creates conditions for further outsourcing of more technologically sophisticated task groups. The development of underdeveloped regions in the 60s and 70s of the previous century is rarely discussed as an endogenous driver of the wave of increased international specialization that we are witnessing from the 80s and 90s onward. It could well be that the endogenous economic drivers are intertwined with the broader socio-political developments and any strict reduction of the problem to political or economic dimension might be overly reductionist.

6.6.3 Variation in the importance of the non-tradable sector

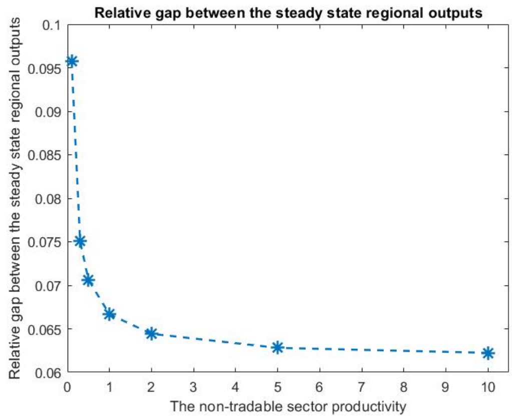
In this subsection we analyse the effect of the non-tradable segment of the economy on the dynamics of the regional development. We analyse 7 different values that characterize non-tradable task group productivity in the equation 6.6.2. The models are analysed with the following values of the constant determining the productivity of the non-tradable tasks: $A^1_{NT} = 10$, $A^2_{NT} = 5$, $A^3_{NT} = 2$, $A^4_{NT} = 1$, $A^5_{NT} = 0.5$, $A^6_{NT} = 0.3$, $A^7_{NT} = 0.1$. Lower or higher productivity of the non-tradable sector can be interpreted as variations in its size. Due to the Leontief production constraint the changes in the productivity of labour in the non-tradable segment inversely determines its size in terms of employment.

In the figure 6.14a we can see that decreasing the productivity of the non-tradable sector reduces the global aggregate output significantly. This is of course intuitive, as the labour available for the production of the tradable tasks becomes increasingly limited by increasing the size of the non-tradable sector. Because one of our main interests of our examination are the effect of the size of the non-tradable sector on the steady state output gap between

Figure 6.14: The evolution of global aggregate output and relative cross-regional output gap for 2 regional model with variation in the productivity of non-tradable segment (Source: own work)



(a) The evolution of the aggregate output



(b) The relative output gap in relation to the productivity of the non-tradable segment

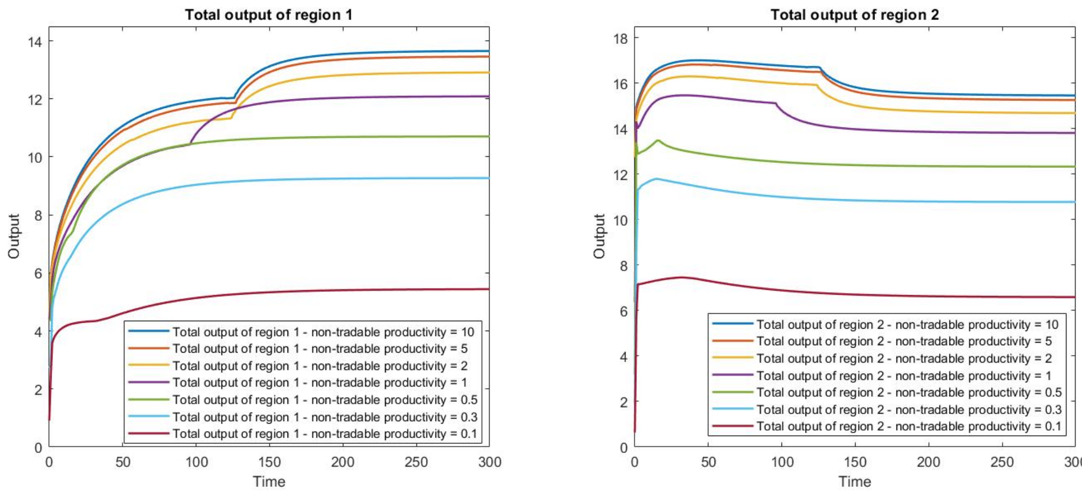
the regions, we define a relative cross-regional output gap $r(t)$, which represents the relative difference between the regional aggregate outputs.

$$r(t) = \frac{Q_{2SS} - Q_{1SS}}{Q_{1SS} + Q_{2SS}} \tag{6.6.21}$$

In the figure 6.14b we can see that the relative development gap between the regions increases with the size and importance of the non-tradable segment of the economy. On the one hand, in a scenario in which labour productivity of the non-tradable segment of the economy is the lowest and highest share of labour is employed in the non-tradable tasks, the gap between the steady state regional outputs approaches 10%. On the other hand, in a scenario in which labour productivity in the non-tradable sectors is high and this segment represents low share of total employment, the cross-regional relative gap approaches 6%.

In the figure 6.15 we can observe the dynamics of total output for each region and how the role of non-tradable sector affects it. We see that not only does the increased size and role of non-tradable sector reduces the global output and increases the relative gap between the regions, but also affects the phase transition process and the period in which it commences, or if it commences at all. General observation is that larger non-tradable sector contributes to faster phase transition to the final steady state.

Figure 6.15: The evolution of regional aggregate output with variation in the productivity of non-tradable segment (Source: own work)



(a) The evolution of the aggregate output - region 1 **(b)** The evolution of the aggregate output - region 2

6.7 Model of international specialization with 2 regions and capital mobility

In this section we analyse the same model of international specialization with two regions as before, with the only change being the introduction of the international capital mobility.

6.7.1 Model equation changes

All the model equations that we do not explicitly mention remain the same as in the previous section. We introduce full capital mobility by altering the investment constraints defined in the previous model by equations 6.6.16 and 6.6.17. Instead of constricting investment to the domestically determined investment, we impose a global investment constraint.

$$I(t) = sQ(t-1) \tag{6.7.1}$$

$$\sum_{j \in S_j} \sum_{c \in (1,2)} i_{cj}(t) = I(t) \tag{6.7.2}$$

In such a framework investment is free to flow across regional borders, to be invested under profit maximizing conditions. This can generate international investment flows between regions. Persistent international investment flows can generate cross-regional income flows, that emerge as profit claims from the investment made by the nationals of one region in another. For that reason we must differentiate between regional aggregate output and gross national income. We define outward investment flow from region c as $f_c(t)$.

$$f_c(t) = sQ_c(t) - \sum_{j \in S_j} i_{cj}(t) \tag{6.7.3}$$

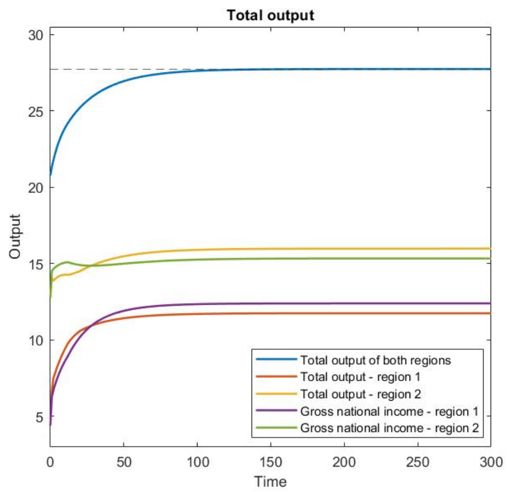
The outward capital stock $fk_c(t)$ owned by the nationals of region c generates profit flows of income proportional to its share in total aggregate capital. We define $G_c(t)$ as gross national income of the region c as the total output of region c modified by the cross-regional profit flows.

$$fk_c(t) = f_c(t) + (1-\delta)fk_c(t) \tag{6.7.4}$$

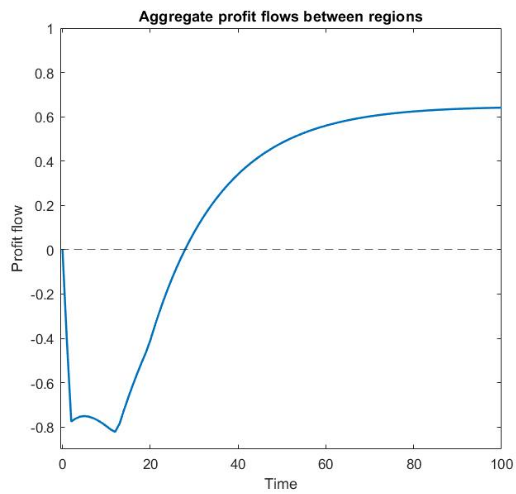
$$G_c(t) = Q_c(t) + msvQ(t)\frac{fk_c(t)}{K_1(t)+K_2(t)} \tag{6.7.5}$$

6.7.2 Model results

Figure 6.16: The evolution of aggregate output, gross national income and cross-regional profit flows in the 2 region model with capital mobility (Source: own work)



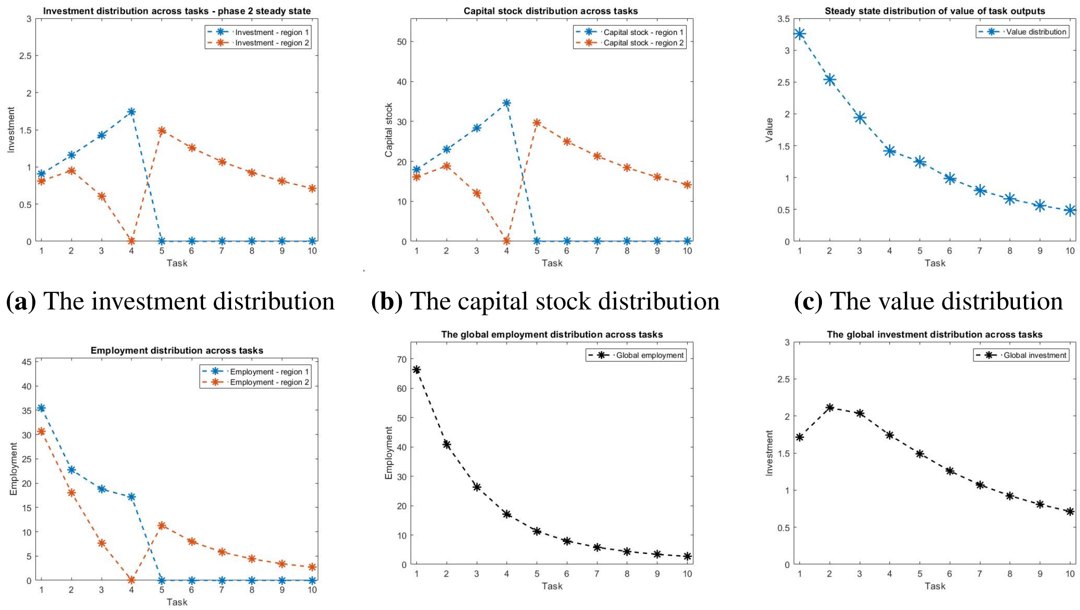
(a) The evolution of the aggregate output and gross national income



(b) The cross-regional profit flows between regions

The results of the model with two regions and capital mobility differ from the results of the model with no capital mobility in many aspects. In the figure 6.16a we can see the evolution of the global and regional aggregate output. There are three main differences when compared to the model with no capital mobility. First, there is no phase transition and the total output converges to a final steady state that remains stable. Second, the difference between the steady state of total output between the two regions is larger than in the model with no capital mobility. Not only is the uneven development stable through time and larger than in the model with no capital mobility, the steady state of the less developed region is below the steady state total output of the closed economy model. This means that in the case of capital mobility, the less developed region is actually worse-off than it would be, should it develop as a closed economy, under given assumptions. Third, the gross national income diverges from the aggregate output produced by each region, as investment and profit is allowed to flow across regional borders. Due to the steady state capital outflows from the less developed region, the gross national income of the less developed country is higher than its output. Nevertheless, the difference between the gross national incomes between the two regions remains larger than in the model with no capital mobility and the gross national income of the less developed region remains below the closed economy steady state value.

Figure 6.17: The distribution of the investment, capital stock, capital intensity and employment in the 2 region model with capital mobility (Source: own work)



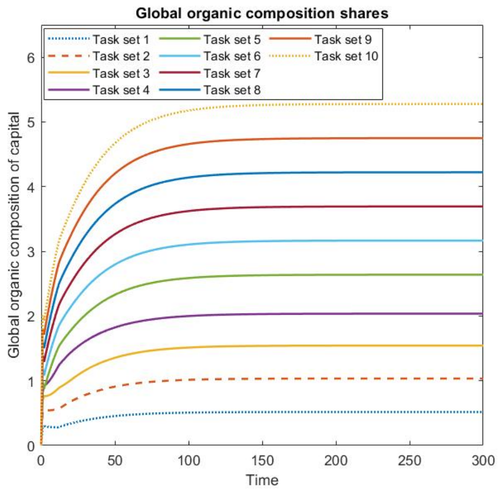
(a) The investment distribution **(b)** The capital stock distribution **(c)** The value distribution

(d) The employment distribution **(e)** The global employment distribution **(f)** The global investment distribution

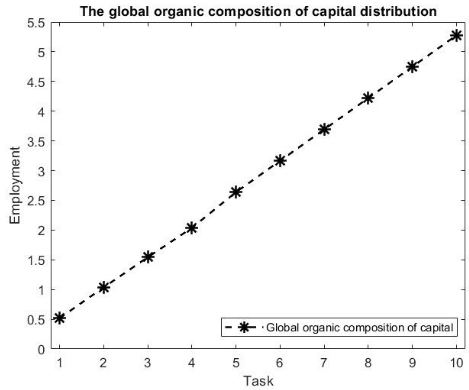
In the figure 6.16b we can see the profit flows between regions. The positive values represent outflows of profits from region 1 to region 2 and negative values represent inflows of profits from region 1 to region 2. We can see that in the initial period investment flows from the developed to less developed region creating negative profit flow for the less developed region, while near the medium-run steady state the flows reverse. The initial above average investment into the less developed region makes it possible to avoid a phase when it specializes in the tier 3 task group, instead immediately going for the structure of the final steady state by specializing in the tier 4 task group. This can be seen in the figure 6.17 that depicts investment, capital stock and employment distribution in the steady state.

The main differences when compared to the development in the model with no capital mobility can be seen on the disaggregate level. While the domestically driven investment in the model with no capital mobility creates non-linearities in the development of capital intensities that do not correspond with their differences in the marginal productivities of investment, leading to over-investment in the lower task group tiers in the less developed region, allowing capital mobility restores balanced growth of capital intensities across task groups. This can be seen in the figure 6.18, which depicts both balanced evolution of capital intensity, as well as its linear distribution in the steady state.

Figure 6.18: The evolution of global capital intensity in the 2 region model with capital mobility (Source: own work)



(a) The global capital intensity evolution

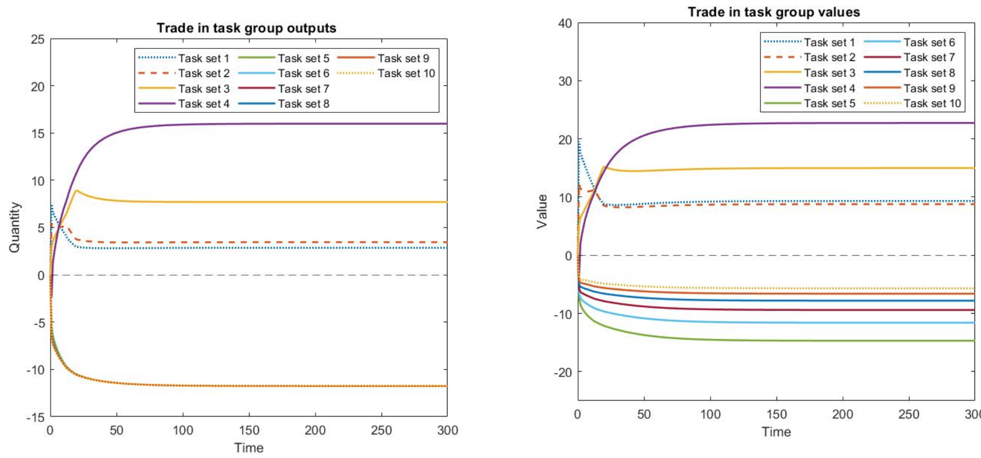


(b) The global capital intensity distribution steady state

The conditions of global capital accumulation increase the aggregate output when compared to the domestically driven accumulation. The global aggregate steady state output of domestically driven accumulation amounts $Q_{SS}(t) = 27.25$, while the global steady state output of the model with global investment flows is slightly larger, amounting $Q_{SS}(t) = 27.74$. We can get three insights regarding the dialectic between the domestic and global capital accumulation and its effects by comparing the two models. First, it is possible to produce larger global output when stable cross regional differences in development are larger in the medium-term. Second, while the domestically driven accumulation can distort the global capital intensity ratios and decrease the global aggregate output, such distortions invariably favour less developed regions. If accumulation of capital is domestically driven, the principal of the relative comparative advantage holds. Despite the fact that gains from international trade and specialization are highly unevenly distributed, both developed and less developed region gain from trade. However, if accumulation of capital is globally driven, the principal of the relative comparative advantage holds no longer, as the less developed region produces lower value when compared to the what it would produce in the closed economy setting.

The results of the model of international specialization with two regions and capital mobility are in sharp contrast with the perception of the effect of the capital mobility within the Marxist paradigmatic framework. Within the discussions concerning unequal exchange, an argument that was often used to describe the effect of capital mobility was its supposedly unifying effect. Completely free capital flows would gradually equalize wages, profits and the overall level of development (Shaikh, 1979, 1980). We have demonstrated that such simplifying assumptions, however intuitive they may appear, do not hold when disaggregate structural dynamics are included in the conceptualization. In fact, capital mobility creates

Figure 6.19: The trade from the perspective of the less developed region - model with capital mobility (Source: own work)



(a) The trade in quantities of task outputs

(b) The trade in international values of task outputs

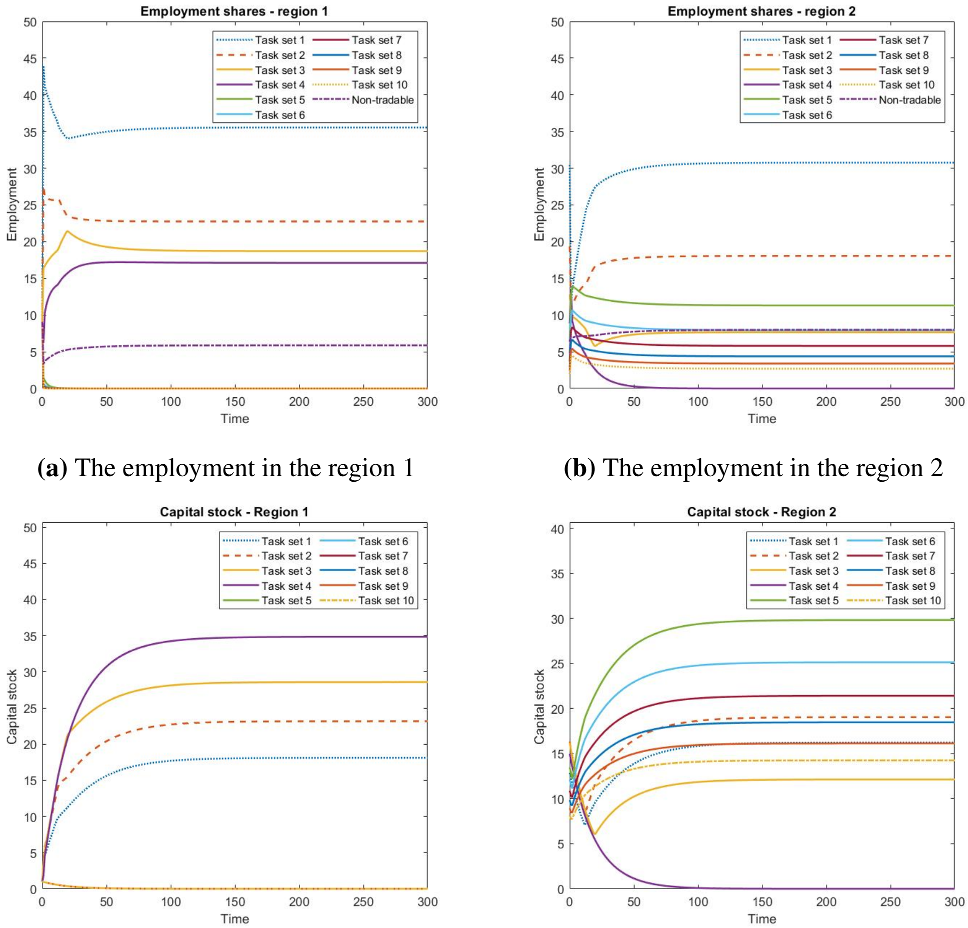
regional specific steady states that are farther apart than steady states with domestically driven capital accumulation. This might indicate that relative labour immobility, compared to the relative mobility of either products, intermediate products or services (task outputs) or capital could be the core structural characteristic of the international capitalist mode of production.

6.8 Model of international specialization with 3 regions

In this section we analyse the model of international specialization with three regions and no capital mobility. The model has the same specifications as the model with two regions (section 6.6), with the only change being the introduction of an additional region $c \in (1, 2, 3)$. All three regions are assumed to have different initial level of development.

The region 1 is assumed to be the periphery, with the lowest initial level of development, region 2 the semi-periphery and region 3 the most developed region. The initial conditions for each region are on the trajectory of the closed economy growth model. The initial condition for the region 1 is the same as in the two region model and is defined by $k_{1j}(0) = 1$ $\forall j \in S_j \backslash NT$. The initial condition for the region 2 is assumed to have the same distribution of capital stock and labour as the analysed region in the closed economy setting at time $t = 10$. If $k_j(10)$ and $l_j(10)$ denote capital stock and labour values at $t = 100$ within the closed economy model, then initial condition for region 2 can be expressed as $k_{2j}(0) = k_j(10)$ and $l_{2j}(0) = l_j(10)$. Similarly as with the two region model, the developed region (region 3) is assumed to have the same distribution of capital stock and labour as the analysed region in the closed economy setting at time $t = 100$. If $k_j(100)$ and $l_j(100)$ denote capital stock and labour values at $t = 100$ within the closed economy model, then

Figure 6.20: The evolution of the employment in the 2 region model with capital mobility (Source: own work)



(a) The employment in the region 1

(b) The employment in the region 2

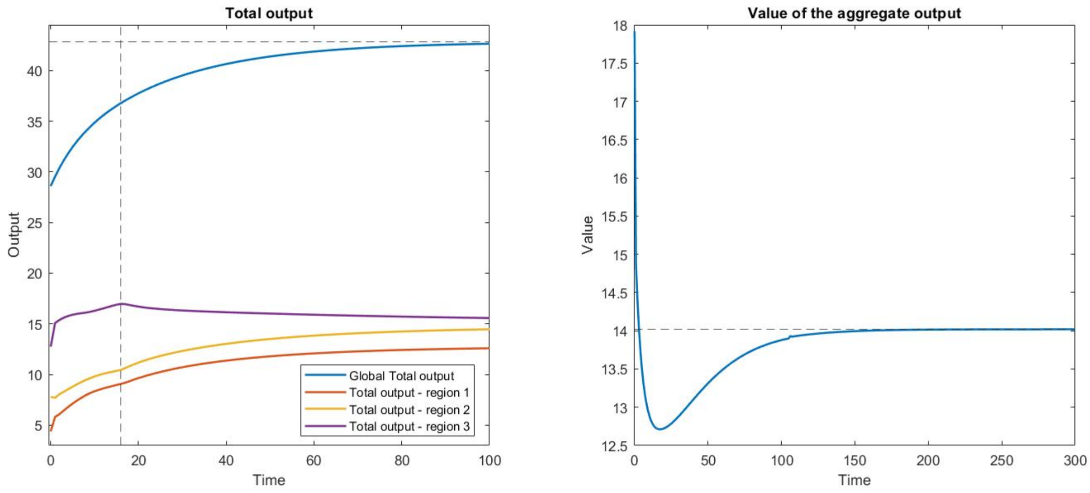
(c) The capital stock in the region 1

(d) The capital stock in the region 2

initial condition for region 2 can be expressed as $k_{2j}(0) = k_j(100)$ and $l_{2j}(0) = l_j(100)$.

The results for global output as well as total output of the each region can be seen in the figure 6.21a. The results for three regions are similar to the results for the two region model. The model similarly exhibits absence of fast convergence to a common steady state for all three regions. The initial state differences determine the long term differences in the steady state aggregate output. The initial state of aggregate output of the three regions is $4,4$ for the peripheral region, $7,8$ for the semi-peripheral region, and $12,75$ for the developed region. After the 16 time units which exhibit a transition period before region 2 fully specializes in the task group 4, the value of aggregate output is $8,96$ for the peripheral region, $10,36$ for the semi-peripheral region, and $16,88$ for the developed region. Initially, peripheral region is closing its gap with the semi-peripheral region and the developed region exhibits a distinctive decoupling from the two. After the period 16, a distribution of task group employment, investment and capital stock is stabilized. A steady state under medium-term constraint yields $12,76$ for the peripheral region, $14,74$ for the

Figure 6.21: Output and value - 3 region model (Source: own work)



(a) The aggregate output

(b) The aggregate output value

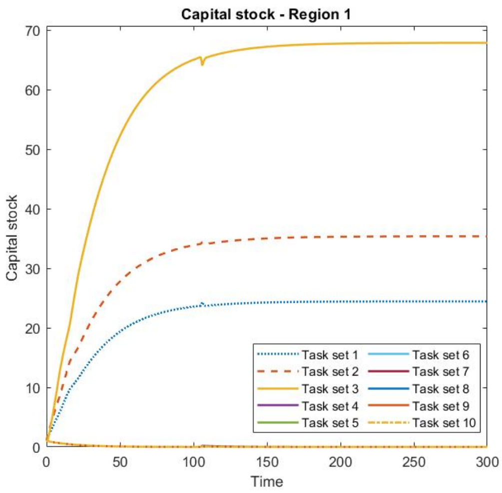
semi-peripheral region, and $15,28$ for the developed region. The process of international specialization widens the gap between the peripheral and semi-peripheral region, while the gap between the developed and the semi-peripheral region is substantially reduced.

The benefits of international trade and specialization are even more pronounced on the aggregate level as in the 2-region model and the closed economy model. The aggregate global output per capita of the 3 regions combined in an international cooperation and trade significantly surpasses the output per capita of the 2 regions. While the output per capita of a closed economy region in steady state amounts to $\frac{Q_{SS}}{L} = 0,129$, and the aggregate output of the 2 regions of the same size joint in international cooperation amounts $\frac{Q_{SS}}{L} = 0,136$, the three internationally connected regions of the same size yield the output per capita equal to $\frac{Q_{SS}}{L} = 0,143$.

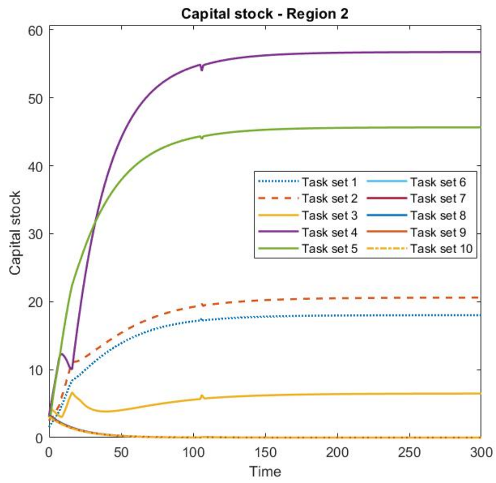
The major difference when compared to the two region model is that the steady state aggregate output of the peripheral region is $0,86\%$ below the steady state of the closed economy model. The prospect of technological upgrading by endogenous phase transition that shifts specialization to task group 4 is not possible in the three region model, due to the stable comparative advantage of the semi-peripheral region in the middle tier task groups. On the other hand, both region 2 and 3 exhibit much higher steady state output than in the closed economy setting, which are $14,6\%$ and $18,7\%$ higher than the closed economy steady state respectively. The benefits of the international specialization are, therefore, highly unequal, similarly as in the two region model.

In the figure 6.22 the evolution of capital stock and employment is presented for each region. The pattern of specialization can be more easily assessed by observing the steady

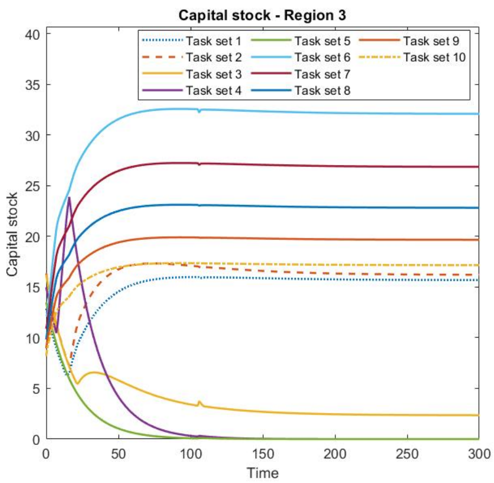
Figure 6.22: The evolution of capital stock and employment in the 3 region model (Source: own work)



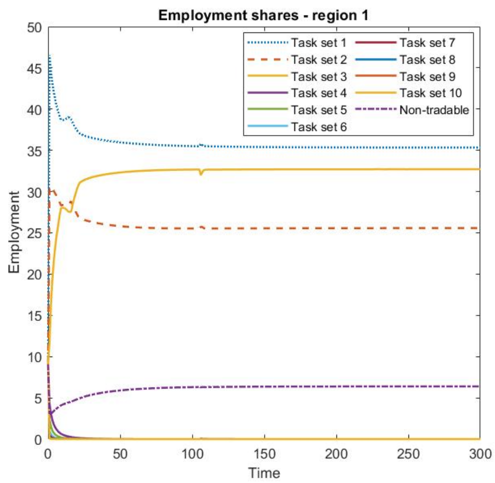
(a) The capital stock in the region 1



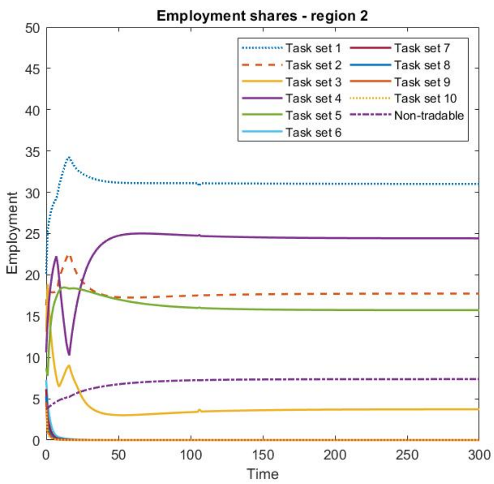
(b) The capital stock in the region 2



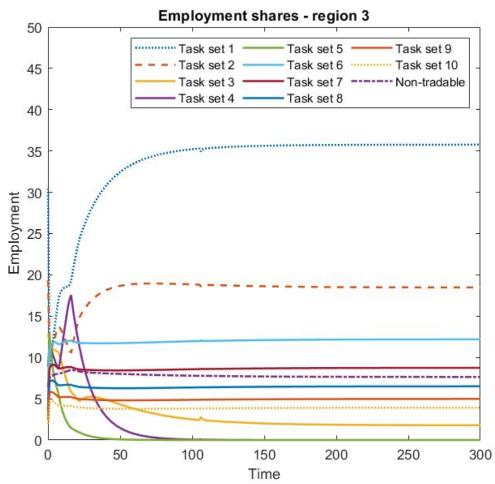
(c) The capital stock in the region 3



(d) The employment in the region 1

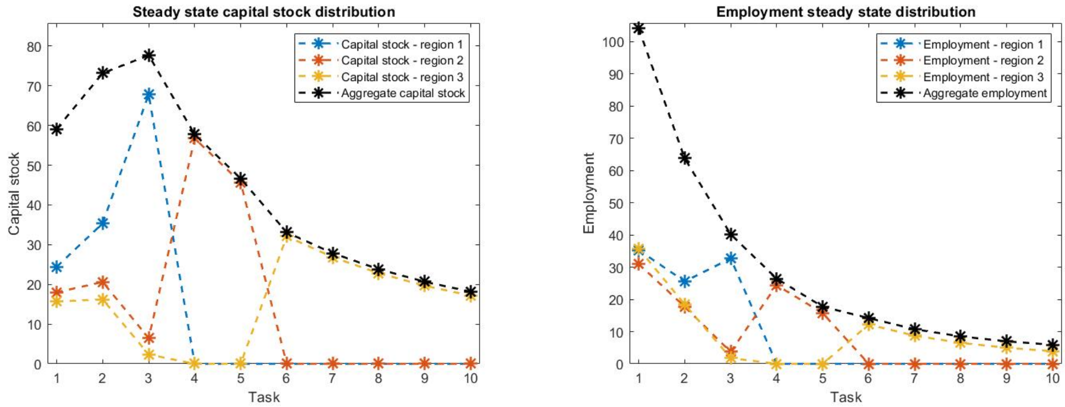


(e) The employment in the region 2



(f) The employment in the region 3

Figure 6.23: The steady state distribution of the capital stock and employment in the 3 region model (Source: own work)



(a) The distribution of capital investment in steady state

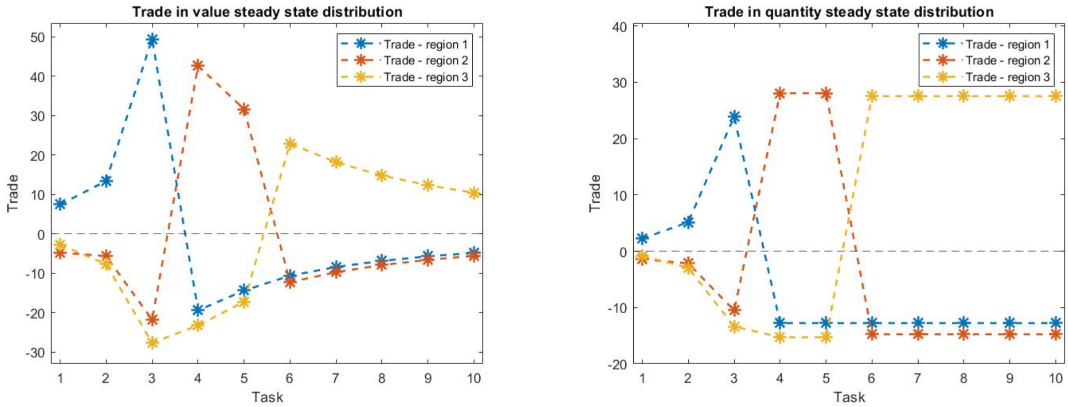
(b) The distribution of capital investment in steady state

state distribution of the capital stock and employment, which is presented in the figure 6.23. The pattern of specialization is similar as the result of the 2 region model in the period before the phase transition, with the addition of a semi-peripheral region that fully specializes in the task groups 4 and 5. The peripheral region fully specializes in the task group 3 and holds comparative advantage in the production of task groups 1 and 2, while the developed region fully specializes in the most productive, capital intensive and knowledge intensive task groups 6, 7, 8, 9, and 10. All three regions contribute to the output of the lowest tier task groups 1 and 2. The polarization effect in the developed region is even more pronounced due to inclusion of the semi-peripheral region.

In the figure 6.24 we present the trade balance in terms of value in steady state and trade in terms of quantities disaggregate for each task group. The specialization pattern can be clearly seen in the figure 6.24b, with all the task groups from 4 onwards exhibiting full specialization (only 1 region producing them) and task groups 1,2 and 3 exhibiting only partial specialization of the region 1. Trade in values conforms to the balance of payments constraint and is balanced.

Overall, the addition of an additional region does not substantial alter the main findings that can be derived from the model's functioning. The model's stability indicates a possibility of an analytical generalizations of the patterns of international specialization with respect to wage levels, potential for productivity improvements in the medium-term and structural changes. The main result is the endogenously induced uneven international specialization that is stable over time and affects the long term development.

Figure 6.24: The steady state distribution of the trade balance in value and quantity (Source: own work)



(a) The trade balance in terms of value for each region **(b)** The trade in terms of quantity for each region

6.9 Conclusion

In this chapter, we have presented a comprehensive framework that aims to analyse the complex disaggregated structural dynamics of growth and development in the context of international trade and specialisation between regions that were originally developed differently. The conceptualization of the model combines insights from neoclassical, Marxian, and evolutionary paradigmatic frameworks.

In recent decades, macroeconomics as a discipline has moved away from the study of broader aggregate variables and their interconnectedness and has been reduced to the aggregation of results obtained from microeconomic behaviour. This did not only happen within neoclassical economics. Much of the heterodox alternatives also focused primarily on the individual - proposing various alternatives to the rational individual and constructing alternative agent-based models. The approach in this chapter is quite different from the mainstream trend described. Instead of deriving macroeconomic outcomes from microeconomic interaction, we propose to introduce structure and heterogeneity at the macroeconomic level. For this reason, our model seems more closely related to general equilibrium models than agent-based approaches. It assumes market clearing, full employment, and a strict trade equilibrium under conditions of profit maximisation. We focus our study on medium-term dynamics (a rough time frame of decades) and therefore any short-term business cycle dynamics arising from unemployment, unclearing markets, and unbalanced trade are not in our primary interest. Similarly, long-term dynamics, characterized by the periodic technological cycles which are characterized by the changes in the global production constraint, are left aside. What is analysed is not a broad long-term growth model, but a medium-term dynamic analysis of economic complexity that commences within an unchanged global technological constraint. Despite this restrictions, the medium-term progress in quantity, quality and variety is analysed as an investment driven technological progress.

The distinctive features of our model of international specialization are its disaggregated structural dynamics and its ability to account for many real socioeconomic phenomena. It incorporates realistic nonlinearities in the structure of production, creating a driving mechanism for the empirically well-documented supply-side structural change. It includes both tradable and nontradable segments of regional economies and accounts for the Balassa-Samuelson effect and the corresponding complexities arising from purchasing power parity differences in the nominal international value system. It allows analysis of the relationship between domestically and globally driven investment and could reshape discussions of the role of the domestic and international capitalist class in international development. In the model, a dynamic phase transition emerges endogenously, representing a discrete technological modernization process in the developing region and an endogenous shift of productive capacity from the developed to the developing region. The dynamics of the phase transition have complex and nonlinear effects on the developed region as well, corresponding to the widely documented polarization effect in First World countries.

While the goal and structure of the model are clear, the question remains: what is the mechanism that contributes to the maintenance of uneven development?

There are 2 fundamental and mutually opposing determinants that shape the functioning of our model. The first is the general property of our reference model that remains throughout all our modifications - diminishing returns to investment. Diminishing returns to investment create a generally converging dynamics, with investment in poorer regions contributing to higher growth rates than in richer regions. The second is the endogenous emergence of relative factor cost differences, due to greater mobility of capital and technology than labour. When granular productivity constraint exists on the task level, the relative factor cost differences create an endogenous dynamic that drives functional international specialization with diverging effects. This contributes to the persistence of uneven development even under generally converging conditions, with resulting multiple steady-states for each region depending on their initial condition, even if their initial production structure was perfectly balanced and on the trajectory to closed economy steady-state.

The phase-transition dynamics that are present in the dynamics of the 2 region model thus arise due to interaction of the two opposing dynamic forces. On the one hand, we have the detrimental effect of functional specialization, which locks-in the development of low income region into specialization of labour intensive tasks and an above average abundance generated in the developed region due to the "freeing up" of its domestic labour power of the need to perform many labour intensive tasks and its specialization in the technology and capital intensive task elements. Despite this specialization lock-in, a diminishing return dynamics contribute to slow but gradual improvement in the general conditions in the low income region, despite its detrimental functional specialization. As the real wages endogenously grow beyond a threshold that makes a whole new set of tasks profitable in the region, a rapid phase transition occurs as the price advantage shift to low income economy in the upgrading phase. Despite of the phase transition, however, there is no long-run steady-state convergence, as multiple steady-state dynamics due to the granularity of the production constraint prevents equalization of the structure of functional specialization that remains detrimental to the long run development.

Fundamental to the model is the notion that regional productivity differences in tradable sectors of the economy determine the international nominal output and wage ratios. The unrealistic neoclassical assumption of equality between the concrete marginal technical productivity of labour and its income may be one of the most important reasons why neoclassical models cannot derive the endogenous mechanism that we captured by our model. The fact that regional productivity collectively determines regional wages is an approximation that is fundamental to explaining our explored mechanism. Aggregate wage differentials lead to a specific structure of international specialisation in which less developed regions specialise in more labour-intensive tasks and more developed regions specialise in more capital- and technology-intensive tasks. However, the structure of production determines not only the specific output, but also the potential for technology and productivity growth. Thus, international specialisation provides greater advantages to more developed regions than to less developed ones. The structure of development in the developed region is much more balanced, as it not only performs capital- and technology-intensive tasks, but also participates in the production of labour-intensive tasks. On the other hand, the production structure of the developing region is limited exclusively to the production of labour-intensive tasks, which have limited potential for productivity growth, so that the less developed region has a stable output in the medium term, which is lower than the output of the developed region.

The results demonstrate that our second hypothesis can be confirmed - the dynamic operation of a supply-side driven economic endogenous mechanism exist that contributes to the perpetuation of uneven development through uneven functional specialization exists, in so far as there exist granularities in the production constraint, relative factor cost differences that are proportional to developmental gaps, and nationally constrained labour markets. Even if these conditions might not apply in each individual case of differently developed countries or regions, in cases in which these assumptions are a good representation of reality, the identified and examined mechanism should have an effect and would contribute to maintaining differences in development.

Conclusion

In the dissertation, we studied two as yet unexplored supply-side endogenous economic mechanisms that we hypothesised to contribute to the perpetuation of uneven development.

The aim of researching endogenous mechanisms that contribute to the perpetuation of uneven development arose due to dissatisfaction with the present state-of-the-art of the understanding of the determinants of uneven development. At the beginning of our research, the main reasoning why there might exist yet unexplored endogenous mechanisms that contribute to the perpetuation of uneven development, were the relative stability and order in the cross-country distribution of uneven development. On the one hand, the cross-country aggregate income rankings only rarely change substantially, while on the other hand, the economic development remains a complex, disordered social process with both decreasing and increasing return non-linear dynamics intertwined with many exogenous and institutional factors. It was the relative stability of cross-country relations that make the global distribution of uneven development stable, that made us focus on the narrow aspect of examining those structural dynamic patterns that emerge in the context of internationally ever more connected global economy. This initial aspect of stability of uneven development was heavily influenced by the world-systems approach that stresses the structural division of the global capital world-system on its core, semi-periphery, and periphery, in a structural, relational sense.

This context explains our reluctance to resort to increasing return dynamics as a general explanation for the object of our study. Increasing return dynamics has been used extensively to demonstrate diverging development outcomes that exhibit path-dependent trajectories. From high-development theories to endogenous growth approaches increasing returns have been demonstrated to drive uneven development through many complex mechanisms, both on the endogenous economic level (for example, endogenous R&D spending), as well as on the endogenous non-economic level (for example, endogenous fertility and educational decisions). The new trade theories and new economic geography have studied agglomeration dynamics and developmental polarization between urban and rural areas by examining dynamic interrelation between the spatial level (introduced through transportation costs) and increasing returns of industrial development and agglomeration. Neither of these approaches studied the international uneven developmental level on a structurally relational level. On the one hand, the closed-economy setting of the endogenous growth theories prevented them exploration of potential complexities and interrelations that arise in the multiregional setting. On the other hand, the new trade and new economic geography focused on the spatial dimension of development, whereas macroeconomic determinants, especially in the relational context, were left largely at side. While both fields analysed and explained various determinants that contribute to uneven development on different levels of abstraction, neither did focus on the relational aspect that links differently developed regions in a structural relationship that makes uneven development a stable and predictable outcome. Conversely, both endogenous growth and increasing return driven trade theories are highly prone to perturbation of parameters and their models lead to not only diverging steady states, but increasing differences in development. Our approach differs from closed economy approaches in that it takes into account the relational aspects associated with international specialization, relationally induced country-specific structural changes, and relational determinants of technology diffusion.

In this context, we were not on the uncharted territory. From the 70s onward, many stylized North-South models were developed precisely to capture the relational dimension of uneven development and have extensively explored the dynamics of international trade and specialization and how its dynamics contribute to uneven development. The derivations are based on predefined structural characteristics of developed and underdeveloped economies, which are assumed to have different structural behaviour and production structure (Findlay, 1980, 1981, 1984). Drawing from various traditions that examine the structural differences between core and peripheral economies, North-South modelling aimed to integrate these structural differences within complex trade models to assess the benefits and drawbacks of economic integration between differently developed countries. While many of the assumed structural differences were already explored by the high development theory (such as the Lewis' developmental dual sector model), Marxian economists, or later World-system theories, these structural and institutional differences were only examined in comprehensive trade models in the fairly complex and highly non-linear North-South modelling frameworks.

However, in our exploration of endogenous mechanisms that contribute to the persistence of uneven development we embraced a completely different direction of research, as we aimed to study the endogenous mechanisms that function without such limiting assumptions. We hypothesised that exogenous, cultural, institutional, and structural differences between differently developed regions are not the only factor in determining persistence of uneven development. The stylised pattern of stable and recurring division of labour led us to focus exclusively on exploring those mechanism, that emerge endogenously due to the normal functioning of the international and national markets. In other words, we hypothesised that some of the structural differences that were assumed *a priori* by the North-South and similar theoretical approaches, could be, at least to some extent, derived endogenously, in the multi-regional setting, without any *a priori* assumptions about structural differences in the functioning of the core and peripheral economy.

The main argument for our direction, was in the complexity of growth, international trade, specialization, and economic and social structural changes, which combined with the long-term stability of uneven development, could only be explained by various endogenous dynamic economic mechanism that contribute to the long-term maintenance of uneven development. This argument was purely methodological: because static heterogeneity (*a priori* and exogenous differences in structure, norms, institutions) cannot explain dynamically stable heterogeneity when considering complex dynamic processes that are highly prone to perturbation, such as economic growth. A stabilizing dynamic feedback mechanism is a prerequisite for any derivation of stable heterogeneity, which is observed in the relative stability of uneven development over time.

The paradigmatic approach that has contributed most extensively in the direction of our narrow focus is the balance-of-payments constraint modelling. Similarly as North-South modelling, it embraces multi-regional trade setting. However, the most typical North-South *a priori* assumption of different structural determinants of differently developed regions is abandoned. Instead, the BOP constraint framework focuses on the demand side dynamics of the international markets that could endogenously lead to path-dependent trajectories and uneven development. However, the balance-of-payments constraint approach to growth modelling focuses predominantly on demand-side processes and neglects supply-side factors. The development outcomes of balance-of-payments constraint modelling rely entirely on assumptions about international demand elasticities. Prebisch-Singer hypothesis, derived from the demand side assumptions of international demand elasticities, reflects the worsening trade terms for countries that specialize in primary production as opposed to manufacturing, but cannot endogenously explain the very persistence of the international specialization pattern that is the supply-side basis for deriving the hypothesised consequences. Similarly, the balance-of-payments constraint framework derives the uneven developmental dynamics out of (much more complex) set of heterogeneous international demand and trade elasticities that endogenously determine uneven distribution of the gains from international trade, thus contributing to persistence of uneven development. However, while demand elasticities can explain some differences in output growth across regions, the underlying factors are not fully understood and likely relate to both supply and demand factors, especially as both demand and supply side constraints are relevant for the inter-sectoral dynamics. In such models, it is thus impossible to disentangle the supply-side effects hidden behind the dynamics driven by the international demand and trade elasticities, as the assumed heterogeneity and dynamics of the elasticities does not represent mere consumer preference structure, but also broader unaccounted supply-side dynamics that constrain or multiply growth in certain conditions.

In contrast to the balance-of-payments constraint framework, the main aim of our dissertation is to contribute to the understanding of the supply-side dynamics of the market that contribute to persistence of uneven development. In the thesis, we explore two supply-side endogenous economic mechanisms that contribute to the perpetuation of uneven development across countries. These mechanisms operate based on the hypothesis that international relative factor costs are structurally related to the level of development. We started with first hypothesis that international relative factor costs depend significantly on the level of development, determining the structural conditions for the adoption of new technologies in ways that maintain the uneven distribution of technology and thus contribute to the maintenance and deepening of uneven development. We also established a second hypothesis that granularity interacts dynamically with international relative factor costs, leading to uneven functional specialization, contributing both statically and dynamically to the persistence of uneven development.

We examine the first hypothesis in the chapter 3. We propose a novel dynamic model for technology diffusion that aims to overcome two key limitations of the existing literature on technology transfer and adoption. Firstly, prior approaches have tended to ignore the highly uneven and asymmetrical nature of the global economy by focusing on technology adoption curves through micro and game-theoretic methods that do not account for developmental differences and relative factor cost distribution. Secondly, previous research has tended to rely heavily on external, non-economic factors to explain the uneven distribution of technology across countries. Our approach, on the other hand, considers the cost of technology implementation as the fundamental driver of technology diffusion, which in turn is directly related to relative international production factor costs. We have developed novel dynamic diffusion equations that capture the changing relative technology density, which depends on the gradient of technology density with respect to generalized distance in terms of relative wage levels.

The key contribution of our approach is a novel conceptual and modelling framework that uses a differential diffusion equation, similar to that used in physical and heat diffusion, to describe technology diffusion. By conceptually combining econophysics and evolutionary approaches, we generalize the spatial parameter in the diffusion equation to capture both converging and diverging elements in the process of technology diffusion that aims to account for endogeneities in technology adoption conditions and link them to relative factor costs. The main result are the country-specific average technology adoption curves that reflect the uneven development of countries on the global stage, presenting a generalization of the classical logistic curve pattern of the technology adoption in the setting of uneven development. Our macroeconomic results align with the evolutionary and cumulative causation approaches to uneven development, thus bridging the gap between specific technology-related dynamics of technology adoption curves and broader evolutionary macroeconomic approaches that consider path-dependent dynamics at an aggregate level.

Our main general result of chapter 3 is to provide empirical evidence for the relevance of the conceptualization of technology that directly links it to labour-saving improvements (Acemoglu, 2010). All contemporary attempts to model technology diffusion at the technology level (modelling technology adoption curves) fail to account for uneven development and to derive uneven processes of technology diffusion from relative factor costs. There are two reasons for this. First, mainstream conceptualizations of technology diffusion abstract from uneven development because they focus on the dynamics that determine the lag of technology diffusion within a homogeneous country and derive the lag of diffusion independently and irrespective of uneven development. Second, the task-based approach, which assumes that technological progress is primarily labour-saving and factor-cost dependent, operates as a closed economic model and does not have a model environment with multiple regions with different relative factor costs, which in turn ignores possible relational effects of uneven development.

Our simple model of technology diffusion is thus the first model to account for the diffusion of the relative use of concrete technologies and to capture the effects of uneven development and relative factor cost structure on the diffusion process. As a result, we obtain not only the distribution of technology in each country and its evolution, but also country-specific technology adoption curves whose shape depends strongly on relative factor costs and initial stage of development, revealing the relative use of technology and its shape over time. The logistic benchmark technology adoption curve is generalized in this context and shows the pattern of relative use of technology over time for differently developed countries.

The empirical results show that the studied pattern of technological diffusion between different concrete technologies is not highly variable and that the general parameters of diffusion driven by the gradient of technology density in the space of relative factor costs provide a very broad explanation for the substantial part of the actual diffusion process over a large number of studied technologies. We consider this main result, which was passed the test for robustness by random sample perturbation, as a confirmation of our first hypothesis that technological diffusion depends on the relative factor cost structure between differently developed countries, which contributes to persistence of uneven development.

On the one hand, the adoption of technology is influenced by differences in wage levels and the cost of implementing technology. On the other hand, the uneven distribution of technology reinforces existing disparities in wage levels and perpetuates uneven development. This circular causation represents an endogenous and economic mechanism that contributes to uneven development. This is an alternative explanation to prevailing ones that focus on external factors such as institutional frameworks, culture, political stability. While these external factors are undoubtedly important for the catch-up process, understanding of endogenous economic supply-side mechanism of technology diffusion that operates structurally can complement both extra-economic and economic explanations of how technology diffusion shapes and determines development outcomes.

The examination of the second hypothesis is primarily conducted in chapter 6 and is related to the dynamic interaction between endogenous supply-side functional specialization, choice of technique, and structural change, with relative international factor costs. The basic idea with respect to the second as yet unidentified economic mechanisms contributing to uneven development - is that there are supply-driven economic endogenous determinants of international specialization in the globally interconnected economy, roughly corresponding with choice between "light" and "heavy" techniques (Amin, 1976), analysed in more current research streams as international "functional specialization." The second hypothesis of the dissertation is that relative international factor costs are a major endogenous economic determinant of functional specialization and structural change, and that such endogenous uneven functional specialization contributes to persistence of uneven development.

One of the main issues with conceptualising disaggregated technological progress is that the issue of inter-sectoral or inter-task structural change is implicit in any modelling attempt or conceptualization involving granular disaggregated production constraint and disaggregated technology. Thus, before offering a dynamic conceptualization, we first addressed the extent to which and how supply and demand side dynamics determine cross-sectoral shifts in resources and employment due to the complex, interlocking features of intersectoral heterogeneities on the supply and demand sides. Chapter 4 concentrates on examining the determinants of intersectoral structural change and its potential interplay with uneven development. A new multiregional structural input-output decomposition method is proposed to break down employment change determinants into 19 distinct components. This new approach offers several innovative features that enhance the methodological and empirical aspects of input-output economics and value chain research. Unlike many prior empirical input-output studies that solely focus on output changes, our analysis investigates both employment and output dynamics to facilitate a more in-depth study of supply-side effects. We code a unique protocol that allows us to conduct simultaneous structural decompositions for all 44 countries in the WIOD dataset, enabling us to analyze trade and value chain dynamics along with demand- and supply-driven structural changes. Our research is the first to integrate all three components comprehensively. We introduce stylized empirical indices to quantify structural shifts in employment and output away from agriculture and from manufacturing toward services for each country in the sample. Our main finding is that the determinants of structural shifts from manufacturing to services are mainly supply-driven, which contradicts the findings of previous input-output-based empirical studies. We attribute this discrepancy to three key factors: 1) most prior studies did not perform structural decomposition in real terms; 2) they did not examine the dynamics of structural change from an employment perspective; and 3) they did not decompose the final demand component into its non-homothetic component, which theoretically drives the dynamics of structural change. Our research reveals that the shift of jobs from manufacturing to services is primarily due to supply-side effects, whereas the shift of jobs away from agriculture is mainly due to the non-homothetic preference structure of final demand. These results highlight the significance of investigating the dynamics of supply-side structural change in the context of uneven development, particularly among developed countries that have already moved beyond agricultural subsistence.

The results of the chapter 4 also better frame our research in relation to the more demand focused balance-of-payments constraint framework (Araujo & Lima, 2007; Dutt, 2002; Thirlwall, 1979) or evolutionary structural change analysis that focuses on the demand side (Lorentz et al., 2016). The results that transition from agriculture is predominantly demand driven gives the frameworks that focus more on the demand side greater relevance for issues of underdeveloped regions that still have not transitioned away from the subsistence agriculture. These multi-regional models thus have similar object of research and explore similar dynamics to the high-development theories and North-South approaches that explore various poverty traps near subsistence level and have been explored extensively in the chapter 2. In the chapter 2, we empirically examined various endogenously determined thresholds in the form of poverty traps and showed that they have limited ability to explain uneven development between countries that are not extremely underdeveloped (say, above $5,000 GDP per capita measured in purchasing power parity). However, the main empirical discovery of chapter 4 is that supply-side dynamics are far more relevant to inter-sectoral structural change dynamics within industrialized regions, as they drive the dynamics between manufacturing and service employment. By focusing on the supply-side dynamics of structural change in the context of uneven international relative factor costs in chapter 6, we thus provide new evidence on dynamic endogenous mechanisms that operate between industrially developed and developing regions and are phenomenally often observed as various middle-income traps.

The conceptual link between the drivers of functional specialization and international relative factor costs are discussed in chapter 5. In it, we examine the functioning of the endogenous mechanism of functional specialization within a Marxian framework. We propose a new conceptual reformulation of the international law of value, which is an price system in a Marxian framework. With this we prepare the conceptual framework for merging some of the Marxian assumptions within a neoclassical modelling framework. On the one hand, the neoclassical approach reduces the social dimension in its entirety to the technical dimension by deriving income distribution from the technical characteristics of the production process (technical marginal productivities). On the other hand, the various Marxian approaches disregard to some extent the independent technical dimensions of the production process (complex production constraints, technical marginal productivities, accounting for the effect of technology and productivity) and often reduce them to the social dimension of value creation and value appropriation, although capital accumulation, value composition, and organic composition of capital can hardly provide a sufficiently detailed account of the technical properties of the production process. In contrast, we have sought to incorporate both dimensions in our approach. We retain the concept of the production function in a disaggregated form, but detach the issue of social distribution from the technical aspects of the production function. Thus, in our framework, the distribution between the two classes is exogenously determined. Individual wages do not reflect individual marginal productivity, but are influenced by the average national productivity of the tradable sector. These assumptions are derived in a framework presented in chapter 5, but are also included in chapters 3 and 6. While our wage theory is to some extent uniquely Marxian and formulated as a generalization of the worldwide law of value, it also draws on the mainstream work of Samuelson and Balassa. While we do not try to conceal the fact that individual marginal productivity and skill can have an impact on wage levels, especially in determining distribution *within* countries, our goal is to focus on the social and economic effects of wage differentials *between* countries, especially those differences that are due to average national productivity differentials rather than differences in individual skill. The first objective of this chapter is thus to formulate Marxian modification of the neoclassical model in order to account for the relative international factor costs, that empirically emerge due to different mobility of factors across countries. Our second main objective in chapter 5 is to extend Amin's descriptive framework and arguments regarding functional specialization between light and heavy techniques. By reformulating descriptive Amin's arguments to ones that fit within a precise analytical Marxian framework of analysis, we set the stage for further reformulation that can be incorporated into a multiregional dynamics modelling framework. In this chapter, we make a crucial conceptual discovery that functional specialization and the distinction between different groups of techniques are not directly related to their capital intensity or relative productivity directly, but rather to their medium-term differences in production constraints that lead to these observable differences. From this point, we develop an alternative aggregate production function that is granular and consists of different complementary sets of tasks that exhibit medium-term differences in their production constraints. This reformulation is a fundamental novelty that allows us to explore endogenous patterns that emerge in a setting with such a global production constraint and unevenly developed but globally connected regions with structural endogenous differences in the relative factor costs.

To explore these dynamics, a novel dynamic model was developed in chapter 6 that combines, on the one hand, supply-side inter-sectoral and inter-task structural change dynamics and, on the other hand, a multi-regional environment with international trade and specialization that accounts for the differences in the international relative factor costs. The absence of such a model represents a yawning research gap in macroeconomic and growth-oriented research. There are three main reasons for the complete absence of such models. First, the a priori neoclassical link between individual marginal productivity and income prevents more complex analyses that would account for more empirically factual international relative factor costs that arise due to heterogeneous mobility of different factors. One can model and analyse the proposed endogenous mechanisms only if it parts with this basic identity. Second, supply-side structural change theories operate in closed-economy setting and no analysis has yet been conducted to examine the dynamic interaction between international relative factor costs and the dynamics of supply-side structural change. Third, the task-based approaches are also based on a closed economy and any generalization to multi-regional setting that would include relative international factor cost differences requires significant and non-trivial methodological changes. Also generalizations of homogeneous closed-economy models into multi-regional setting represents only very limited fraction of modelling effort, as solving non-linear models in a multi-regional setting is mostly done by numerical methods and can only rarely provide analytically solvable results and insights.

In the chapter 6, we investigated the interplay of these dynamic features within a dynamic multi-regional model. To begin with, we utilized a neoclassical benchmark model for supply-side structural change (Acemoglu & Guerri, 2008) and gradually modified it to incorporate all the features that were examined in the previous three chapters and found to be significant for our examination of how supply-side granularities in the production constraint interact with the relative factor costs. These modifications included introducing a more detailed production constraint that allowed for the study of functional specialization and the differentiation between various levels of 'light' and 'heavy' task-based techniques, incorporating a Marxian price system that considered wage disparities and established relative factor costs, and expanding the closed economy model to a multiregional framework by introducing tradable and nontradable sectors to account for the Balassa-Samuelson effect.

Our model is shaped by two fundamental and opposing factors. The first is the concept of diminishing returns to investment, which is assumed in all our modifications. This means that investing in poorer regions leads to higher growth rates than investing in richer regions, resulting in a generally converging trend. However, the second factor is the emergence of relative factor cost differences due to the greater mobility of capital and technology compared to labour. When granular and complementary productivity constraints exist at a task level, these cost differences create a dynamic that drives functional international specialization, resulting in diverging specialization - poorer regions specialize for tasks that have lower potential for productivity growth and lower scale effects due to investment. This contributes to the persistence of uneven development, even under generally converging conditions, and leads to multiple steady-states for each region depending on their initial condition. This can occur even if their initial production structure was perfectly balanced and on balanced growth track towards a closed economy steady-state.

The results of the model thus support our second hypothesis. Patterns of functional specialization emerge endogenously and contribute to the persistence of uneven development and diverging steady-state despite working within modified neoclassical growth model with diminishing returns to investment. This endogenous mechanism relies on the existence of granular and complementary production constraints, variations in relative factor costs that are proportionate to developmental gaps, and labour markets constrained by national boundaries. Although these conditions may not be present in every instance of uneven development among countries or regions, they would likely form dynamic endogenous interaction with significant impact in cases where they do occur, sustaining developmental disparities.

The model presented in chapter 6 has several unique features. It simultaneously accounts for the dynamics of supply-driven structural change, its inclusion of the nontradable sector accounts for the Balassa-Samuelson price effect, it accounts for the relative international factor costs, and it accounts for international trade. The main goal of the chapter 6 was to theoretically examine the existence of a previously unidentified endogenous mechanism that contributes to the perpetuation of uneven development. The results of the multi-region international specialization model support our goal and prove that such a mechanism is an inherent part of the competitive international economy in which differently developed regions cooperate, compete, and trade with each other, and can be explain elusively from the supply-side dynamics. Compared to the expected results of the unmodified neoclassical supply-side structural change model, which is based on Solow-Swan production functions and dynamics of diminishing return to investment, the results of the modified model that include uneven relative factor costs and more finely granular and complementary production constraints show that diverging steady-states are the general and final outcome of such dynamics. The dynamic results show that international specialization endogenously leads to an unbalanced production structure, a phase transition associated with the technological upgrading of the backward economy, and an endogenously induced polarization effect in the developed region. A non-linear effect of the size of the nontradable sector on the output gap between regions is found, and capital mobility is shown to negatively affect the output gap and the national income gap.

In the model, we have assumed that technology is freely available to all regions. We have assumed that the acquisition of technology is free, except for direct investment costs. We assumed that there are no structural differences between regions, except for the initial level of development - the initial level of development and its structure were assumed to be on the balanced growth path derived under the closed economy model. We also assumed that there is no friction in employment and investment between task groups.

Despite these relatively unrealistic assumptions, which strongly favour the less developed, endogenously induced structural change and specialisation alone lead to the pattern of uneven development that persists in the medium term. If we were to add additional realism to the model by, for example, making employment and investment somewhat sticky with respect to the existing structure and making structural change costly, this would further exacerbate the pattern of uneven development by further reducing the prospects for technological improvement. Although technology was assumed to be free and cost-neutral, its distribution among regions remained uneven due to uneven international functional specialization.

The potential frictions and stickiness of both employment and investment could keep the less developed region stuck in a suboptimal steady state. If the benefits of international specialization are very unevenly distributed in the post-phase transition steady state, the pre-phase transition steady state will be even lower than the steady state of the closed economy model. This could mean that protecting infant industries could be a relevant policy in some cases to enable the transition to higher value-added production, the expansion of more productive roles, and consequently a larger share of value added in international markets in the longer run. Without a government-led industrial policy, a less developed country is cut off from the highly productive roles that also have the greatest returns to scale.

Fundamental to the model is the notion that regional productivity differences in tradable sectors of the economy determine international nominal output and wage rates. The unrealistic neoclassical assumption of equality between labour's concrete marginal technical productivity and its income may be one of the most important reasons why neoclassical models fail to explain the main dynamics of uneven development. The fact that regional productivity collectively shapes regional wages is an approximation that is fundamental to explaining the functioning of the endogenous mechanism that contributes to the perpetuation of uneven development. Differences in relative factor costs lead to a specific structure of international specialisation in which less developed regions specialise in more labour-intensive tasks and more developed regions specialise in more capital- and technology-intensive tasks. However, the structure of production determines not only specific output but also the potential for technology and productivity growth. Thus, international specialisation provides greater advantages to more developed regions than to less developed regions. The structure of growth in the developed region is much more balanced, as it not only performs capital- and technology-intensive tasks, but also participates in the production of labour-intensive tasks. On the other hand, the production structure of the developing region is limited exclusively to the production of labour-intensive tasks, which have limited potential for productivity growth, so the less developed region has a stable output in the medium term, which is lower than the output of the developed region.

As the chapter 6 draws from various economic traditions, our contribution to the literature differs depending on the paradigmatic perspective. In the realm of Marxian economics, we transform Amin's descriptive framework into a Marxian analytical framework and formulate his ideas in terms of granular production constraints and specific assumptions about factor markets. From a Marxian analytical perspective, steady-state economics and rationality have always been the basis for various analytical derivations reflecting the core components of the Marxian paradigm. While some Marxian approaches have relied on disequilibrium and agent-based analyses, our goal of deriving the previously unidentified endogenous supply-driven mechanism as a normal steady-state operation of the market mechanism led us to combine ideas and assumptions from the analytical foundations of Marx, Amin's choice of technology analysis, and the basic neoclassical supply-driven structural change model. Our contribution to the mainstream supply-side literature lies in exploring the specific functional form of the production constraint that leads to the persistence of uneven development. The empirical evidence we present in Chapter 4 indirectly supports the functional form of granularity, revealing that supply-side productivity growth is not only highly uneven across sectors but also has direct implications for employment patterns. While supply-side heterogeneities have been extensively studied theoretically, there is a gap in the exploration of these heterogeneities on multi-regional and open economy settings, in which relative factor costs contribute to their cross-country dynamics. Our contribution extends the supply-side understanding of structural change to a multi-regional setting. The interaction between the granular and complementary supply-side constraint and the relative factor costs creates an endogenous dynamics of global value chain specialization that contributes to persistently uneven development. This results in multiple diverging steady states which coexist even under conditions of diminishing returns to investment. The converging dynamics assumed by the neoclassical production function coexist with the technology feedback loops and specialization lock-ins driven by endogenous dynamics observed in the model.

The model has significant limitations. First, it is limited to medium-term cyclical technological growth patterns, without an endogenous driver of long-term cycles and technological change that restructures the global production constraint. Such asymmetric long-run cyclical technological growth could be implemented as in similar neo-Schumpeterian models inspired by Kondratiev wave theory. Such long-run cyclical models, merged with the disaggregated task-group production functions of the medium-run constraint analysed in chapter 6, would allow further analysis of the way innovation necessarily takes a specific form that depends on factor costs and the existing level of development, enabling analysis of the asymmetric effects of innovation-induced changes in the long-run production constraint in the context of differently developed countries. Second, reducing the distribution of wages to cross-country differences in nationwide productivities in the tradable sector represents a crude stylized simplification that allowed us to demonstrate the existence of an endogenous effect driven precisely by average cross-country wage differentials. The wage theory underlying the dissertation requires further empirical, analytical, and theoretical testing. To bring the idea that average cross-country productivity differences, and not just individual marginal productivities, matter for wage determination to the general public, further research and more detailed modelling attempts in either agent-based or market equilibrium models are needed. Moreover, while skill and quality of capital are implicit in our aggregate output measure, a more detailed breakdown of factors of production in terms of skill and quality of capital could further improve the explanatory power of the theory.

While our conceptual framework has allowed us to capture a certain dynamic pattern and functioning endogenous mechanism, the discovered dynamic endogenous effects of uneven international specialization, the mechanism of polarization in industrialized countries, and the endogenous phase transition involving technological upgrading of the backward region observed in the framework established in the last chapter are not specific phenomena limited to this particular conceptual framework. Therefore, the most immediate future research arising from this dissertation would be to formulate the analytical theoretical basis of the discovered and studied dynamics within the mainstream framework. There are three possible and complementary ways to accomplish this. On the one hand, a multiregional generalization of Zeira's task-based model could allow an analytical derivation of some of the results we obtained numerically and within a substantially different framework. This would also require an adjustment of the mainstream wage theory. On the other hand, a simple replacement of the worldwide value system by the neoclassical price system with an adjusted wage theory would mainstream an existing model presented in chapter 6. A third option, probably the most technically complicated, would be to extend Comin and Hobijn's neoclassical model of technological diffusion to account for differently developed regions with adjusted wage dynamics. I believe that all three generalizations should lead to similar dynamic outcomes of persistently uneven development, as examined in chapter 6, because of the complex interaction of international specialization, technology diffusion, factor costs, and structural change.

Overall, the proposed theoretical framework, model, its structural conceptualization, and results could have the potential to initiate a whole range of variations in dynamic macroeconomic growth modelling that could uniquely complement the existing theoretical literature as a distinct class of models. The unique combination of supply-driven dynamics of structural change, driven by labour saving improvements and international specialization, can shed new light on a range of phenomena, from various polarization effects, processes of technological upgrading, discrete waves of outsourcing that depend on the growth of underdeveloped regions, to the dynamics of labour migration, to links between structural change and institutional change, and contribute to theories of regional development. The notion that international specialization frames uneven development not only in a quantitative sense, but more importantly in a structural sense, conditioned by uneven specialization, uneven potential for productivity growth, uneven access to different aspects of the production process, without the assumption of monopoly power, uneven access to technology, or uneven institutional structure, can change the perspective on many contemporary development issues. The idea that fundamental complexities arise at the relational level can also challenge the relevance and applicability of models of growth and development that are conceptualized as closed economic models. Simple aggregations of variables created in the context of a closed economy ignore not only the dynamics of structural change but also the relational dynamics that characterize international specialization.

To conclude with, our analytical and modelling innovations presented in chapter 3 that explored endogenous dynamics of technology diffusion in the setting of uneven development and country differences in factor costs, and chapter 6 that examined endogenous drivers of functional specialization identified, analysed and explored the functional operation of both endogenous mechanisms that were set as the object of our study, and examined their contribution to the persistence of uneven development. With functional identification and explanation of these mechanisms, we contribute and complement vast field of research consisting of various paradigmatic approaches and complement existing endogenous and exogenous, economic and extra-economic mechanisms, determinants, and explanations of the persistent uneven development.

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Appendices

Appendix A

Solution of the Technology Diffusion Model

We have the following problem:

$$\frac{\partial \Phi(x,t)}{\partial t} = D\frac{\partial^2 \Phi(x,t)}{\partial x^2} \tag{A.1.1}$$

And the following initial condition:

$$\Phi(x,0) = \delta(x) \tag{A.1.2}$$

We derive the shape of the solution by defining:

$$\Phi(x,t) = a\Phi(bx,ct) \tag{A.1.3}$$

We insert the shape of the function into the initial condition equation:

$$\Phi(x,o) = a\Phi(bx,0) = a\delta(bx) = \frac{a}{b}\delta(x) \tag{A.1.4}$$

$$a = b \tag{A.1.5}$$

We insert the shape of the function in the diffusion equation:

$$ac\frac{\partial \Phi(x,t)}{\partial t} = ab^2 D\frac{\partial^2 \Phi(x,t)}{\partial x^2} \tag{A.1.6}$$

$$c = b^2 \tag{A.1.7}$$

This leads us to the following shape of the solution:

$$\Phi(x,t) = a\Phi(ax,a^2t) \tag{A.1.8}$$

We define $a = \frac{1}{\sqrt{t}}$ in order to reduce the problem to one dimension:

$$\Phi(x,t) = \frac{1}{\sqrt{t}}\Phi(\frac{x}{\sqrt{t}},1) \tag{A.1.9}$$

We solve the diffusion equation again with this specification and obtain:

$$-\frac{t^{-3/2}}{2}\Phi(\frac{x}{\sqrt{t}},1) - \frac{t^{-3/2}}{2}\frac{x}{\sqrt{t}}\frac{\partial\Phi(\frac{x}{\sqrt{t}},1)}{\partial(\frac{x}{\sqrt{t}})} = Dt^{-3/2}\frac{\partial^2\Phi(\frac{x}{\sqrt{t}},1)}{\partial(\frac{x}{\sqrt{t}})^2} \tag{A.1.10}$$

Simplifying and integrating we get:

$$\frac{x}{\sqrt{t}}\Phi(\frac{x}{\sqrt{t}},1) + 2D\frac{\partial\Phi(\frac{x}{\sqrt{t}},1)}{\partial(\frac{x}{\sqrt{t}})} = 0 \tag{A.1.11}$$

Solving the ordinary differential equation, we get:

$$\Phi(\frac{x}{\sqrt{t}},1) = C\ exp(\frac{-x^2}{4Dt}) \tag{A.1.12}$$

Which simplifies into:

$$\Phi(x,t) = \frac{1}{\sqrt{t}}\ C\ exp(\frac{-x^2}{4Dt}) \tag{A.1.13}$$

We use normalization condition for determination of the constant C:

$$\int_0^\infty \Phi(x,t)dx = 1 \tag{A.1.14}$$

$$\int_0^\infty \frac{1}{\sqrt{t}}\ C\ exp(\frac{-x^2}{4Dt})dx = 1 \tag{A.1.15}$$

$$C\sqrt{4D}\int_0^\infty exp(-x^2)dx = 1 \tag{A.1.16}$$

$$C\sqrt{4D}\frac{\sqrt{\pi}}{2} = 1 \tag{A.1.17}$$

$$C = \frac{1}{\sqrt{D\pi}} \tag{A.1.18}$$

This concludes the derivation of the model solution:

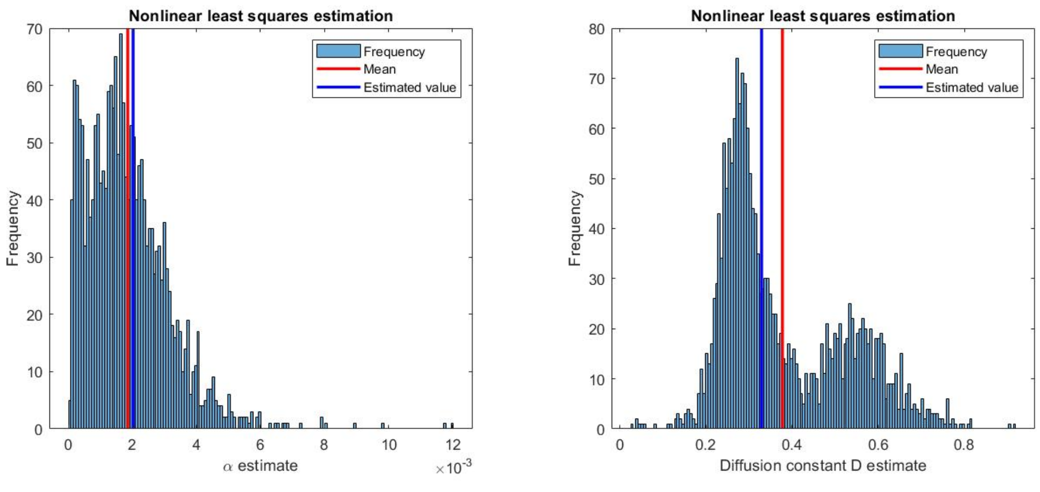
$$\Phi(x,t) = \frac{1}{\sqrt{\pi Dt}}exp(\frac{-x^2}{4Dt}) \tag{A.1.19}$$

Appendix B

Robustness tests

In order to test the stability of the results with respect to sample selection and potential stability issues due to the selection of technologies from the CHAT database we conduct further robustness tests. For each of the two analysed estimations we make a random sampling experiment. We draw without replacement 10 random technologies out of the CHAT database and make both the nonlinear least squares estimation, as well as mixed effects estimation on the sample. Repeating such sampling for 2000 times, we obtain the distribution of the estimated model parameters (figure B.1 and B.2).

Figure B.1: Nonlinear least square regression random sampling distribution

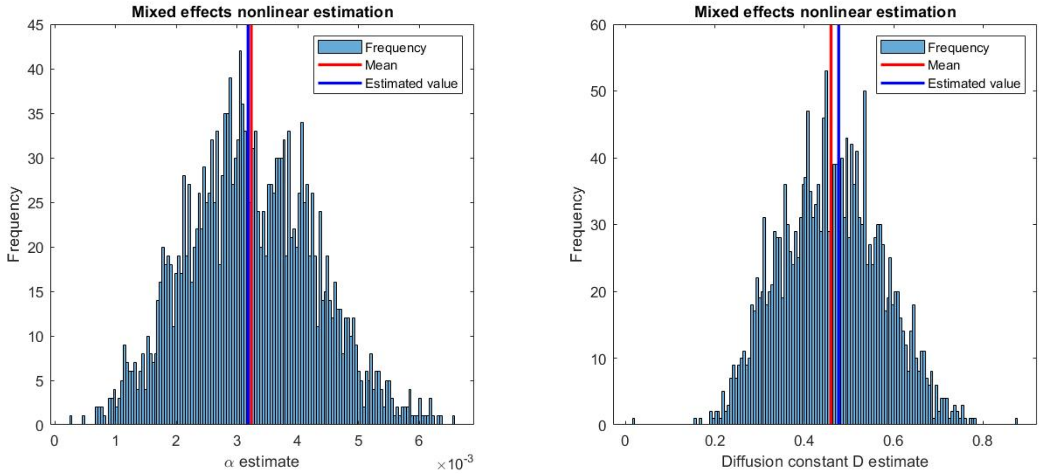


(a) Estimation of α

(b) Estimation of the diffusion constant D

In the case of nonlinear least squares estimation (figure B.1) the treatment of all technologies as having a homogeneous diffusion process is demonstrated to be insufficient. This is particularly visible in the case of estimating the diffusion constant D as there is a hidden heterogeneity among different technologies, characterized by the bimodal normal distribution observed in figure B.1b. This is result is expected, as its was shown already by Comin and Hobijn (2010) that earlier technologies required approximately twice as much time to diffuse than more modern technologies. As CHAT database includes both old (e.g. rail-

Figure B.2: Mixed effects with technology specific random effects random sampling distribution



(a) Estimation of α

(b) Estimation of the diffusion constant D

Table B.1: Robustness test means and standard deviations

	Nonlinear least squares		Mixed effects	
	α	D	α	D
Mean of sample estimations	0.0018	0.377	0.0032	0.460
Estimated mean	0.0020	0.329	0.0032	0.477
Standard deviation of sample estimations	0.0013	0.146	0.0010	0.113

ways, tractor) and modern (e.g. internet) technologies, bimodal normal distribution roughly corresponds to differences in the diffusion process for different technologies in different periods.

To obtain a stable global result a technology specific random effects must be introduced. This is corroborated by much higher stability of the sampling estimations in the case of mixed effects estimation that include technology specific random effects for both α and the diffusion constant D (figure B.2 and table B.1).

Appendix C

World Input-Output Database and Social and Economic Accounts

The World Input-Output Database consists of harmonized national accounting data. It comprises 43 countries in a time-frame from 2000-2014. The data is structured as a multi-regional dataset that covers all country-sector intermediate productive linkages, final consumption, total output and value added (figure C.1). Two sets of tables exist for each year, one in nominal terms and another in previous year prices, to enable analysis of productivity and other indices in real terms. The most relevant variable included in the Socio Economic Accounts is employment statistics for each country-sector. The following list comprises the basic input-output notation and derivation of most fundamental objects used in input-output structural decomposition.

			Use by country-industries							**Final use by countries**			**Total use**
			Country 1			…	Country M			Country 1	…	Country M	
			Industry 1	…	Industry N	…	Industry 1	…	Industry N		…		
Supply from country-industries	Country 1	Industry 1											
		…											
		Industry N											
	……												
	Country M	Industry 1											
		…											
		Industry N											
Value added by labour and capital													
Gross output													

Figure C.1: Schematic Outline of a World Input–Output Table (Timmer et al., 2015)

$n_S \in \mathbb{N}$ number of sectors.
$n_C \in \mathbb{N}$ number of countries.
$n \in \mathbb{N}$; $n = n_S * n_C$ number of country-sectors.
$\mathbf{1} \in \mathbb{R}^n$ vector of ones.
$\vec{1} \in \mathbb{R}^{n_C}$ vector of ones.

$\vec{e_i} \in \mathbb{R}^n$; $e_{ij} = \delta_{ij}$ standard orthonormal basis of $\mathbb{R}^n$.
$I \in \mathbb{R}^{n\times n}$ identity matrix.
$EMP \in \mathbb{R}^n$ employment.
$\Psi \in \mathbb{R}^n$ is employment to value added ratio (inverse productivity).
$x \in \mathbb{R}^n$ total output vector.
$\hat{x} \in \mathbb{R}^{n\times n}$; $\hat{x} = diag(x)$ total output matrix.
$C \in \mathbb{R}^{n\times n}$ intermediate consumption matrix.
$F \in \mathbb{R}^{n\times n_C}$ final consumption matrix on country level.[1]
$f \in \mathbb{R}^n$; $f = F\vec{1}$ total final consumption vector.
$\hat{f} \in \mathbb{R}^{n\times n}$; $\hat{f} = diag(f)$ total final consumption matrix.

$A \in \mathbb{R}^{n\times n}$; $A = C\hat{x}^{-1}$ Leontief technical coefficient matrix.
$G \in \mathbb{R}^{n\times n}$; $G = \hat{x}^{-1}C$ Ghosh technical coefficient matrix.

$v \in \mathbb{R}^n$; $v^T = x^T - \mathbf{1}^T C = \mathbf{1}(\hat{x} - A\hat{x}) = \mathbf{1}^T(I - A)\hat{x}$ vector of total value added.
$\hat{v} \in \mathbb{R}^{n\times n}$; $\hat{v} = diag(v)$ total value added matrix.
$c \in \mathbb{R}^n$; $c^T = v^T\hat{x}^{-1} = \mathbf{1}^T(I - A)$ vector of value added coefficients - value added share in total output.
$\hat{c} \in \mathbb{R}^{n\times n}$; $\hat{c} = diag(c)$ value added coefficients matrix.

Δ denotes yearly real change in variable X, namely $\Delta X_t = X_{pyp\,t} - X_{t-1}$, where $X_{pyp\,t}$ represents variable X expressed in previous year prices based on the Laspeyres index.

C, A and G have block matrix structure $\mathbb{R}^{(n_S\times n_S)\times(n_C\times n_C)}$, while F has a block vector structure $\mathbb{R}^{n_S\times(n_C\times n_C)}$. Diagonal block elements with respect to countries represent domestic intermediate transfers and domestic consumption and off diagonal block elements represent transactions that crossborder either for intermediate use or final consumption.

$C = C_{CB} + C_D$
$A = A_{CB} + A_D$
$G = G_{CB} + G_D$
$F = F_{CB} + F_D$
$f_{CB} \in \mathbb{R}^n$; $f_{CB} = F_{CB}\vec{1}$ total final consumption by exporting.
$f_D \in \mathbb{R}^n$; $f_D = F_D\vec{1}$ total final consumption by domestic transactions.
$\hat{f}_{CB} \in \mathbb{R}^{n\times n}$; $\hat{f}_{CB} = diag(f_{CB})$ total final consumption by exporting matrix.

[1]In international I-O framework F is usually disaggregated on country level as well as in additional dimension of final consumption (household, government and non-profit consumption, fixed capital formation and changes in inventories), which is in our derivation irrelevant and left out. Disaggregation by countries is relevant to enable separation of domestic final consumption and export.

$\hat{f}_D \in \mathbb{R}^{n \times n}$; $\hat{f}_D = diag(f_D)$ total final consumption by domestic transactions matrix.

Appendix D

Cumulative Country Level Results of Structural Change Determinants

In this appendix we present the determinants of structural change for every country available in the WIOD dataset and for the whole world (WRL).

Table D.1: Legend

Indicator	Description
E1	Productivity effect
E2	Domestic outsourcing propensity effects
E3	Foreign outsourcing propensity effects
E4	Change in the structure of domestic supplier linkages
E5	Change in the domestic structure of intermediate import linkages
E6	Change in domestic intermediate import propensity
E7	Change in the structure of foreign supplier linkages
E8	Global homothetic income effect
E9	Uneven growth of income effect
E10	Price effect
E11	Domestic household non-homothetic preference effect
E12	Domestic household import propensity and structure
E13	Domestic government non-homothetic preference effect
E14	Domestic government import propensity and structure
E15	Domestic investment non-homothetic preference effect
E16	Domestic investment import propensity and structure
E17	Foreign demand non-homothetic preference effect
E18	Foreign demand import propensity and structure
E19	Inventory changes
TOT	Aggregate structural change

Table D.2: Country specific structural change determinants - manufacturing to service employment relocation

	AUS	AUT	BEL	BGR	BRA	CAN	CHE	CHN	CYP	CZE	DEU
E1	0.041	0.155	0.350	0.471	-0.222	-0.120	0.079	1.121	-0.255	0.515	0.160
E2	0.023	0.028	-0.090	-0.101	0.026	0.049	-0.008	-0.288	0.079	-0.080	-0.020
E3	0.034	0.047	-0.077	0.012	-0.004	0.004	0.004	-0.034	0.014	-0.022	-0.015
E4	0.129	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E5	0.000	0.000	0.002	0.000	0.000	0.003	0.000	-0.004	0.000	0.000	0.000
E6	0.038	-0.001	-0.001	0.000	0.000	-0.001	-0.001	-0.001	0.000	-0.001	-0.001
E7	0.094	-0.024	0.134	-0.168	0.058	0.090	0.100	-0.445	0.127	-0.092	0.056
E8	0.000	0.006	0.006	0.003	0.001	0.000	0.004	0.014	-0.005	0.008	0.007
E9	0.009	-0.073	-0.075	0.050	0.000	0.048	-0.031	0.276	0.036	-0.021	-0.123
E10	-0.011	-0.011	-0.014	0.001	-0.001	-0.006	-0.005	-0.056	0.000	-0.028	-0.006
E11	0.019	0.027	0.023	0.128	0.155	0.008	0.021	-0.057	0.191	0.032	0.003
E12	0.087	0.012	0.012	0.143	0.016	-0.017	0.016	-0.001	0.225	0.035	0.022
E13	-0.025	-0.001	0.020	-0.083	-0.013	-0.018	-0.003	-0.015	0.042	-0.013	0.032
E14	-0.001	0.001	0.002	0.001	0.000	0.000	0.000	-0.003	0.004	0.002	0.000
E15	-0.037	0.027	0.001	-0.028	-0.009	-0.003	-0.008	-0.055	0.350	0.012	0.030
E16	0.044	0.011	-0.006	0.059	-0.004	0.004	0.001	-0.009	-0.143	0.030	0.017
E17	0.007	0.015	0.016	0.025	0.012	0.005	0.004	0.015	0.012	0.005	-0.001
E18	0.042	-0.057	0.125	-0.293	-0.002	0.155	-0.006	-0.276	-0.067	-0.252	-0.024
E19	0.008	0.038	-0.004	0.030	-0.013	0.001	-0.007	-0.064	0.207	0.042	0.047
TOT	0.501	0.201	0.424	0.250	0.000	0.200	0.161	0.120	0.818	0.174	0.185

	DNK	ESP	EST	FIN	FRA	GBR	GRC	HRV	HUN	IDN	IND
E1	0.240	0.205	0.436	0.252	0.246	0.246	-0.169	0.072	0.320	0.430	0.046
E2	-0.009	0.017	0.042	-0.099	-0.084	0.017	0.262	0.082	0.074	0.021	0.136
E3	0.007	0.021	0.050	-0.013	-0.032	0.021	0.026	0.049	0.087	-0.021	0.019
E4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E5	0.001	0.000	-0.001	0.002	0.001	0.003	0.000	0.000	0.000	-0.001	-0.001
E6	-0.002	-0.001	-0.002	-0.001	-0.001	-0.002	0.000	0.000	-0.001	-0.005	0.000
E7	0.164	0.066	-0.280	0.197	0.094	0.017	0.079	0.041	-0.066	0.114	-0.074
E8	0.004	0.003	0.004	0.006	0.004	0.005	-0.004	0.000	0.012	0.007	0.001
E9	-0.070	-0.048	0.070	-0.087	-0.052	-0.025	-0.017	0.007	-0.064	0.102	0.068
E10	-0.004	0.001	-0.036	-0.028	-0.010	-0.007	-0.002	-0.010	-0.040	-0.035	-0.031
E11	0.010	0.121	0.024	0.035	0.059	0.095	0.069	0.079	0.061	0.025	-0.020
E12	0.003	0.072	0.117	0.017	0.026	0.065	0.046	0.081	0.055	0.036	0.002
E13	0.019	0.060	-0.016	0.013	0.022	0.027	0.056	-0.005	0.047	0.043	-0.057
E14	0.000	0.004	0.000	0.000	0.003	0.001	0.003	-0.001	0.006	0.017	0.002
E15	0.007	0.035	-0.016	0.044	0.054	0.004	0.098	0.000	0.009	-0.036	-0.043
E16	0.011	0.006	0.053	0.002	0.014	0.006	0.016	0.026	0.005	-0.003	0.008
E17	0.021	0.001	0.036	0.002	-0.002	0.003	0.006	0.017	0.008	0.032	0.020
E18	0.071	-0.012	-0.241	0.092	0.048	0.118	-0.004	-0.057	-0.174	-0.061	-0.047
E19	0.018	0.040	0.037	0.047	0.068	0.010	0.114	0.026	0.014	-0.039	-0.035
TOT	0.490	0.590	0.277	0.481	0.457	0.603	0.579	0.410	0.354	0.626	-0.006

	IRL	ITA	JPN	KOR	LTU	LUX	LVA	MEX	MLT	NLD	NOR
E1	0.106	0.174	0.321	0.655	0.654	-0.175	0.070	0.133	-0.211	0.138	0.200
E2	0.017	0.003	-0.095	0.051	-0.080	-0.091	0.063	0.031	-0.046	-0.011	-0.026
E3	0.024	-0.012	-0.019	0.047	-0.032	0.011	-0.015	0.020	-0.067	-0.031	0.000
E4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E5	0.004	0.000	0.000	0.001	-0.001	0.000	0.000	0.000	0.002	0.001	-0.001
E6	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	0.000	-0.001	-0.001	-0.001	-0.001
E7	0.147	-0.019	0.079	-0.130	-0.220	0.509	-0.150	0.019	0.437	-0.018	0.072
E8	0.005	0.005	0.006	0.009	0.011	-0.003	-0.002	0.000	-0.005	0.004	0.002
E9	0.014	-0.159	-0.124	-0.039	0.103	0.051	0.051	0.019	-0.094	-0.113	0.028
E10	0.023	-0.012	-0.009	-0.021	-0.035	-0.013	0.000	-0.018	-0.005	-0.007	-0.010
E11	0.069	0.157	0.011	-0.021	0.070	0.019	0.131	0.027	0.161	0.066	0.008
E12	-0.053	0.063	0.045	0.017	0.234	0.037	0.202	0.033	0.004	0.031	0.043
E13	0.034	0.038	0.031	0.039	-0.102	0.021	-0.076	-0.029	0.112	0.093	-0.046
E14	0.000	0.001	0.000	0.003	0.007	0.000	0.001	0.002	0.002	-0.001	0.009
E15	0.019	0.035	0.023	0.012	-0.011	0.011	0.011	0.011	0.084	-0.005	-0.008
E16	0.018	0.001	0.027	0.021	0.025	0.006	0.092	0.016	0.007	0.010	-0.043
E17	0.017	0.012	-0.016	-0.022	0.042	0.030	0.020	-0.001	0.039	0.033	-0.001
E18	0.115	0.026	0.017	-0.044	-0.239	0.153	-0.108	0.006	0.393	0.071	0.049
E19	0.037	0.036	0.050	0.033	0.013	0.017	0.102	0.027	0.091	0.005	-0.050
TOT	0.594	0.346	0.346	0.610	0.436	0.581	0.392	0.295	0.902	0.265	0.225

	POL	PRT	ROU	RUS	SVK	SVN	SWE	TUR	TWN	USA	WRL
E1	0.602	0.281	0.235	0.552	0.830	0.381	0.243	0.432	0.460	0.283	0.572
E2	0.112	0.031	0.065	-0.069	-0.136	0.002	-0.085	0.002	0.072	-0.094	-0.084
E3	0.041	0.009	0.040	-0.006	-0.088	-0.012	-0.043	-0.012	0.109	-0.015	-0.009
E4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
E5	-0.001	0.001	0.000	0.000	0.001	-0.001	0.002	-0.001	0.001	0.001	-0.001
E6	-0.001	-0.001	0.000	0.000	-0.001	-0.001	-0.002	-0.001	-0.003	-0.001	-0.001
E7	-0.535	-0.010	0.100	0.133	-0.264	0.004	0.165	-0.073	-0.260	0.153	-0.146
E8	0.008	0.005	0.001	0.013	0.014	0.006	0.010	0.005	0.006	0.004	0.008
E9	0.077	-0.101	0.159	0.037	0.020	-0.118	-0.032	0.058	-0.159	-0.032	-0.043
E10	-0.040	-0.014	-0.027	-0.065	-0.053	-0.023	-0.020	-0.057	-0.014	-0.007	-0.029
E11	-0.073	0.096	0.023	0.037	-0.044	0.058	0.035	-0.028	0.046	0.054	0.019
E12	0.006	0.040	0.063	0.138	0.115	0.058	0.016	0.048	0.011	0.028	0.020
E13	-0.010	0.054	-0.206	-0.250	0.034	0.049	-0.045	0.011	-0.012	-0.010	-0.020
E14	0.003	0.001	0.001	0.002	0.007	0.002	0.000	0.047	0.003	0.000	0.001
E15	-0.022	0.050	-0.010	-0.027	0.051	0.048	0.038	0.012	0.016	0.042	-0.024
E16	0.002	0.009	0.034	0.015	0.082	0.018	0.008	0.047	-0.036	0.013	0.004
E17	0.021	0.027	0.016	0.006	0.007	0.012	0.014	0.019	-0.019	-0.005	0.011
E18	-0.143	0.003	0.041	0.019	-0.346	-0.040	0.097	-0.246	0.036	0.027	-0.108
E19	-0.020	0.059	0.024	-0.013	0.133	0.066	0.046	0.059	-0.020	0.055	-0.020
TOT	0.027	0.538	0.559	0.522	0.362	0.509	0.445	0.324	0.238	0.495	0.150

Table D.3: Country specific structural change determinants - agriculture to non-agriculture relocation

	AUS	AUT	BEL	BGR	BRA	CAN	CHE	CHN	CYP	CZE	DEU
E1	0.318	-0.227	-0.677	-0.347	0.637	0.172	-0.013	-0.073	0.449	0.058	-0.395
E2	0.036	-0.107	0.113	0.068	-0.006	-0.091	-0.044	0.103	-0.336	0.082	-0.037
E3	0.001	-0.025	0.093	0.000	-0.010	-0.028	-0.004	0.026	-0.011	0.029	0.029
E4	-0.040	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E5	0.000	-0.001	0.001	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000
E6	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000
E7	0.175	0.047	-0.124	0.132	-0.122	0.059	0.158	0.436	0.089	0.107	0.164
E8	0.006	-0.002	-0.004	-0.005	0.010	0.005	-0.005	-0.002	-0.002	-0.011	-0.011
E9	0.004	0.017	0.005	0.008	-0.009	0.013	0.020	-0.058	0.038	-0.001	0.024
E10	-0.013	-0.004	-0.011	-0.006	0.008	0.005	-0.005	0.019	0.011	0.005	0.019
E11	0.052	0.114	0.065	0.381	0.095	0.053	0.095	0.397	0.167	0.058	0.051
E12	0.028	0.121	0.023	0.055	-0.003	0.036	0.059	0.007	-0.009	0.131	0.086
E13	-0.020	-0.001	0.018	-0.053	-0.010	-0.016	-0.002	-0.012	-0.301	-0.005	0.021
E14	0.001	0.000	0.002	-0.002	0.000	0.000	0.000	-0.001	-0.011	0.000	0.000
E15	0.017	0.025	0.019	0.075	0.032	0.011	0.011	0.109	-0.038	0.028	0.003
E16	-0.007	-0.003	0.001	-0.018	0.001	-0.001	-0.002	0.002	0.016	-0.011	-0.006
E17	0.050	0.057	0.162	0.026	0.031	0.068	0.015	0.012	0.078	0.037	0.045
E18	-0.005	-0.140	-0.105	0.020	-0.049	-0.055	-0.116	0.057	-0.039	-0.044	-0.082
E19	0.010	0.023	0.020	0.057	0.033	0.010	0.009	0.111	-0.022	0.017	-0.003
TOT	0.617	-0.105	-0.398	0.391	0.636	0.243	0.177	1.132	0.079	0.479	-0.093

	DNK	ESP	EST	FIN	FRA	GBR	GRC	HRV	HUN	IDN	IND
E1	0.092	-0.005	0.513	0.048	0.020	-0.072	0.504	0.132	0.569	-0.751	0.164
E2	-0.106	0.053	-0.166	-0.162	-0.054	0.111	-0.033	-0.029	-0.271	-0.014	-0.032
E3	-0.052	0.005	-0.052	-0.026	-0.011	0.020	-0.011	-0.040	-0.049	-0.002	0.002
E4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	0.000
E6	0.000	0.000	-0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
E7	0.060	-0.186	0.020	0.066	0.028	-0.302	-0.024	0.093	0.015	0.018	0.247
E8	0.003	0.000	0.006	-0.004	-0.004	-0.004	0.007	-0.002	0.001	-0.011	0.004
E9	-0.064	-0.002	0.002	-0.022	0.007	0.012	-0.020	0.009	0.010	-0.001	-0.019
E10	-0.003	-0.013	-0.015	-0.016	0.002	-0.011	-0.021	-0.008	0.005	-0.024	0.025
E11	0.025	0.257	0.064	-0.008	0.126	0.135	0.103	0.175	0.103	0.245	0.388
E12	0.005	0.048	0.107	0.037	0.019	0.044	-0.011	0.002	0.093	0.010	0.010
E13	0.013	0.048	-0.014	0.011	0.018	0.018	0.048	-0.002	0.033	0.019	-0.029
E14	0.000	0.002	0.000	0.002	-0.001	0.001	-0.001	-0.001	0.000	0.010	0.002
E15	-0.011	-0.032	0.034	0.016	0.021	-0.017	-0.093	0.030	0.012	-0.033	0.022
E16	-0.005	-0.002	-0.023	0.000	-0.006	-0.002	0.001	-0.005	-0.001	0.002	-0.003
E17	0.129	0.110	0.045	0.022	0.058	0.027	0.037	0.048	0.048	0.011	0.011
E18	-0.036	-0.209	-0.029	-0.029	-0.046	0.005	-0.068	-0.094	-0.062	-0.020	0.018
E19	-0.016	-0.034	0.011	0.017	0.015	-0.020	-0.091	0.024	0.011	-0.032	0.019
TOT	0.032	0.040	0.504	-0.048	0.193	-0.055	0.328	0.331	0.517	-0.572	0.829

	IRL	ITA	JPN	KOR	LTU	LUX	LVA	MEX	MLT	NLD	NOR
E1	-0.221	-0.042	-0.188	0.244	-0.276	-1.268	0.159	0.031	0.300	-0.005	0.504
E2	0.409	-0.016	-0.085	-0.123	0.341	0.260	0.023	0.029	-0.326	-0.015	-0.186
E3	-0.070	0.005	0.002	-0.019	0.053	0.168	-0.046	-0.002	-0.008	-0.014	-0.037
E4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E5	-0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000
E6	-0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E7	-0.384	-0.260	-0.021	0.043	-0.012	-0.132	-0.051	0.151	-0.137	-0.113	0.185
E8	-0.006	-0.003	-0.004	0.003	-0.013	-0.028	0.000	-0.001	-0.003	-0.001	0.009
E9	0.014	0.012	0.043	0.020	-0.030	0.123	0.008	0.007	0.068	-0.068	0.001
E10	0.006	-0.013	0.008	-0.006	0.004	0.005	-0.014	-0.006	-0.025	-0.006	-0.014
E11	0.139	0.272	0.044	0.234	0.073	0.155	0.167	0.053	0.135	0.051	0.059
E12	-0.101	0.083	0.011	0.043	0.238	0.236	0.113	0.020	0.093	-0.047	0.090
E13	0.018	-0.008	0.025	0.022	-0.079	0.016	-0.052	-0.019	0.073	0.080	-0.038
E14	-0.004	-0.001	0.000	0.001	-0.007	-0.001	-0.001	0.001	0.005	0.000	0.007
E15	-0.041	-0.020	-0.033	-0.016	0.055	-0.020	0.041	-0.016	0.047	-0.024	0.021
E16	-0.071	0.002	-0.007	0.001	-0.007	-0.017	-0.015	-0.005	0.004	-0.006	0.009
E17	0.085	0.043	0.006	0.020	0.044	0.139	0.031	0.070	0.047	0.267	0.073
E18	-0.247	-0.086	-0.009	0.028	-0.137	0.105	-0.088	-0.217	-0.019	-0.108	-0.010
E19	-0.112	-0.018	-0.040	-0.015	0.048	-0.037	0.026	-0.021	0.051	-0.030	0.030
TOT	-0.594	-0.050	-0.248	0.481	0.296	-0.294	0.300	0.076	0.306	-0.039	0.703

	POL	PRT	ROU	RUS	SVK	SVN	SWE	TUR	TWN	USA	WRL
E1	-0.140	0.003	0.546	0.029	1.116	0.635	-0.338	-0.217	-0.381	0.131	0.203
E2	-0.159	0.063	-0.085	0.189	-0.208	-0.080	0.111	0.004	-0.055	-0.214	0.053
E3	-0.025	0.003	-0.019	0.024	-0.039	-0.009	0.016	0.007	-0.037	-0.028	0.011
E4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
E5	0.000	0.001	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000
E6	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000
E7	0.275	-0.030	0.340	0.117	-0.086	-0.108	-0.056	0.198	0.246	0.042	0.284
E8	-0.006	0.000	-0.011	-0.004	0.012	0.008	-0.003	-0.006	-0.003	-0.003	0.003
E9	0.005	0.009	-0.086	-0.046	0.011	0.034	0.022	-0.018	0.112	-0.024	-0.402
E10	0.007	-0.017	-0.072	-0.104	-0.040	-0.003	-0.011	-0.005	0.029	0.021	0.019
E11	0.226	0.068	0.116	0.445	0.007	0.104	0.037	0.106	0.090	0.102	0.401
E12	0.070	0.027	0.041	-0.009	0.095	0.069	0.101	0.000	0.005	0.027	0.004
E13	-0.009	0.036	-0.100	-0.162	0.026	0.029	-0.027	0.006	-0.001	-0.010	-0.012
E14	0.003	-0.001	0.001	0.001	-0.003	-0.001	-0.001	0.029	0.001	0.000	0.001
E15	-0.005	-0.048	0.058	0.009	0.038	0.028	0.015	0.028	-0.005	-0.008	0.029
E16	-0.001	-0.004	-0.014	-0.006	-0.023	-0.009	-0.006	-0.019	0.024	-0.001	-0.002
E17	0.029	0.027	0.009	0.011	0.039	0.026	0.032	0.035	0.061	0.026	0.015
E18	-0.062	-0.133	0.024	-0.026	0.030	0.008	-0.059	-0.057	-0.068	-0.031	-0.017
E19	-0.007	-0.052	0.044	0.003	0.015	0.020	0.009	0.010	0.019	-0.009	0.028
TOT	0.202	-0.049	0.793	0.471	0.993	0.753	-0.157	0.102	0.041	0.021	0.617

Appendix E

Regression results

Table E.1: Regression results of scatter plot linear trends in figure 4.5a, 4.5b, 4.5c, and 4.5d

VARIABLES	(1) Yearly SC	(2) Yearly SC	(3) Cumulative SC	(4) Cumulative SC
Cumulative			0.770***	
Productivity			(0.0728)	
Cumulative				0.217
Non-homothetic				(0.409)
Yearly	0.691***			
Productivity	(0.0218)			
Yearly		0.452***		
Non-homothetic		(0.0876)		
Constant	0.0203***	0.0294***	0.264***	0.437***
	(0.00125)	(0.00202)	(0.0276)	(0.0591)
Observations	602	602	43	43
R-squared	0.627	0.042	0.732	0.007

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table E.2: Regression results of scatter plot linear trends in figure 4.8a and 4.8b

VARIABLES	(1) International SC yearly effects	(2) International SC cumulative effects
Domestic SC yearly effects	-0.640***	
	(0.0333)	
Domestic SC cumulative effects		-0.634***
		(0.0667)
Constant	0.0129***	0.388***
	(0.00193)	(0.0233)
Observations	602	43
R-squared	0.381	0.688

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix F

Regional results for every determinant

Figure F.1: Manufacturing to services - part 1

Figure F.2: Manufacturing to services - part 2

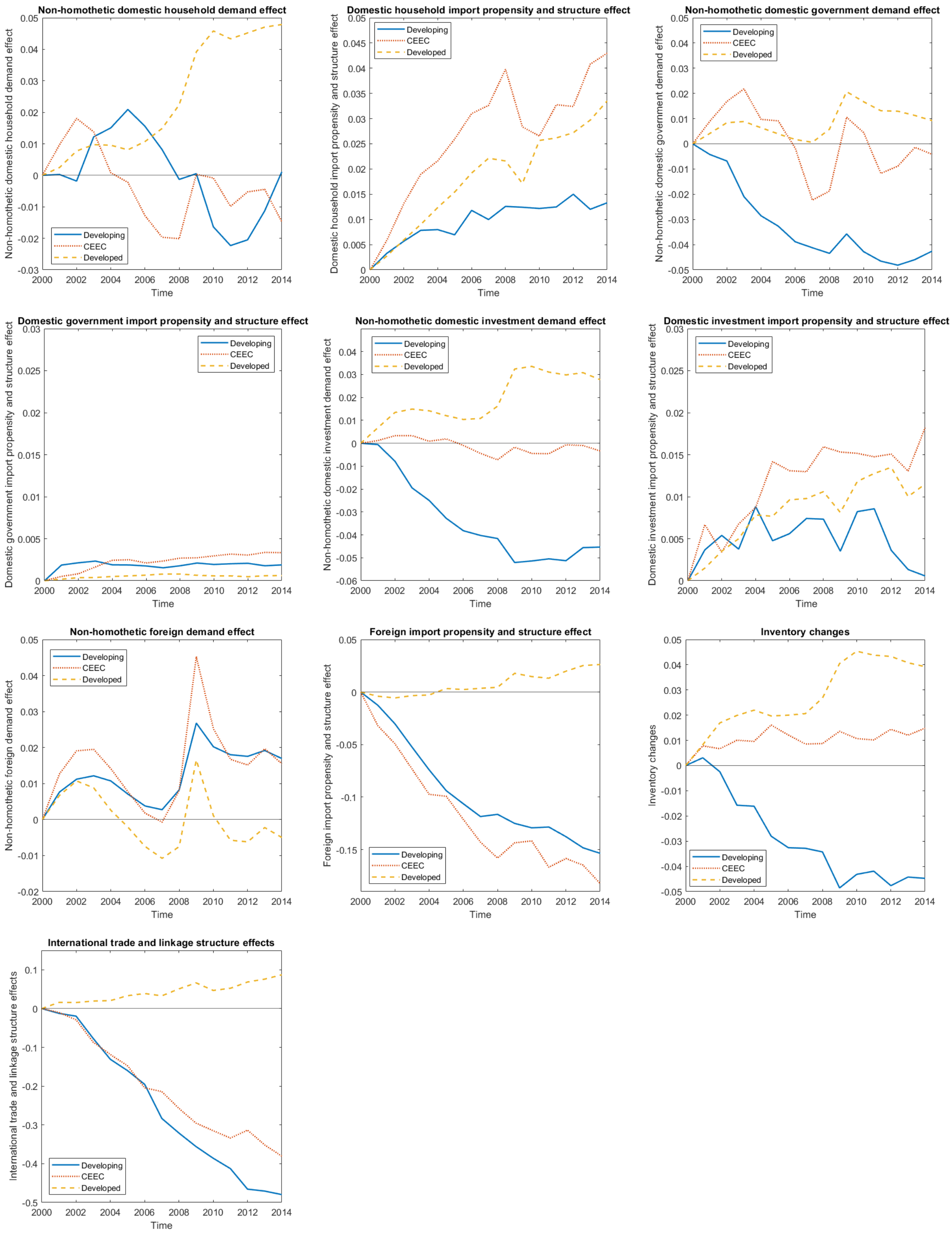
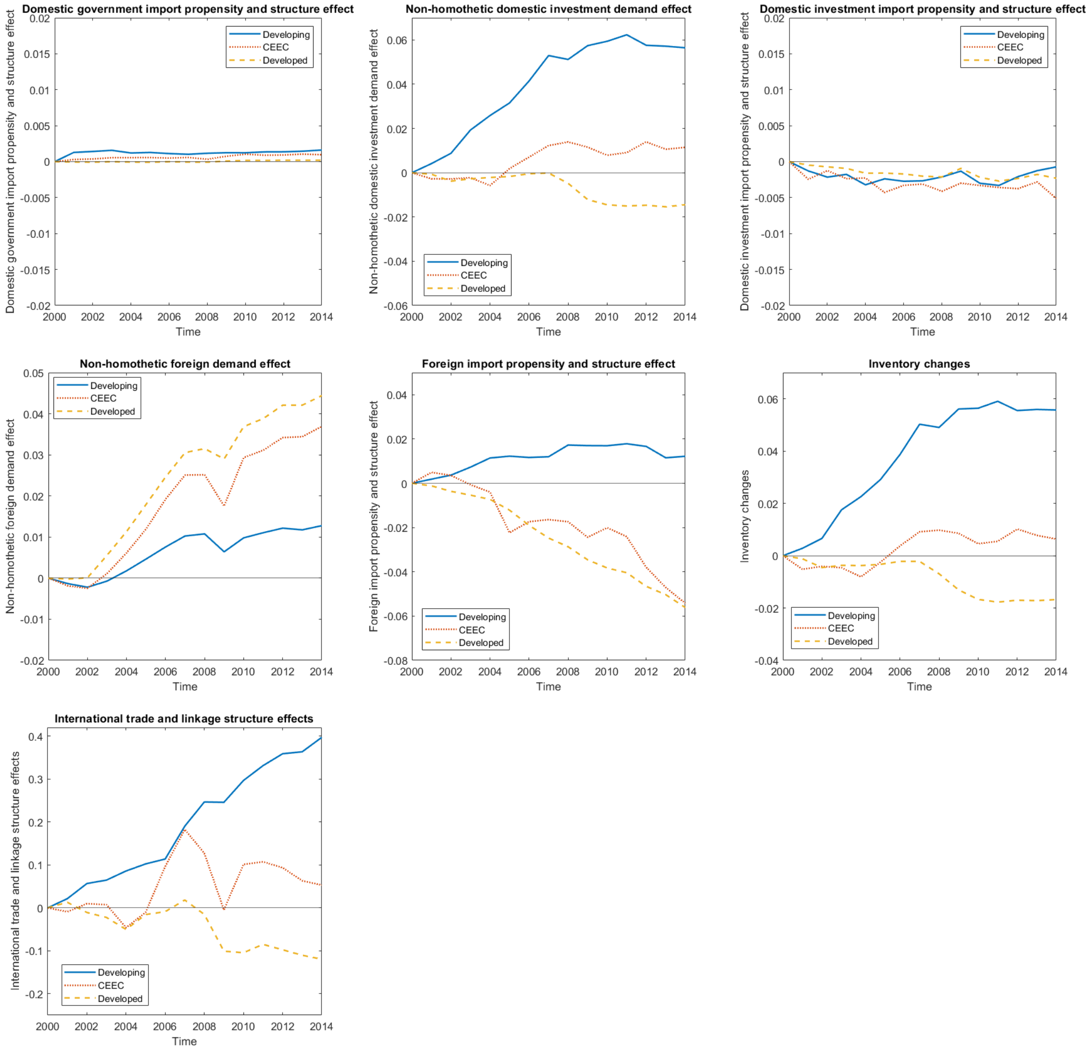


Figure F.3: Agriculture to non-agriculture - part 1

Figure F.4: Agriculture to non-agriculture - part 2



Daljši povzetek disertacije v slovenskem jeziku

V disertaciji obravnavamo dva še ne raziskana endogena ekonomska mehanizma, ki prispevata k poglabljanju ali ohranjanju neenakega razvoja med državami. Osredotočamo se na tiste mehanizme, katerih delovanje ni odvisno od kvalitativnih ekonomskih ali izvenekonomskih institucionalnih ali strukturnih razlik med državami, temveč njihov asimetrični učinek na razvoj držav izhaja izključno iz razlike v razvitosti ter delovanja trga. V disertaciji se osredotočamo na dva neraziskana mehanizma, ki dinamično delujeta predvsem na strani ponudbe, tehnološke rasti in mednarodne specializacije.

Osnovna zamisel glede predmeta naše študije - dveh še neidentificiranih ekonomskih endogenih mehanizmov, ki prispevata k neenakomernemu razvoju - je, da obstajata dva endogena ekonomska procesa na ponudbeni strani, ki prispevata k neenakomernemu razvoju. Oba mehanizma sta povezana s strukturnim razmerjem med stopnjo razvitosti in mednarodnimi relativnimi stroški proizvodnih dejavnikov. Empirične raziskave so pokazale, da so relativni stroški kapitala, tehnologije in znanja nižji v bolj razvitih državah in višji v manj razvitih državah (Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997). V Marxističnem okviru je to mogoče razložiti s predpostavko, da je mobilnost delovne sile bolj omejena kot mobilnost kapitala, tehnologije in znanja, lokalni stroški akumulacije teh proizvodnih dejavnikov pa so v manj razvitih državah relativno višji.

Prvi v disertaciji obravnavani mehanizem se nanaša na povezavo med neenakomernimi relativnimi stroški proizvodnih dejavnikov in širjenjem tehnologije. Če je tehnologija povezana s cenami tehničnih proizvodnih dejavnikov, kar raziskujejo pristopi, ki industrializacijo proučujejo kot širitev nalog, ki jih lahko dobičkonosno opravljajo stroji, kar vodi v neposredno povezavo med ravnmi plač in nadomeščanjem dela s stroji (Acemoglu, 2010; Acemoglu & Autor, 2011; Acemoglu & Restrepo, 2017a, 2017b, 2019; Sylos-Labini, 1984; Zeira, 1998), to lahko endogeno prispeva k ohranjanju neenakomernega razvoja zaradi neenakomerne porazdelitve relativnih stroškov dejavnikov in njihovega vpliva na širjenje tehnologije.

Drugi obravnavani mehanizem je povezan z endogenimi vzorci mednarodne specializacije v globalno povezanem gospodarstvu, ki so skladni s tem, kar Amin (1974) imenuje determinante izbire med "lahkimi" in "težkimi" tehnikami, v sodobnejših tokovih znane kot "funkcionalna specializacija". Glavna hipoteza disertacije je, da so relativni stroški proizvodnih dejavnikov glavna endogena ekonomska determinanta širjenja tehnologije, funkcionalne specializacije, strukturnih sprememb in s tem globalnih vzorcev neenakomernega razvoja. V zvezi s tem nas preseneča, da razlike v relativnih stroških dejavnikov v sodobni literaturi o rasti in razvoju nikoli niso bile uporabljene kot glavni pojasnjevalni dejavniki funkcionalne specializacije, medsektorskih strukturnih sprememb in vzorcev tehnološke rasti v večregionalnem okolju, kljub številnim dokazom o njihovem učinku v okviru zaprtega gospodarstva (Sylos-Labini, 1984; Zeira, 1998). Namen te disertacije je zapolniti to vrzel v ekonomiji ponudbene strani.

V prvem poglavju napravimo pregled področja, v katerem se osredotočimo na pregled različnih paradigmatskih pristopov z vidika njihovega doprinosa k razumevanju mehanizmov, ki prispevajo k ohranjanju neenakega razvoja. V pregled zajamemo klasično in moderno marksistično teorijo mednarodnega razvoja, zgodnje teorije industrializacije, strukturalne modele Sever-Jug, Kaldorjev pristop k teoriji rasti in razvoja, teorije rasti z omejitvami plačilne bilance, neoklasično teorijo rasti in endogene rasti, pristope, ki analizirajo rast in tehnološki napredek skozi prizmo razčlenitve posameznih opravil v produkciji in pristope, ki obravnavajo globalne verige vrednosti in njihov vpliv na mednarodno ekonomijo.

Obstajata dve zelo široki skupini študij, katerih cilj je endogeno pojasniti ohranjanje neenakomernega razvoja. Prva skupina se osredotoča na endogeno dinamiko, povezano predvsem z negospodarskimi dejavniki, kot so demografija, izobraževanje, institucije ali geografija. Jedro naše disertacije (z izjemo poglavja 2) nima enakega predmeta preučevanja kot te teorije, saj se pri raziskovanju osredotočamo na dejavnike, povezane predvsem z delovanjem trga. Druga skupina je za našo študijo pomembnejša, saj se osredotoča na endogene ekonomske razlage neenakomernega razvoja. Vključuje različne teorije z različnih paradigmatskih področij. V prvem poglavju disertacije podajamo natančen pregled teh pristopov, ki segajo od visoke razvojne teorije, različnih teorij endogene ekonomske rasti, pristopov, ki temeljijo na evolucijski dinamiki, proučevanja različnih dinamik prehodov in razvojnih pasti, ter teorije mednarodne rasti, ki upoštevajo omejitve plačilne bilance. Te teorije konceptualizirajo različne endogene mehanizme, ki prispevajo k ohranjanju neenakomernega razvoja. Razdelili smo jih v pet večjih skupin:

1.) Dinamika naraščajočih donosov obsega;
2.) Dinamika aglomeracije;
3.) Dinamika večkratnih stacionarnih stanj;
4.) Dinamika ter modeli sever-jug;
5.) Večregionalna dinamika, ob upoštevanju omejitev plačilne bilance.

Naraščajoči donosi obsega so v literaturi o rasti in razvoju najpogostejša oblika funkcionalnega sklepanja o divergentni gospodarski dinamiki. Analizo naraščajočih donosov obsega lahko zasledimo že pri Youngu (1928), visoka razvojna teorija se pogosto opira na argumente in konceptualizacije naraščajočih donosov (Kaldor & Mirrlees, 1962; Myrdal, 1957; Rosenstein-Rodan, 1943), široko področje teorije endogene rasti (Lucas, 1988; Romer, 1986, 1990) pa predstavlja nadaljnje poskuse preučevanja rasti in razvoja z osrednjimi predpostavkami naraščajočih donosov obsega. Glavni raziskovalni predmet te disertacije - doslej neznana endogena ekonomska mehanizema, ki prispevata k ohranjanju neenakomernega razvoja - ne delujeta zaradi naraščajočih donosov obsega in, kolikor nam je znano, v literaturi, ki se osredotoča na dinamiko naraščajočih donosov, še nista bila raziskana. Obstaja še drugi pomemben dejavnik, zakaj so teorije, ki se osredotočajo na naraščajoče donose, manj pomembne za raziskovanje objektov naše analize. Teorije naraščajočih donosov se osredotočajo predvsem na analizo rasti v zaprtem gospodarstvu in tako zanemarjajo ključne strukturne vzorce in soodvisnosti, ki se pojavljajo v okviru globalno povezanih in integriranih držav v večregionalnem kontekstu. Nasprotno pa naš predmet raziskave učinkuje v večregionalnem okolju, saj se njegovi osrednji vzorci delovanja pojavljajo v mednarodnem kontekstu v obliki relacijskih razmerij.

Dinamiko aglomeracij raziskujejo predvsem nova ekonomska geografija, nova teorija trgovine ter urbana in regionalna ekonomija (Krugman, 1981, 1991; Krugman & Venables, 1995). Družina modelov, temelječa na kombinaciji učinkov obsega v okvirih monopolistične konkurence in uvedbe prevoznih stroškov, kaže izjemno polarizirajočo dinamiko. Že majhna motnja ali razlika v začetnih pogojih sproži verigo dogodkov, ki vodijo v popolno polarizacijo in aglomeracijo industrije. Mehanizem, ki vodi dinamiko teh modelov, ne ustreza dinamiki med velikimi regionalnimi enotami, razvitimi državami, državami v razvoju in nerazvitimi državami, temveč je dinamika aglomeracije značilna za dinamiko znotraj regije. Razmerje med razvojem mest in podeželja je do neke mere značilno za vsako državo, vendar preprosta dinamika aglomeracij ne more predstavljati dinamične konceptualizacije preučevanja dolgoročnega neenakomernega razvoja med državami in večjimi regijami. Zato učinke aglomeracije v tej disertaciji puščamo ob strani. Delovanje še neidentificiranega endogenega ekonomskega mehanizma, ki je osrednji raziskovalni predmet te disertacije, ni odvisno od uvedbe prevoznih stroškov in nima nič skupnega z dinamiko aglomeracije, preučevano na zgornjih področjih.

Razvojne pasti so dinamične rešitve modelov, ki vodijo do več diskretnih stacionarnih stanj, običajno nizkega (blizu nič) in visokega stacionarnega stanja. Endogene spremenljivke v teh konceptualizacijah pogosto niso predvsem ekonomske, kot sta endogena rodnost ali izobrazba. Kljub temu so številne razvojne pasti izpeljane s pomočjo endogenih ekonomskih mehanizmov, pri čemer so najboljši primeri različne konceptualizacije pasti tehnološke difuzije (Fagerberg, 1987; Frey, 2019; Gomulka, 1990). Navkljub temu raziskave tehnoloških pasti niso opredelile in raziskale razmerja med dinamiko relativnih stroškov dejavnikov in difuzijo tehnologije v mednarodnem okolju, ki je v središču naše študije. Funkcionalni mehanizmi, uporabljeni za izpeljavo mnogoterosti ustaljenih stanj, se večinoma opirajo na eksogeno sposobnost učenja (Fagerberg, 1987) ali tehnološko skladnost, ki jo je opredelil Abramovitz (1986). Eden od prispevkov te disertacije je v endogenizaciji neenakomernih vzorcev širjenja tehnologije, ki jih predstavljamo v novem modelu, ki kot prvi zagotavlja funkcionalno izpeljavo krivulj uvajanja tehnologije, ki so specifične za stopnjo razvitosti in odvisne od relativnih stroškov dejavnikov. To je predstavljeno v poglavju 3. Različne elemente zgodovinsko pogojenih trajektorij dinamike tehnološkega razvoja raziskuje predvsem neoschumpeterjanska evolucijska ekonomija, pa tudi različna področja, ki se včasih prekrivajo z dinamiko razvojnih pasti, dinamiko strukturnih sprememb, dinamiko naraščajočih donosov ter dinamiko mednarodne trgovine (Araujo & Lima, 2007; Gabardo et al., 2020; Lorentz et al., 2016; Pasinetti, 1983, 1993).

Modeli Sever-Jug (Darity, 1990; Dutt, 1989; Findlay, 1980, 1981, 1984) v nasprotju z zgornjimi pristopi analizirajo predvsem mednarodno ekonomijo in trgovino. Ta tradicija predpostavlja eksogene razlike v strukturnih značilnostih gospodarstev Severa in Juga, iz katerih izpeljuje razvojne rezultate ter distribucijo dobrobiti iz trgovine. Praviloma se predpostavlja, da imajo režimi rasti različno funkcionalno obliko za Sever in Jug, ponavadi so opredeljeni bodisi kot neoklasični Solow-Swanov model, Lewisov model dveh sektorjev ali modifikacije z nekaterimi Kaleckijevimi, postkeynesianskimi ali Marxovimi predpostavkami. Zaradi tega različna stacionarna stanja, ki jih izpeljujejo, niso niti popolnoma endogeno izpeljana niti povsem ekonomska, temveč izhajajo iz predpostavljenih strukturnih razlik med gospodarstvi, ki niso le eksogene, temveč so lahko tudi zunajekonomske narave. Tako se na ravni konceptualne analize njihov predmet raziskovanja ne ujema s predmetom naše študije. Vendar pa nekatera temeljna spoznanja o tem, kako strukturne razlike, zlasti razlike v sektorskem razvoju, vplivajo na distribucijo dobrobiti iz trgovine in razvojone rezultate, ponujajo pomembna spoznanja za naš cilj, da jih izpeljemo endogeno in v okviru normalnega delovanja tržnega sistema.

Modeliranje rasti, ki upošteva omejitve plačilne bilance, predstavlja konceptualno nadgradnjo modelov Sever-Jug, kot večregijski okvir mednarodne trgovine, ki omogoča analizo trgovine in razvoja v okviru mednarodnega povezovanja (Dutt, 2002; Spinola, 2020; Thirlwall, 1979; Vera, 2006). Gre za področje, ki se ukvarja z neenakomernim razvojem in njegovo endogeno izpeljavo v večregionalnem mednarodnem okolju - zato je njegov raziskovalni predmet najbolj skladen z raziskovalnim predmetom naše disertacije. Strukturne spremembe v smislu kompleksne medsektorske dinamike, endogene tehnološke rasti in difuzije ter kompleksne mednarodne trgovinske elastičnosti opredeljujejo niz medsebojnih povezav in soodvisnosti, ki izhajajo iz delovanja mednarodnih trgov in vodijo v neenakomeren razvoj (Araujo & Lima, 2007; Gabardo et al., 2020; Lorentz et al., 2016).

Vendar se v tem okviru pojavljajo nekatere konceptualne omejitve.

Pristop k modeliranju rasti, ki upošteva omejitve plačilne bilance, se osredotoča izključno na dinamiko in procese, ki izhajajo iz povpraševanja in ne upošteva temeljnih dejavnikov na strani ponudbe, kot so endogeni tehnološki napredek, napredek, ki ga spodbujajo naložbe, in strukturne spremembe, ki jih spodbuja ponudba. Ta ozka osredotočenost na procese na strani povpraševanja preveč poenostavlja zapletena vprašanja rasti in neenakomernega razvoja. Razvojni rezultati modeliranja ob plačilnobilančnih omejitvah temeljijo izključno na predpostavkah o elastičnosti mednarodnega povpraševanja. Čeprav lahko elastičnost povpraševanja pojasni nekatere razlike v rasti proizvodnje med regijami, temeljne determinante te elastičnosti niso povsem razumljene in so verjetno povezane tako z dejavniki ponudbe kot povpraševanja, saj elastičnost mednarodne trgovine zakriva zapleteno dinamiko na strani ponudbe. V takšnih modelih je zato nemogoče ločiti učinke na strani ponudbe, ki se skrivajo za trgovinskimi elastičnostmi. Kljub številnim podobnostim v splošnem pristopu je predmet naše disertacije, za razliko od pristopa plačilne bilance, v celoti na področju ekonomije ponudbe in na tem področju še ni bil opredeljen.

Predmet naše študije sta dva endogena ekonomska mehanizma, ki ju poganja dinamika na strani ponudbe in ki prispevata k ohranjanju neenakomernega razvoja. Prvi se nanaša na difuzijo tehnologije ter njeno morebitno interakcijo in soodločanje z relativnimi stroški dejavnikov (Acemoglu & Restrepo, 2017a, 2017b, 2019, 2022; Zeira, 1998). Drugi se nanaša na delovanje, sestavljeno iz več znanih in raziskanih dinamičnih vzorcev in interakcij, od katerih je bil vsak opisan v izoliranih okvirih zaprte ekonomije (Acemoglu & Guerri, 2008) ali opisno preučen (Amin, 1974, 1976), pa tudi empirično ovrednoten (Timmer et al., 2019). Osnovno idejo delovanja drugega preučevanega endogenega ekonomskega mehanizma lahko povežemo z Aminovim razlikovanjem med lahkimi in težkimi tehnikoam. Razlikovanje se osredotoča na relativni potencial za rast produktivnosti v danem tehnološkem okviru. Specializacijo v lahke ali težke tehnike je mogoče opazovati kot funkcionalno specializacijo v določenih sektorjih ali, v bolj globalno integriranem gospodarstvu z dodano vrednostjo, v določenih opravilih, ki proizvajajo vmesne proizvode. Relativna intenzivnost kapitala ali dela je tako le posledica takšne specializacije.

Sodobnejšo formulacijo razlikovanja med "lažjimi" in "težkimi" tehnikami so prevzele nedavne študije mednarodne funkcionalne specializacije (Timmer et al., 2019), v katerih so lahko konceptualna analogija "težkim" nalogam kapitalsko, spretnostno ali tehnološko intenzivne naloge. Študije funkcionalne specializacije empirično kažejo, da se ob mednarodnem gospodarskem povezovanju različno razvitih držav pojavi zelo neenakomerna funkcionalna specializacija. Takšni vzorci vodijo do različnih razvojnih rezultatov, povezanih z zgodovinsko pogojenimi trajektorijami, in s tehnološkimi blokadami, povezanimi s srednje-dohodkovno razvojno pastjo (Bárány & Siegel, 2018; Eichengreen et al., 2013; Hartmann et al., 2021; Krūminas et al., 2019; Myant, 2018; Timmer et al., 2019) ali hipotezo konvergenčnih klubov (Battisti et al., 2016; Quah, 1993). V ekonomiji še ne obstaja teoretično razumevanje, kako tak neenakomeren razvoj funkcionalne specializacije poganjajo avtonomni, decentralizirani in tržno usmerjeni procesi. Kljub empiričnemu zanimanju, ki izhaja iz preučevanja podatkov na ravni poklicev in posamičnih opravil, funkcionalna specializacija ni bila preučevana kot endogeni, s ponudbo pogojeni gospodarski pojav. To vrzel skušamo zapolniti z ugotavljanjem in opredelitvijo delovanja endogenega mehanizma na strani ponudbe, ki ekonomsko endogeno ustvarja neenake vzorce funkcionalne specializacije in tako prispeva k ohranjanju neenakomernega razvoja.

Naša metodologija za reševanje tega vprašanja se začne z najširšo opredelitvijo elementov, ki lahko endogeno prispevajo k takšni dinamiki na strani ponudbe. Naš pregled literature, predstavljen v prvem poglavju, opredeljuje štiri glavne elemente, ki se zdijo temeljni za delovanje predmeta naše študije:
1.) narava tehnološkega napredka in vloga stroškov proizvodnih dejavnikov;
2.) Vloga medsektorske heterogenosti in dinamika, ki jo spodbuja;
3.) Vloga zakona vrednosti na mednarodni ravni;
4.) Vloga mednarodne delitve dela, ki jo določajo relativni stroški proizvodnih dejavnikov.

V skladu z opredelitvijo teh elementov smo postavili naslednje raziskovalne hipoteze, povezane z endogenima mehanizmoma, ki sta predmet naše študije:

Prva hipoteza pravi, da sta v okolju mednarodno povezanih, različno razvitih držav splošni tehnološki razvoj in sprejemanje proizvodnih tehnologij strukturno odvisna od relativnih stroškov proizvodne tehnologije, ki so odvisni od stopnje razvitosti. Razlike v tehnični sestavi odražajo razlike v produktivnosti in hkrati določajo razlike v plačah med državami. Po drugi strani pa se heterogene kapitalske dobrine med državami pretakajo veliko bolj mobilno kot delovna sila (Hsieh & Klenow, 2007; Huisman & Kort, 2000; Jovanovic & Rob, 1997). To vodi do različnih relativnih cen dejavnikov, ki so neposredno odvisne od stopnje razvoja. Ker so relativni stroški proizvodnih tehnologij neposredno odvisni od relativnih cen proizvodnih dejavnikov, so relativni stroški proizvodnih tehnologij odvisni tudi od stopnje razvoja, kar bi lahko bil pomemben endogeni mehanizem za ohranjanje neenakomernega razvoja zaradi odvisnosti difuzije tehnologij od relativnih stroškov.

Druga hipoteza pravi, da je razvoj, specifičen za posamezne sektorje in naloge, v okolju mednarodno integriranih, različno razvitih držav strukturno odvisen od začetne stopnje razvitosti, in sicer zaradi sektorsko specifičnih učinkov tehničnih omejitev proizvodnje in različnih relativnih stroškov proizvodnih tehnologij. Součinkovanja granularne in komplementarne oblike tehničnih omejitev proizvodnje ter relativnih stroškov endogeno vodi v neenako funcionalno mednarodno specializacijo v sektorski in opravilni strukturi proizvodnje, kar dodatno ohranja neenakomeren razvoj. Če je značilnost vsakega sektorja ali funkcionalnega sklopa nalog edinstven vpliv različnih tehničnih sestav na produktivnost dela, potem bi lahko meddržavno sektorsko ali funkcionalno specializacijo endogeno določale razlike v relativnih stroških dejavnikov in relativnih stroških proizvodne tehnologije med različno razvitimi državami. Takšen razvoj neenake sektorske ali funkcionalne specializacije proizvodnje bi lahko predstavljal še en dinamični endogeni mehanizem za ohranjanje neenakega razvoja zaradi sektorskih in za naloge specifičnih funkcionalnih razlik v potencialu za rast produktivnosti med različno razvitimi državami.

Struktura disertacije je razdeljena na 6 poglavij. V prvem poglavju opravimo obsežen pregled literature, v katerem obravnavamo raziskave in literaturo iz različnih paradigmatskih tradicij, ki obravnavajo vprašanje neenakomernega razvoja z eksogenega in endogenega vidika, pa tudi z ekonomskega in izvenekonomskega vidika. To daje našemu raziskovalnemu objektu širok okvir in ga povezuje z različnimi drugimi endogenimi mehanizmi neenakomernega razvoja, ki so bili raziskani in lahko komplementarno pojasnjujejo dinamiko neenkaga razvoja.

Poglavje 2 je namenjeno nadaljnjemu raziskovanju ekonomskih in zunajekonomskih endogenih mehanizmov, ki so bili v literaturi že opredeljeni na različnih paradigmatskih področjih, kot je podrobno povzeto v prvem poglavju. Zagotavlja izčrpen empirični pregled različnih prehodnih režimov razvojnih pasti, ki so empirično analizirani z uporabo logistične funkcije za opredelitev dinamike pasti in prehoda. Cilj poglavja je razmejiti pomen različnih pragovnih režimov razvojnih pasti, ki so že bili preučeni za različne ravni razvoja. Glavna ugotovitev tega poglavja je, da preučevani režimi zunajekonomskih razvojnih pasti pojasnjujejo znaten del neenakomernega razvoja podrazvitih držav z nizkimi dohodki, medtem ko je njihova pojasnjevalna moč za dinamiko industrializiranih držav s srednjimi dohodki bolj omejena. To vzpostavlja večji pomen preučevanja endogenega ekonomskega mehanizma, ki ga poganja ponudba in je glavni predmet našega preučevanja v naslednjih poglavjih, saj bi lahko dopolnil razlage vztrajnega neenakomernega razvoja, preučevane z drugimi znotraj- in zunajekonomskimi endogenimi mehanizmi, zlasti v kontekstu vztrajnega neenakomernega razvoja med industrijsko razvitimi državami in regijami.

Poglavje 3 otvori osrednja konceptualna poglavja disertacije. To poglavje obravnava odnos med tehnološko difuzijo in neenakomernim gospodarskim razvojem v državah ter želi premostiti vrzel med teorijami sprejemanja tehnologije (Comin & Hobijn, 2010; Griliches, 1957; Stokey, 2021), ki se osredotočajo na krivulje sprejemanja tehnologije, vendar abstrahirajo od makroekonomske dinamike neenakomernega razvoja, in agregatnimi evolucijskimi pristopi do tehnologije in od analiz zgodovinsko pogojenih trajektorij neenakomernega tehnološkega razvoja (Fagerberg & Godinho, 2018; Verspagen, 1991), ki se osredotočajo na različne tehnološke razvojne pasti in dinamiko večkratnih stacionarnih stanj, vendar s poenostavljenimi in enodimenzionalnimi konceptualizacijami tehnologije, ki nimajo pojasnjevalne moči na ravni krivulj sprejemanja tehnologij. Predlagamo novo dinamično konceptualizacijo difuzije tehnologij, ki temelji na analogijah s fizikalnim procesom širjenja toplote ali delcev ter vključuje gospodarske in družbene učinke neenakomernega razvoja kot glavne dejavnike širjenja tehnologij. Razvijemo koncept prostora relativnih stroškov uvajanja tehnologije, da bi endogeno pojasnili nastanek krivulj uvajanja tehnologije v okviru neenakomernega razvoja. Naš glavni rezultat je, da relativne ravni proizvodnih stroškov pomembno določajo krivulje uvajanja tehnologij za posamezne države ter oblikujejo družbeno neenakomeren proces širjenja tehnologij in splošnega razvoja. Dinamični model in hipotezo preverjamo z uporabo podatkovnih zbirk CHAT in PENN ter dobimo zanesljive rezultate, ki kažejo, da je difuzija tehnologije endogeno pogojena z neenakomernim razvojem in da imajo pri tej dinamiki pomembno vlogo relativni stroški dejavnikov proizvodnje. Z zapolnitvijo te vrzeli v raziskavah prevzemanja tehnologij prispevamo k obema smerema literature - po eni strani nam je uspelo reproducirati osrednje rezultate evolucijske teorije pogojene z zgodovinsko dinamiko, ki je v našem primeru celo razširjena v primerjavi z diskretno dinamiko večih stacionarnih stanj in vsebuje cel kontinuum različnih razhajajočih se stacionarnih stanj, po drugi strani pa hkrati endogeno izpeljemo povprečne krivulje prevzemanja tehnologij za posamezne države glede na njihovo raven razvitosti, kar še nikoli ni bilo del katere koli študije prevzemanja tehnologij.

V poglavju 4 se osredotočamo na empirično oceno dejavnikov medsektorskih strukturnih sprememb in njihove možne interakcije z neenakomernim razvojem. Predlagamo novo multiregionalno strukturno input-output dekompozicijo, ki determinante sprememb v zaposlovanju razgradi na 19 različnih elementov. Predlagana strukturna dekompozicija vsebuje več novih elementov, ki metodološko prispevajo tako k področju input-output ekonomike kot empirično k področju analize strukturnih sprememb in raziskav globalanih vrednostnih verig. Za razliko od večine empiričnih input-output študij strukturnih sprememb (Appelbaum & Schettkat, 1999; Raa & Schettkat, 2001; in Savona & Lorentz, 2005) se naša študija osredotoča na dinamiko zaposlovanja in proizvodnje, kar omogoča podrobnejše preučevanje učinkov na strani ponudbe, kot če bi analizirali samo spremembe proizvodnje. Izvedemo vrsto hkratnih strukturnih dekompozicij za vseh 44 držav iz podatkovnega niza WIOD, kar omogoča novo kompleksno dekompozicijo dinamike trgovine in vrednostne verige hkrati z dinamiko strukturnih sprememb, ki jo spodbujata povpraševanje in ponudba. Naša študija je prva, ki celovito združuje vse tri elemente. Opredelimo stilizirane empirične indekse, ki smo jih razvili za merjenje strukturnih premikov v zaposlovanju in proizvodnji iz kmetijstva ter iz predelovalne industrije v storitve ločeno za vsako državo v vzorcu. Ključni empirični prispevek je ugotovitev, da so dejavniki strukturnih premikov iz predelovalne industrije v storitve predvsem odvisni od ponudbe, kar je v nasprotju z dozdajšnjimi input-output empiričnimi študijami(Appelbaum & Schettkat, 1999; Raa &

Schettkat, 2001; in Savona & Lorentz, 2005). Razlogov, zakaj je naša študija v protislovju z empiričnimi rezultati drugih študij, je lahko več: prvič, večina prejšnjih študij ni izvedla strukturne dekompozicije z realnimi spremenljivkami (s sektorsko defliranimi vrednostmi za končno in vmesno proizvodnjo) temveč z nominalnimi vrednostmi; drugič, ker te študije ne obravnavajo dinamike strukturnih sprememb z vidika zaposlenosti, temveč z vidika proizvodnje; in tretjič, ker komponenta končnega povpraševanja ni segmentirana na nehomotetično komponento, ki teoretično poganja dinamiko strukturnih sprememb, in različne druge učinke končnega povpraševanja, kot so homotetični učinki rasti dohodka, cenovni učinki in spremembe v strukturi trgovine. Naša glavna ugotovitev v tem poglavju je, da je selitev delovnih mest iz kmetijstva odvisna od drugačnih dejavnikov kot selitev iz predelovalnih panog v storitve. Premik delovnih mest iz proizvodnje v storitve je predvsem posledica učinkov na strani ponudbe, medtem ko je premik delovnih mest iz kmetijstva predvsem posledica nehomotetične preferenčne strukture končnega povpraševanja (Engelovega zakona). Ti rezultati opredelijo pomen preučevanja dinamike strukturnih sprememb na strani ponudbe v okviru neenakomernega razvoja, zlasti v okviru neenakomernega razvoja med industrijsko razvitimi državami, ki so že izšle iz razvojne pasti samooskrbne agrikulturne proizvodnje.

V nadaljevanju sledi konceptualno poglavje, katerega namen je preučiti delovanje drugega endogenega mehanizma, ki je predmet naše študije, v marksističnem okviru. V obstoječi marksistični literaturi obstajata dve glavni tradiciji, ki obravnavata zakon vrednost v mednarodnem okviru. Prva predpostavlja, da je vrednost nacionalno določena in izpeljuje prenose konkretnega upredmetenega dela med različno razvitimi državami (Amin, 1974; Emmanuel, 1972). Druga predpostavlja, da je vrednost mednarodno določena in da obstajajo svetovne razlike v konkretni mednarodni vrednosti, proizvedeni na enoto dela v različno razvitih državah. To je posledica delovanja mednarodnega zakona vrednosti in mednarodne konkurence med državami, za katere so značilni različni tehnološki in tehnični pogoji ter različna intenzivnost dela (Dashkovskij, 1927a, 1927b; Matsui, 1970). Sledimo idejam druge tradicije, saj redukcija analize na konkretno delo in konkretne prenose vrednosti, značilne za različne različice teorije neenake menjave, ne le mistificira razmerja med različno razvitimi regijami, temveč tudi opušča ključne elemente teorije vrednosti (njeno družbeno obliko in družbeno določitev), ki utelešajo njen potencial za zajem dinamičnih mehanizmov delovanja kapitalistične konkurence. Navkljub temu neposredna aplikacija teorije vrednosti v globalni okvir zahteva konceptualne spremembe. Glavna težava se pojavi v primerih, ko je mednarodna delitev dela neenakomerna in ima obliko skoraj popolne specializacije. V teh primerih preprosta uporaba nespremenjene teorije vrednosti vodi do zavajajočih rezultatov in ne zajame dejanskega dinamičnega procesa v mednarodnem gospodarstvu. Zato uvedemo posplošen zakon mednarodne vrednosti, ki prispeva k razumevanju delovanja mednarodne konkurence, mednarodne delitve dela in neenakomernega razvoja. Takšen koncept nam omogoča zajeti dinamično delovanje mednarodne konkurence, kjer je stopnja izkoriščanja v različno razvitih državah konstantna, posplošena teorija mednarodne vrednosti pa endogeno vodi v ne le tehnološki napredek, temveč tudi mednarodno delitev dela, ki je specifična za posamezne sektorje in naloge, kadar imajo sektorji in naloge neenak potencial za povečanje produktivnosti in tehnološke izboljšave.

Glavna ideja tega poglavja je poskus razširitve Aminovega opisnega okvira in glavnih argumentov glede funkcionalne specializacije na lahke in težke tehnike v mednarodnem gospodarstvu. S preoblikovanjem opisnih argumentov, predstavljenih v Aminovem delu, v analitični marksistični okvir analize, smo vzpostavili predpogoje za nadaljnje preoblikovanje, ki bi bilo primerno za vključitev v model multiregionalne dinamike. Glavno konceptualno odkritje, ki nam omogoča dokončno oblikovanje in združitev vseh dinamičnih komponent delovanja našega drugega endogenega ekonomskega mehanizma, je, da funkcionalna specializacija in razlikovanje med različnimi skupinami tehnik nista neposredno povezana z njihovo kapitalsko intenzivnostjo ali produktivnostjo, temveč z njihovimi srednjeročnimi razlikami v proizvodnih omejitvah, ki te razlike v pojavnosti povzročajo. Na tej osnovi opredelimo alternativno agregatno proizvodno funkcijo, ki je za razliko od gladke neoklasične proizvodne funkcije granularna: sestavljena je iz različnih komplementarnih skupin nalog, ki izkazujejo srednjeročne razlike v svojih proizvodnih omejitvah. To preoblikovanje predstavlja temeljno novost, ki jo uporabimo za endogeno izpeljavo vztrajnosti neenakomernega razvoja zaradi neenakomerne funkcionalne specializacije, ki je podkrepljena z učinki strukturnih sprememb v mednarodnem večregionalnem modelu, predstavljenem v naslednjem poglavju.

V zadnjem poglavju 6 združimo vse glavne ugotovitve analiz iz prejšnjih treh poglavij, da bi raziskali dinamično delovanje našega drugega preučevanega endogenega dinamičnega mehanizma v okviru večregionalnega modela. Našo izpeljavo začnemo z uporabo neoklasičnega modela za preučevanje pondubenih strukturnih sprememb v zaprtem gospodarstvu Acemogluja in Guerrija (2008) kot osnove, saj model omogoča uvedbo granularne omejitve ponudbe, ki smo jo preučili v prejšnjem poglavju. Sprememba neoklasičnega modela in njegova razširitev na večregijsko okolje omogočata analizo, kako posebne lastnosti spremenjene funkcije proizvodne omejitve in njena interakcija z relativnimi stroški proizvodnje vodi v trgovinsko in funkcionalno specializacijo ter naposled do ohranjanja neenakomernega razvoja. Prav tako je lažje izluščiti učinke modifikacij iz referenčnega modela, če gre za konvergenčni model enega stacionarnega stanja, kot če referenčni model že vsebuje elemente drugih endogenih mehanizmov, ki prispevajo k neenakomernemu razvoju in so bili v literaturi že obširno raziskani. Glavna ideja tega poglavja je zajeti endogeno oblikovanje funkcionalne specializacije z mehanizmom, ki deluje na strani ponudbe, za katero so značilni granularna proizvodna omejitev, dinamika strukturnih sprememb, ki jo poganja ponudba, mednarodna trgovina in integracija globalne vrednostne verige. V ta namen skušamo predmet naše študije modelirati pod pogoji *ceteris paribus*. Neoklasični referenčni model spreminjamo z dodatnimi marksističnimi in evolucijskimi predpostavkami in spremembami, ki predstavljajo osrednjo dinamiko, raziskano v prejšnjih poglavjih, razširjamo model tako, da vključuje več regij za potrebe upoštevanja dinamike, ki jo poganjajo trgovina in vrednostne verige, ter uvajamo tržne in netržne sektorje, da upoštevamo Balassa-Samuelsonov učinek. Osrednji model, predstavljen v poglavju 6, ni model rasti in njegovih rezultatov ne razlagamo deterministično. Nasprotno, namen modeliranja je osredotočiti se na ozko specifično vprašanje - kako granularna proizvodna omejitev in njena interakcija z relativnimi cenami dejavnikov v mednarodnem okolju različno razvitih držav endogeno prispevata k vztrajnosti neenakomernega razvoja na konkurenčnih trgih. Rezultati razkrivajo zapletene funkcionalne vzorce, ki se pojavljajo navkljub splošno predpostavljeni padajoči mejni donostnosti faktorjev. Granularnost proizvodne omejitve in njena interakcija z relativnimi cenami dejavnikov lahko endogeno privedeta do funkcionalne specializacije, ki prispeva k ohranjanju neenakomernega razvoja na celotnem spektru porazdelitve razvojnih neenakosti in lahko privede do povratnih zank v tehnologiji, tehniki in funkcionalni specializaciji, ki delujejo kot blokade tako v državah z nizkim, srednjim, višjim-srednjim in celo visokim dohodkom.

Ker izhajamo iz različnih ekonomskih tradicij, je naš splošni prispevek k literaturi različen iz vsake paradigmatske perspektive. Na področju marksistične ekonomije prispevamo tako, da Aminov opisni okvir najprej preoblikujemo v marksistični analitični okvir, nato pa njegove zamisli v zadnjem poglavju matematično formuliramo z opredelitvijo granularnih in komplementarnih proizvodnih omejitev ter predpostavk o delovanju trga proizvodnih dejavnikov, ki določa raznolike relativne stroške proizvodnje. Z marksistične analitične perspektive sta bila ekonomika stacionarnega stanja in racionalnost vedno izhodišče za različne analitične izpeljave, ki odražajo ključne sestavine marksistične paradigme (Roemer, 1982). Medtem ko se številni sedanji in prejšnji marksistični pristopi opirajo na analize neravnovesja in modele, ki temeljijo na agentih (Chiarella et al., 2005; Cogliano et al., 2018, 2022; Flaschel, 2008; Flaschel et al, 2012), nas je naš cilj izpeljave endogenega mehanizma, ki temelji na ponudbi, kot običajnega delovanja tržnega mehanizma v stacionarnem stanju vodil v smer združevanja idej in predpostavk iz analitičnih temeljev Marxove in Aminove analize izbire tehnologije ter osnovnega neoklasičnega modela ponudbenih strukturnih sprememb (Acemoglu & Guerri, 2008).

Prispevek k neoklasični literaturi predstavlja raziskovanju posebne funkcijske oblike proizvodne omejitve, ki vodi k specifičnim in neenakim oblikam specializacije in prispeva k ohranjanju neenakomernega razvoja navkljub splošni neoklasični predpostavki o padajočih donosih investiranja. Funkcionalno obliko granularnosti posredno potrjuje empirično poglavje 4, v katerem najdemo empirične dokaze, da rast produktivnosti na strani ponudbe ni le zelo neenakomerna med sektorji, ampak ima tudi neposredne posledice za vzorce zaposlovanja. Poleg tega najdemo dokaze substancialne komplementarnosti med dodano vrednostjo različnih sektorjev. Čeprav so bile heterogenosti na strani ponudbe obsežno teoretično preučevane (Alvarez-Cuadrado et al., 2017, 2018; Baumol, 1967; Ngai & Pissarides, 2007), je bilo to vedno v makroekonomsko homogenem ali zaprtem gospodarskem okolju. Kako se dinamika strukturnih sprememb na strani ponudbe in granularna omejitev proizvodnje povezuje z relativnimi cenami dejavnikov, ki so prisotni v mednarodnem okolju, in endogeno funkcionalno specializacijo v okviru integriranih, različno razvitih gospodarstev ali regij, ni bilo nikoli raziskano. Naš prispevek v okviru neoklasične literature je zato mogoče razumeti kot razširitev razumevanja strukturnih sprememb določenih s strani ponudbene heterogenosti na večregijsko okolje, kjer interakcija med dinamiko ponudbe in njeno heterogeno granularno strukturo ter dinamiko globalne specializacije vrednostne verige prispeva k vztrajno neenakemu razvoju tudi v splošnih pogojih zmanjševanja donosnosti naložb. Konvergenčno dinamiko, ki jo predpostavlja neoklasična proizvodna funkcija, sistematično preprečujejo povratne zanke, ki jih povzročajo endogeni vzorci specializacije.

Naš glavni prispevek k evolucijski tradiciji je predstavljen v poglavju 3. Preoblikovali smo ključne ideje iz Verspagnovega (1991) evolucijskega modela, ki analizira procese tehnološka difuzijo, ki vodijo do večkratnih diskretnih stacionarnih stanj, in jih integrirali v klasično obliko difuzijske enačbe, ki izhaja iz tradicije ekonofizike. S to novo konceptualno reformulacijo povežemo dva različna pristopa k preučevanju tehnološke difuzije in neenakomernega gospodarskega razvoja v državah. Prvi pristop se osredotoča na krivulje prevzemanja tehnologij, a zanemarja makroekonomsko dinamiko (Comin & Hobijn, 2010; Stokey, 2021), medtem ko drugi pristop raziskuje neenakomerni razvoj in tehnološke pasti, vendar ne omogoča celovitega razumevanja posameznih krivulj prevzemanja tehnologij (Fagerberg & Godinho, 2018; Verspagen, 1991). S povezovanjem teh dveh pristopov lahko bolje razumemo medsebojno vplivanje med širjenjem in sprejemanjem tehnologij ter gospodarskim razvojem. Naš pristop zajema celoten razpon zgodovinsko pogojene dinamike, in kontinuum večkratnih stacionarnih stanj, hkrati pa endogneo izpelje krivulje sprejemanja tehnologije za posamezne države glede na njihovo stopnjo razvitosti. Ta sinteza prispeva k obema področjema preučevanja ter omogoča bolj diferencirano in celovito razumevanje zapletenega odnosa med tehnologijo in gospodarskim razvojem.

Poleg specifičnih prispevkov k različnim raziskovalnim paradigmam je najpomembnejši prispevek te disertacije opredelitev, raziskovanje in preučevanje delovanja dveh endogenih ekonomskih mehanizmov, ki ju poganja ponudba in ki še nista bila raziskana na nobenem paradigmatskem področju. Te odkritji in njuna konceptualna formulacija predstavljata delovanje dveh objektivnih mehanizmov, katerih notranje delovanje in razumevanje prispeva k splošnemu razumevanju delovanja trgov v heterogenih pogojih, naša raziskava pa zagotavlja nekatere dokaze ne le za obstoj obeh mehanizmov, temveč tudi opredeljuje njun konkretni način delovanja. To bi lahko imelo pomembne posledice za naše razumevanje neenakomernega razvoja, ne glede na paradigmatsko področje.

V poglavju 3, v katerem smo raziskali endogeno dinamiko širjenja tehnologije v pogoju neenakmernega razvoja in razlikah v stroških proizvodnih dejavnikov med državami, in v poglavju 6, v katerem smo preučili endogene dejavnike funkcionalne specializacije, smo opredelili, analizirali in raziskali funkcionalno delovanje dveh endogenih mehanizmov, ki sta bila predmet naše študije, ter preučili njun prispevek k ohranjanju neenakomernega razvoja. S funkcionalno identifikacijo in razlago teh mehanizmov prispevamo in dopolnjujemo obsežno raziskovalno področje, sestavljeno iz različnih paradigmatskih pristopov, ter dopolnjujemo obstoječe endogene in eksogene, ekonomske in izvenekonomske mehanizme, dejavnike in razlage ohranjanja neenakomernega razvoja.