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ANALYSIS OF HETEROGENEITY IN THE EMU USING DYNAMIC FACTOR MODELS

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The undersigned Marko Glažar a student at the University of Ljubljana, Faculty of Economics, (hereafter: FELU), declare that I am the author of the doctoral dissertation entitled Analysis of heterogeneity in the EMU using dynamic factor models, written under supervision of prof. dr. Igor Masten.

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ANALYSIS OF HETEROGENEITY IN THE EMU USING DYNAMIC FACTOR MODELS

SUMMARY

Recent discussions on the challenges for the EMU and the remodelling of its architecture are sometimes referred to as the return of the optimum currency area theory (OCA). The criterion at the core of the OCA theory is the business cycle synchronisation. We revisit the issue of business cycle synchronisation and inflation differentials by examining disaggregated sectoral data for the manufacturing sector.

Using disaggregated sectoral data and a hierarchical structure of the dynamic factor model (DFM) with overlapping blocks, we examine the comovement of output and producer prices in the manufacturing sector. We decompose the output and producer price fluctuations as follows: (i) common or euro area wide; (ii) sector specific that are common to a manufacturing subsector across all countries; (iii) country specific that are common across all manufacturing subsectors in a given country; and (iv) an idiosyncratic component that is specific to a subsector and country.

We tackle the issue of the endogeneity of currency areas by introducing a rolling window methodology to the hierarchical DFM. The factors are used to quantify the relative importance of common, sector, country, and sector and country specific components for each period. Changes in the variance decomposition and the evolution over time are monitored and estimated, respectively. Euro area factors represent the determinants of business cycle variations that are common across the countries and industries. Sector specific factors still cover the euro area and summarise the sources of sector specific economic activities in addition to those accounted for by the common euro area factors. We interpret the rising share of variance explained by the common and sector specific factors as a rise in the business cycle synchronisation.

We find that the degree of synchronisation of output growth in euro area countries increased mainly in the run-up to the EMU and less so in the euro period. Furthermore, we find a decrease in synchronisation after the financial crisis in 2008 and especially after the sovereign debt crisis in 2011; however, the degree of the synchronisation of manufacturing business cycles is still above that in the first half of the 1990s.

Furthermore, we find that the degree of business cycle synchronisation is not equal across the countries and sectors. Periphery euro area countries exhibit a lower level of synchronisation with the euro area business cycle than the core euro area countries. Moreover, we find even lower synchronisation with the euro area for new Member States, including new euro area members.

The results for the new member states are important since the existing literature on business cycle synchronisation mainly focuses on the founding euro area countries. Although our results confirm that the periphery euro area countries are less synchronised with the euro area, we find the new Member States to represent an even greater challenge for the EMU architecture in the light of OCA.

One of the fundamental imbalances that have led to the euro crisis is the increased divergence of competitive positions of countries (De Grauwe, 2011). The countries most severely hit by the crisis could increase their output by improving their competitive positions. However, if a country cannot devalue its own currency, internal devaluation is the only option. We should observe increasing producer prices differentials if this adjusting mechanism is taking place. We investigate the sectoral producer prices comovement using a hierarchical DFM in the second empirical part of the research.

We find that the heterogeneity of producer price inflation has even decreased in the post crisis period, exhibiting no sign of increased sectoral producer price convergence across the countries. With regard to the effect of the euro on prices comovement, we do find some increased synchronisation of producer price inflation rates at the time of the introduction of the euro. The importance of EA wide factors increased in the periods that covered the time after the euro's introduction compared to the first observed period of 1996–2000.

Keywords: synchronisation of business cycles, optimum currency area, manufacturing, sectoral industrial production, sectoral producer prices, variance decomposition, common factor models

ANALIZA HETEROGENOSTI GOSPODARSTEV V EMU Z DINAMIČNIM FAKTORSKIM MODELOM

POVZETEK

Nedavne razprave o izzivih za Ekonomsko in monetarno unijo (EMU) in njenem preoblikovanju se včasih označuje kot vrnitev optimalnega denarnega območja. Kriterij, ki je v jedru teorije optimalnega denarnega področja, je sinhronizacija poslovnih ciklov. V disertaciji osvetlim vprašanje sinhronizacije poslovnih ciklov in gibanja cen z analizo razčlenjenih sektorskih podatkov za predelovalne dejavnosti.

Z uporabo razčlenjenih sektorskih podatkov po državah in hierarhičnim dinamičnim faktorskim modelom (DFM) z medsebojno prepletenimi sklopi analiziram sočasno gibanje rasti industrijske proizvodnje in proizvodnih cen pri proizvajalcih. Cilj raziskave je razčleniti rast industrijske proizvodnje in proizvodnih cen v posameznem oddelku predelovalnih dejavnosti in državi na (i) skupno komponento, značilno za evrsko območje, (ii) komponento, značilno za posamezen oddelek v področju predelovalnih dejavnosti – sektorsko komponento, (iii) komponento, značilno za državo, in (iv) idiosinkratično komponento, značilno za sektor in državo.

Pristop k reševanju problema endogenosti optimalnega denarnega področja v moji raziskavi temelji na vpeljavi rekurzivne metode z drsečim oknom stalne velikosti. Z uporabo faktorjev kvantificiram relativno pomembnost skupne, sektorske in državne komponente za vsako obdobje. Spremembe razčlenitve variance v času kažejo na spremembe v usklajenosti poslovnih ciklov in gibanja cen v predelovalnih dejavnostih. Skupni faktorji predstavljajo determinante variabilnosti, ki so skupne za vse države in sektorje. K simetričnemu delu variance prispevajo tudi sektorski faktorji, ki so še vedno skupni za evrsko območje in predstavljajo ekonomske sektorsko specifične determinante. Stopnjo usklajenosti poslovnih ciklov na agregatni ravni držav, sektorjev oz. evrskega območja predstavim kot povprečje simetrične pojasnjene variance po sektorjih, državah ali sektorjih in državah.

Moji rezultati niso pokazali, da bi se sinhronizacija med državami evro območja po uvedbi evra dejansko povečala. Namesto tega so pokazali, da se je sinhronizacija, merjena s povprečnim doprinosom simetričnega dela variance v rasti industrijske proizvodnje, ki je pojasnjena s skupnim in sektorsko specifičnimi faktorji, povečala v obdobju pred uvedbo evra v letu 1999. Nadalje ugotavljam padanje stopnje sinhronizacije po finančni krizi v letu 2008 in še posebej po nastopu dolžniške krize v letu 2011. Vendar je tudi v tem obdobju sinhronizacija poslovnih ciklov v predelovalnih dejavnostih še vedno nad ravnjo v prvi polovici 90. let.

Ugotavljam, da se usklajenost poslovnih ciklov razlikuje med državami in sektorji. V perifernih državah evrskega območja je usklajenost poslovnih ciklov z evrskim območjem nižja, kot je v centralnih državah evrskega območja. Nadalje, ugotavljam še nižjo usklajenost poslovnih ciklov za nove države članice EU, vključno z državami, ki so že del evrskega območja.

V raziskavi predstavim tudi rezultate za nove države članice EU, ki so v literaturi prepogosto zapostavljene. Ugotavljam, da te predstavljajo še večji izziv za delovanje EMU, kot je to primer s perifernimi ustanovnimi državami evrskega območja, z vidika usklajenosti poslovnih ciklov z evrskim območjem. Usklajenost poslovnih ciklov novih držav članic je namreč pod ravnjo usklajenosti perifernih držav evrskega območja pred uvedbo evra.

Eno osnovnih neravnovesij v evrskem območju predstavlja povečana divergenca konkurenčnih pozicij držav v evrskem območju (De Grauwe, 2011). Zato se med potrebnimi ukrepi za izhod iz krize in ponovno vzpostavitev rasti v gospodarstvih evrskega območja pogosto omenja tudi zvišanje inflacije, ki je daleč pod ciljno inflacijo ECB. Za vzpostavitev prostora za izboljšanje relativne konkurenčnosti v krizi najbolj prizadetih držav brez deflacijskih pritiskov, je namreč nujna višja inflacija v centralnih državah evrskega območja. Zato sem k problemu pristopil dodatno tudi z analizo proizvodnih cen v podsektorjih predelovalnih dejavnosti.

Ugotavljam, da se usklajenost gibanja cen v pokriznem obdobju celo poveča in je v zadnjih obdobjih na zgodovinsko visokih ravneh. To pomeni, da gospodarstva v okolju nizke inflacije oz. deflacije ne zmorejo izboljšati konkurenčnosti in zvišati rasti, kar se kaže v povečani usklajenosti gibanja cen v rezultatih. V disertaciji preverjam tudi vpliv uvedbe evra na usklajenost gibanja proizvodnih cen v sektorju predelovalnih dejavnosti. Analiza pokaže večjo usklajenost gibanja cen v evrskem območju po uvedbi evra v primerjavi z obdobjem 1996−2000.

Ključne besede: usklajenost poslovnih ciklov, predelovalne dejavnosti, sektorska industrijska proizvodnja, sektorske proizvodne cene, razčlenitev variance, faktorski modeli

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INTRODUCTION

In a report from 2008 (EC, 2008), the European Commission stated that the euro had been a major success, bringing financial and trade integration, job creation and price stability, also arguing that business cycles in the euro area were highly synchronised. However, the financial crisis in 2008, and the subsequent European sovereign debt crisis in 2011, had a major impact on output growth in the euro area and called for a reassessment of the Economic and Monetary Union (hereinafter: EMU).

The creation of the EMU triggered capital flows from Europe's core to its periphery, leading to economic boom and higher inflation rates in countries such as Spain and Portugal. Since the European Central Bank (hereinafter: the ECB) has been given a mandate to maintain price stability for the euro area as a whole, it did not concern itself directly with these inflation and unit labour cost differences that reflected dangerous macroeconomic trends (Whelan, 2014). Moreover, the ECB (2005) considered inflation differentials to be a desirable phenomenon that should be allowed to perform its equilibrating role without hindrance.[1] The financial crisis in 2008 put a stop to these capital flows, and periphery countries were left with excessive relative prices and unit labour costs. Since labour mobility could not mitigate the imbalances, and (downward) labour cost flexibility was not at the levels required to close the gap in the relative labour costs, a major euro crisis ensued. An established fiscal transfer system could have helped alleviate the crisis, which put such strain on national budgets that the deficits were no longer sustainable. However, even critics of the euro share the opinion that the EMU can be rescued if appropriate action is taken. Krugman (2013) proposes a higher inflation target and European bank guarantees, with the ECB acting as a lender of last resort to governments.

A higher inflation (target) in the euro area is needed in order to provide room for the adjustment of prices and unit labour costs in the periphery countries, without the need to resort to deflationary processes, which have adverse effects (Krugman, 2013). Inflation differentials in a monetary union could be an important macroeconomic adjustment mechanism in the absence of an exchange rate mechanism for individual countries; however, at present, the inflation differentials are too low as a consequence, among other things, of the ECB's failure to meet its goal of keeping inflation close to two percent (Whelan, 2014).

Recent discussions of the challenges for the EMU and remodelling of its architecture is sometimes referred to as the return of the optimum currency area theory.[2] Optimum currency area theory (hereinafter: OCA theory) addresses the costs and benefits of forming a currency union. One of the criteria that is at the core of OCA theory is the business cycle

[1] The ECB (2005) does warn against the persistence of inflation differentials.

[2] Krugman (2013) even uses the term "revenge of the OCA".

synchronisation. Asynchronicity of a business cycle which is caused by a high frequency of asymmetric shocks simply implies that common policies in a currency union lead to a suboptimal degree of business cycle stabilisation. Moreover, the heterogeneity of the economic structures of member countries may lead to common policies having destabilising instead of stabilising effects on the economies of individual member states.

A special issue in this context is the endogeneity of OCA criteria. There are competing views on the theoretical connection between economic integration and business cycle synchronisation. One strand of literature is represented by Frankel and Rose (2000) who state that stronger international trade, achieved by stimulating its intra-industry component, leads to less asymmetric shocks in business cycle synchronisation. When applied to the euro area, these views lead to conjecture that an increase in business cycle synchronisation between the euro area countries could be expected over time, potentially with a strong stimulus given to the process through the introduction of the euro post-1999. Krugman (1993), on the other hand, argues that international trade encourages specialisation, thereby increasing the heterogeneity of the economies. Kalemli-Ozcan, Soernesen and Yosha (2000) propose increased capital market integration to be yet another source of specialisation and thus increased inter-industry trade. In the event of increased specialisation, the level of business cycle synchronisation should wane over time.

Subject and purpose of the research

In this thesis we analyse the synchronisation of output growth and producer price inflation in manufacturing sectors of the euro area and the EU, covering the period of establishing the euro and the recent euro crisis. The main motivation for the research into output synchronisation is to examine the endogeneity hypothesis of OCA introduced by Frankel and Rose (2000). We examine whether the synchronisation of business cycles in the EMU increased after the introduction of the euro. We also investigate whether the synchronisation of output growth in manufacturing decreased after the financial crisis in 2008 and the subsequent euro crisis. Since inflation differentials played a crucial part in the progress of the euro crisis and could also play an important role in bringing the euro area out of the slump, we investigate the synchronisation of producer price inflation in the manufacturing sector. We ascertain whether the synchronisation of producer prices inflation increased in the post-crisis period, thereby preventing the equilibrating role of the inflation differentials.

These issues are tackled by analysing the degree of business cycle synchronisation in the euro area and the EU in 14 manufacturing industries. Given that the OCA literature emphasises that the pattern in industry-level economic activity is the key determinant in the endogenous evolution of the degree of business-cycle synchronisation, it is natural to work with industry-level data. In this way we have a large multi-country panel of sectoral data, with a monthly frequency, at our disposal which, when analysed using factor models, allow us to identify four different groups of underlying factors of economic activity in the manufacturing sectors of euro area countries: (i) common euro area factors; (ii) sector specific factors; (iii) country specific factors; and (iv) idiosyncratic country-sector specific effects. Euro area factors represent the determinants of business-cycle variations that are common across the countries and industries. Sector specific factors still cover the euro area and summarise the sources of sector specific economic activities in addition to those accounted for by the common euro area factors. From the perspective of the economic activity of a given sector in a certain country, both these groups of factors, when taken together, represent the *symmetric part* of a stochastic variation in output.[3] The third group, country specific factors, together with the idiosyncratic country-sector specific component, represent the *asymmetric part* of output variation in this regard. Factor models allow us to measure the contribution of each of these three groups of factors to the variability of output. By tracking the evolution of these contributions over time, using a rolling window method, it is possible to continuously track the degree of business cycle synchronisation over time and thereby evaluate which of the underlying factors emphasised by the OCA theory – intra or inter-industry trade – dominates.[4] The setup also enables us to estimate an alternative measure of the extent of the idiosyncratic country-sector specific risks and additional risks at the country level that could be taken into consideration in establishing euro area mechanisms for alleviating asymmetric shocks.

We use the same empirical setup to examine the synchronisation of producer price inflation in manufacturing, disaggregated to the subsector level. Since producer price inflation is an important input in analyses of country competitiveness indices, we believe that the additional insight into country-sector analysis provided by our research can be of good use. This part of the research also complements the research on output variability, especially in the context of the euro and the recent Great Recession in Europe.

We first focus on the synchronisation of founding euro area countries before extending the analysis to all EU countries[5], which is important given the past and future enlargement of the EMU. We assess the suitability of non-euro EU member states for the EMU and compare this to existing euro area countries from the perspective of producer price inflation and business cycle synchronisation in the manufacturing sector. Given the present euro crisis and the discussion of the additional mechanisms required in order to bring the EMU closer to OCA, we find the synchronisation of EU countries to be equally important. If the synchronisation of EU countries' output growth is weaker than the synchronisation of the founding euro area countries, the imposition of strong mechanisms to alleviate or prevent asymmetric shocks prior to enlarging the EMU is even more important.

[3] This holds for an aggregate country level only by assuming a similar composition of manufacturing sectors across the countries.

[4] Naturally, this does not allow us to evaluate what would have happened in a counterfactual situation of the absence of the EMU. This implies that we only infer the effects of currency union from the time series dimension of the data.

[5] Subject to data availability.

We use two approaches to investigate the heterogeneity in output growth and producer price inflation for the EU countries. The first is by decomposing the underlying factors of activity and producer price inflation in the manufacturing industries into the following: EU wide factor, EU sector specific factors, country specific factors, and the country-sector specific component. This enables us to compare the synchronisation of business cycles in the EU with synchronisation of more integrated euro area countries.

In the second approach we decompose the variation in sectoral output growth and producer price inflation for EU countries into the euro area wide factor, euro area sector specific factors, country specific factors and country-sector specific components. In this way we are able to examine the synchronisation of business cycles with the euro area for some euro area countries for which we have shorter time series. Further, we can assess the degree of synchronisation with the euro area for countries that are potential candidates for EMU membership.

This thesis proposes an alternative method of identifying countries and subsectors that are less synchronized with the common euro area movements in the manufacturing sector. We measure the asymmetric part of variance that the existing or future mechanisms in the euro area should be able to cope with. By introducing the rolling window method of factor estimation we can monitor the changes of heterogeneity over time and determine the countries or sectors in a given country that present idiosyncratic risks at a certain time.

Thesis hypotheses

The *main hypothesis* of the thesis is that business cycle synchronisation in the EMU increased after the introduction of the euro. Our research is concentrated on the business cycles in the manufacturing sector, where we examine whether the creation of the EMU promoted increased business cycle synchronisation, i.e. we look into the issue of the endogeneity of OCA criteria first proposed by Frankel and Rose (2000). A disaggregated analysis also enables us to examine the synchronisation of individual subsectors in the manufacturing sector.

Closely related to the first hypothesis is the *first sub hypothesis,* which posits that synchronisation is lower in the EU than in the euro area. If the euro represents an important step towards the integration of EU countries, we expect EU countries to have less synchronised business cycles than the euro area countries.

The *second sub hypothesis* is that new member states that acceded to the EU after the creation of the euro increased synchronisation with the euro area over time. The issue of synchronising the business cycles of non-euro EU countries with the euro area is especially important in the context of the EMU enlargement process.

The financial crisis in 2008 and the subsequent sovereign debt crisis (or the euro crisis) in 2011 revealed the asymmetries that had been forming since the introduction of the euro. We expect the disturbances from the financial sector and sovereign debt crises to also have had an effect on the manufacturing sector. Since the labour market institutions and financial systems in euro area countries are heterogeneous, we expect the financial crisis shock to have asymmetric effects, even though the shock itself might be symmetric in nature. On top of that the sovereign debt crisis caused more stress in some countries. Therefore, our *second hypothesis* is that heterogeneity in the manufacturing sector increased in the euro area during the last recession period.

One of the fundamental imbalances that led to the euro crisis was the increased divergence in the competitive positions of countries (De Grauwe, 2011). The competitive position of countries in the euro area can only be improved by lowering the prices of tradables. We argue that producer price inflation differentials have not played an important role in the equilibrating process for the manufacturing sector in the post-crisis period. The *sub hypothesis of the second hypothesis* is that the degree of synchronisation of producer price inflation in the manufacturing sector did not fall in the periods following the 2008 financial crisis.

Scientific method

The fundamental scientific method used in our research is the method of dynamic factor models (hereinafter: DFM), which has recently gained significant attention in macroeconomic analysis and forecasting. It has also been successfully applied to analyses of the heterogeneity and synchronisation of business cycles in a currency union or other supranational unions.

The use of disaggregated sectoral data and a hierarchical structure for the DFM allow us to decompose the output fluctuations as follows: (i) common or euro area wide; (ii) sector specific that are common to a manufacturing subsector across all countries; (iii) country specific that are common across all manufacturing subsectors in a given country; and (iv) an idiosyncratic component that is specific to a subsector and country.

Kose, Otrok and Whiteman (2003) present one of the first studies to use a hierarchical DFM approach to investigate business cycle synchronisation. Our study extends the hierarchical DFM by introducing not only geographical but also sectoral data in the investigation of the business cycle synchronisation. Furthermore, the geographical and sectoral data blocks overlap, meaning that we have a certain subsector present in all the observed countries, and so the hierarchical DFM needs to be adapted in order to account for this overlapping of countries and manufacturing subsectors. For the factor extraction we use the principal components method proposed by Stock and Watson (2002a, 2002b).

Beck, Hubrich and Marcellino (2012) first introduce a similar hierarchical DFM with overlapping blocks of data for the analysis of sectoral consumer price inflation in the euro area regions.

In the second, empirical part of this thesis, in which we investigate producer price inflation differentials, we use disaggregated sectoral data for producer prices, with a breakdown by country, and apply the hierarchical DFM. The disaggregated sectoral data and DFM allow us to decompose the producer price inflation into symmetric and asymmetric components, thereby facilitating additional insight into producer price differentials.

A key objective of the thesis is to investigate the evolution of business cycles and producer price inflation differentials over time. Del Negro and Otrok (2008) propose a DFM approach with time varying factor loadings. We tackle this issue by introducing a rolling window methodology to our hierarchical DFM. Thus obtained factors are used to quantify the relative importance of common, sector, country, and country-sector specific components for each period. Changes in the evolution and variance decomposition over time are estimated and monitored respectively.

Scientific contribution

The novelty of our approach with regard to existing literature on business cycle synchronisation is the use of industry-level data. As explained previously, we use this higher level of data disaggregation because it allows us to extricate more precisely the factors that the OCA theory emphasises as key determinants of business cycle synchronisation.

We argue that sector specific factors are important in the analysis of comovements in the manufacturing sector. We should observe a decrease in importance of sector specific factors over time for a given manufacturing subsector in the euro area if the inter-industry specialization would take place in this subsector.

A study that uses a similar approach to investigate output fluctuations in manufacturing is, to the best of our knowledge, Helg et al. (1995). They examine a sample of 11 European countries and find that the differences in the cyclical fluctuations of industrial production can be explained by country specific effects, while sector specific effects are less important. Our study, however, differs from theirs in three important ways. Firstly, we use the dynamic factor model as a more efficient tool for the analysis of large datasets. Secondly, our analysis covers a wider range of countries. Thirdly, the time span for our data covers the formation of the EMU as the ultimate stage of monetary integration. Forni and Reichlin (2001) investigate output fluctuations measured in GDP in the euro area on a regional level using a hierarchical DFM. We use a similar empirical setup, but our study differs from their study mainly in including overlapping sectoral level of data in the hierarchical DFM and focusing on industrial production in manufacturing.

The second major contribution is that we identify the underlying factors that cause producer price inflation variability: euro area wide, sector specific, country specific, and country-sector specific effects. The factors are used to quantify the relative importance of the symmetric and asymmetric components for each observable variable. In a similar analysis, Beck, Hubrich and Marcellino (2012) decompose consumer price inflation variation into euro area wide, country specific, sector specific and regional factors. Our study focuses on producer price inflation in more disaggregated manufacturing sector, which is of special interest in the present debate on asymmetries and competitiveness issues in the euro area, given that the manufacturing sector represents a large share of trade. Further, our dataset covers the periods of the financial crisis in 2008 and the sovereign debt crisis in 2011.

This thesis contributes to European integration literature by analysing the evolution of comovements across EU countries on disaggregated sectoral data. Previous studies of business cycles with DFM usually tackle the evolution of business cycle synchronisation in the context of the endogeneity of OCA criteria by comparing the comovement for the pre-euro period with the comovement for the euro period. Lee (2012) uses the approach proposed by Del Negro and Otrok (2008) and introduces time varying parameters in a hierarchical DFM to investigate the endogeneity of the OCA criteria asserted by Frankel and Rose (2000). Our study of the evolution of synchronisation over time is instead based on a rolling window analysis, and further differs from Lee's study in the use of disaggregated sectoral data, the coverage of a wider range of EU countries, and the inclusion of the sovereign debt crisis period in the data.

Structure

The dissertation comprises four chapters, which can be divided into two parts. The first part, which includes chapters one and two, presents the theoretical background. The second part is the empirical part of the dissertation, where in the third chapter we present the results on the heterogeneity of industrial production in the manufacturing sectors and, in the fourth chapter, the results of the heterogeneity in producer price inflation in the manufacturing sectors.

The introduction is followed by theoretical background on the importance of business cycle synchronisation. The theory on currency unions is covered by optimum currency area literature. We cover the basic findings of the theory, which deals mostly with the prevention or dampening of the effects of asymmetric shocks to the currency union. We also tackle some of the recent issues of the currency area, although we concentrate on the possible endogeneity of the OCA criteria by means of the trade channel.

In the next section we present the dynamic factor model, the scientific method that is used in our research. We outline the theoretical background of the generalised dynamic factor models.

We divide the empirical research first on the basis of type of heterogeneity, the heterogeneity of industrial production in manufacturing, and the heterogeneity in producer prices. For each of these heterogeneity types we perform three separate analyses according to the area of focus: euro area countries with euro area factors, EU countries with EU factors, and EU countries with euro area factors.

The third chapter begins the empirical part of the thesis with research on the industrial production heterogeneity. We begin with a stylised description of the available data and continue with the empirical framework of our research. The empirical framework is presented only in this chapter, but we use the same setup in the next chapter with producer prices as well. The results are presented for the euro area and EU countries. Special attention is devoted to the case of Slovenia.

The fourth chapter is similar to the third, but in this chapter we deal with the heterogeneity of producer prices in the euro area and the EU. Due to low labour mobility and the absence of fiscal transfers in the euro area, wage and price flexibility play a crucial role in adjustment to asymmetric shocks. Again we open by describing some stylised facts with regard to price heterogeneity across the euro area and the EU manufacturing sectors before presenting the results. In this chapter we also provide some additional insight on the case of Slovenia.

Finally, the conclusion of the thesis is devoted to briefly highlighting the importance of business cycle synchronisation in a currency area, and to summarising the findings of the empirical part of the research. Attention is drawn to common findings with regard to price and industrial production heterogeneity, the aims of the research, and our contribution to the understanding of the business cycle synchronisation evaluated.

1 OPTIMUM CURRENCY AREA

In this chapter we present the available literature on optimum currency areas (OCA). We follow the reasoning that business cycle synchronisation is important for an OCA. In the first subsection we present an overview of the theory and criteria for an OCA. We follow the hypothesis of endogeneity of OCA criteria and the channel of trade in the second subsection. In the last subsection, we discuss the possible sources or effects of increased trade, intra-industry or inter-industry specialisation. Inter- vs intra-trade could be the decisive factor for the heterogeneity of the manufacturing sector.

1.1 Overview

The advantages of a common currency include reduced transaction costs, the elimination of currency risks, and greater transparency. These can in turn promote trade and increase competition. However, a currency union also comes with disadvantages. Countries lose the power to control their own monetary policy, and the common monetary policy has to fit all the countries in the currency union. The high relative wages and prices currently faced by EMU countries could be more easily offset by devaluing their own currencies than through deflationary processes, which increase unemployment.[6]

In the first stages of the EMU, the European Union Commission (1990) (hereinafter: the EC) stated five broader effects of the EMU:

- *Efficiency and growth.* The elimination of exchange rate risks and transaction costs would be beneficial to efficiency, which would in turn promote growth.
- *Price stability.* The EC believed that the newly established monetary union would be built on the reputation of the countries with the lowest rates of inflation.
- *Public finance.* Countries would still have autonomy to deal with country specific problems, but excessive deficits would be avoided and coordination among countries would ensure an appropriate policy mix in the EMU. A further benefit for many countries' public finances would be the decreased interest rate which would outweigh the cost of the loss of seigniorage revenue by some countries.
- *Adjusting to economic shock.* The EC highlighted this point as the main potential cost of the EMU because the countries lose their control over their own monetary and exchange rate policies as an instrument of adjustment on the national level. However, the EC believed that the occurrence of country specific shocks would be reduced in the EMU and that the changes in relative real labour costs, together with coordinated budgetary policies, would be able to absorb the shocks.

[6] There is no guarantee that countries would have responded to the crisis better if they had had control over their own monetary policy, as the case of Sweden illustrates. The Riksbanken (the national bank of Sweden) also increased Swedish interest rates too soon, as some economists point out (e.g. Svensson, 2014).

- *The international system.* With the ecu (later the euro) becoming an important international currency, banks and enterprises would conduct more international transactions in their domestic currency.

The formation of the European Monetary Union in 1999 was conditional on the fulfilment of the Maastricht criteria (1992 Maastricht Treaty). The convergence criteria specify goals in areas such as inflation, long-term interest on bonds, exchange rates, and country debt and deficit. A criticism of these convergence criteria is that they have little in common with the optimum currency area (OCA) criteria (Darvas, Rose & Szapary, 2005).

Less than 20 years after the research undertaken by the EC, the financial crisis confirmed the fears of those economists who had warned that the case of adjustment to economic shocks has not been well thought through, and that the EC should have taken the theory of optimum currency areas more seriously.

The intellectual father of the OCA theory is often considered to be Robert Mundell with his original contribution in his 1961 paper titled "A Theory of Optimum Currency Areas". In his work, Mundell emphasises the importance of labour mobility for an efficient currency union in order to assuage the consequences of an asymmetric shock. Additional criteria have since been incorporated into the theory, but all share a common denominator – the prevention or dampening of the effects of asymmetric shocks to the currency union. An important criterion that tackles heterogeneity is the criterion of product diversification. It states that countries in a currency union are less prone to asymmetric shocks if they have a similar structure and diversified production and exports.

Although the concept of an OCA was first presented by Mundell (1961), McKinnon and Kenen are also recognised as co-founders of the theory based on their papers: McKinnon (1962) and Kenen (1969). The theory deals mainly with asymmetric shocks or the asymmetric effects of the shocks, their probability of occurrence and how they should be accommodated if they occur.

Asymmetric shocks, where only some countries are affected, pose a great threat to a monetary union since monetary policy cannot suit all countries. For example, in a simple case where two countries form a monetary union, where only the first is hit by an adverse shock, the monetary policy implemented that would, on average, depreciate the currency to the equilibrium required in the union would cause disequilibria in both countries. The first country would still be faced with relatively high prices and wages, and the second country's prices and wages would be too low. The additional adjustment required would have to be made through disinflation and, as a result, recession in the first country, accompanied by inflation and boom in the second country. Moreover, symmetric shocks can have asymmetric effects due to country specificities. An OCA has to be able to deal with asymmetric shocks, or symmetric shocks with asymmetric effects.

Based on the work of the founders of the theory, there are three criteria in order for an OCA to operate.

The first criterion, *mobility of labour,* was suggested by Mundell (1961). An OCA needs a high level of labour mobility in order to assuage the consequences of an asymmetric shock in the monetary union. In the event of an adverse shock in one country, in a two-country model, the disequilibria can be resolved simply by relocating excess labour to the second country experiencing inflationary pressures. The problem is that full labour (and physical capital) mobility is difficult to achieve in practice.

The next criterion, *product diversification* (Kenen, 1969), specifies the economic areas in which the occurrence of an asymmetric shock is too small to present a risk, and that countries with diversified production and exports, but a similar structure, form an OCA. The reasoning behind this criterion suggests that countries are less prone to shocks if they have diversified but similar production. In the event of a shock in a particular sector, the small relative weight of the sector in a diversified economy dilutes the overall effect of the shock. Even for greater shocks, the similarity between the countries should prevent the shocks from being asymmetric, instead being symmetric in nature. If symmetric shocks and effects arise, the monetary policy should have a straightforward solution.

The third criterion is *openness of the economy* (McKinnon, 1962). Open economy countries with high levels of trade between each other are less likely to be subjected to an asymmetric shock and therefore form an OCA as a result. Small open economies have little ability to influence prices on the international market and so prices in domestic currency are no longer sticky. A change in the exchange rate therefore has no influence on competitiveness. In this case, the forfeiture of the monetary policy tool does not present a loss, at least for moderate shocks. In the case of a common currency, greater trade also leads to more savings in terms of transaction costs and risks.

Baldwin and Wyplosz (2006) state three additional, more political, criteria. The first is the criterion of *fiscal transfers*; countries that use fiscal transfers to balance the consequences of an asymmetric shock form an OCA. In the event of an adverse shock in one country in a two-country monetary union, the second country also suffers. The second country can compensate the first country financially in order to alleviate the impact of the shock. In this way the recession in the first country and the boom with inflation in the second are mitigated. This criterion is often attributed to Kenen (see Helpman, 1999) and his work on OCAs in the 1960s.

Homogeneity of preferences is the next criterion proposed by Baldwin and Wyplosz (2006); countries need to agree on how to deal with a symmetric shock. Symmetric shocks do not pose a threat to a currency union as long as all the countries react in the same way to the shock. If this is not the case, a symmetric shock may have asymmetric effects, which would pose a problem.

The last criterion proposed by Baldwin and Wyplosz is *solidarity*, which means that countries in a monetary union must surrender their pursuit of exclusively national interests. When confronted by a shock, especially an asymmetric shock, some countries may have different preferences as to which policies are required to deal with it. Residents of a country in a currency union need to feel a sense of solidarity with the rest of the union in order to prevent inflexible actions from being taken by the country's officials in the monetary institution.

In the light of the recent events in the euro area, De Grauwe (2011) and Krugman (2013), among others, propose another prerequisite that could be considered a criterion for an OCA, the criterion of *banking union.*

In order to satisfy OCA criteria, the countries that form a monetary union require open and diversified economies. In the absence of asymmetric shocks, this alone would suffice for an OCA. However, since asymmetric shocks (or symmetric shocks with asymmetric effects) are more than likely, and in the absence of full wage and price flexibility, the additional criterion of labour mobility needs to be satisfied. Owing to language and culture barriers, labour mobility in the EMU is more difficult than it is in the USA. In the event of such, political support in the form of fiscal transfers, solidarity and common preferences are additional criteria that need to be fulfilled for an OCA.

The EC (1990) believes that country-specific shocks can be alleviated through high labour cost flexibility and discipline over debt and deficits, which would enable an appropriate reaction to such shocks. The central bank is seen as the main institution that would grant price stability in the EMU, while centralised powers over budgetary policy have not been estimated as a prerequisite. The EC (1990) states that effective policy coordination functions are required in order to tackle the overall macroeconomic policy mix. However, Member States would be responsible for managing national budgets. The formation of the EMU has been based on the convergence criteria, which specify goals in areas such as inflation, long-term interests on bonds, exchange rates, and country debt and deficit.

The financial crisis in 2008 and the prolonged recessions in some EMU countries have demonstrated that the EMU does not do well in terms of the OCA criteria. What happened in the euro area was an asymmetric shock which went above and beyond what is understood by the term "country-specific shock".[7] The creation of the EMU has caused capital flows from Europe's core to the periphery, leading to economic boom and higher inflation rates in countries such as Spain and Portugal. The financial crisis in 2008 put a stop to these capital flows, and periphery countries were left with excessive relative prices and unit labour costs. Since labour mobility could not mitigate the imbalances, and (downward) labour cost flexibility was not at the levels required to close the gap in the relative labour costs, a major euro crisis ensued. An established fiscal transfer system could have helped alleviate the crisis, which put such strain on national budgets that the

[7] Krugman (2013) uses the phrase "mother of all asymmetric shocks".

deficits were no longer sustainable. However, even critics of the euro share the opinion that the EMU can be rescued if appropriate action is taken. Krugman (2013) proposes a higher inflation target and European bank guarantees, with the ECB acting as a lender of last resort to governments.

De Grauwe (2011) highlights another important drawback to the monetary union. Members of the union lose the ability to issue debt in a currency over which they have full control. In effect, countries have no longer a means of last resort in the form of their central banks. Member countries are therefore exposed to changing market sentiments and liquidity crises when growing interest rates arise. This causes fiscal policies that could act counter-cyclically and alleviate asymmetries in the event of a shock to be less effective. Acting as a lender of last resort to governments, the ECB could alleviate this drawback.[8]

Another point made by Krugman (2013) is that neither the OCA nor the EMU paid sufficient attention to banking issues. National bank guarantees and the bank bailouts had a huge effect on government debt in some countries. EMU-wide bank guarantees (as is the case in the USA) could mitigate the effects of the crisis. The case for a banking union for the euro area has been stressed by, among others, the IMF (2013), Wheelan (2012) and, last but not least, Mario Draghi, the president of the ECB (Draghi, 2013). Banking union in the euro area is well underway at present, with the Single Supervisory Mechanism implemented in November 2014 and the Single Resolution Mechanism to be enacted in 2015 (Draghi, 2014).

Draghi (2014) also calls for the unification of capital markets and genuine economic union in Europe. However, whilst fiscal transfers as they exist in the USA are unlikely in the euro area at present, some form of fiscal policy focused on confronting the crisis can be achieved.

Although the debate about the OCA and EMU is currently mainly focused on the criteria of fiscal transfers and banking union, the other criteria are still important. If the euro project is solved by establishing institutions for fiscal and banking union, the question of the time evolution of other criteria, which concentrate mainly on preventing the occurrence of asymmetric shocks or the asymmetric effects of symmetric shocks, remains open.

Therefore, it is also important to understand how the monetary union influences the OCA because the OCA fulfilment criteria can change due to the fact that a monetary union has been formed. Some take the view that the OCA criteria are endogenous and that they would be increasingly fulfilled after the introduction of a single currency.

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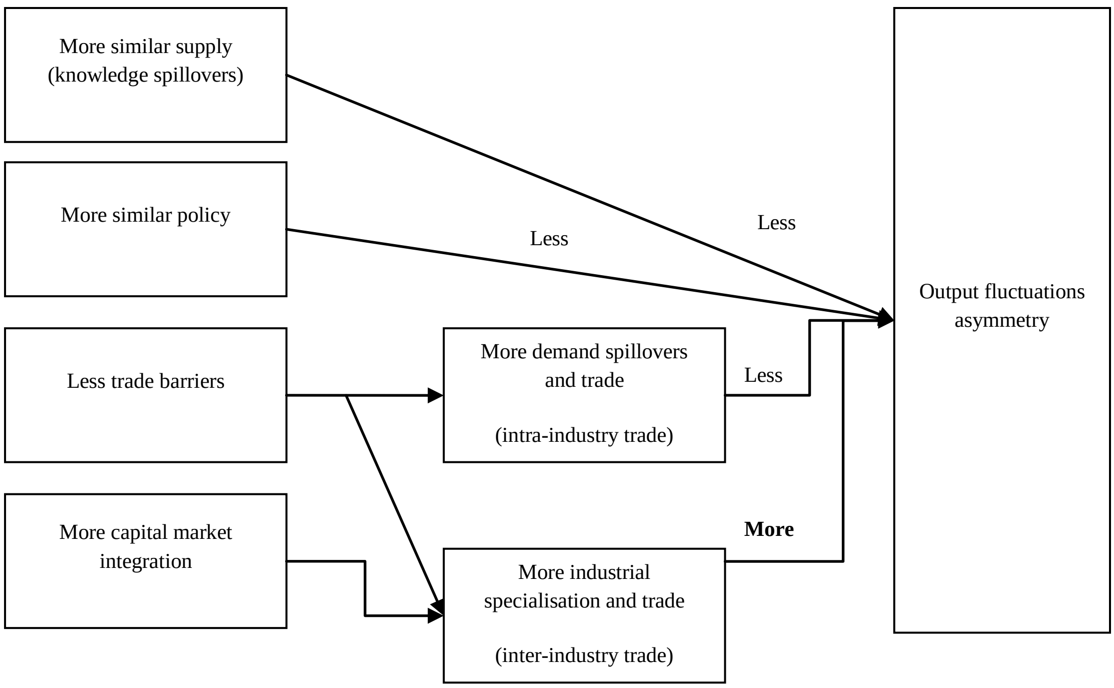
[8] After the speech of the President of the ECB, where he stated that the ECB was ready to do whatever it took (Draghi, 2012), the credit default swap rates decreased.

1.2 Endogeneity of OCA criteria

There are more possible channels for the endogeneity of OCA criteria. Artis (2002) highlights monetary policy and trade. The reasoning for the first channel is that idiosyncratic monetary policy can in itself be a source of idiosyncratic shocks. In a currency union the shocks that arise from monetary policy are common, if we assume that they do not have asymmetric effects. The other channel is the trade channel. Monetary union should promote trade due to the reduction of exchange rate volatility. However, there are competing theories as to whether increased trade creates more or less synchronised business cycles. If the increased trade is intra-industry in nature, more common shocks are expected, thereby increasing synchronisation as a result. On the other hand, if the inter-industry type prevails, this can lead to inter-industry specialisation, thereby reducing business cycle synchronisation.

Kalemli-Ozcan, Soerenen and Yosha (2001) depict the possible sources, as shown in Figure 2 below. The channel of knowledge spillovers was first proposed by Coe and Helpman (1995), and the policy channel is mentioned in Frankel and Rose (1998). Kalemli-Ozcan et al. (2001) find that greater industrial specialisation, induced by increased capital market integration, causes more asymmetry in output fluctuations.

Figure 1. The effects of economic integration on output fluctuations asymmetry.



Source: Kalemli-Ozcan, Soerensen & Yosha (2001), *Economic integration, industrial specialization, and the asymmetry of macroeconomic fluctuations*, p. 109, Figure 1.

The evolution of the asymmetry of output fluctuations in the euro area depends on the relative contributions of these various effects. We discuss the effects of the currency union on trade and intra- vs. inter-industry trade in the following sections, but note that channels other than trade might also be important.

1.2.1 Currency union effects on trade

European policy makers have traditionally believed that stable exchange rates promote trade integration, which enhances the fulfilment of the McKinnon criterion (Baldwin and Wyplosz, 2006). Stable exchange rates should reduce the uncertainty that discourages international trade. Not only would transaction costs be eliminated, trade would also be promoted. Even though there is an argument that these uncertainties can be eliminated through the use of derivatives to hedge the exchange rate risks, there was strong support in the empirical literature for the view that trade integration does indeed deepen in a currency union.

Based on a gravity model cross-sectional approach on a large dataset of 186 countries for the period 1970–90, Rose (2000) finds that a currency union more than triples trade with the countries in the union. The positive effect of the currency union on trade is often referred to as the Rose effect.[9]

This effect is confirmed in a study by Frankel and Rose (2000). They also find increased output due to increases in the trade in the range of a one third of a percent increase in output over twenty years for every percentage increase in the trade. They suggest that these results confirm the hypothesis that the beneficial effects of monetary union come through the promotion of trade.

Glick and Rose (2002) use a gravity model which eliminates some of the drawbacks to the cross-sectional model, such as pair-specific fixed effects or inability to estimate the effect of a country joining or leaving the currency union. The gravity model approach also exploits the time series variation as well as of the cross-sectional variation. They estimate the model on a large dataset of 217 countries for the period 1948-97. The fixed-effect estimate for γ is 0.74 which means that currency union approximately doubles bilateral trade. This effect is large and statistically significant. The OLS estimates of the same equation are even higher than those of previous studies by Rose (2000) and Frankel and Rose (2000).

The findings of the above studies have garnered much attention and many papers have tried to bring down the estimated effect. Baldwin (2006) states that the gravity models used in the studies above have some serious flaws, the most serious of which is the omitted variables problem as this caused a biased result in the first study by Rose (2000). Persson (2001) uses a matching technique on the same dataset and gets much smaller effects: between 15 and 66 percent. His procedure should avoid the omitted variables problem.

[9] In Baldwin (2006), for example.

The study by Glick and Rose (2002) has also been criticised by Baldwin (2006) since the number of entries to the currency union is much smaller than that of the number of exits (16 compared to 130) in their dataset. Their estimate for the trade effect could thus be interpreted as the effect of a breakup of a currency union, which is often accompanied by other factors.[10]

The results of the studies discussed above may not even be relevant to the EMU, since most of the currency union countries in the samples used were either small or poor, or both. The EMU, on the other hand, is an unprecedented major currency union. There are a variety of views on the effects of the EMU on trade. Krugman (2013) states that the explosion of trade after the establishment of the EMU did not occur as had been predicted from the above studies. Instead there has only been a relatively modest increase in trade, especially when compared to previous studies.

The first estimate of the EMU's effect on trade was performed by Micco, Stein, and Ordonez (2003) on a dataset up to 2002. Using a fixed-effect estimate for a sample comprising 15 EU countries, they estimate the effect to be 6 percent more trade among EMU members. Using other techniques and data samples they record an increase in trade of up to 28 percent. These numbers are small relative to the results in the papers by Rose.

Another widely cited paper which deals with the euro's effects on trade is by Flam and Nordstrom (2003). Their findings are quite similar to the previously mentioned study. Using only non-euro EU countries as a control, they record an 8 percent increase in trade due to currency union. When using other non-EU countries in the control group, this figure rises to 15 percent. Currency union also promotes trade with countries outside the euro zone by about 8 percent. Their study is disaggregated to the sector level, and they find the effect to be present only in those sectors with differentiated products.[11]

Herwartz and Weber (2010) estimate a version of a gravity model on a dataset comprising only three euro and three non-euro EU countries, with data up to 2006 and disaggregated to 99 trade sectors. They find euro-area trade exports to increase by 15 to 25 percent relative to non-euro EU countries. Another interesting finding of the study is that most of this relative increase occurred in the period between 2000 and 2002, and that a substantial amount of heterogeneity is present at a sectoral level.

[10] There were some "natural experiments" in the form of a break-up of the currency unions in the case of Central and Eastern European countries, and Ireland and the United Kingdom. In the case of Ireland and the United Kingdom no significant decrease in trade has been detected, at least not at the levels predicted by Rose (2000), for example. In the case of the Soviet Union, Czechoslovakia and Yugoslavia there were major trade reductions after the breakup of the currency (and political) union. It is very difficult, however, for these reductions to be attributed solely to the currency union breakup since political disintegration occurred at the same time (Fidrmuc and Fidrmuc, 2001).

[11] As discussed later, this is in line with the theory that intra-industry trade is important. Baldwin, Skudelny, and Taglioni (2005) report a 25% increase in intra-EU trade.

There are some disagreements or different interpretations as to the exact timing of the currency effect on trade. As the de facto start of the euro as an electronic currency, January 1999 has become the convention, although some authors, e.g. Berger and Nitsch (2008), argue that several major events are appropriate candidates for the shifts in EMU trade costs. An alternative date is January 2002, which marked the introduction of the euro as a physical currency. Another date is the end of 1997, which is when the third stage of the EMU was introduced. Some authors, such as Micco et al. (2003) and Flam and Nordstrom (2006) report an increase in euro area trade in 1998, and interpret this increase as an anticipation effect. On the other hand, some take the view that there can be no exact timing of the trade effect, since the euro may create medium to long-run effects (De Nardis & Vicarelli, 2007). The results of Herwartz and Weber (2010) on a sector level imply that this gradual and spread out adjustment may simply be a consequence of different sectors adjusting at distinct times.

Some authors point to endogeneity issue of the estimation of currency union trade effects. Countries that trade a lot with each other have an incentive to stabilize exchange rates. Devereaux, Lane and Xu (2006) find that nations tend to stabilise their bilateral exchange rates against nations with whom they trade a lot. A currency union is then only irrevocable form of stabilization of exchange rates.

Barro and Tenreyo (2007) use an instrumental variables (IV) approach to the gravity model of trade to cope with the endogeneity issues and confirm the positive effects of currency union on trade and prices comovement. However they also find that currency unions might decrease the degree of synchronisation of output.

1.2.2 Effects of currency union on diversification of economies

The next question is whether increased trade can have an effect on the Kenen criterion of diversification and what this effect would be. More specialisation in a specific industry in a country would result in more inter-industry trade and worsen Kenen's diversification criterion, while on the other hand increased intra-industry trade would improve the Kenen criterion.

As stated before, the opinions of economists on the effects of monetary union on diversification are polarised. On one side are economists, such as Paul Krugman (1993), who take the view that the introduction of monetary union leads to inter-industry specialisation processes. In the event of such, the level of business cycle synchronisation in countries in the monetary union should become weaker over time because specific industries concentrate in specific countries. The opposite view was first argued by Frankel and Rose (1998) who state that an increase in trade among countries leads to higher business cycle correlations. In this case, intra-industry specialisation is expected, where most of the trade occurs within a specific industry.

Traditionally, comparative advantage models based on the Heckschner-Ohlin trade theory have been used to model foreign trade. The Heckschner-Ohlin model states that a country will export products that use its abundant and cheap factors of production and import products that use the country's scarce factors. An important part of the model is the Stolper-Samuelson theorem, which states that a rise in the relative price of one capital (labour) intensive good will lead to a rise in the return to capital (labour) and in turn, to a fall in return to labour (capital). Due to the importance of this contribution by Samuelson, the theory is sometimes referred to as the Heckschner-Ohlin-Samuelson trade theory.

The Heckschner-Ohlin-Samuelson two-factor, two-sector model underwent some additions when encountering conflicting empirical results.[12] Even though the refinement of Heckschner-Ohlin model types is an ongoing process[13], a new trade theory emerged, which attempted to explain the large share of intra-industry trade between countries with similar factor endowments.

Krugman (1981) presents a stylised model, based on the work of Dixit and Stiglitz (1977), which shows the theoretical grounds for intra-industry specialisation to occur, in contrast to comparative advantage theory which only predicts inter-industry specialisation. Krugman demonstrates that economies of scale limit the variety of products produced in one country and so similar countries do have an incentive to trade products with similar factor proportions. In an industry which comprises a large number of firms that produce differentiated products, there will be international trade within the same industry because firms in different countries will produce different differentiated products. Countries do not produce a complete range of products in each industry due to the presence of fixed production costs.

Krugman's theoretical model goes some way to confirming previous empirical literature on the existence and causes of intra-industry trade and specialisation.[14] Horizontal intra-industry trade can be explained by economies of scale, based on the theoretical models by Krugman and Helpman (1981), and Dixit and Norman (1980). Without economies of scale, a country would have all its products produced domestically.[15]

[12] For example, the Leontief paradox – Leontief (1954) found that the USA, the world's most capital-rich country, imported more capital intensive products than it exported, the opposite of the Heckschner-Ohlin theory prediction.

[13] More in Helpman (1999).

[14] Balassa (1967) and Kravis (1971), also referenced in Krugman's 1981 paper.

[15] Some empirical studies, however, have found a negative relationship between intra-industry trade and economies of scale. Balassa (1986) argues that vertical specialisation with production stages located in different countries can contribute to a negative relationship between economies of scale and intra-industry trade since vertical specialisation tends to reduce rather than increase firm size. Clark and Stanley (2003), among others, also find there to be a negative relationship. Helpman (1999) argues that the degree of economies of scale is in fact not as important as its mere existence.

The explanations of trade provided by economies of scale and product differentiation do not substitute, but rather complement, the traditional models with comparative advantages (Helpman, 1999).

Helpman and Krugman (1985) present an integrated approach to foreign trade including economies of scale, product differentiation and factor endowments. They admit that, even with economies of scale and imperfect competition, the factor endowments are a major predictor for patterns of trade. However, comparative advantages are not the only incentive to trade when increasing returns are present. Countries will engage in specialisation so as to exploit the benefits of increasing returns and this will lead to trade, even in cases where factor endowments are equal and do not promote trade. Their model of international trade is based on the Heckschner-Ohlin view of inter-industry specialisation, and an economies-of-scale view of intra-industry trade.

A definition of intra-industry trade is first presented in the context of the substitutability of products or, in other words, from a consumption perspective (Grubel & Lloyd, 1975). For the purpose of distinguishing between the comparative advantages based theories and the new trade theory put forward by Helpman and Krugman (1985), for example, the definition changes to substitutability in production.[16]

Vertical intra-industry trade is trade in varieties of the same goods, differentiated in terms of quality. Linder's (1961) theory predicts that less developed countries specialise in the production of low quality varieties of the goods, whereas more developed countries export high quality varieties. Faustino (2008) claims that this theory is consistent with Vernon's (1966) theory of product cycles, in which a product goes through three stages: the new product stage; the maturing product stage; and the standardised product stage. In the last product stage, foreign direct investment provides less developed countries with the technology required for production, and so less developed countries start to produce and export low quality varieties of a product, while the more developed countries continue to export high quality varieties. Vertical intra-industry trade can be explained by the Heckschner-Ohlin type of comparative advantage model (Davis, 2005).

Horizontal intra-industry trade, on the other hand, contributes mostly to countries which are more similar to each other. Differentiation in quality is not a factor in this case. Horizontal intra-industry trade is explained by economies of scale and product differentiation in new theories of trade.[17]

1.2.3 Effects of currency union on business cycles synchronisation

The high level of business cycle synchronisation is emphasised in the OCA literature, since the costs associated with currency union decrease when business cycles are more

[16] A suitable disaggregation of industries is needed in empirical research of intra industry trade.

[17] The empirical results of Faustino (2008) suggest that also horizontal intra-industry trade can be explained by comparative advantage.

symmetric. Common monetary policy can only be effective if the business cycles are synchronised.

A business cycle refers to a fluctuation in production, trade and activity over a time period.[18] Usually, the term is used for fluctuations of GDP around potential GDP, on the assumption that GDP can be decomposed into trend and cyclical components. Since there are also fluctuations in the disaggregated components of GDP, the term may also be used for specific parts of the economy, such as industry. Industrial data are often used for business cycle analysis since monthly frequency data are available and the industry sector accounts for the bulk of cyclical variation (EC, 2008). Furthermore, the historical close correlation between industrial production and GDP is highlighted.

The main question put forward for examination in this thesis is whether the euro has strengthened the synchronisation of the participating countries' business cycles. Based on the suggested channels of OCA endogeneity (Figure 2), we should observe an increased degree of business cycle synchronisation if the currency union effects which decrease output fluctuations prevail.

The OCA endogeneity channel that receives the most attention in the literature is the channel of trade. Frankel and Rose (1998) find empirical evidence that closer trade links result in more closely correlated business cycles across the countries. This can happen if demand shocks or common shocks across the countries predominate, or if intra-industry trade accounts for most of the trade.[19] Their empirical results predict the convergence of business cycles in the EMU due to further trade liberalisation. A further point made by Frankel and Rose is that countries that join the EMU can satisfy OCA criteria *ex post* even if they do not *ex ante*. The structure of the economies after joining the currency union is likely to change. Further, Engel and Rose (2002) find a direct positive causal effect of currency unions on business cycle synchronisation.

On the other hand, trade links might not be sufficient to ensure the convergence of business cycles if countries are not similar enough (Kenen, 2000; and Huges Hallet & Piscitelli, 1999).

Some models predict that increased inter-industry trade will be followed by a geographical concentration of production and a consequent drop in intra-industry trade. Krugman (1993) and Krugman and Venables (1996) warn against inter-industrial specialisation in Europe, which could arise with the growing integration of the market. They show that increased integration makes it more likely that firms in the same industry will cluster together. The effect would be increased inter-industry trade due to geographical industrial specialisation, which would hinder the fulfilment of the Kenen criterion. Critics of the specialisation hypothesis by Krugman claim that the specialisation effect might occur due to capital

[18] Burns and Mitchell, 1946.

[19] Fidrmuc (2004) confirms (on OECD countries data) that intra-industry trade is the main cause of business cycle convergence, and that trade intensity alone is not related to business cycles.

market integration and not monetary integration (Artis, 2002). Kalemli-Ozcan, Sorensen, and Yosha (2001) confirm that increased trade and the associated financial links can reduce business cycle synchronisation as they stimulate industrial specialisation by means of capital relocation to countries with comparative advantages.

The Maastricht criteria are often deemed to have not accommodated OCA criteria to a desirable level; however some studies show that some Maastricht criteria could contribute to satisfying OCA criteria, such as those pertaining to fiscal deficits, could contribute to satisfying OCA criteria. Darvas, Rose and Szapary (2005) use a panel of OECD countries to show that reduced fiscal deficits increase business cycle synchronisation.

There are various methods to investigate the degree of business cycles synchronisation in the literature. Alesina, Barro and Tenreyo (2002), e.g., estimate comovements using annual time series and compute second-order autoregression for a pair of countries i and j:

$$\ln\frac{Y_{it}}{Y_{jt}} = b_0 + b_1 \ln\frac{Y_{i,t-1}}{Y_{j,t-1}} + b_2 \ln\frac{Y_{i,t-2}}{Y_{j,t-2}} + \varepsilon_{tij}, \qquad (1.2.1)$$

The root mean square error of the equation (1.2.1) is used as a measure of comovement. On a sample for 1960–1997 Alesina et al. (2002) find higher output comovement of European countries with the euro area countries.

Probably the most widely used approach in the investigation of business cycle synchronisation is based on the assumption that economic time series can be decomposed into trend and cyclical component. Even though there is no consensus on how to estimate the trend, this approach is found useful since it is conceptually close to the output gap measure, which plays an important role in monetary and budgetary surveillance (EC, 2008).

Giannone and Reichlin (2006) investigate trends and cycles in the euro area output dynamics. When comparing the output level gaps of euro area countries compared to aggregate euro area, there is quite a stable gap pattern during the period 1970–2003. Ireland is an outlier, with an exceptional performance, increasing GDP per capita at PPP from just above 50 percent of the euro area level in 1970 to 123 percent in 2003. Some improvement can also be observed for Spain and Portugal. The correlation coefficients between GDP growth in euro area countries and the EA show that business cycle synchronisation increases in the last decade observed, which implies that the deeper integration of euro area countries leads to more synchronised business cycles. The correlation coefficient is also high for EU countries that have not been involved in the process of single currency formation, i.e. in their sample, Sweden and the UK. With the EMU only being in place for the last five years of observation, it is difficult to estimate the effects of the currency union on output synchronisation, but there are signs that the euro area is composed of relatively more synchronised countries. Another stylised fact that supports the idea of highly synchronised euro area countries is the synchronicity of the recessions (Giannone and Reichlin, 2006).

EC (2008) uses correlation based approach to investigate the synchronisation of 11 euro area countries in the period 1975–2007 . Using monthly series of industrial production and four-year rolling window they find that recession phases are marked by higher degree of correlation than the recovery periods. They also find a modest increase of the degree of synchronisation in the euro period. Also other studies based on correlations generally find evidence that business cycles in the euro area are highly synchronised. Examples of studies are Bergman (2004), Breitung and Eickmeier (2005).

Artis (2003), on the other hand, states that European business cycle cannot be clearly defined. He argues that the globalization caused the world business cycle to emerge and prevail in the last observed period 1993–2001. He approaches the issue by panel data estimation for 1970–2001, divided into 3 periods. He examines bilateral correlation of country business cycles to business cycles of Germany and US and finds the EU and EMU dummy in the panel regressions as not significant in explaining correlation with Germany.

Camacho, Perez-Quiros and Saiz (2006) confirm that the existence of euro area business cycle can be rejected, however when focusing on individual euro area countries, the similarities across euro area countries are relatively larger when compared to other countries.

While majority of the studies focuses on old member states, Fidrmuc (2004) investigates also some new member states. He finds that business cycles in Hungary, Slovenia and to a lesser extent Poland are strongly correlated with business cycle in Germany in the period 1993–1999. Czech Republic and Slovakia as the other two countries in the sample do not exhibit strong correlation.

Darvas and Szapary (2008) confirm the study of Fidrmuc (2004) and extend the country sample with the Baltic states. They find very low level of synchronisation of Estonia, Latvia and Lithuania in the observed period 1993-2002, based on quarterly GDP data. Similar results for new member states are obtained by Artis, Marcellino and Proietti (2005) when investigating business cycle synchronisation using industrial production index.

Research by Levasseur (2008) with SVAR methodology finds Slovenia and Latvia as suitable members of the EMU based on the demand shocks synchronisation. However, if supply shocks are given more weight, Slovakia, Estonia and Poland join the group of EMU suitable countries as well. The research is based on correlation of main components of GDP based on expenditure disaggregation.

The literature is scarcer on the analysis of sectoral business cycle synchronisation. Afonso and Furceri (2009) investigate correlation of business cycles for sectors of industry, building and construction, agriculture, fishery and forestry, and services (1980-2005) with aggregate euro area business cycle. They find that in majority of EU countries, the industry sector contributes the most to the business cycle synchronisation with the euro area.

Barro and Tenreyo (2007) criticise the approach of a correlation based assessment of business cycle synchronisation for OCA purposes. Two countries can be highly correlated but one exhibits a greater variability of output. In the event of such, the country with higher variability would require a stronger monetary policy response than the country with lower variability.

1.3 Dynamic factor models on business cycles and heterogeneity

An alternative approach to investigate business cycles is built around dynamic factor models, which usually extract common factors from large multidimensional databases. This strand of literature is also most closely related to the research in our thesis. The investigation of business cycles for EU countries is limited to the availability of data, and so the use of dynamic factor models is advantageous because, when confronted with data covering a short time span, a large cross-dimension mitigates for this (Banerjee, Marcellino and Masten, 2004).

In comparison to other methods, the factor models have the advantage of capturing the extent of comovement of a large number of variables simultaneously. A large number of economic series can better capture the cyclical movements of business cycles (Zarnowitz, 1992).

Marcellino, Stock and Watson (2000) used a dynamic factor model on the founding euro area members' data. Their large quarterly dataset (N=550) covers the period 1982–1997. In order to estimate the factors, they use Stock and Watson's (1998) nonparametric approach in the time domain, based on the principal components method. Marcellino et al. (2000) find that much of the variance, almost half for the period 1990–1997, in the dataset can be explained by the six common euro area factors. This represents a significant increase on the 37 percent of the explained variance for the whole of the period 1982–1997. Further, their approach to investigating the homogeneity of euro area countries is to also estimate six common factors for each country in addition to this, and to check for correlation with the euro area factors. When they regress country specific factors on the euro area factors, they find smaller shares of explained variances for smaller countries, most notably Ireland, Portugal and Luxembourg.

Stock and Watson (2003) use a factor augmented VAR methodology to extract common international shocks. They use two common international shocks to investigate the business cycles in G7 countries. They find that the business cycles do not become more synchronised over time in the EA as a whole. The main reason for the decreased synchronisation in the period 1984–2002 relative to 1960–83 is the decrease in the importance of common shocks. However, one of the findings of their research is the emergence of a euro area factor in the second half of their dataset (1981–2001) for three euro area countries included in the G-7 sample: Italy, Germany and France.

Kose, Otrok and Whiteman (2003) investigate a set of 60 countries for the period 1960–1990. They studied the decomposition of the variance to investigate business cycle synchronisation. For the factor extraction they used a Bayesian dynamic latent factor model[20] and extract the common, regional and country specific factors in a hierarchical structure.[21] They find the regional factor belonging to European countries to be far less important than the world factor in terms of variance decomposition. The European factor accounts for only 2.3 percent of the output variance, whereas the world factor accounts for 32.3 percent, on average, across the countries. Country specific factors are the most important when it comes to explaining variance in the European countries, and account for an average of 48.2 percent. While the study is important for the hierarchical DFM methodology and, in a sense, reminds us of the importance of worldwide comovements, the results have little relevance to euro area business cycle synchronisation. First, the data sample ends in 1990, which is when only stage one of the EMU had started. Secondly, their European dataset also includes countries outside the EU.

Kose, Otrok and Whiteman (2005) analyse the evolution of business cycles in a smaller sample of G-7 countries for the period 1960–2003. They use three main macroeconomic variables: output, consumption and investment, and extracted the common G-7 and country specific factors. The common G-7 factor explains, on average, 26 percent of the volatility in output, while the figures are lower for consumption and investment at 16 and 19 percent, respectively. The use of the long time series available for these developed countries enables Kose et al. (2005) to investigate the evolution of the roles of the factors in discrete time periods. In line with Stock and Watson (2003), they also find the common G-7 factors to have greater importance in the period of common shocks (the oil price and contractionary monetary policy shocks from 1972–86) than in the later period of globalisation.

Forni and Reichlin (2001) go a step further and propose the study of the synchronisation of output fluctuations at different levels of aggregation to those of previous studies. They introduce the level of regions and use a regional annual GDP dataset for nine European countries[22] which includes 138 regions for the period 1980–1993. Apart from investigating the output fluctuations symmetry in the EU, they also analyse a US dataset composed of 48 countries and 3075 counties for the period 1963–1993. They compose a hierarchical DFM consisting of common and country specific factors, and a regional component.[23] They find that the common EU factor accounts for almost half of the variance of the dataset. There is some country heterogeneity in the results: for Greece, Portugal and the UK, the common EU factor is less important. Country specific factors account for about a third of the variance, while the rest is the region specific idiosyncratic component. The comparison

[20] This methodology is developed in Otrok and Whiteman (1998).

[21] The study is among the first to introduce a hierarchical structure in the DFM.

[22] Eight euro area countries and the UK. They also use a smaller sample with 82 regions and 6 countries for a longer period (1973–1993).

[23] In order to estimate the model they use the procedure proposed in Forni and Reichlin (1996, 1998).

with the US demonstrates that EU integration measured by the importance of common factors is comparable to the US.

De Bandt, Bruneau and Flageollet (2006) use a non-stationary setup of factors using the approach of Stock and Watson (1998)[24] to extract common euro area factors from a large dataset (N=220) of EA12 countries. Their quarterly dataset coveres the period 1980–2003, and they find five common euro area factors to account for 39 percent of the total variance. They further use the first factor to construct a business cycle index for the euro area. They find that the correlation between the cyclical component of the euro area factor and the cyclical components of GDP for France, Germany and Italy increases in the second period (1992–2003) when compared to the first period (1980–1991).

A stationary and non-stationary quarterly setup is also used in Eickmeier's (2006) dynamic factor model setup. The large dataset (N=172) for the observed period was from 1982–2003. The dataset coveres EA-12 countries, and includes some additional aggregate series for the euro area and some global series that could have an impact on euro area economic activity. Eickmeier uses a principal component approach to factor estimation, as proposed in Stock and Watson (1998) and Bai and Ng (2004), and finds that five common factors account for 32 percent of the variance of the dataset. In the next step she uses a structural VAR approach to estimate five common shocks: two EA supply shocks, an EA demand shock, a common monetary policy shock and a US shock. With this setup she analyses the evolution of the common and idiosyncratic components of GDP and CPI inflation for individual euro area countries. She finds that the heterogeneity across the euro area countries' output and inflation has decreased in the run-up to the EMU. There is some heterogeneity in the importance of common factors in terms of explaining the GDP variance. The smallest shares are explained for Greece, Luxembourg and Ireland.

A more recent study by Lee (2012) tackles the issue of the convergence of business cycle dynamics with a dynamic factor model with time varying factor loadings, building on the work of Del Negro and Otrok (2008). Time varying factor loadings enable Lee to analyse the evolution of comovements over time. He investigates the period 1970–2010 on GDP per capita quarterly data. Analysis of the variance decomposition confirmes an increase in output synchronisation in the EMU during the period prior to the launch of the euro in 1999, but there are no further increases in the degree of synchronisation in the period after the euro launch. Furthermore, Lee finds that the euro area comovements are not apparently stronger than their comovements with other European countries.[25]

The study by Lehwald (2013) also covers the same period of the euro as a common currency. Lehwald uses quarterly data on GDP and components that covere the period

[24] Bai (2004) shows that the factors extracted using the principal component estimators are consistent with large N and T, even in cases where the series are in level; however, the specific component needs to be of order I(0) as shown by Bai and Ng (2004).

[25] Lee (2012) does not include new Member States in the analysis.

1991–2010 for nine founding euro members and Greece. She investigates the changes in the degree of synchronisation by analysing the pre-euro and euro periods separately. Kose et al.'s (2003) model setup, with a Bayesian method that exploits Gibbs sampling techniques, is used to estimate the dynamic factor model, which comprises area-wide and country specific factors. Based on variance decomposition, the findings of this study are that only the core euro area countries increased synchronisation in the euro period, while the degree of synchronisation with the euro area decreased for the periphery countries (Portugal, Ireland, Greece, Spain). Furthermore, using a control group of four additional non-euro G-7 countries, they conclude that the increase in euro area factor importance for the core euro countries can be attributed to the worldwide increases in business cycle synchronisation.

Applications to the data of new EU member countries are scarcer. Breitung and Eickmeier (2005) find a smaller correlation between the business cycles of new member states from Central and Eastern Europe[26] and the euro area than between non-euro old member states and the euro area using dynamic factor methodology. They investigate the period from 1993–2003. A structural factor model is used to estimate five common EA factors. They find less synchronisation between Central and Eastern European countries and the euro area than among euro area countries.

Sectoral disaggregation

Finally, we highlight another strand of literature that is important for our research concerning disaggregated sectoral data. The main question in the literature is the relative contributions of sector specific and aggregate shocks to the variability in the aggregate sector. One of the approaches to this issue includes the use of factor models to determine the share of variance attributed to aggregate shocks.[27]

Forni and Reichlin (1998) analyse US manufacturing data on a disaggregated sectoral level for the period 1958–86. They impose a dynamic factor model on the dataset, consisting of 450 sectors in the US economy. After extracting the common factors, they find sector specific shocks to explain for 60 and 70 percent of the variance of the output and productivity, respectively. Sector specific shocks generate mainly high frequency dynamics, while in the case of common shocks extracted from the full dataset, they find business cycle patterns in the idiosyncratic component.

Foerster, Sarte and Watson (2008) on the other hand argue that the common factors from the factor model may reflect not only aggregate shocks but also sectoral shocks due to input-output linkages. The correlation due to input-output linkages can cause common factor to overestimate the importance of aggregate shocks. Their approach of dealing with the issues is to include the multisector growth model by Horvath (1998) in composing a

[26] Romania and Bulgaria are not included.

[27] The other approach relies on input-output linkages across the sectors (e.g. Long and Plosser, 1983).

structural factor model. For the period 1984-2007 on quarterly data for manufacturing, disaggregated to 117 subsectors using a structural factor model, they estimate that 69 percent of the variance was attributable to aggregate shocks, while with statistical model the share was at 87 percent.

However, the factor model approaches to disaggregated sectoral analysis only extract common factors and attribute the entire idiosyncratic component to the sector specific shocks. We argue in the same fashion as Beck et al. (2012)[28] that the problem with this approach is that the residual can also capture effects that are not attributable to sectoral movements, such as measurement errors. Since the bulk of the literature analysing the sectoral effects relies on US data, the geographical component has not been investigated.[29] We argue that at least in the case of disaggregated EU data, the geographical component is an important additional effect.

Helg, Manesse, Monacelli and Rovelli (1995) investigate the manufacturing sector disaggregated to 11 subsectors for 11 EU countries for the period 1975–1992. The approach of their study is to model the output growths in a subsector in a given country using a vector error correction model (VECM). The estimated residuals (output innovations) of a VECM model are then grouped first by subsector and next by country. The principal components for the subsector and country groups are computed in the last steps. They find that the principal components explained the larger share of variance in the country groups than in the subsector groups. Helg et al. (1995) also find that the correlation of the principal components of the subsector groups is higher than in the case of country groups, indicating sector specific shocks to be more symmetric across the countries, while country specific shocks represent the asymmetric area wide effects.

Inflation differentials

The second part of our work relates to the literature on inflation differentials. As we have already stated, a more disaggregated approach to the monitoring of prices has become crucial as a consequence of the recent euro crisis. One of the fundamental imbalances in the euro area is the increased divergence of competitive positions of countries (De Grauwe, 2011), which is reflected in diverging unit labour costs. Higher labour costs can decrease the competitiveness of an economy if other costs are not adjusted. If other costs are not adjusted, increases in the producer prices are a logical consequence.

[28] Beck et al. (2012) investigate the sectoral properties of CPI inflation.

[29] Using US disaggregated data for 1958-1986, Shea (2002) finds that industries that cluster together geographically tend to exhibit more comovement.

After the introduction of the euro, the speed of adjustment of the real effective exchange rate[30] slowed down, which implies that output and inflation differentials tend to become more persistent (EC, 2008).

The issues of inflation differentials are sometimes also tackled by DFM. Altissimo, Benigno and Palenzuela (2005) estimate a DFM on the inflation differentials in ten euro area countries and five sectors (services, industrial goods, energy, processed and unprocessed food). They use additional macroeconomic time series (1993(1)-2003(6)) to compose five euro area factors. Next, they estimate the share of variance of the country-sector inflation differential explained by the euro area component, and attribute the idiosyncratic component to sectoral and country specific effects. They find the industrial goods to exhibit the largest variance share (67 percent, averaged across countries) explained by the common euro area component.

Beck, Hubrich and Marcellino (2009) approach the inflation differentials issue by analysing regional disaggregated consumer price inflation data for six euro area countries for the period 1995–2004 on a monthly frequency. They impose a hierarchical DFM to investigate the regional inflation heterogeneity and decompose the variance into euro area wide, country and regional components. They find the euro area wide component to explain for about 50 percent of the variation in regional inflation rates, while an additional 25 percent is attributed to the country component. They estimate that euro area wide and country specific factors have asymmetric effects across the regions, thereby implying that inflation differentials can also arise due to common euro area or country developments. By splitting the dataset into pre-euro and euro periods, they find no evidence of the effect of the EMU on the inflation heterogeneity.

Beck, Hubrich and Marcellino (2012) decompose consumer prices inflation variation into euro area wide, country specific, sector specific and regional factors. They use monthly regional sectoral[31] consumer price index for five euro area countries for the period 1995–2004. A hierarchical DFM with overlapping blocks is imposed on the dataset. Since blocks of variables grouped by sectors overlap with blocks of variables grouped by countries, the hierarchical DFM has to be modified. They approach the problem by extracting first the common factors, using principal components method. In the next step the country specific factors are estimated by grouping the residuals (idiosyncratic component) by countries. Next, both common and country specific effects are eliminated from the variables, and thus obtained residuals are used to extract sector specific factors. They use iterative method to estimate the sector and country specific factors by alternating the order of estimation. In the next step, country-sector specific factors are estimated, and the remaining residual is further decomposed into region specific and idiosyncratic component.

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[30] The international competitiveness of countries is usually tackled by real exchange rate rates that take into account the country's trade composition and a cost measure. The cost measure can be broad (such as unit labour cost or GDP deflator) or more narrow (export prices) (EC, 2008). More in EC (2008), pp. 276–278.

[31] There are 11 sectors of goods and services.

Beck et al. (2012) find that on average only 8 percent of the variance in monthly inflation is explained by common euro area factor and area wide sector specific factors account for additional 14 percent. Country specific factors explain 10 percent of variance and country-sector specific factors another 21 percent. Regional factors explain 13 percent and the remaining 35 percent of the variance is idiosyncratic. Beck et al. (2012) report also the variance decomposition of year-on-year inflation. The common euro area factor in this case is more important, accounting for 22 percent of the variance. Importance of country specific factors increases as well, to 20 percent of explained variance, while sectoral and country-sector specific factors account for about the same share of variance as in the case of monthly inflation series.

This study focuses on producer prices inflation in the finer disaggregated manufacturing sector which is of special interest in the present debate of asymmetries and competitiveness issues in the euro area, given that the manufacturing sector represents a large share of trade. Further, the dataset covers the periods of the financial crisis in 2008 and the sovereign debt crisis in 2011.

2 DYNAMIC FACTOR MODELS

In this section we present the basic methodology used in this research – dynamic factor models (DFMs); more specifically, we outline the generalised dynamic factor model.

Traditionally, these models have been used in the calculation of economic indicators and for forecasting. Factor analysis in general is used to uncover the latent structure of a set of variables. DFMs are a time series extension of factor models.[32] Usually DFMs are used in order to reduce the number of variables in a dataset to a smaller number of factors for modelling purposes. The factors are uncorrelated and this property of the factors is also one of the approaches used to treat multicollinearity in regressions. Furthermore, the use of factor models can alleviate omitted variable problems in small scale models (Favero, Marcellino and Neglia, 2005).

Recently, DFMs are also more widely used in the areas of monetary policy and international business cycles (Breitung and Eickmeier, 2005). Recent reviews of the literature on DFMs and empirical applications in the construction of economic outlook indicators, macroeconomic forecasts, and macroeconomic and monetary policy analyses are presented by Bai and Ng (2008), Stock and Watson (2011), and Barhoumi, Darne and Ferrara (2013).

2.1 An approximate dynamic factor model

In this section we introduce the methodology for estimating the DFM. The method applied in our research is proposed by Stock and Watson (1998) who use a principal component estimation of the dynamic factors, and so the rest of the section closely follows the description of that paper.[33]

The main factor model used in the past to extract dynamic factors from economic time series has been the state space model estimated using maximum likelihood. This model was used in conjunction with the Kalman filter in a number of papers such as, for example, Stock and Watson (1993). However, the maximum likelihood estimation of a state space model is not practical when the dimension of the model becomes too large, due to the computational costs involved. In order to solve this problem, Stock and Watson (1998) suggest a principal component estimation. This method can accommodate a very large number of time series and can consistently estimate the factor space asymptotically (Kapetanios and Marcellino, 2003).

The premise of the dynamic factor model is that the co-variation among economic time series variables at leads and lags can be traced to a few underlying unobserved time series

[32] Proposed by Geweke (1977).

[33] For a more detailed description of the factor models, their estimation and use in forecasting, see Stock and Watson (1998, 2002a, 2002b).

or factors. The disturbances to these factors might represent major aggregate shocks to the economy, such as demand or supply shocks. Accordingly, dynamic factor models express the observed time series as a distributed lag of a small number of unobserved common factors, plus idiosyncratic disturbances.

We introduce the dynamic factor models by first presenting *the strict factor model*. Formally, in a dynamic r – factor model each element of the vector $y_{it} = [y_{1t}, \dots, y_{1t}]'$ that is a stationary random variable (integrated of order 0) can be represented as:

$$y_{it} = \lambda_i{}' f_t + u_{it}, \tag{2.1.1}$$

where $\lambda_i' = [\lambda_{i1}, \dots, \lambda_{ir}]$ and $f_t = [f_{1t}, \dots, f_{rt}]'$. The vector $u_i = [u_{1t}, \dots, u_{Nt}]'$ consists of N idiosyncratic disturbances, f_t is a vector of r common factors, and λ_i is a vector of factor loadings. Loadings λ_{ir} represent the contributions of the variable i to the common factor f_{rt}.

We can rewrite the model in matrix notation:

$$Y_t = \Lambda f_t + u_t \tag{2.1.2}$$

$$Y = F\Lambda' + U \tag{2.1.3}$$

where $\Lambda = [\lambda_1, \dots, \lambda_N]$ is a weighting matrix of dimension $(N \times r)$, $Y = [y_1, \dots, y_t]'$ is of dimension $(T \times N)$, F is of dimension $(T \times r)$, and $U = [u_1, \dots, u_T]'$ is of dimension $(T \times N)$.

Factors f_t, loadings Λ and disturbances u_t are unobserved, and u_t are assumed to be a vector of uncorrelated errors with following properties:

$$E(u_t) = 0 \tag{2.1.4}$$

$$E(u_t u_t') = \Sigma = diag(\sigma_1^2, \dots, \sigma_N^2). \tag{2.1.5}$$

When the conditions (2.1.4 to 2.1.5) for the vector of common factors hold, the strict factor model can be discussed.

$$E(f_t) = 0 \tag{2.1.6}$$

$$E(f_t f_t') = \Omega \tag{2.1.7}$$

$$E(f_t u_t') = 0 \tag{2.1.8}$$

We can derive $E(y_t y_t')$ by substituting y_t with equation (2.1.2), and taking the above conditions into account.

$$E(y_t y_t') = E\big((\Lambda f_t + u_t)(\Lambda f_t + u_t)'\big) =$$

$$= \Lambda E(f_t f_t')\Lambda' + E(u_t u_t') + \Lambda E(f_t u_t') + E(f_t{}' u_t)\Lambda' =$$

$$= \Lambda\Omega\Lambda' + \Sigma = \Psi \quad (2.1.9)$$

The loading matrix can be estimated by minimising the residual sum of the squares (Breitung and Eickmeier, 2005):

$$\sum_{t=1}^{T}(y_t - \Lambda f_t)'(y_t - \Lambda f_t) \quad (2.1.10)$$

The equation above is subject to constraint $\Lambda'\Lambda = I_r$. We get the first order conditions by differentiating equation (2.1.9) with respect to Λ and F:

$$(\mu I_N - T^{-1}\sum_{t=1}^{T} y_t y_t')\hat{\beta}_k = 0 \quad (2.1.11)$$

for $k = 1, \dots, r$.

$\hat{\beta}_k$ is the *k*-th column of $\hat{\Lambda}$, the loading matrix that minimises the equation (2.1.9). Breitung and Eickmeier (2005) show that the matrix $\hat{\Lambda}$ is the principal component estimator of Λ, since the columns of $\hat{\Lambda}$ result as the eigenvectors of the r largest eigenvalues of $T^{-1}\sum_{t=1}^{T} y_t y_t'$.

They analyse the properties of the principal components estimator by rewriting it as an IV estimator and show that it solves the condition:

$$\sum_{t=1}^{T} \hat{\Lambda}' y_t \hat{u}_t' = 0 \quad (2.1.12)$$

They demonstrate that the principal component estimator is inconsistent for fixed N and $T \to \infty$, unless the variances are homogeneous: $E(u_t u_t') = \Sigma = \sigma^2 I$. In the case of homogeneous variances, the principal components estimator is the maximum likelihood estimator.

In *approximate factor models*, some of the assumptions of the strict factor model are relaxed if it is assumed that the number of variables (*N*) tends to infinity. Approximate factor models are more general than strict factor models. Firstly, they allow for weak serial correlation of idiosyncratic errors. Thus, the principal component estimator remains consistent if the idiosyncratic errors are generated by a stationary ARMA process. Second, the idiosyncratic errors may be weakly cross-correlated and heteroscedastic. Third, the model allows for weak correlation among factors and idiosyncratic components (Breitung & Eickmeier, 2005).

In the case of generalised dynamic factor models we impose a dynamic relationship between Y_{it} and F_t, so the equation (2.1.1) is replaced by the following two equations:

$$Y_{it} = \lambda_i(L)'F_t + u_{it} \quad (2.1.13)$$

$$F_t = F_{t-1} + e_t \quad (2.1.14)$$

$\lambda_i(L)$ is a vector of polynomials of the lag operator.

The relationship between Y_{it} and F_t is now dynamic in contrast to the approximate factor models, where the relationship was static (F_t itself was dynamic). A dynamic model is more flexible than a static model in terms of empirical analysis. It allows shocks to affect different sectors or countries in a multi-country multi-sector model at different times and allows for transmission effects (Bai, 2003).

If the lag polynomial $\lambda_i(L)$ is assumed to have a finite order q, (2.1.13) can be written as:

$$y_{it} = \Lambda f_t + u_{it} \tag{2.1.15}$$

in which there are s static factors[34] consisting of the current and lagged values of r dynamic factors, and where $\Lambda = [\lambda_1, \dots, \lambda_N]$. The representation (2.1.15) is called the static representation of the dynamic factor model.

Because f_t and u_t are uncorrelated at all leads and lags, the covariance matrix of y_t, Σ_{yy} is the sum of two parts, one arising from the common factors and the other arising from the idiosyncratic disturbances:

$$E(y'y) = \Sigma_{yy} = \Lambda \Sigma_{ff} \Lambda' + \Sigma_{uu} \tag{2.1.16}$$

where Σ_{ff} and Σ_{uu} are the variance matrices of f_t and u_t. This is the usual variance decomposition of classical factor analysis.

A dynamic factor model can be estimated using principal components. The starting point in the approach proposed by Stock and Watson (1998, 2002a) is the estimation of factors and loadings. Under the assumption that the number of factors is known, they define the estimators $\widehat{\Lambda}$ and $\widehat{F}_t$ of Λ and F_t, respectively, by solving the nonlinear least squares problem:

$$\min_{f_1,\dots,f_T} (NT)^{-1} \sum_{i=1}^{N} \sum_{t=1}^{T} (y_{it} - \Lambda_i f_t)^2 \tag{2.1.17}$$

such that $T^{-1} f' f = I_r$.

The estimated factor matrix $\hat{f}$ is simply $\sqrt{T}$ times the eigenvectors corresponding to the r largest eigenvalues of the matrix yy' with dimensions $T \times T$. Given $\hat{f}$, the optimal estimators of Λ are the OLS estimators of the coefficients in a regression of y_{it} on the estimated factors $\hat{f}$:

$$\hat{\Lambda} = (T)^{-1} \hat{f}'x \, . \tag{2.1.18}$$

The estimates $\hat{f}$ could be rescaled so that:

$$(N^{-1}) \Lambda' \Lambda = I^r \, . \tag{2.1.19}$$

[34] The factors are dynamic, since they contain current and past values of dynamic factors. “Static” refers to representation.

2.2 Determining the number of factors

When dealing with factor models we cannot bypass discussion of the determination of the number of factors. Assuming that $\hat{f}$ is given, and $\widehat{\Lambda}$ are the OLS estimators of the coefficients in a regression of y_{it} on the estimated factors $\hat{f}$, the problem can be solved by choosing a number of factors that best capture the variations in y . Higher number of factors can better fit the model; however efficiency is lost as more factor loadings are estimated.

As a general rule, it is usually safer to overestimate than underestimate the number of factors, since they are still consistent in the event of overestimation the factors, as shown by Stock and Watson (1998).[35]

Forni and Reichlin (1998) and Forni et al. (2000) propose some more informal methods for estimation of the number of factors. The first is a graphical approach and the second a multivariate variant of the AIC criteria. El Karoui (2007), Onatski (2008) and Onatski (2009) present formal tests that are based on a graphical approach with scree plots. Stock and Watson (1998) use a modified Bayesian information criterion to determine the number of factors that is the most suitable for forecasting a specific time series.

In order to determine the number of factors empirically, a number of information criteria have been suggested; we present the estimators of Bai and Ng (2002) and Onatski (2005).

For the approximate factor model, Bai and Ng (2002) formulate the problem of estimating the number of factors as that of model selection, each model allowing for a different number of latent factors. They introduce three information criteria based on the residuals of the time series regressions of the predictors on a given set of r factors corrected by a penalty term. Both T and N are considered to be large. Two of the information criteria apply to the principal components method:

$$IC_{p1}(k) = \ln\left(V\left(k, \hat{F}^k\right)\right) + k\left(\frac{N+T}{NT}\right)\ln\left(\frac{NT}{N+T}\right) \tag{2.2.1}$$

$$IC_{p2}(k) = \ln\left(V\left(k, \hat{F}^k\right)\right) + k\left(\frac{N+T}{NT}\right)\ln(C_{NT}^2) \tag{2.2.2}$$

$$V\left(k, \hat{F}^k\right) = (NT)^{-1}\sum_{i=1}^{N} u_i' u_i \tag{2.2.3}$$

The estimated number of factors is obtained by minimising the information criteria for $k = 1, .. k_{max}$, where k_{max} is a (subjectively) predetermined upper bound for the number of factors. Bai and Ng (2002) show that the criterion is consistent as $N, T \rightarrow \infty$, since in this case $\left(\frac{N+T}{NT}\right) \rightarrow 0$.

The most popular[36] Bai and Ng (2002) test is the second information criterion (2.2.2.).

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[35] See also Kapetanios and Marcellino (2003), Artis, Banerjee and Marcellino (2005).

Onatski (2005) also develops an estimator of the number of factors in the approximate factor models. The advantage of his proposed estimator is in the circumstances when the common factors explain small amount of variance relative to the variance due to idiosyncratic term. He shows that a consistent estimator $\hat{r}_\delta$ can be defined as cardinality ($\#\{.\}$):

$$\hat{r}_\delta = \#\{i \leq n : \lambda_i > (1+\delta)\hat{u}\}, \tag{2.2.4}$$

with $\hat{u} = w\lambda_{r_{max}+1} + (1-w)\lambda_{2r_{max}+1}$ and $w = 2^{2/3} \big/ \left(2^{2/3} - 1\right)$ (2.2.5)

λ_i is the i-th largest eigenvalue of the data's sample covariance matrix, and δ is a parameter with positive value.

Onatski (2005) shows that his estimator works better than the Bai and Ng (2002) estimator when the variance of idiosyncratic component is large relative to the variance explained by the common factors.[37]

2.3 Hierarchical DFM

In a standard two level factor model the data are modelled as:

$$y_{it} = \lambda_i f_t + u_{it} \tag{2.3.1}$$

As an alternative, a hierarchical structure can be used if the series can be organized into blocks. Kose, Otrok, and Whiteman (2003) use a multi-level factor model in the form:

$$y_{it} = \lambda_i f_t + \mu_i g_{rt} + \eta_i h_{ct} + u_{it} \tag{2.3.2}$$

They use the multi-level factor structure in analysing international business cycles. They define f_t as a world factor, g_{rt} is a factor specific to a region of the country c (e.g. Europe, Africa, North America, Asia), h_{ct} is a factor specific to the country c and u_{it} is an idiosyncratic component specific to a variable i in country c. The total number of the factors to be estimated in the model is C country specific factors, R regional factors and one world factor.

Beck, Hubrich and Marcellino (2009) use a similar setup for the investigation of inflation differentials in euro area regions. f_t, g_{rt}, and h_{ct} in the equation (2.3.2) represent area wide, country specific and regional factors. They use the principal component method to estimate the factors at each level.

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[36] According to Breitung and Eickmeier, 2005.

[37] The penalty term in the Bai and Ng (2002) specification may not be appropriately scaled to the large residuals of the series' regressions on the factors, irrespective of the factors used (Grenouilleau, 2006).

Moench, Ng and Potter (2013) propose an alternative approach to the hierarchical structure of the DFM. While the usual approach to the hierarchical DFM is to estimate first the common factors, they propose a bottom up approach, where factors for the blocks of variables at the lowest level are estimated first.

Beck, Hubrich and Marcellino (2012) present a hierarchical DFM structure with overlapping blocks. They investigate consumer prices inflation for euro area regions on a sectoral level. The sectoral block (variables grouped by sector) overlaps with blocks of countries (variables grouped by country) and regions. Their study contributes to the literature by proposing an iterative method for the estimation of overlapping blocks in case when the number of variables in a block is small. To be specific, the number of variables needs to be sufficiently large in order to ensure that the estimated factor is consistent and can be used as a regressor in the subsequent regressions ($\sqrt{T} / N \rightarrow 0$).

In our study we use a hierarchical DFM with overlapping blocks to model disaggregated dataset for manufacturing output growth and producer prices inflation in the form:

$$x_{ijt} = \lambda_{ij} f_t + \mu_{ij} g_{jt} + \eta_{ij} h_{it} + e_{ijt}. \tag{2.3.3}$$

f_t, g_{jt}, and h_{it} in our case represent common, sector specific and country specific factors. Since the geographical and sectoral data blocks are overlapping, meaning that we have a certain subsector present in all the observed countries, so the hierarchical DFM needs to be adapted to account for overlapping of countries and manufacturing subsectors. For the factor extraction we use the principal components method proposed by Stock and Watson (1998, 2002a, 2002b), similarly as in Beck et al. (2009).

3 BUSINESS CYCLE SYNCHRONISATION IN MANUFACTURING SECTOR

3.1 Introduction

In a report from 2008 (EC, 2008), the European Commission stated that the euro had been a major success, bringing financial and trade integration, job creation and price stability, also arguing that business cycles in the euro area were highly synchronised.[38] However, the financial crisis in 2008, and the subsequent European sovereign debt crisis in 2011, had a major impact on output growth in the euro area and called for a reassessment of the EMU.

As a results of the crisis, a number of proposals have been presented to remodel the architecture of the EMU. Firstly, economists propose banking union (e.g. Whelan 2012a; 2012b; Krugman, 2013; Goyal et al , 2013; Wyplosz, 2013). Secondly, the ECB should act as a lender of last resort (e.g. De Grauwe, 2011; Krugman, 2013; Whelan, 2014). Third, a new fiscal framework design for the euro area is required (e.g. De Grauwe, 2011; Bordo, Markiewicz and Jonung, 2011; Wyplosz, 2013). Finally, ECB should meet its goal of keeping the inflation close to two percent (e.g. Krugman, 2013; Whelan, 2014)[39].

While there are steps being taken toward banking union (the Single Supervisory and Resolution Mechanisms) and the ECB acting as a lender of last resort (Draghi, 2012), a fiscal union is more controversial (Buti and Carnot, 2013). Finally, the current low inflation and forecasts of well below the two percent goal in the medium term forecasts (EC, 2014) remain an important issue. The issue with regard to low inflation at present in the euro area is important, because one of the fundamental imbalances in the euro area is the increased divergence in the competitive positions of euro area countries since the adoption of the euro in 1999 (De Grauwe, 2011).[40] In order for the equilibrating process to succeed, the prices in the periphery countries need to decrease relative to their competitors. However, in an environment of low inflation or even deflation in the euro area, this process in these countries is necessarily deflationary and causes recessions.[41]

Given the recent developments in the euro area and the rethinking of the euro area architecture in the light of the OCA, we revisit the business cycles synchronisation issue that is at the core of OCA criteria.

[38] Business cycle synchronisation is the criterion that is at the core of OCA theory and its discussion of the cost and benefits of forming a currency union.

[39] Krugman (2013) even proposes a higher inflation target that could more easily accommodate inflation differentials.

[40] Wyplosz (2013) on the other hand argues that competitiveness is not the issue for the euro area crisis.

[41] De Grauwe (2011) warns that solvency crises in the EMU may occur when countries attempt to improve the competitiveness, as recessions would cause increasing budget deficits. The sovereign debt crisis confirmed his claims.

The OCA literature emphasizes the pattern in industry-level economic activity to be the key determinant of endogenous evolution of the degree of business-cycle synchronisation. It is therefore natural to work with industry-level data. The focus of this thesis is the manufacturing sector. This chapter provides additional insight into heterogeneity in the manufacturing sector on the country and subsector level, which is relevant in the context of asymmetries in the euro area and also the endogeneity of OCA criteria.

The goal of this chapter is a contribution of sectoral disaggregation to the existing literature on the output fluctuations of the manufacturing sector in the euro area and the EU. We investigate heterogeneity on a level of 14 manufacturing subsectors for the euro area and EU countries. A disaggregated dataset of industrial production for individual countries and subsectors and a factor model approach enable us to disentangle output variation in a subsector in a certain country into four source levels: euro area wide, euro area sector specific, country specific, and an idiosyncratic component that is country-sector specific. This part of the research is complemented by the research on producer price inflation variability in the next chapter, especially in the context of the potential of producer price inflation differentials to serve as an equilibrating mechanism in response to asymmetric shocks.[42]

We tackle the issues with a hierarchical DFM setup in order to decompose output fluctuation into four source levels, similarly to Forni and Reichlin (2001), who investigate regional fluctuations in GDP. The smallest geographical unit in our analysis is an individual country. However, our dataset consists of overlapping blocks of variables, since each variable belongs to a particular manufacturing subsector's block and a country block of variables. The overlapping blocks of variables were first examined by Beck, Hubrich and Marcellino (2012), where they investigate regional sectoral inflation fluctuations. We further expand the method by introducing a rolling window method of factor estimation to monitor the changes of heterogeneity over time.

Once we decompose the output variation in a specific sector in a given country we can answer the questions pertaining to the share of the symmetric and asymmetric parts of the industrial output variation for each sector and country. We consider the averages of the variance shares across the sectors or countries, explained by common and sector specific factors, to be an indicator of the importance of euro area wide comovements in industrial production. The asymmetric part formed by the variance explained by the country specific factors and country-sector specific component can be considered idiosyncratic risks from a currency perspective. By tracking the evolution of these contributions over time we can answer the question of the temporal dimension of business cycle synchronisation in manufacturing.

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[42] Producer price inflation differentials in the pre-crisis period are associated with the building up of the asymmetries in the EA.

The results for individual countries and sectors can provide useful information as a reference point for limitations of the common euro area policies for countries and sectors that are less synchronised with the euro area business cycle.

We find that around half of the variance of the euro area dataset can be explained by a common euro area factor. The sector specific factors account for about a quarter of the remaining variance of the industrial production dataset, around 15 percent of the absolute variance. Country specific factors explain less than 10 percent of the variance. We find that the common euro area factor, sector specific factors and country specific factors affect country-sectors output fluctuations quite asymmetrically. We identify the countries and sectors with larger idiosyncratic risks.

Next, we evaluate the trends in synchronisation of output fluctuation in the manufacturing sector. The trend for the contribution of the common EA factor rose in the period before the financial crisis in 2008 and sharply declined thereafter. On the other hand, the specific factors exhibit a reverse pattern, partly offsetting the drop in the common EA factor. Combined, the two groups of factors, forming a symmetric part of the output variation, have been in slight decline since 2008, whereas the trend for country specific factors, the asymmetric part of output variation, has grown slightly. Trade in the euro area, measured in terms of exports to other euro area countries[43] decreased in 2009, but returned to or above pre-crisis levels quite rapidly, in 2010 or 2011, for the majority of the euro area countries. This indicates that channels other than trade are also important for the endogeneity of the OCA criteria.

In the next steps we investigate the heterogeneity of output fluctuation in manufacturing for the EU countries. The results of this analysis can serve as a comparison to results we obtain for a more integrated euro area. Since our dataset for the euro area case consists solely of euro area countries, we may miss global international comovements that could be the underlying cause of the evolution of the degree of synchronisation in the euro area.[44] Further, the results for the EU countries may prove to be useful with regard to the past and future enlargement of the EMU.

Our analysis also contributes to the literature analysing the sector-specific versus aggregate sources of variation in the manufacturing business cycle. Recent studies that mostly rely on the US data usually find a high share of aggregate sources, while the rest of the variation is attributed to sectoral shocks.[45] We argue that at least a part of the variance can be attributed neither to aggregate nor sectoral effects. Using a hierarchical DFM setup, we show that the

[43] Source: Eurostat (2014c), December 2014.

[44] Lee (2012) finds a small and decreasing importance of the world factor for our observed period.

[45] For example, Foerster et al. (2008), Forni and Reichlin (1998), Shea (2002)

country specific and country-sector specific components cannot be disregarded with respect to the euro area and EU.[46]

The remaining parts of this chapter are structured as follows: We first present the manufacturing sector and put it into a broader perspective of the economy in the first subsection. We then attempt to point out the sources of heterogeneity in the manufacturing sectors across the countries and assess the heterogeneity using descriptive statistics. The methodology used in our research is described in the third subsection.

The empirical results of the DFM analysis of the manufacturing sector are presented in three subsections, depending on the geographical area we examine. First we examine the euro area, more specifically eight of the countries which founded the euro area in 1999 (with the exception of Luxembourg, Austria and Portugal). Second, we examine the EU, conditional on the available data, in the same manner. Third, we use euro area factors to examine EU countries' synchronisation with the euro area business cycle in manufacturing. Finally, we investigate the heterogeneity of the broader sectors of the economy. The last subsection concludes the chapter.

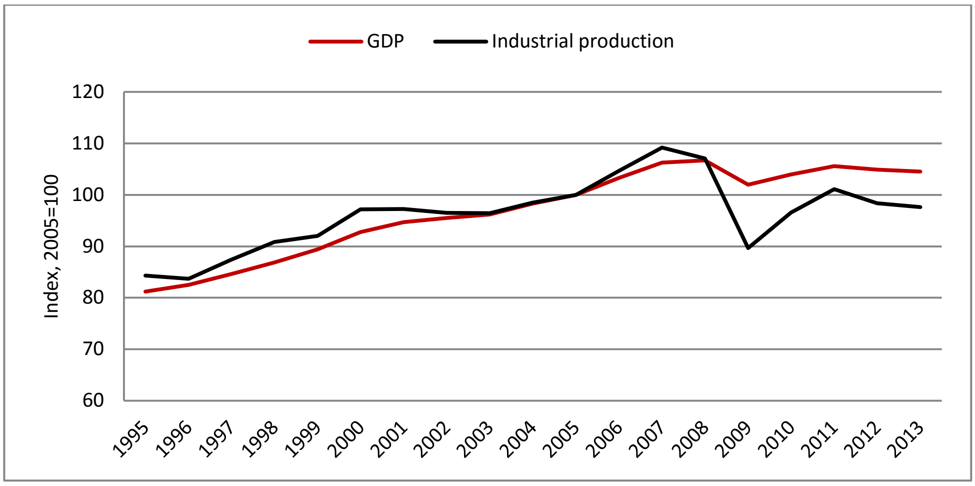
3.2 Heterogeneity of industrial production in manufacturing sector

The manufacturing sector represents almost 20 percent of the total value added and employs about 14 percent of the workers in the EA17 economy, with noticeable differences across the countries. The economic importance of the manufacturing sector is higher, since it accounts for 75 percent of EU exports and each additional job in manufacturing creates 0.5–2 jobs in other sectors (Rueda-Cantuche, Sousa, Andreoni, and Arto, 2012).

Industrial production in the manufacturing in the euro area shows similar patterns as for GDP; however, volatility in the industrial production in manufacturing is more pronounced. Even though the manufacturing sector accounts for less than a fifth of the total value added in terms of GDP for the EA17 countries (Source: Eurostat, August 2014), the correlation coefficient of the two series on an annual sample for the period 1995–2013 is over 0.83.

[46] Helg et al. (1995) also investigate the data of EU countries and find there to be an important national component.

Figure 2. GDP and industrial production in manufacturing for EA17, index (2005=100).

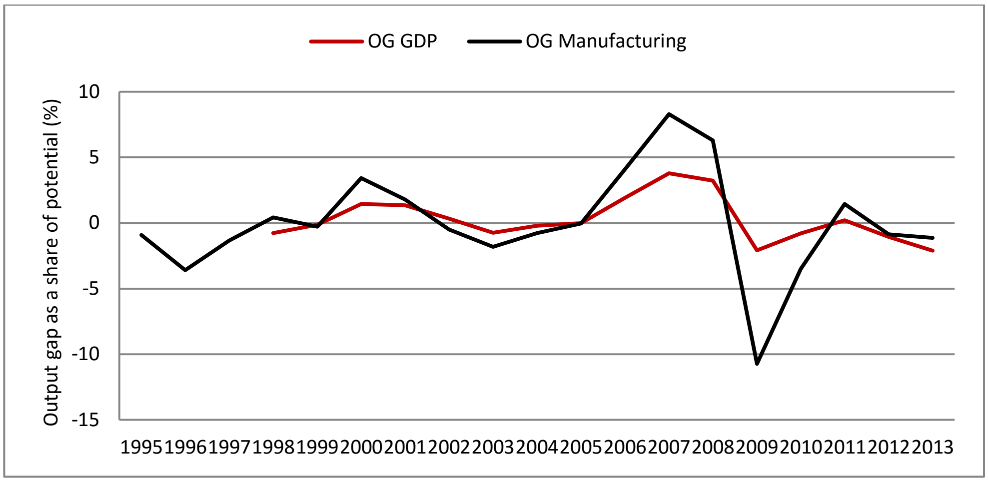


Source: Eurostat, *National Accounts* and *Short term business indicators*

A business cycle refers to fluctuation in production, trade and activity over a time period.[47] Usually, the term is used for fluctuations of GDP around potential GDP. Since there are also fluctuations in disaggregated components of GDP, the term may also be used for specific parts of the economy, such as industry.

In Figure 3, we show a comparison of output gaps (OG) for GDP and industrial production, calculated as a deviation of GDP and industrial production from the trend (Hodrick-Prescott, HP) as a share of the trend (potential).

Figure 3. Output gaps for EA17 GDP and industrial production in manufacturing, as a share of potential in %. HP filter (λ=100).



*The EC calculation of GDP OG includes forecasts

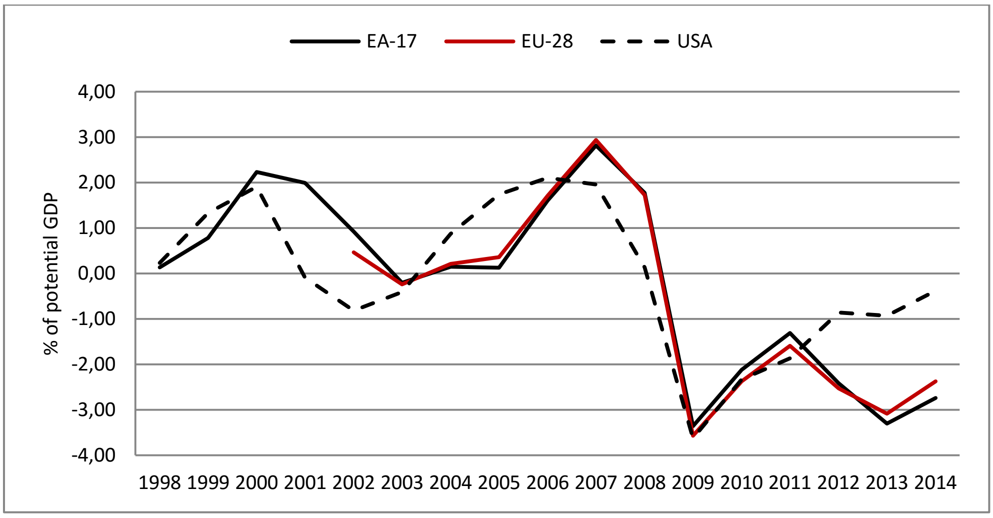
Source: CIRCABC, Output Gaps (Spring 2014 forecast); Eurostat, Own calculations

[47] Burns and Mitchell, 1946.

It can be observed that the fluctuations in GDP and industrial production evolve similarly over time, with industrial production exhibiting larger deviations. Although we do not deal with the issue of causality, we can say that the investigation of business cycles in industrial production provides additional insight into the business cycle of the economy.

There is some synchronisation of business cycles in the euro area and the EU on an aggregate level, especially when compared to the US business cycle. One way to look at the synchronisation of the business cycles is to compare the output gaps of EA17 and EU27. As can be seen from Figure 4 below, there are small differences in the output gap measure for the euro area and the EU, especially when compared to the USA which exhibits quite different business cycle. From this figure alone it could be assumed that one policy (one which is appropriate) could suit all countries; however, other data and deepened recessions in some countries cannot confirm this.

Figure 4. Output gaps for EA17, EU28, and USA in % of potential output. Production function methodology.[48]



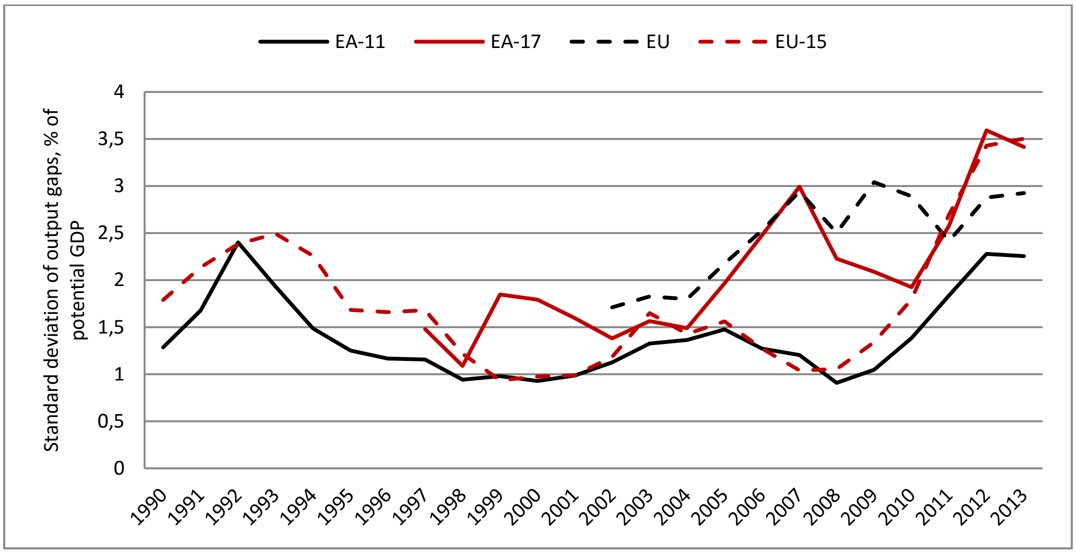
Source: CIRCABC, Output Gaps (Spring 2014 forecast)

Data on output gaps for individual countries show a more heterogeneous distribution across the countries. In 2007 all the observed countries in the EU had a positive output gap, albeit with quite substantial differences. While most of the old member states had smaller than average output gaps, new member states, in particular the Baltic states, had output gaps close to or exceeding 10 percent of the potential output. Germany, on the other hand, had an output gap of 1.9 percent of the potential output. In 2013 the output gap of the EU as a whole was negative as a consequence of the recession, but the heterogeneity was still present. This time, however, there are some clear outliers on the negative side of the output gap spectrum. The most crisis hit countries experienced a huge fall in output, causing large negative output gaps in Greece and Spain, for example. The Baltic states are still among

[48] The production function methodology of the European Commission is described more in detail in D'Auria et al. (2010).

the countries with positive or least negative output gaps, with only a non-euro UK having a larger positive output gap at 1.7 percent of potential output.

Figure 5. Standard deviation of output gaps, in % of potential output. Production function methodology.



Note. Annual data. CY, MT, LU and HR are excluded. Output gap for Slovenia: Own calculation, using EC methodology.

Source: CIRCABC, Output Gaps (Spring 2014 forecast); Own calculations

The rising standard deviation of the output gaps (Figure 5) indicates that the degree of business cycle synchronisation has decreased in Europe in recent years.

Even the studies of business cycle synchronisation that are based on the analysis of a cyclical component generally use the cyclical component of industrial production, rather than GDP. This is supported by the close correlation of industrial production with GDP and the convenient monthly frequency of the data. However, the greater exposure of manufacturing to external shocks could indicate less synchronisation than is the case for GDP synchronisation (EC, 2008).

In the next subsections we show that the manufacturing sectors in euro area are heterogeneous across the sectors and countries. We present descriptive statistics on the heterogeneity in the manufacturing sector in the euro area and the EU, both on the levels of individual subsectors and countries.

From a stylised perspective, heterogeneity in the manufacturing sectors on different cross sections may be considered, depending on the level of disaggregation:

- heterogeneity among countries,
- heterogeneity among subsectors,
- or heterogeneity among countries and subsectors.

Industrial production in an individual subsector can have a sector specific evolution in terms of production output. For example, food production and the production of electronics can have different demand and supply curves, causing differences in the evolution of the sectors' output. On the other hand, industrial production is also heterogeneous across the countries. On an aggregated level for the manufacturing sector, the differences among countries can, to some extent, be attributed to the different composition of the manufacturing sector. However, there are also differences on the subsector level (conditional on the level of disaggregation).

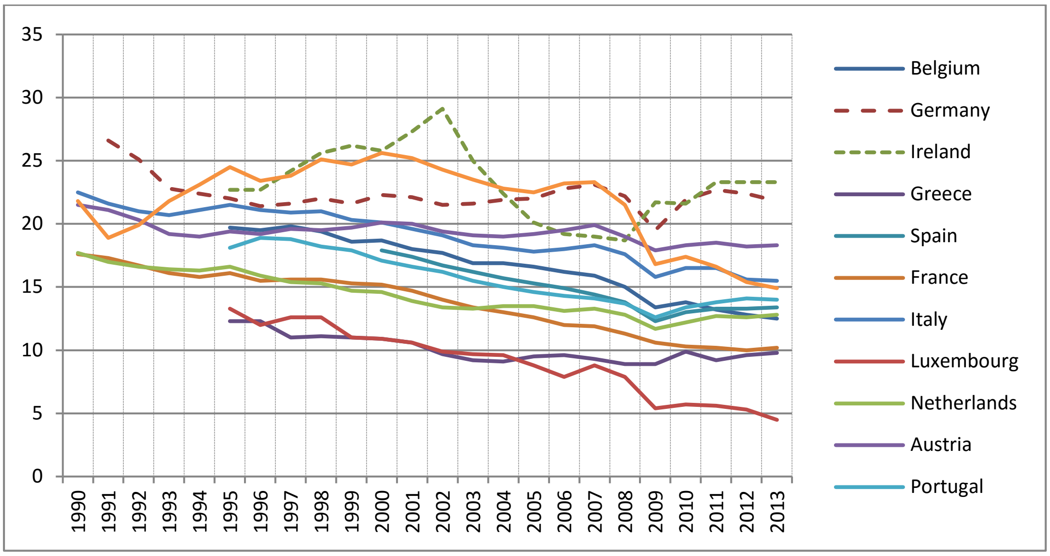
In the first subsection we attempt to draw attention to some sources of heterogeneity, and in the second we show the differences in the size of subsectors across the countries and their evolution over time. We continue with the country differences on the level of the whole manufacturing sector in the third subsection. In the fourth subsection we deal with the differences between the subsectors on an aggregated euro area and EU level. The next subsection attempts to present heterogeneity on a country-sector level, which is also the main objective of this research. In the last, descriptive, subsection we briefly outline the data used for our research in the sections to follow.

3.2.1 Manufacturing sector size

As previously stated, the size of the manufacturing sector – in terms of OCA criteria – matters from a business cycle synchronisation perspective. First, the size of the manufacturing sector in an economy is important; countries with relatively small manufacturing sectors are less affected by a shock in manufacturing, for example. Our research deals with heterogeneity within the manufacturing sector, which is more affected by the composition of this sector across the countries.

The importance of the manufacturing sector, measured using the share of total value added in GDP, has decreased over time, most notably in 2009, as can be seen in Figure 6. There is some country heterogeneity in the euro area as regards the share of the manufacturing sector in the total value added, especially in terms of the level (Figure 6).

Figure 6. Share of manufacturing sector in the total value added for the 12 EA countries, in %.



Source: Eurostat, *National accounts*

As far as evolution over time is concerned, there are two notable exceptions. Germany shows a relatively constant share of manufacturing in the total value added after an initial decline in the early 90s and Ireland with rising share of manufacturing sector in 2009. In the case of Ireland, the rising share is merely a consequence of the total value added decreasing to a greater extent, mostly as a result of the fall in the financial sector.

Employment in the manufacturing sectors as a share of total employment in the euro area was, on average, 14 percent in 2011.[49] There was a decreasing trend in the employment shares in all EA countries; however, there are cross country differences in the levels of employment in line with the data on value added across the countries.

3.2.2 Manufacturing sector: country heterogeneity

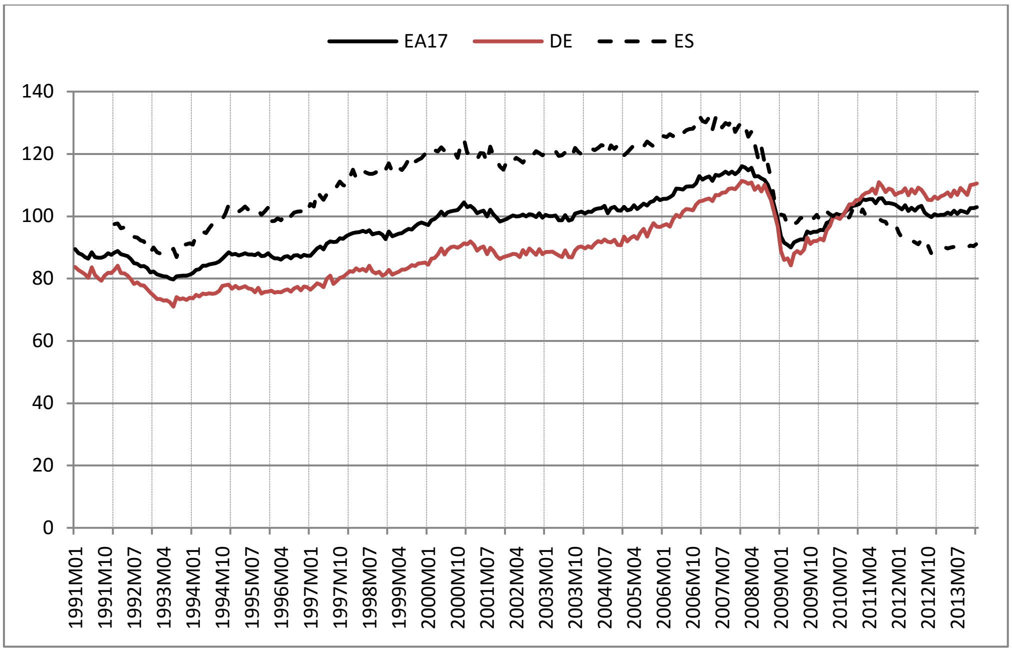
The development of industrial production in the EA over time is shown in Figure 7. We can observe some periods where the year-on-year comparison shows a contraction: in the period 1992–1993, in 1996, in 2001–2002 and the most serious contraction in 2008. The financial-crisis induced recession caused a 20 percent decline in industrial production in less than a year. There was a slow recovery in 2010, followed by another contraction in 2011. A slow recovery can be observed only in 2013.

There is also considerable heterogeneity on a country level. For illustrative purposes, two countries are shown in Figure 7: Germany as the core country of the EU and Spain as one of the countries on the EMU periphery. Spain is a country that has benefited from the low interest rates in the euro period, when compared to the pre-euro period. The massive inflow of capital and high growth up to 2008 cannot be attributed to the manufacturing sector. The

[49] The most recent available Eurostat observation (August, 2014).

manufacturing sector grew faster in the EA-17 and Germany than in Spain in the period 1999–2007.[50] However, when the crisis in 2008 struck, more noticeable differences in the behaviour of the manufacturing sectors across the countries began to emerge. The crisis was harsher on this sector in Spain and there was no significant recovery followed by the second dip in 2011. In Germany, the levels returned to the pre-crisis levels followed by only a mild second dip and subsequent recovery.

Figure 7. Indices of industrial production for the manufacturing sector for the EA17, Germany (DE) and Spain (ES) (2010=100), seasonally adjusted.

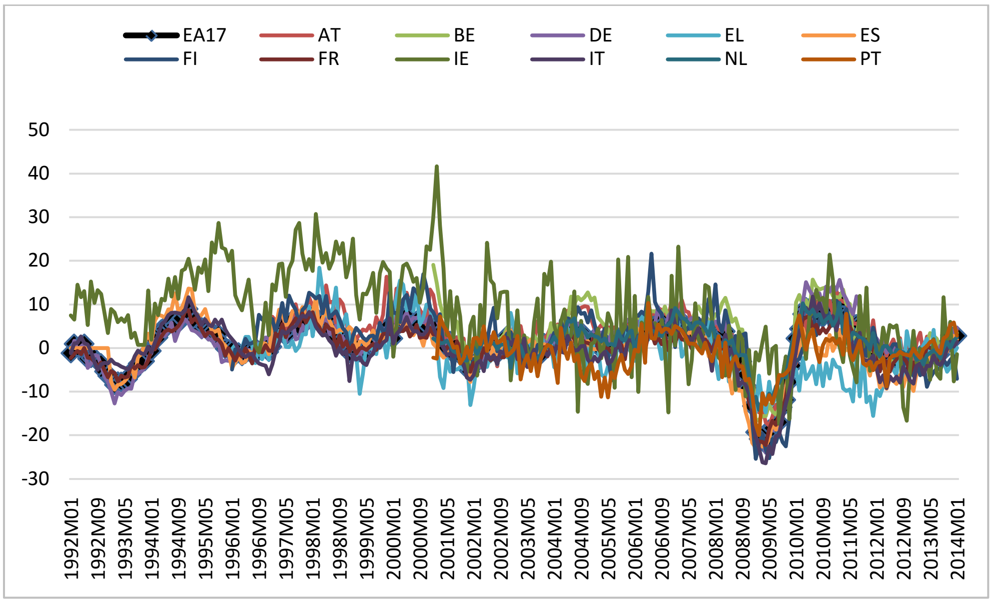


Source: Eurostat, *Short term business indicators*

The heterogeneity of output growths on the country level can be observed in Figure 8, where the annual growth rates of the industrial production in the manufacturing sector are shown for EA17 aggregate and twelve 2002 euro countries. The standard deviation of the annual growth rates in a given year is on average almost 4 p.p.

[50] The reason for the lower growth in Spain could also be attributed to competitiveness losses resulting from higher inflation. This issue is tackled in the next chapter.

Figure 8. Annual growth rates of industrial production in manufacturing for EA12 countries, in %.



Note. Luxembourg is excluded.

Source: Eurostat, *Short term business indicators*

Table 1 reports the variances of growth gaps and the correlations between selected EU countries and the EA17 growth rates for different time intervals.

Table 1. Descriptive statistics of industrial production in manufacturing for selected countries.

	Var ($\Delta y_t^i - \Delta y_t^{EA}$)			**Corr($\Delta y_t^i, \Delta y_t^{EA}$)**		
Country *(i)*	92-98	01-08	09-13	92-98	01-08	09-13
AT		4.53	7.54		0.85	0.95
BE		9.95	7.05		0.70	0.96
DE	2.25	1.73	4.53	0.95	0.95	0.99
FR	1.16	2.07	2.67	0.97	0.90	0.99
NL		3.63	13.01		0.83	0.96
FI		12.42	14.02		0.73	0.92
EL		13.54	72.68		0.58	0.33
ES		7.26	11.60		0.81	0.93
IE	32.89	90.87	81.53	0.65	0.27	0.41
IT	6.38	2.03	3.43	0.84	0.92	0.98
PT		17.08	28.63		0.43	0.82
BG		39.30	27.70		0.49	0.89
CZ		15.76	6.38		0.82	0.97
EE		27.91	129.56		0.55	0.94
HU		17.00	11.78		0.80	0.97

(table continues)

(continued)

	Var (Δy_t^i- Δy_t^{EA})			Corr(Δy_t^i,Δy_t^{EA})		
Country *(i)*	92-98	01-08	09-13	92-98	01-08	09-13
LT		107.81	61.69		0.03	0.74
LV		32.39	50.43		0.32	0.89
PL		29.63	21.51		0.69	0.85
RO		17.76	28.10		0.75	0.80
SI		6.49	9.66		0.82	0.95
SK		110.22	33.18		0.43	0.88
DK		16.20	36.55		0.40	0.77
SE		8.27	11.42		0.75	0.95
UK		4.35	14.09		0.78	0.98
core EA mean*		4.38	6.96		0.85	0.97
periphery EA mean*		26.16	39.57		0.60	0.69
NMS mean*		40.43	38.00		0.57	0.89
OMS mean*		9.61	20.69		0.64	0.90

Note. *Unweighted mean. Δy_t^i represents annual growth of industrial production of a country *i* at time *t*, Δy_t^{EA} represents annual growth of industrial production of EA17 at time *t*.

Source: Eurostat, *Short term business indicators*; Own calculations

The degree of synchronisation or comovements, measured by a correlation coefficient, is quite high for the founding euro area countries, with the exception of Ireland, Greece and Portugal. The degree of synchronisation increased in all euro area countries after the introduction of the euro.[51] The cases of Portugal and Ireland support the theory that 2002 was the year that could have been the most important as far as the EMU's effects on business cycle synchronisation are concerned (or the more gradual effects theory).

The correlation coefficients for new member states (NMS) are lower; however, the countries that stand out are the Czech Republic, Estonia, Hungary and Slovenia with a correlation in the range of the EA countries. The time series for NMS are too short to investigate in the period before 2000 but there is some evidence, if we compare the 99-13 and 02-13 results, that synchronisation increased after the EU accession.

Sweden and the UK are also highly synchronised with the EA, especially in the last decade, while Denmark lags behind. Sweden and the UK are highly synchronised with the euro area despite not being members of the EMU, suggesting that EU integration, rather than the euro, is important.

[51] Studies based on correlations generally find evidence that business cycles in the EA are highly synchronised. Examples of such studies are Giannone and Reichlin (2006), Bergman (2004), Breitung and Eickmeier (2005).

3.2.3 Manufacturing sector: heterogeneity across subsectors

One of the main goals of this thesis is to examine the synchronisation of business cycles in the euro area and the EU on a level of individual subsectors in manufacturing. We use industrial production indices for manufacturing for EU countries disaggregated to 14 subsectors, according to the 2008 version of the Statistical classification of economic activities, NACE Rev.2 classification. We list the subsectors in the Table 2.

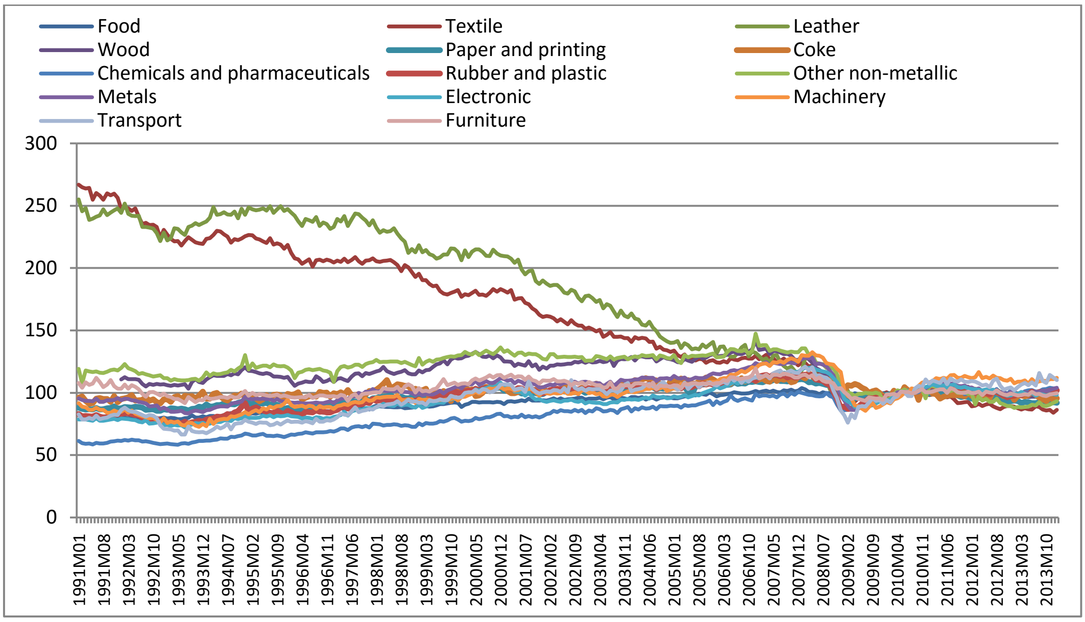
Table 2. Manufacturing subsectors used in the analysis.

Eurostat code	Description	Short label	Series name prefix
C10_C12	Manufacture of food products; beverages and tobacco products	Food	da
C13_C14	Manufacture of textiles and wearing apparel	Textile	db
C15	Manufacture of leather and related products	Leather	dc
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Wood	dd
C17_C18	Manufacture of paper and paper products; printing and reproduction of recorded media	Paper	de
C19	Manufacture of coke and refined petroleum products	Coke	df
C20_C21	Manufacture of chemicals and chemical products; basic pharmaceutical products and pharmaceutical preparations	Chemicals and pharmaceuticals	dg
C22	Manufacture of rubber and plastic products	Rubber and plastic	dh
C23	Manufacture of other non-metallic mineral products	Other non-metallic	di
C24_C25	Manufacture of basic metals and fabricated metal products, except machinery and equipment	Metals	dj
C26_C27	Manufacture of computer, electronic and optical products; manufacture of electrical equipment	Electronic	dl
C28	Manufacture of machinery and equipment n.e.c.	Machinery	dk
C29_C30	Manufacture of motor vehicles, trailers, semi-trailers and of other transport equipment	Transport	dm
C31_C32	Manufacture of furniture; other manufacturing	Furniture	dn

Source: Eurostat, *Short term business indicators*

We present the evolution of manufacturing subsectors for the aggregate level of EA17 in Figure 9.

Figure 9. Industrial production indices in manufacturing for EA17, disaggregated to 14 subsectors, 2010=100.



Source: Eurostat, *Short term business indicators*

Two subsectors, textiles and the leather industry, are clear outliers when we compare the subsectors' performance over the last two decades. However, there is also considerable heterogeneity on the sector level in other manufacturing subsectors, as can also be seen in Table 3, where annual (y-o-y) growth in the aggregated manufacturing sector for the euro area (EA17) (MF in table) is compared to the growth of individual subsectors *(j)*. The correlation between individual subsectors' annual growth and the growth of the manufacturing sector is between 0.43 and 0.99, which suggests the presence of sector heterogeneity.[52] We therefore cannot address the manufacturing sectors in a one-size-fits-all fashion and we can conclude that a disaggregated approach is more appropriate.

Another fact that speaks for a disaggregated approach to manufacturing subsectors is their relative importance in the total value added. Table 3 summarises the share of subsectors in the manufacturing sector. Some subsectors exhibit greater importance in the EA-17 than others in terms of value added. For example, textiles, leather and fuels comprise a relatively low share in the total value added, whereas food, metals, machinery, chemicals, electrical and transport equipment present more important subsectors on an aggregate EA level.

[52] The correlation of a specific subsector also depends on the contribution of this subsector to the weighted composite index.

Table 3. Descriptive statistics of industrial production in manufacturing for subsectors. EA17.

Sector *(j)*	Var (Δy_t^j - Δy_t^{MF})			Corr(Δy_t^j,Δy_t^{MF})			VA^j /VA^{MF}
	92-98	01-08	08-13	92-98	01-08	08-13	2011
Food	11.88	8.82	62.65	0.65	0.46	0.64	0.13
Textile	4.58	6.12	16.50	0.87	0.84	0.89	0.04*
Leather	20.58	15.54	17.18	0.51	0.47	0.88	
Wood		15.17	7.71		0.66	0.95	0.02
Paper and printing	10.29	5.33	23.29	0.68	0.73	0.95	0.05
Coke	28.22	16.59	62.66	0.12	0.15	0.44	0.01
Chemicals and pharmaceuticals	5.68	6.30	26.00	0.84	0.72	0.82	0.12
Rubber and plastic	6.01	3.49	10.94	0.93	0.89	0.93	0.05
Other non-metallic	8.96	6.79	8.80	0.82	0.80	0.94	0.04
Metals	4.31	2.45	18.09	0.96	0.95	0.99	0.15
Electronic	3.18	12.47	10.54	0.92	0.87	0.98	0.10
Machinery	17.83	5.35	62.60	0.81	0.88	0.92	0.12
Transport	34.48	8.04	34.61	0.85	0.88	0.95	0.12
Furniture	7.14	4.07	11.20	0.82	0.83	0.96	0.05

Note. *Combined share of textiles and leather; see Footnote 53. $\mathbf{\Delta y_t^j}$ represents annual growth of industrial production of a manufacturing subsector *j* at time *t*, $\mathbf{\Delta y_t^{MF}}$ represents annual growth of aggregated industrial production in manufacturing at time *t*.

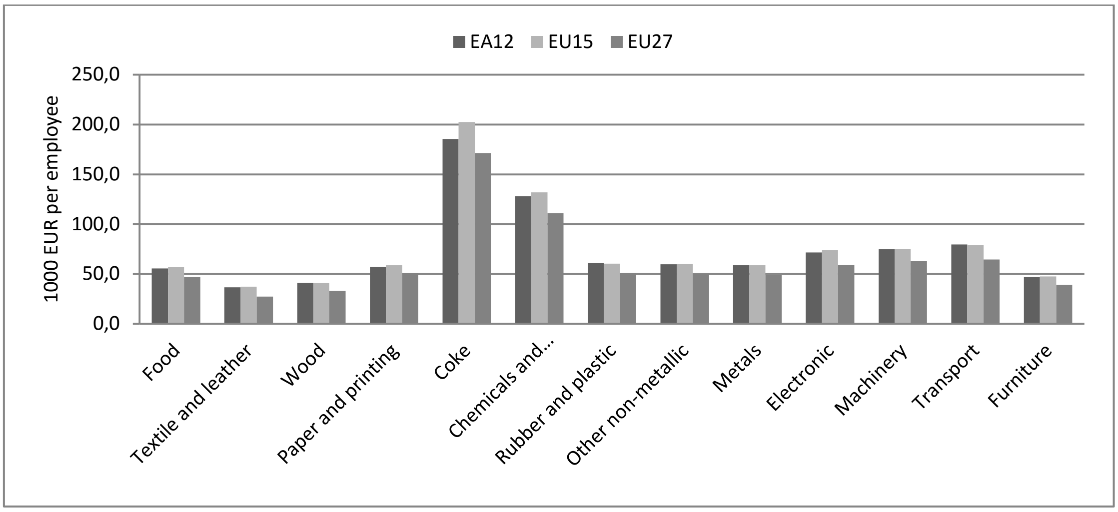
Source: Eurostat, *Short term business indicators*; Own calculations

Further, subsectors in manufacturing have different productivity levels. We calculate productivity as the value added per employee (Figure 10). Productivity in the sector of coke and refined fuel for EA12 countries is even EUR 185,000 per employee, while the least productive sector, textiles and leather,[53] has productivity of only EUR 37,000 per employee. Another sector that stands out is the sector of chemicals and pharmaceuticals, also above EUR 100,000 per employee.

We can also observe differences in the productivity levels among different groups of EU countries. EA12 countries have higher rates of productivity than the EU27 countries in all the sectors observed.

[53] Eurostat national accounts data (disaggregated to 64 sectors, NACE Rev.2) do not report on the subsectors of textiles and wearing apparel separate from the leather and leather products subsector.

Figure 10. Productivity in the manufacturing subsectors in 2011. Value added per employee, current prices.



Source: Eurostat, *National accounts*; Own calculations

3.2.4 Manufacturing sector: heterogeneity across subsectors and countries

This subsection attempts to present heterogeneity on a country-sector level, which is also the main objective of this research. There is a substantial heterogeneity in the size of a specific manufacturing subsector across the countries for the euro area and the EU. While in the euro area as a whole, the textile industry might not be important in terms of size (measured in value added), in Portugal for example, the textile industry lags only behind the food industry. The leather industry is relatively small for all the countries in the EA12 sample. In the case of wood products, Austria and Finland due to factor endowments exhibit greater importance for this subsector, whereas this subsector is relatively small in other countries. Another subsector worthy of mention is the manufacture of basic metals, which is among the most important in terms of value added for all the countries in the sample.

In order to get a comprehensive idea about the similarities in the composition of the manufacturing sector across the countries, we construct an indicator of structural similarities S_j for a country j for the manufacturing sector following Eickmeier (2006) and Krugman (1991):

$$S_j = \sum_{I=1}^{I} |s_{ij} - s_{iEA}|, \quad (3.2.1)$$

where s_{ij} and s_{iEA} denote the shares of subsector i in a country j and the euro area aggregate (EA17), respectively. The shares are defined as the value added of a subsector in the total value added in the manufacturing sector. Small values of this composite indicator signal a greater structural similarity between the manufacturing sector of a given country and the euro area aggregate. In Table 4 below we show the unweighted averages of this indicator for founding euro area countries and Greece, excluding Luxembourg (EA), new member states (NMS) and non-euro old member states (OMS). The complete set of results may be found in the Table A1 in Appendix A.

Table 4. Indicator of structural similarities in the composition of the manufacturing sector.

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**Δ11-00**
mean EA*	42.7	42.5	44.1	43.6	42.8	43.1	44.4	44.1	43.7	42.9	48.4	48.6	5.9
mean NMS*	57.5	57.0	56.0	55.1	53.3	54.6	53.8	53.8	53.1	56.8	58.2	56.2	-1.3
mean OMS*	33.7	35.3	34.0	34.0	35.1	36.2	35.4	35.8	33.1	38.4	41.3	39.6	5.9
st dev EA	24.3	24.1	25.1	22.9	23.4	21.5	22.6	22.0	23.2	24.8	27.7	29.1	12.4
st dev NMS	20.9	19.9	20.3	19.5	16.9	17.5	17.5	16.7	17.0	22.3	21.7	19.7	11.0
st dev OMS	10.7	10.2	10.5	9.4	9.8	11.2	10.0	10.2	6.3	8.9	8.8	6.3	4.9

Note. *Unweighted mean

Source: Eurostat, *Short term business indicators*; Own calculations

Different manufacturing sector structures may be the cause of decreased synchronisation in euro area and EU countries’ business cycles in manufacturing when we take sector heterogeneity into account. However, when we look into more detailed manufacturing subsector data on a country level, we also notice heterogeneity on a country-sector level. Table 5 below reports the variance of the manufacturing subsectors' annual growth rates across the countries for three different groups of countries.

Table 5. Descriptive statistics of industrial production in manufacturing for subsectors, variance of annual growth in a sector *(j)* across the countries *(i)* for selected years *(T).*

	Var (Δy^{j}_{iT})								
Sector (*j*)	T=2001	T=2007	T=2013	T=2001	T=2007	T=2013	T=2001	T=2007	T=2013
	EA	EA	EA	EU	EU	EU	EU-EA*	EU-EA	EU-EA
Manufacturing	18.29	4.98	3.13	23.73	22.46	10.13	28.64	34.66	12.18
Food	7.21	4.46	2.97	12.28	28.19	7.13	16.31	44.26	9.69
Textile	39.35	42.29	11.31	59.96	38.99	26.90	70.25	39.65	32.75
Leather	52.01	185.90	62.61	55.46	260.52	52.28	64.37	350.03	41.48
Wood	35.53	67.63	18.89	79.72	54.30	74.60	125.71	54.21	125.40
Paper and printing	6.31	6.85	3.60	103.11	26.30	42.35	155.56	39.74	51.19
Coke	29.15	11.87	32.86	41.29	80.89	57.41	54.40	142.74	85.14
Chemicals and pharmaceuticals	74.75	22.76	12.61	77.16	195.46	25.29	83.51	340.56	39.06
Rubber and plastic	2.25	6.76	2.93	96.67	47.02	15.19	131.23	69.79	21.95
Other non-metallic	8.24	6.30	13.22	84.20	101.16	34.53	142.51	168.14	34.90
Metals	22.16	16.90	9.94	48.52	35.58	22.48	70.76	52.25	28.54
Electronic	73.78	64.17	19.48	190.09	77.39	53.21	279.71	89.45	79.75
Machinery	24.40	19.92	9.99	143.86	39.85	51.71	240.44	57.49	81.78
Transport	87.12	19.35	213.91	119.54	74.32	128.00	157.43	110.54	78.27
Furniture	164.47	17.61	15.39	111.56	53.99	40.12	98.14	49.49	40.05

Note. EA stands for 11 founding EA countries, not including Luxembourg. *EA-EU stands for EU countries, not including EA (NMS+OMS), excluding Cyprus and Malta.

Source: Eurostat, *Short term business indicators*; Own calculations

In general, the variance of output growth in subsectors across the countries in the last observed year was smaller in the euro area than in the EU countries, with the exception of the leather and transport equipment subsectors.

We performed an analysis of the subsector variances for three different time periods in order to also examine the evolution over time. In the euro area the general trend is in diminishing variances, but the results are not clear cut. Some sectors, such as transport equipment, had the highest variance across the countries in 2013, while some, such as leather, had peaks in 2007.

Variances in the growth rates in the EU countries also seem to be decreasing, but they are still well above euro area levels. These data confirm the observations that manufacturing business cycles are more synchronised in the euro area than in the EU.

3.2.5 Data

The analysis in the research with factor models uses data composed of industrial production indices in manufacturing on a monthly frequency, disaggregated to 14 subsectors (Table 2) and EU countries.[54]

Table 6. Dataset of industrial production indices in manufacturing used in the analysis. Dataset covers the period of 1990(1)–2014(6).

Country	Country code	Data starting point	EA membership	EU membership	Group*
Austria	AT	1996	1999	1995	II, III, IV
Belgium	BE	1990	1999	1957	I,II,III, IV
Bulgaria	BG	2000	/	2007	IV
Czech Republic	CZ	2000	/	2004	IV
Germany	DE	1991	1999	1957	I,II,III, IV
Denmark	DK	1990	/	1973	I,II,III, IV
Estonia	EE	2000	2011	2004	IV
Greece	EL	2000	2001	1981	IV
Spain	ES	1990	1999	1986	I,II,III, IV
Finland	FI	1990	1999	1995	I,II,III, IV
France	FR	1990	1999	1957	I,II,III, IV
Hungary	HU	2000	/	2004	IV
Ireland	IE	1990	1999	1973	I,II,III, IV
Italy	IT	1990	1999	1957	I,II,III, IV
Lithuania	LT	1998	/	2004	III, IV
Latvia	LV	2000	2014	2004	IV
Netherlands	NL	1990	1999	1957	I,II,III, IV
Poland	PL	1995	/	2004	II, III, IV
Portugal	PT	1995	1999	1986	II, III, IV
Romania	RO	2000	/	2007	IV
Sweden	SE	1990	/	1995	I,II,III, IV
Slovenia	SI	1998	2007	2004	III, IV
Slovakia	SK	1998	2009	2004	III, IV
United Kingdom	UK	1990	/	1973	I,II,III, IV

Note. HR, LU, MT, CY are not included in the sample due to data availability and/or country particularities.
*Groups of countries by starting data point, used in section 3.5.

Source: Eurostat, *Short term business indicators*

We use Eurostat data on industrial production indices in manufacturing, Nace Rev.2. The data for Slovenia, Slovakia and Ireland are obtained at their respective national statistical offices. For Slovenia, we use data obtained from Statistical Office of the republic of

[54] We use different datasets for each of the following sections with results, depending on the selection of countries.

Slovenia (SORS) and group the available data for 24 subsectors into 14 subsectors, based on the weights provided by SORS.[55]

A factor analysis requires some pre-treatment of the data. We follow the three-stage approach used in Marcellino, Stock and Watson (2003). Firstly, the series are seasonally adjusted with the X-11 ARIMA procedure. Secondly, the series are transformed to account for stochastic and deterministic trends. In principle we treat the data as I(1) around a deterministic trend and transform them to stationarity by calculating first differences of logarithms. All the series are further standardised to have a zero sample mean and unit sample variance. Finally, the series are screened for large outliers (outliers exceeding ten times the inter-quartile range), and the outliers are replaced as missing data. The expectation-maximisation (EM) algorithm is then used to interpolate the missing data and estimate the factor model for the resulting panel.

3.3 Methodology

As we have demonstrated in the previous section, the sources of heterogeneity in manufacturing output growth may stem from different levels: area wide, sectoral, national and country-sector specific. Using disaggregated data for manufacturing subsectors and countries, we propose the analysis of a hierarchical DFM which includes all these sources of heterogeneity.

We assume that the data on output growth in manufacturing[56] in country *i*, subsector *j* and time *t*, denoted x_{ijt}, obey the following factor structure:

$$x_{ijt} = \lambda_{ij} f_t + \mu_{ij} g_{jt} + \eta_{ij} h_{it} + e_{ijt} , \qquad (3.3.1)$$

where f_t represents common European factors with factor loadings λ_{ij}, g_{jt} represent sector specific factors with loadings μ_{ij}, h_{it} country specific factors with loadings η_{ij} and e_{ijt} the idiosyncratic component.

We see this representation as a static representation of an otherwise dynamic factor model in which a smaller number of dynamic factors of each type are allowed to load on observable variables with time lags. It is additionally assumed that common EA and sector specific factors are orthonormal, orthogonal to the idiosyncratic component and potentially auto-correlated and cross-correlated (the approximate factor model).

The methodological approach is most closely related to Kose et al. (2003), Beck et al. (2009), Stock and Watson (2010) and Beck et al. (2012) with regard to the hierarchical

[55] The data for 2014 are constructed using weights for 2013.

[56] Industrial production indices for manufacturing subsectors transformed by applying differences of natural logarithm.

approach to DFMs. The estimation of factors follows the principal components method proposed by Stock and Watson (1998, 2002a, 2002b).

The estimation of factors is applied in three steps. At each step we determine the number of factors by combining the formal tests of Bai and Ng (2002) [57] and the estimated shares of explained variance.

In the first step we extract the common EA factors f_t from all the series of the panel, i.e. we start with the representation

$$x_{ijt} = \lambda_{ij} f_t + u_{ijt}, \quad (3.3.2)$$

and obtain the estimates $\hat{f}_t$, $\hat{\lambda}_{ij}$ and $\hat{u}_{ijt}$. Further, we express the residuals $\hat{u}_{ijt}$ as following:

$$\hat{u}_{ijt} = x_{ijt} - \hat{\lambda}_{ij} \hat{f}_t. \quad (3.3.3)$$

From the series of thus estimated residuals $\hat{u}_{ijt}$ we can use the principal component method to estimate common sector specific factors g_{jt} with factor loadings μ_{ij}.[58]

$$\hat{u}_{ijt} = \mu_{ij} g_{jt} + \varepsilon_{ijt} , \quad (3.3.4)$$

Given that g_{jt} are assumed to be sector specific their corresponding loadings are restricted: $\mu_{is} = 0$ for $s \neq j$. These restrictions imply that we can estimate the sector specific factors by applying the principal component method on each panel of sectoral data individually $(I \times T)$. We thus obtain J sector specific factors, where J is the total number of sectors.

With estimates $\hat{f}_t$ and $\hat{g}_{jt}$[59] we can eliminate the effects of common EA factors and EA sector specific factors from the original series with the following regression:

$$x_{ijt} = \lambda_{ij} \hat{f}_t + \mu_{ij} \hat{g}_{jt} + v_{ijt} \quad (3.3.5)$$

and obtain the estimates of the residuals

$$\hat{v}_{ijt} = x_{ijt} - \hat{\lambda}_{ij} \hat{f}_t - \hat{\mu}_{ij} \hat{g}_{jt} , \quad (3.3.6)$$

which is a panel of data from which we can, in step three, estimate the country-specific factors h_{it} by assuming the following factors structure:

[57] Our preferred choice is the second criterion, IC_{p2}. We choose the criterion IC_{p2} since it has proven to be more robust than the others, initially suggested by Bai and Ng (2002), when the residuals have serial-correlation (De Bandt, Bruneau and Flageollet, 2006).

[58] Alternatively we could estimate country specific factors first.

[59] Note that the number of countries *(I)* in a sector needs to be large in order to ensure the consistency of the estimator $\hat{g}_{jt}$ (Bai and Ng, 2002), so it can be treated as data in the next stage of the OLS

$$\hat{v}_{ijt} = \eta_{ij} h_{it} + \mathrm{e}_{\mathrm{ijt}}. \qquad (3.3.7)$$

The country specific factors can be estimated from each individual country's data using the principal components method.

The estimated factors for the equation (3.3.1) allow us to compute the contribution of each factor to the share of explained variance of each individual series. Since the factors are orthogonal, the variance of output growth in country *i* and subsector *j* can be decomposed as follows:

$$var(x_{ijt}) = (\hat{\propto}_{ij})^2 var(\hat{f}_t) + (\hat{\mu}_{ij})^2 var(\hat{g}_{jt}) + (\hat{\eta}_{ij})^2 var(\hat{h}_{it}) + var(\widehat{e_{ijt}}). \qquad (3.3.8)$$

The common EA factor f_t and sector specific factors g_{jt} are both common across the countries. Their contribution to the share of the explained variance of each individual measure of sectoral output thus measure the level of synchronisation of the variation in sectoral outputs across the countries.

We use the above presented order of factors estimation, (i) common factors, (ii) sector specific factors, and (iii) country specific factors, as our preferred choice. We are interested in the possible occurrence of inter industry specialization of specific manufacturing subsectors and sector specific factors are important for this evaluation.

Since one of our main objectives is to track the evolution of synchronisation over time, we perform the above procedure for different time intervals with a fixed rolling window. The effect of establishing the EMU as a currency union can then be traced through time by performing the steps described above recursively with a fixed rolling window.

3.4 Results for the euro area

In this section we report the results of the analysis on our euro area sample (EA8: BE, DE, ES, FI, FR, IE, IT, NL).[60] In subsections 3.4.1–4 we present the construction of factors with a procedure described in the methodology chapter using the rolling window method (T=50). For each level of factors we discuss the appropriate number of factors and their explanatory value. The evolution over time of factors importance in explaining variance on an aggregate level is assessed as well. In the next subsections, 3.4.5 and 3.4.6, we present the results for individual subsectors and countries for the most recent periods, respectively. In subsection 3.4.7 we present the evolution of factors by country. Robustness checks are presented in the last subsection.

[60] The selection of countries depends on the availability of data. The EA8 dataset spans from 1991(1)–2014(6). We also perform an analysis using data for Austria and Portugal and report on this in the Appendix B, section B.5. The time span of the analysis reduces to 1996(1)–2014(6) .

3.4.1 Common euro area factors

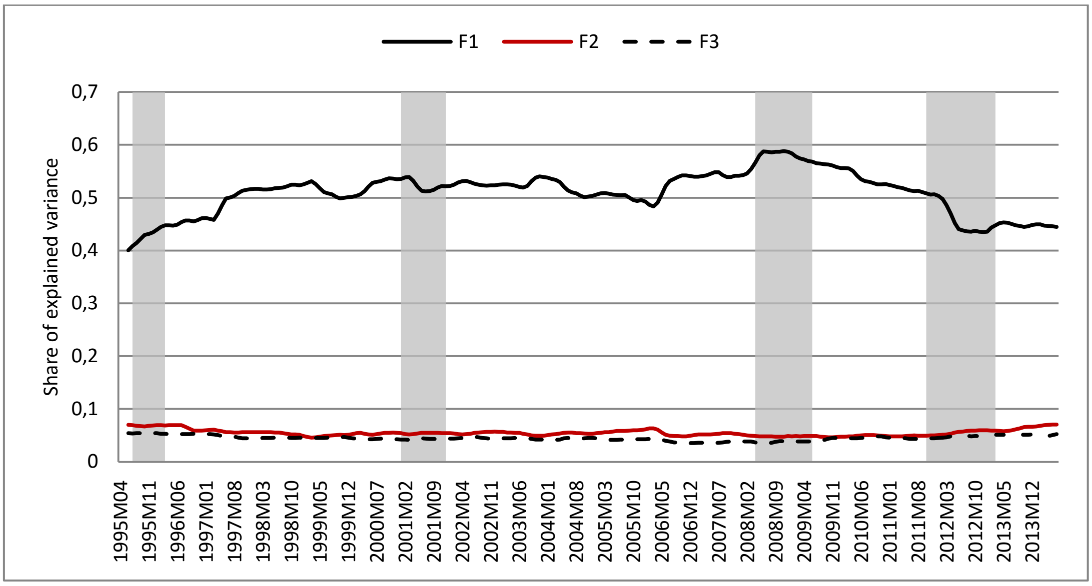
As explained above, the first step in the analysis involves extracting the common euro area factors (common EA factors) f_t (see equations 3.3.2 and 3.3.3) from the euro area dataset. To determine the number of factors we initially use the information criteria proposed by Bai and Ng (2002). The second information criterion (IC_{p2}, eq. 2.2.2) indicates that one common factor is sufficient for all the observed periods (233 periods with T=50) for which we estimate common factors. Using the first criterion (IC_{p1}, eq. 2.2.1) we obtain changing number of sufficient factors. For the majority of periods (142) the maximum number of predetermined factors (3) is predicted, while one or two factors are sufficient for 50 and 41 periods, respectively. In the most recent periods, from 2012M07 onwards, only one common factor is sufficient also according to the first criterion.[61]

Eickmeier (2006) finds five common trends identified by a structural factor setup. It transpires that this could be excessive in our setup, as sector specificities might emerge in specific common factors. In Figure 11 we show the variance of the dataset explained by the first three factors measured by the average of the corresponding R^2. The first factor accounts for 40 to 60 percent of variance of the dataset, depending on the observed period. The next two factors combined explain roughly a 10 additional percent of the variance, which already point to the limited importance of the second and third factor.

We examine the factors by regressing the aggregate industrial production index of manufacturing for the EA17 on the three common factors for all of the observed periods with T=50. We notice that R^2 are relatively small in all the observed periods for a model with one common EA factor, with the largest value of 0.32 for the period 2004(09) – 2008(11) . If we increase the number of factors, the R^2 obviously improves and reaches its maximum for the period 2004(10) – 2008(12) for a model with 3 common EA factors. Using F-tests we can reject the null hypothesis that a model with two common EA factors does not provide a significantly better fit than a model with one factor in less than half of the periods observed. These instances are concentrated for the periods ending in the 1995–98 and 2007–08 intervals (see Table A3 in Appendix A). Instances where three factors are better than two are even less frequent.

[61] A summary of the Bai and Ng (2002) information criteria results are reported in Table A2 in Appendix A.

Figure 11. Variance of output growth in manufacturing explained by the first 3 common EA factors as a share of total variance of the sample.



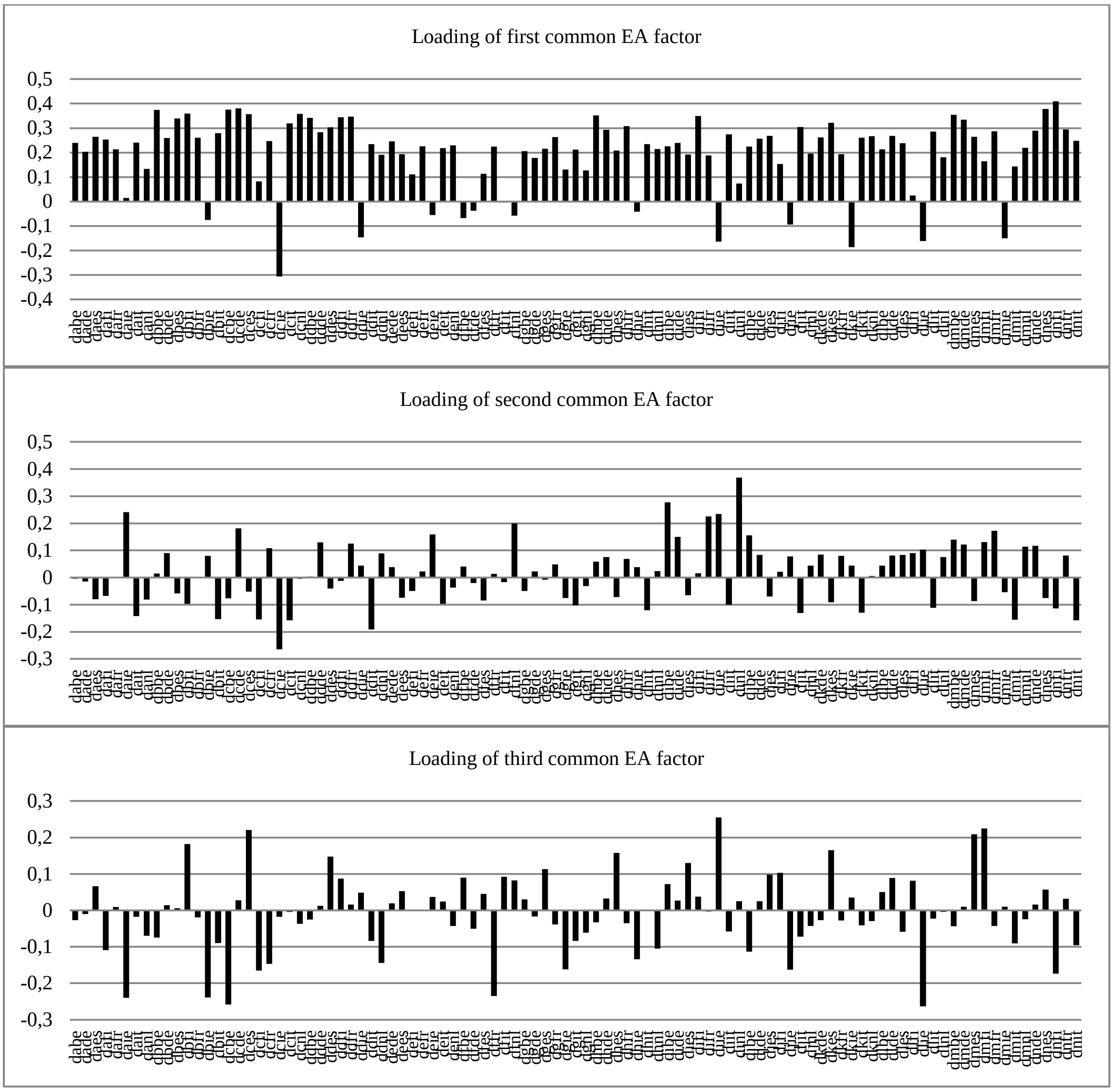
Note. The depicted variance share is for period *T-50* to *T*, e.g. the variance share depicted for 2014(6) is for the period 2010(4) - 2014(6). Further, three month moving averages are applied.
The recession periods are shaded. We define recession in terms of contracting industrial production for more than two consecutive quarters for the weighted average of EA8 countries quarterly seasonally adjusted data.

Source: Own calculations; Eurostat, *Short term business indicators*

The importance of factors is further ascertained by examining their corresponding loadings. In Figure 12 we report the loadings of common factors on an EA series for the last observed period. We can observe relatively high loadings on the first factor, while they are relatively smaller on the second and third factors, which points to the limited explanatory role of the second and third factors. The average absolute value of loadings on the first factor is 0.22, while the values for the second and third factors are 0.09 and 0.07 respectively. There is no general sectorial or country pattern of the series loadings on the first factor. There are two exceptions, however. The series in the "manufacture of coke and refined petroleum products" subsector have small loadings of the first factor.[62] The second exception is the loadings on some of the series for Ireland, which have the opposite sign.

[62] Sector of coke for France has a higher loading at 0.23.

Figure 12. Loadings of first three common EA factors on the manufacturing output growth series for the last observed period.



Note. 2010(5)–2014(6), T=50, N=99.

Since IC_{p1} and IC_{p2} could underestimate the appropriate number of factors when $min\{N,T\} < 60$ (Bai and NG, 2002) we also analyse the factor model imposed on the full length of the dataset (1991(1)–2014(6); T=282, N=99). We obtain similar results when using an approach with a full length of series.[63] The first common factor accounts for 49 percent of the total variance, whereas the second and third factor add 3 percent each. In this case, both of the Bai and Ng (2002) criteria suggest that only one common EA factor is sufficient. The regression of aggregate industrial production index for the EA17 on the three common EA factors shows that all three factors are statistically significant, but the R^2 is quite low.

[63] The loadings for this exercise are reported in Figure B1 in Appendix B.

On the basis of this evidence, we can conclude that a single factor is common to the overall EA dataset and use this as a choice in the next steps of factor extraction.

We can assess the evolution of the importance of the common EA factor over time from Figure 11. Its contribution to the explained variability of the whole panel exhibits an increasing pattern by 2001, indicating an increasing degree of synchronisation in the pre-euro period. The period until 2006 shows a slight decrease in the importance of the common EA factor. In the next period up to the beginning of the financial crisis, the factor gains 10 percentage points in terms of the explained variance. This could indicate an increasing symmetry of output fluctuations of manufacturing in the euro area prior to the crisis. After 2008, the pattern reverses. The common EA factor loses 15 percent of explanatory power in the years after its peak in 2008.

3.4.2 Sector specific factors

In the second step we estimate sector specific factors. From the data series we remove the common EA effects for each observed period by regressing the series on the common EA factor (eq. (3.3.3)) and then we calculate the sector-specific factors g_{jt} using the model (3.3.4) for each sector j.

We assess the importance of the sector specific factors on an aggregate level by calculating the explained variance by the sector specific factors at a sectoral level and then aggregating the results.

The Bai and Ng (2002) criteria (IC_{p1} and IC_{p2}) suggest one sector specific factor for all subsectors and periods (T=50, N_{max}=8). When using the dataset with T=282, the second criterion (IC_{p2}) suggests two sector specific factors for the textile and furniture subsectors.

An analysis of the factor loadings on individual series shows that a setup with more than one sector specific factor for each sector might be excessive since the second and third sector specific factors could also incorporate some country specificities. We report loadings of the sector specific factors for the last period with T=50 in Figure A1, Appendix A. [64]

We further analyse the importance of factors by regressing each aggregate industry index of production at the euro area level[65] on the common EA factor and sector-specific factors for their corresponding sector. We report instances where we reject the hypothesis that two factor model does not significantly improve the fit of the model compared to the one sector specific factor model in Table A4 in Appendix A. It can be observed that the models change over time and subsector. While in the majority of periods only one sector specific factor is sufficient for some sectors, for others more factors are needed.

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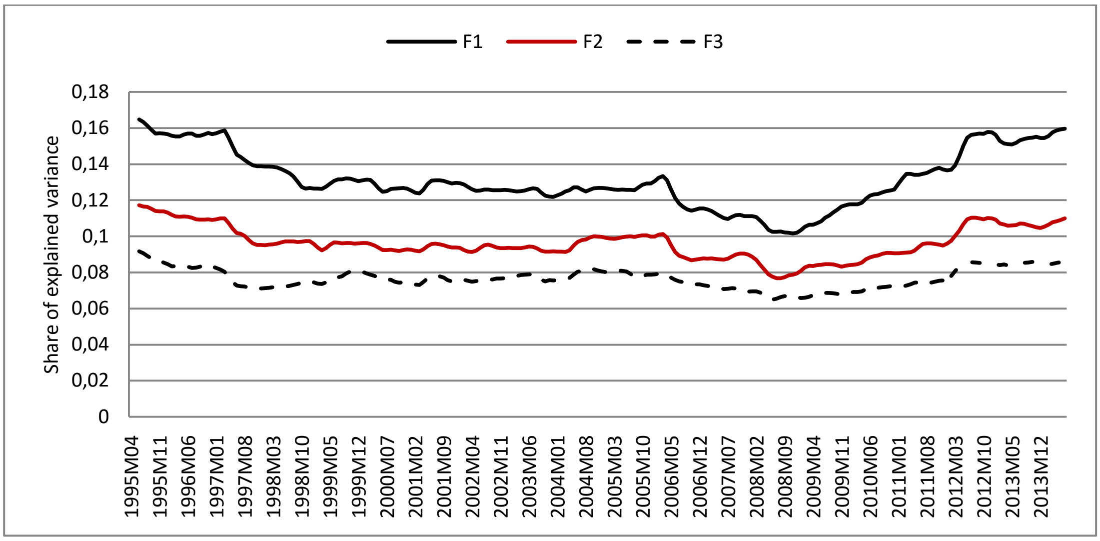
[64] Loadings of the sector specific factors for T=282 are reported in Figure B2 in the Appendix B.

[65] Industrial production indices by subsector aggregated on the euro area level. Log differences of the Eurostat weighted series for EA17, seasonally adjusted series.

In the case of the sector-specific factors we decide to use one sector specific factor for each of the 14 subsectors in the subsequent analysis, as suggested by the Bai and Ng criteria.

Figure 13. Share of total variance of output growth in manufacturing explained by three sector specific factors for the EA dataset.



Note. 3 month moving averages.

The first sector-specific factor explains 29 percent of the remaining variance of the dataset, while three sector-specific factors for each subsector explain 64 percent of the remaining variance in the last observed period. In Figure 13 we report an explained variance in absolute terms for each of the three sector-specific factors for all the periods observed.

In absolute terms, as a share of the variance of the euro area dataset, the first sector specific factor explains more than 15 percent of variance at the end of the observed period. The share of variance explained by the first sector specific factor decreased over time until the beginning of the financial crisis of 2008, partly as a consequence of the common EA factor gaining in importance. After the second half of 2008, the sector specific factor gained importance, offsetting the increased asymmetry of the output fluctuations indicated by the decreased variance share explained by common EA factors.

3.4.3 Country specific factors

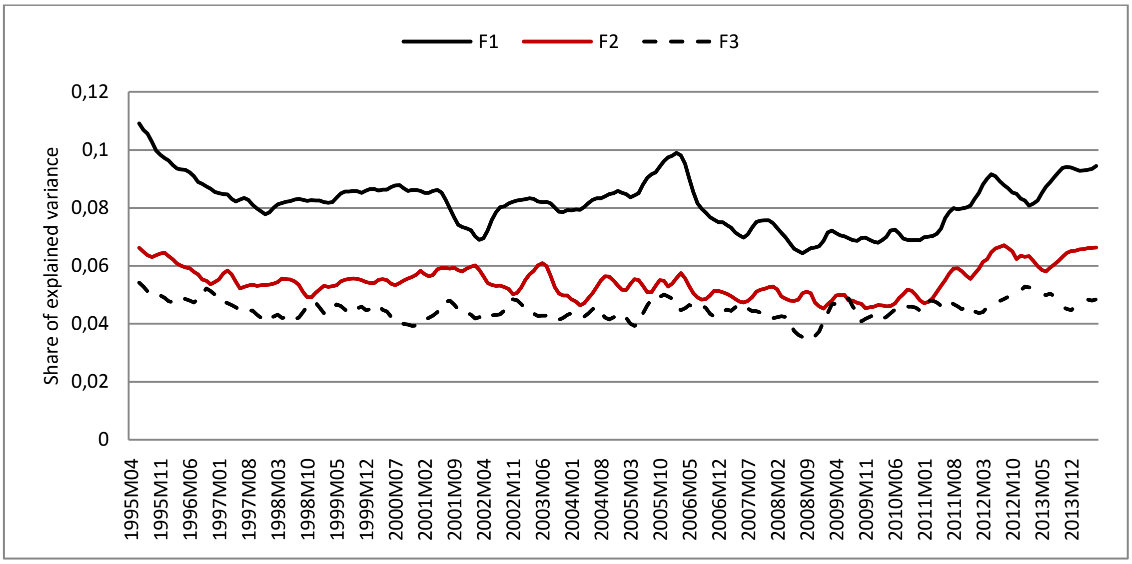
In the next step we extract the residuals for each country and observed period by regressing the industrial production indices for each country and sector on the common EA factor and EA sector specific factor belonging to the particular series (eq. (3.3.6)). Using principle components we then extract the country specific factor(s) from the residuals of the series grouped by each country (eq. (3.3.7)).

We extract three country specific factors for each observed period. The first country specific factor accounts for less than 10 percent of the total variance, which is about a quarter of the remaining variance. The second and third country specific factors account for an additional 7 and 5 percent of variance in the last observed period (Figure 14). Combined, three country specific factors account for approximately one half of the remaining variance after common EA and sector specific effects are extracted.

Since the number of series for each country is 14 or less ($N \leq 14$), one country specific factor is sufficient for the analysis for all countries and periods according to the Bai and Ng (IC_{p2}) criterion. Analysis of the dataset with T=282 yields one country specific factor for all countries with IC_{p2} criterion. Using the criterion IC_{p1} we get three sufficient factors for Spain and two for France.

Our preferred choice is the IC_{p2} criterion, so we use one country specific factor for each country for our analyses.

Figure 14. Proportion of total variance of output growth in manufacturing explained by three country specific factors, aggregated across the countries and subsectors.



Note. 3 month moving averages.

The evolution over time of the first country specific factor is roughly a mirror picture of the common EA factor. While the common EA factor has lost importance in explaining the variance of the EA dataset from 2001 to 2006, the opposite is the case for country specific factors. The reverse can be observed in the period up to 2008. There is one difference, however; the common EA factor started to decline in 2009, while country specific factors rebounded only at the start of 2011.

The idiosyncratic component, or the share of variance not accounted for by factors, is specific to a country and sector. The proportion of the country-sector specific component in the total variance of the EA sample dataset is about 30 percent. The highest levels of unexplained variance are in the last observed years, just over 30 percent.

The rising share of variance explained by a country sector specific component and country specific factors in the last years observed already point to a decreasing degree of synchronisation in the euro area manufacturing sector in recent periods.

3.4.4 Geographical differences in factors' importance

Variance explained by factors varies across the countries. The share of variance explained by the common EA factor in the last periods is highest for the two core EA countries, Germany and France (Table 7). On the other side of the spectrum, we find two countries from the euro area periphery, Ireland and Finland.

Sector specific factors explain a proportion of the variance in the range of 8 and 24 percent for the countries' datasets. Finland has the smallest share, while the Netherlands has the highest share of variance explained by sector specific factors. Ireland has a substantial part of the variance explained by sector specific factors, but this cannot offset the low common EA factor importance and so Ireland is the country with the lowest importance for EA factors (the combined effect of common EA and sector specific factors). France is the country with the highest share of EA factors in terms of explained variance.

Table 7. Proportion of variance of output growth in manufacturing explained by factors for EA countries in the sample. Average for 2014.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
BE	0.45	0.14	0.59	0.07	0.34
DE	0.67	0.12	0.79	0.08	0.13
ES	0.52	0.11	0.63	0.10	0.27
FI	0.30	0.08	0.39	0.13	0.48
FR	0.64	0.18	0.82	0.05	0.13
IE	0.07	0.16	0.24	0.15	0.61
IT	0.48	0.18	0.66	0.10	0.24
NL	0.41	0.24	0.65	0.07	0.28
Mean*	0.44	0.15	0.60	0.09	0.31
St. dev.	0.19	0.05	0.20	0.04	0.16

Note. T=50.
*Unweighted mean

Country specific factors are in the range of 5 and 15 percent as a proportion of the explained variance. Again, Germany and France are among the countries with the least important country specific factors, while Ireland and Finland have the most important country specific factors. The higher importance of country specific factors for Ireland and Finland does not offset the relatively low importance of EA factors, and so these countries have high shares of unexplained variance or country-sector specific effects.

The high synchronisation of Spain and Italy suggests that common EA policies could boost growth in these "problematic" countries, whereas countries such as Finland and Ireland need more country specific policies or, given the high proportion of country-sector specific effects, even country-sector targeted policies. Recent events in the euro area show that monetary policy has considerable limitations (more so in the event that the homogeneity of preferences and solidarity criteria for the OCA are not fulfilled); therefore, a euro area fiscal policy that would act as an automatic insurance mechanism is justified.

In a setup with T=282 we get similar results across the countries.[66] The main difference was the higher synchronisation of Finland, which points to a decrease in the EA factors for this country.

3.4.5 Sectoral differences in in factor importance

Similarly to the case with countries, the explained variance by factor also varies across the subsectors. The subsector of coke and refined petroleum is a clear outlier with 30 percent of the variance explained by sector specific factors and negligible common EA effects. On the other end of the spectrum, we find the paper and printing as well as basic metals subsectors with only 8 percent variability explained by sector specific factors. However, these two subsectors have high shares of variability explained by the common EA factor.

In the context of sensitivity to asymmetric shocks, the subsector with the lowest proportion of EA factors in the variance decomposition is the coke and refined petroleum subsector, with only 34 percent of variance explained by the EA factors. Leather, machinery, and transport equipment are the subsectors with shares of variance explained by EA factors of just above 50 percent, which is below average.

Table 8. Variance of output growth in manufacturing explained by factors for the manufacturing subsectors for the last observed period.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.58	0.13	0.71	0.07	0.22
Textile	0.49	0.10	0.59	0.07	0.34
Leather	0.33	0.17	0.50	0.07	0.42
Wood	0.53	0.10	0.63	0.15	0.22
Paper and printing	0.55	0.08	0.64	0.08	0.29
Coke	0.04	0.30	0.34	0.02	0.64
Chemicals and pharmaceuticals	0.46	0.15	0.61	0.05	0.35
Rubber and plastic	0.60	0.13	0.74	0.10	0.16
Other non-metallic	0.36	0.35	0.70	0.11	0.19

(table continues)

[66] Table B2 in Appendix B.

(continued)

	Common EA factor	Sector specific factor	EA factors	Country specific factor	Unexplained variance
Metals	0.54	0.08	0.61	0.18	0.20
Electronic	0.49	0.13	0.62	0.08	0.30
Machinery	0.40	0.11	0.50	0.12	0.38
Transport	0.33	0.18	0.51	0.09	0.40
Furniture	0.59	0.14	0.72	0.08	0.20
Mean*	0.41	0.12	0.53	0.11	0.35
St. dev.	0.14	0.06	0.11	0.04	0.14

*Note.**Unweighted mean

The results of the setup with T=282 are reported in Table B3 in Appendix B. In general, the results for the common EA factors are slightly higher, but lower for the sector specific factors.

3.4.6 Evolution of variance decomposition over time

Our setup with rolling windows to estimate the factors enables us to investigate the evolution of the (a)symmetry in output fluctuations over time. We find that the shares of variance explained by factors changes over time, as indicated by previous subsections with aggregated results. We further find that the evolution of factors' importance over time is heterogeneous across the countries and sectors.

Table 9 shows the evolution of EA wide factors – the combined effect of the common EA and sector specific factors for individual countries. It can be observed that there is an increasing synchronisation in the first years of our analysis, covering the pre-euro period (T=50). The only exceptions are the Netherlands and Ireland. The synchronisation of Italy also begins to decrease before the euro's introduction in 1999. We cannot confirm a uniform effect in relation to the introduction of the euro across the countries. Our results are more in line with the theory that synchronisation is a gradual process that started before the euro's formal introduction.

Table 9 shows an increase of the degree of synchronisation for all countries, except Italy and Netherlands, in the pre-crisis euro period, compared to period 1991–1995 (Δ07-95).

The results for Finland confirm that this country has only had a low degree of synchronisation with the euro area in recent years, during the period of recession and at the beginning of the sample, which also covers the period before Finland's accession to the EU in 1995. In 2009, for example, the level of synchronisation was similar to other euro area countries in our sample.

Table 9. Proportion of variance of output growth in manufacturing explained by the EA factors (common and sector specific). Annual averages.

	BE	**DE**	**ES**	**FI**	**FR**	**IE**	**IT**	**NL**	**Mean***
1995	0.55	0.68	0.57	0.45	0.63	0.25	0.76	0.73	0.58
1996	0.54	0.73	0.63	0.57	0.66	0.25	0.78	0.70	0.61
1997	0.52	0.80	0.69	0.64	0.64	0.25	0.80	0.71	0.63
1998	0.57	0.79	0.71	0.69	0.67	0.26	0.78	0.68	0.64
1999	0.56	0.80	0.69	0.66	0.66	0.24	0.76	0.67	0.63
2000	0.62	0.82	0.65	0.70	0.72	0.23	0.74	0.69	0.65
2001	0.65	0.81	0.62	0.65	0.73	0.22	0.74	0.72	0.64
2002	0.65	0.81	0.65	0.66	0.76	0.24	0.71	0.69	0.65
2003	0.67	0.81	0.69	0.65	0.74	0.20	0.69	0.66	0.64
2004	0.70	0.79	0.67	0.62	0.74	0.24	0.67	0.63	0.63
2005	0.68	0.78	0.70	0.65	0.69	0.22	0.66	0.61	0.62
2006	0.72	0.77	0.74	0.62	0.67	0.24	0.70	0.63	0.64
2007	0.69	0.78	0.78	0.64	0.67	0.30	0.71	0.64	0.65
2008	0.67	0.84	0.83	0.68	0.72	0.26	0.73	0.67	0.68
2009	0.67	0.83	0.83	0.71	0.74	0.20	0.72	0.67	0.67
2010	0.63	0.82	0.81	0.64	0.73	0.24	0.68	0.67	0.65
2011	0.61	0.82	0.74	0.52	0.81	0.24	0.68	0.70	0.64
2012	0.61	0.79	0.62	0.40	0.81	0.25	0.64	0.64	0.60
2013	0.58	0.80	0.63	0.40	0.81	0.29	0.66	0.63	0.60
2014	0.59	0.79	0.63	0.39	0.82	0.24	0.66	0.65	0.60
Δ14-95	0.05	0.11	0.06	-0.06	0.19	-0.01	-0.10	-0.08	0.02
Δ07-95	0.14	0.10	0.21	0.19	0.05	0.06	-0.05	-0.09	0.08
Δ14-07	-0.10	0.01	-0.16	-0.25	0.15	-0.07	-0.05	0.01	-0.06

Note. T=50.
*Unweighted mean

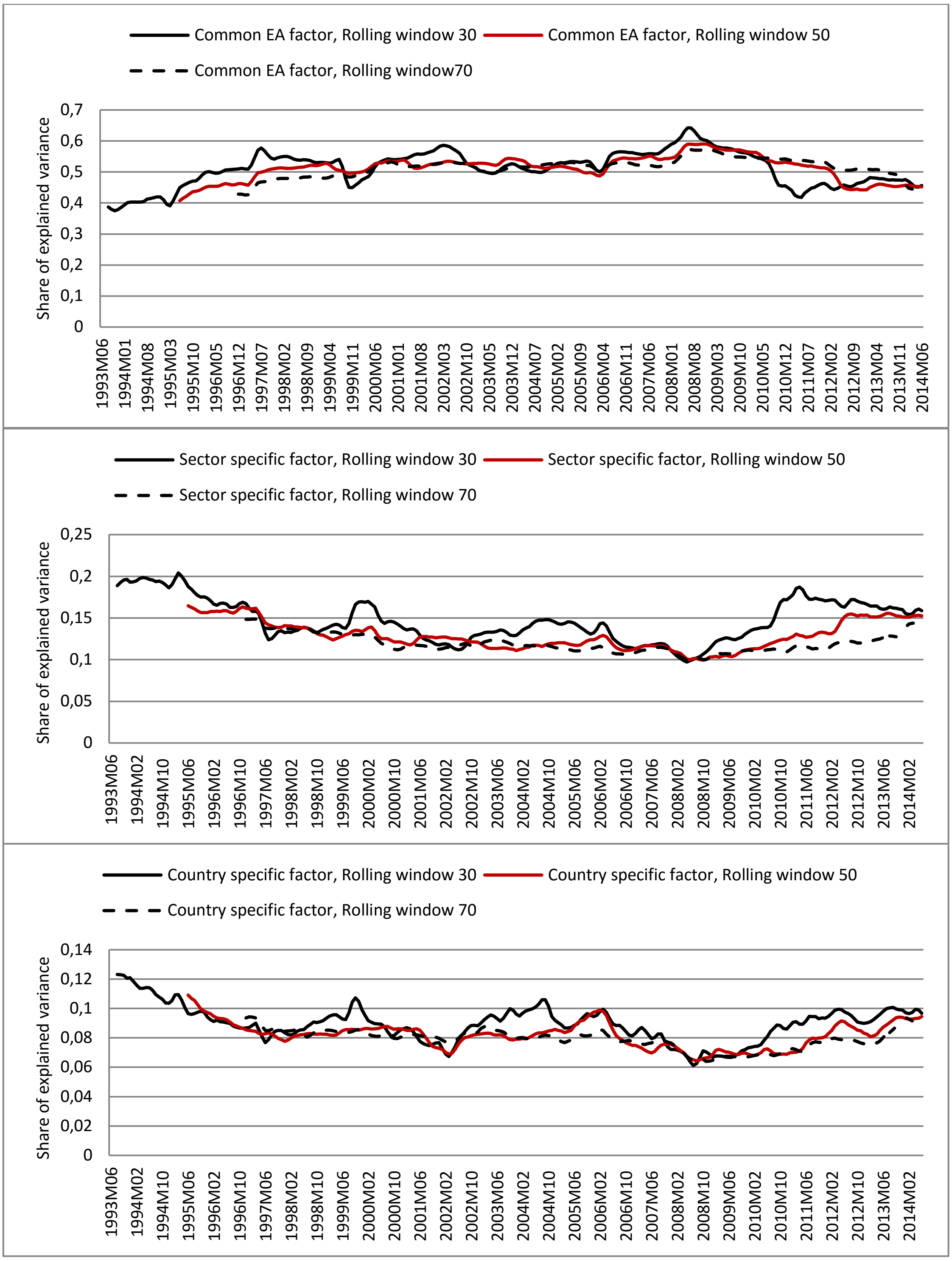
3.4.7 Robustness checks

In this subsection we consider as to whether and to what extent our results can be affected by alternative approaches to the analysis. We consider: rolling window size, degree of sectoral disaggregation, monthly vs year-on-year growth, and the order of factor estimation.

Rolling window size

Since the size of the rolling window is selected arbitrarily, we check all the above results with different sizes of rolling windows in the analysis, *ceteris paribus*. In addition to a rolling window size of 50 observations, we also use rolling windows with 30 and 70 observations. The overall results do not change substantially, but a smaller sized window can be used for a more precise estimation of the changes in the patterns of behaviour of the data. In a larger rolling window, recent observations have a smaller weight in the results, than is the case with a smaller sized window. However, in a smaller sized window we can encounter problems with degrees of freedom in the regression estimations, if the number of observations is not sufficiently large.

Figure 15. Share of variance of output growth in manufacturing explained by factors using different rolling window size.



A smaller rolling window with T=30 reveals some additional information compared to our preferred setup. The common EA factor started declining as soon as in the first half of 2008, prior to the full outbreak of the financial crisis. Another observation is the second large dip in 2010, which is not as pronounced in our preferred setup.

When considering the proportion of explained variance of the sector specific factors we find the three alternative rolling window sizes to have similar trends, but smoothness increases with the size of the rolling window. The smallest sized window reveals an additional peak in 2011, mirroring the bottom of the common EA factor.

The results for the country specific factors are similar: different sized windows result in the same trends with regard to the country specific effects albeit with different smoothness. A rolling window of size 30, similarly to the previous sets of factors, reveals a rise in importance in the second half of 2010, while the larger sized window analysis only picks up the rise in importance in 2012.

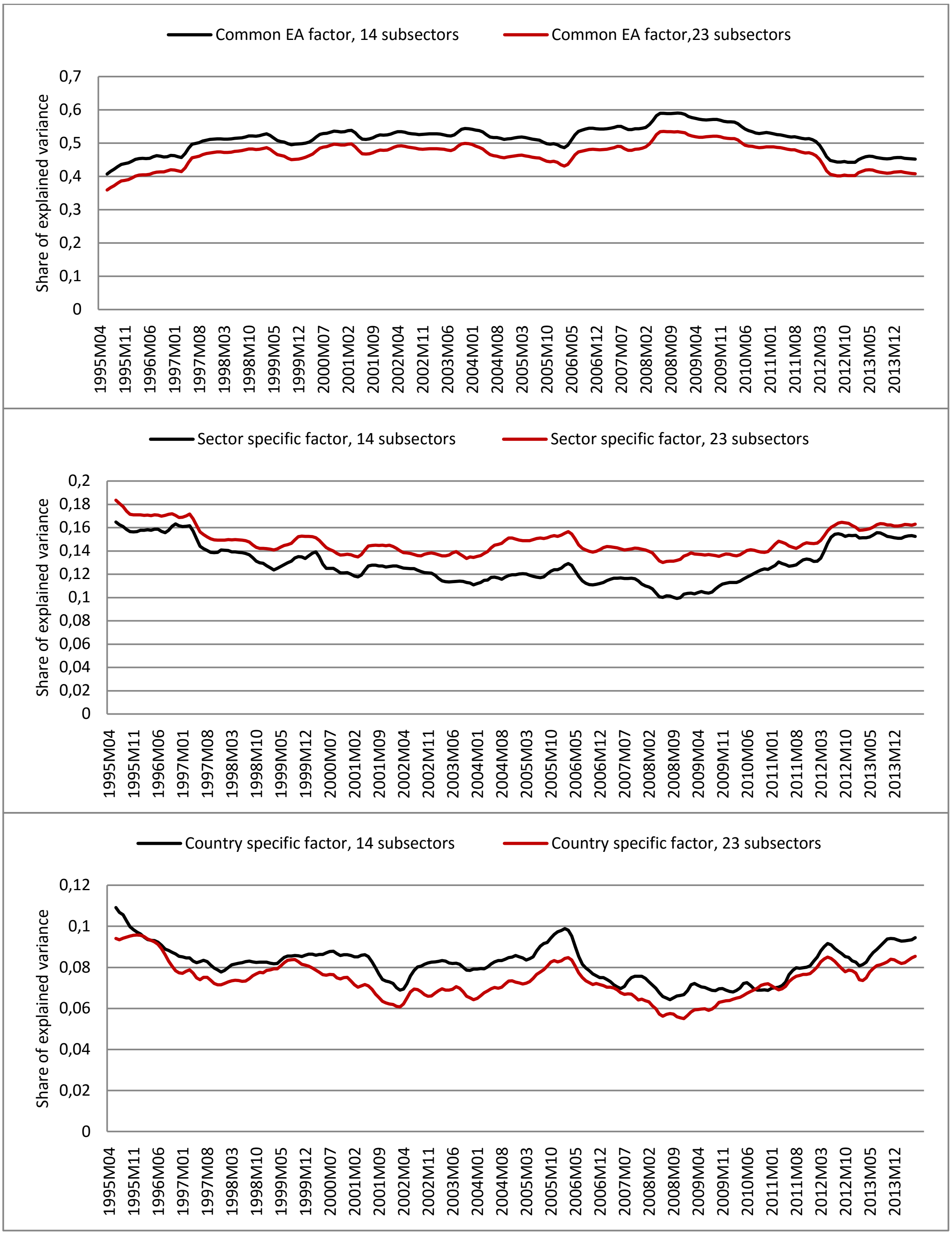
Level of sector disaggregation

We perform additional analysis with a dataset comprising 23 subsectors (NACE Rev.2).[67] Comparison of results for the importance of common, sector specific and country specific factors for our EA sample and rolling window of size 50 is presented in Figure 16. The importance of the common EA factor is lower in the case of a more detailed disaggregation for all the observed periods, but the evolution of factor importance over time has the same properties as is the case with the 14 subsectors. The difference in level is not huge either, averaging less than 5 p.p. of the explained variance. The results are expected, since Forni and Reichlin (1996) argue that the weight of the common component decreases with the level of disaggregation.

We expect that the subsectors exhibit greater comovement at more detailed disaggregation, since with increased disaggregation we draw closer to the substitutability in production criteria often used in intra-industry trade literature. We find the importance of sector specific factors to be higher in the case of 23 subsectors, by an average of almost 2 p.p. of the explained variance. This is partly a direct consequence of the lower common EA factor importance, thereby extracting less variance from the 23 subsectors dataset.

[67] We report more detailed results in section B.4 of Appendix B.

Figure 16. Share of variance of output growth in manufacturing explained by factors, by level of disaggregation.



In the case of country specific factors we also get similar results in both exercises with different levels of subsector disaggregation. On average, we obtain a difference of less than 1 p.p. in the share of explained variance by the country specific factors, with a similar pattern of evolution over time.

Order of factor estimation

In the section 3.3 we setup a model in a way to estimate sector specific factors first, while country specific factors are estimated from the residuals after we clean the series of common and sector specific components.

However, we could rewrite equation (3.3.4) as:

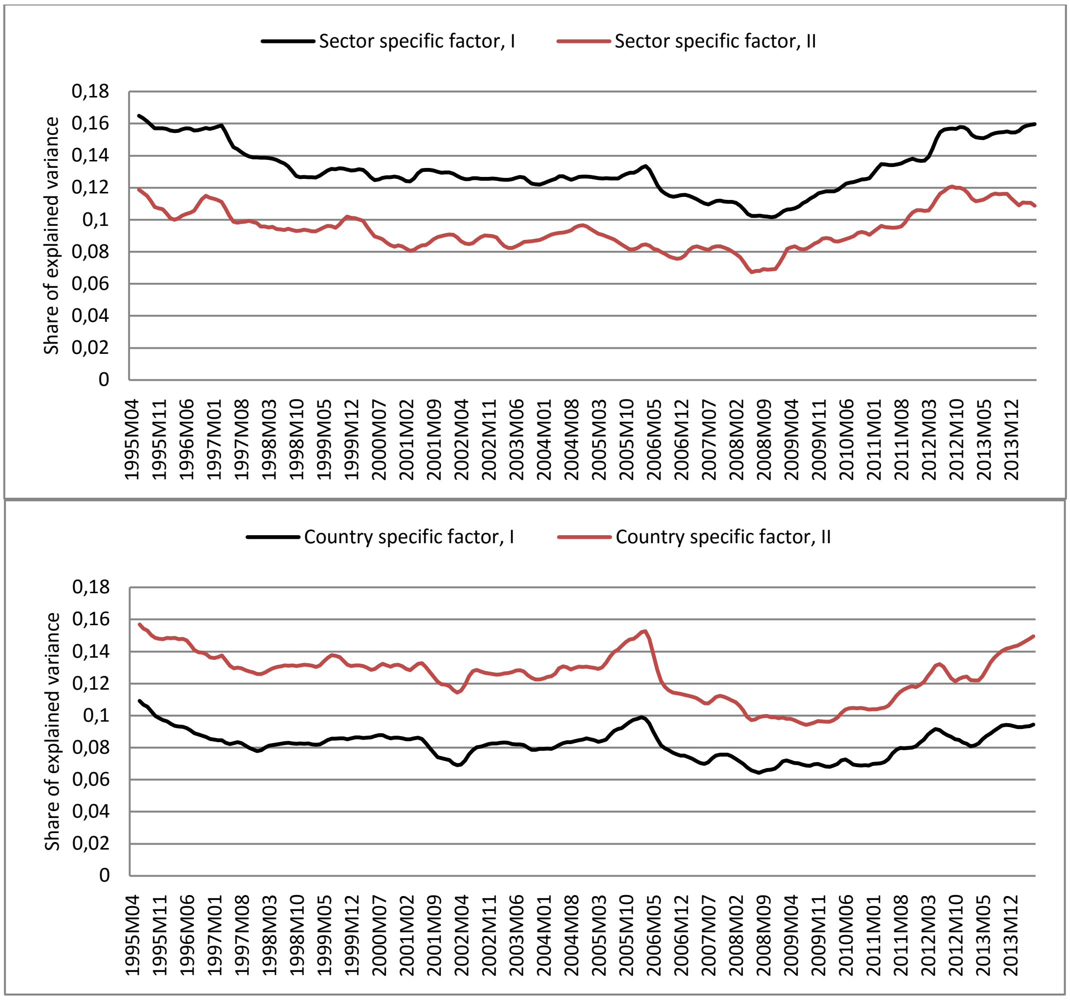
$$\hat{u}_{ijt} = \mu_{ij} h_{it} + \varepsilon_{ijt} \ , \qquad (3.4.1)$$

and estimate country specific factors h_{it} first. In the next step we eliminate the effects of common and country specific factors:

$$\hat{v}_{ijt} = x_{ijt} - \hat{\lambda}_{ij}\hat{f}_t - \hat{\mu}_{ij}\hat{h}_{it}. \qquad (3.4.2)$$

From thus obtained residuals $\hat{v}_{ijt}$ we estimate sector specific factors.

Figure 17. Share of variance of output growth in manufacturing explained by factors, by order of estimation.



Note. (I) stands for estimation of the factors as described in section 3.3; (II) stands for reverse order where country specific factors are extracted first.

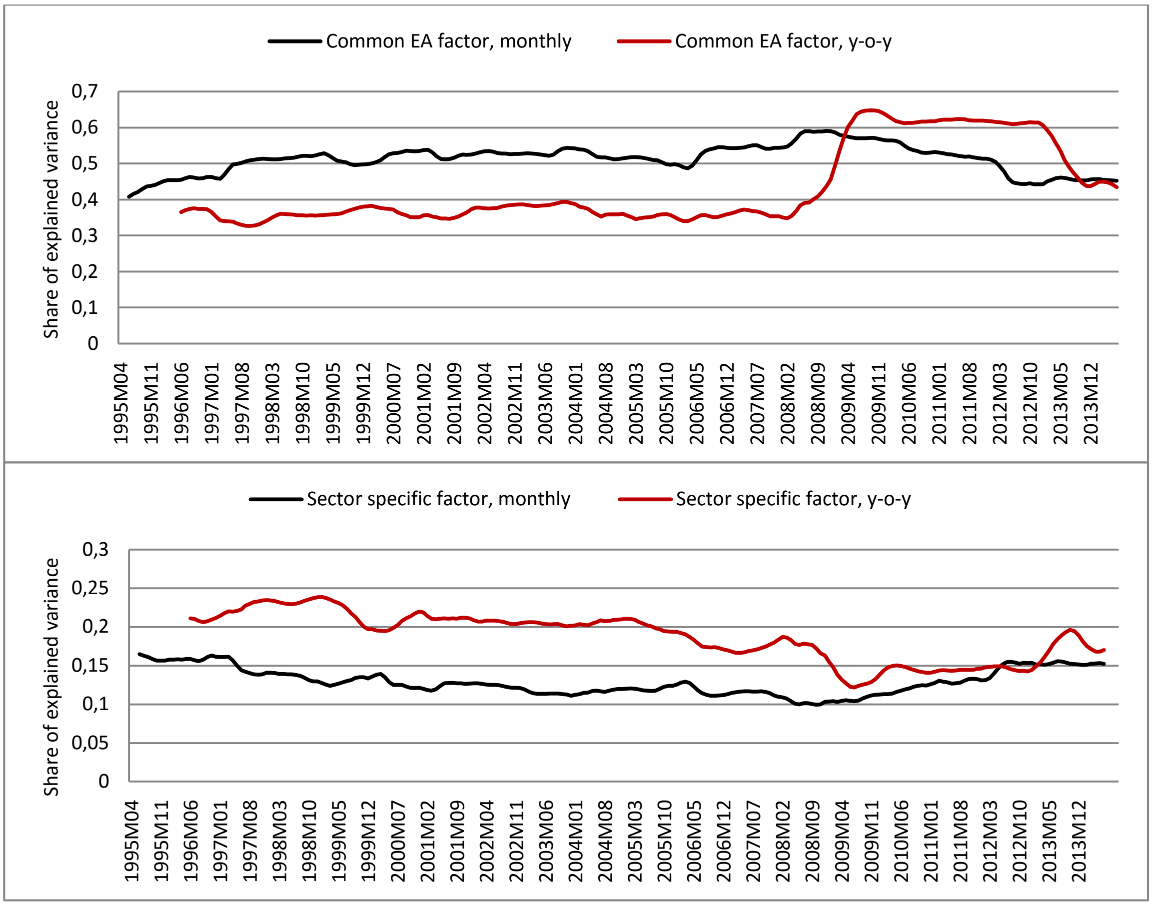
A shift in the explained variance of the sector and country specific factors can be observed in Figure 17. However, the evolution of factors is similar to our baseline results. Further, the order of the estimation of factors does not influence the relative importance of factors by the countries and subsectors.

Beck et al. (2012) tackle this issue with an iterative method. We could estimate first the sector specific factors, second the country specific factors and then feed thus obtained country specific factors in the equation (3.4.2). In the next step, the second iteration of sector specific factors is obtained. By repeating the procedure we would get closer to the true sector and country specific factors (Beck et al., 2012 for more details).

Monthly vs year-on-year growth

We perform the analysis using year-on-year growth rates instead of the deseasonalized monthly growth. In this case, we obtain a quite different picture of the heterogeneity in the euro area. The main difference is in the relatively low importance of the common EA factor in the case of the explained variance of year-on-year growth rates up to the start of the financial crisis in late 2008 (see Figure 18).

Figure 18. Share of variance of output growth in manufacturing explained by factors, by transformation of data.



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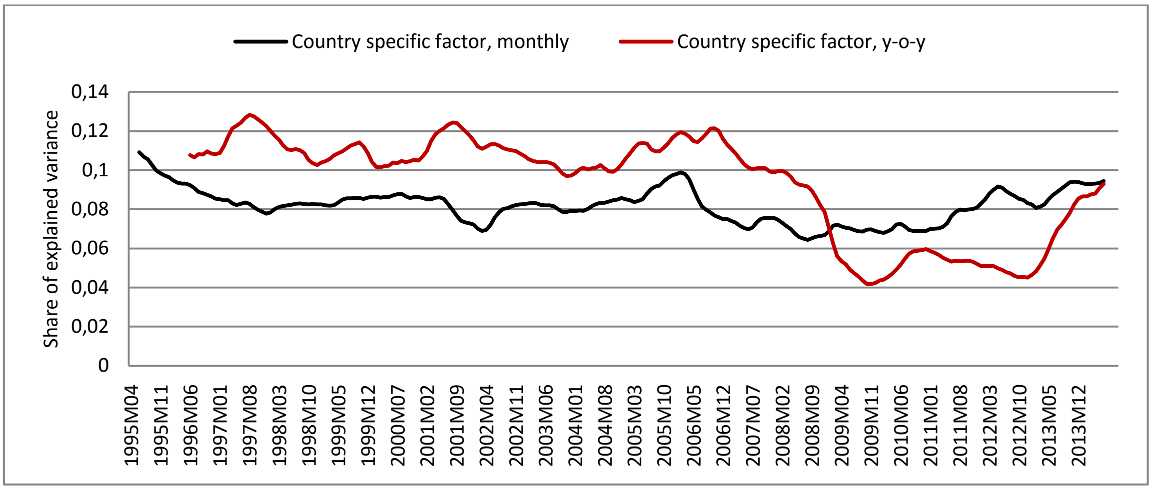


The use of year-on-year output growth does not seem to strengthen our factor structure in the periods preceding the financial crisis. The increased variance share explained by the common factor since 2008, depicted in Figure 18, reflects the decreased growth differentials depicted in Figure 8.

When we add the variance share explained by sector specific factors, which exhibit a decreasing trend even in the years before the financial crisis, we obtain a different picture of the synchronisation of the manufacturing sectors in the euro area. It seems that the increased synchronisation we observe in our main analysis of the euro period before the financial crisis was more a consequence of increased common short term fluctuations.

The results of the variance share explained by country specific factors also show that the asymmetric part of the variance attributed to sources stemming from the countries remains on about the same levels in the first part of the euro period.

3.5 Business cycle synchronisation in the EU

In this section we analyse the heterogeneity of manufacturing sectors in the EU. EU countries should be more heterogeneous than those in the EA for more reasons. The most obvious reason is that the monetary union that does not include all EU countries and the other is that 13 countries have joined the EU since the euro was introduced.

As we show in Table 1, the correlation coefficients of non-euro EU countries' industrial production growth with the EA17 aggregate industrial production growth are generally smaller than those of the euro area countries; however, there is considerable heterogeneity regarding synchronisation with the euro area aggregate on the country level.

Variances in annual growth on the subsector level are larger in the EU than in the euro area (Table 5). We thus expect the common EU factor to have less explanatory power for the EU data than the common euro area factor for our euro area dataset.

In this section we use the same methodology described in section 3.3 to estimate heterogeneity in the manufacturing sector for EU countries.[68]

3.5.1 Data

In this section we use data for EU countries industrial production in manufacturing sector, depending on the data availability (Table 10).

The series in our EU dataset are of different length, depending on the availability of Eurostat data. In the group of countries with the longest series, we find the founding euro area countries that we use in the previous subsection and three additional non-euro old member states: Denmark, Sweden and the UK. In the second batch of countries with data starting from 1996, there are two founding euro area countries, Austria and Portugal, and Poland as a new member state (NMS) outside the euro area. In the next group are Slovenia and Slovakia, both of whom entered the euro area in 2007 and 2009 respectively, and Latvia[69] which joined the euro area in 2014. In the last batch of observed countries, with data series starting in 2000 we have Greece as a euro member from 2001 and Estonia, which adopted euro only in 2011. The Czech Republic, Bulgaria, Hungary, Lithuania, and Romania are NMS without the euro as a currency.

There are more cross-sections on an aggregated sample that will be of interest in the analysis:

- 1999: the adoption of the euro as an electronic currency,
- 2002: the implementation of the euro as a formal currency,
- 2004: the large expansion of the EU (new member states).

There were other interesting years, such as 1995, when three countries joined the EU or 2007, when the first new member states entered the euro area; however, these cases will receive more thorough analysis in the next section.

3.5.2 Results

We are interested in the differences in heterogeneity in the EU and the euro area on a more aggregated level. Therefore we retain the setup of factors used in the previous section. We extract one common EU factor, a sector specific factor for each subsector and a country specific factor for each country from the EU dataset. Since we are limited by the data availability, especially for the new member states, we aggregate the countries into four different groups (Table 6) in order to make use of as much information as possible.

Although we prefer to retain the setup of the calculations for the EA dataset, we still examine what the appropriate number of the common EU factors would be. For the rolling

[68] Note that it applies for i in equations (3.3.1)-(3.3.8): $i = 1, \dots, N_{EU}$, where N_{EU} is the number of the countries in the EU sample.

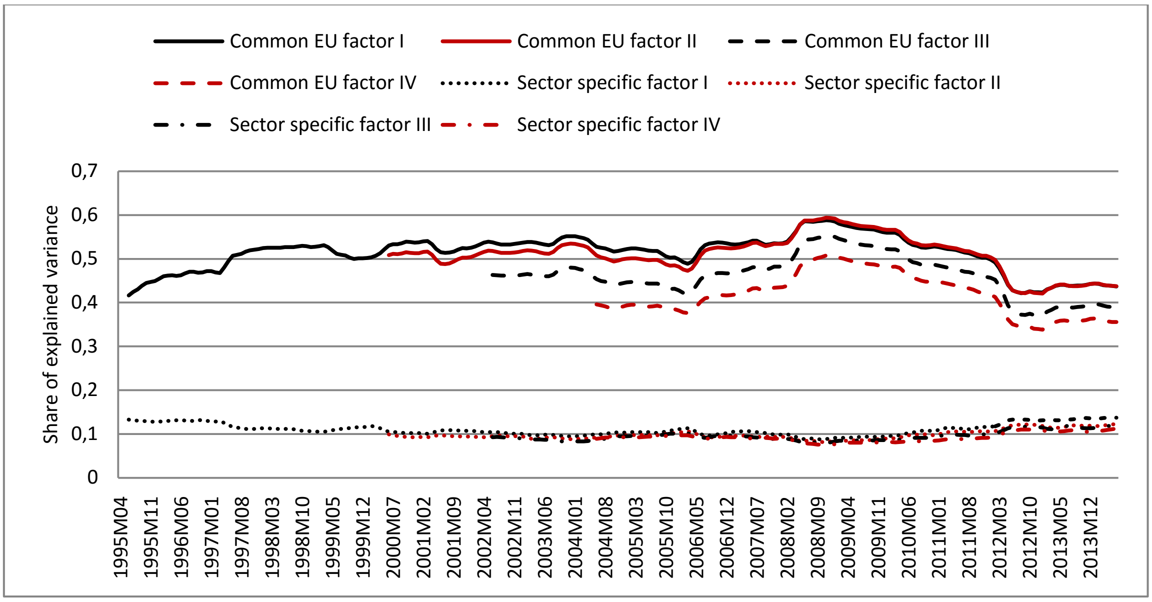
[69] We treat Latvia as a non-euro NMS in the presentation of results.

window setup with T=50 and the largest group of EU countries (group IV, N=310) we get one single common factor according to both the IC_{p1} and IC_{p2} Bai and Ng (2002) criteria for all of the observed periods. The second and third factor on average explain 5 and 4 percent of the variance in the dataset, respectively. The first factor explains on average almost 50 percent of the variance, and so the setup with one single EU factor seems a logical choice nevertheless.[70]

Bai and Ng (2002) IC_{p2} criterion suggests using one sector specific factor for all subsectors in every observed period (group IV, N_{max}=24).[71] For the number of country specific factors we get one sufficient factor for almost all the countries and periods using IC_{p2} criterion.[72]

Variance explained by common EU and sector specific factors is presented in Figure 19. We observe that the share of variance explained by the common EU factor diminishes when more countries, mostly new member states are added to the sample. The same can be said for the sector specific factors, where the largest set exhibits the least important of these. However, the differences in absolute terms are less than in the case of the common EU factor.

Figure 19. Variance of output growth in manufacturing explained by common EU and sector specific factors for four different subsets of countries.



Note. Group I: BE, DE, DK, ES, FI, FR, IE, IT, NL, SE, UK; Group II: Group I + AT, PL, PT; Group III: Group II + LT, SI, SK; Group IV: Group III+ BG, CZ, EE, EL, HU, LV, RO.

As expected, less variance is explained by the common EU factor for the largest group than in the case for the common EA factor for the EA8 sample from the previous section. The common EU factor explains, on average, 42 percent of the variance in the EU dataset for

[70] We report loadings of the 3 common EU factors in the Appendix B, Figure B5.

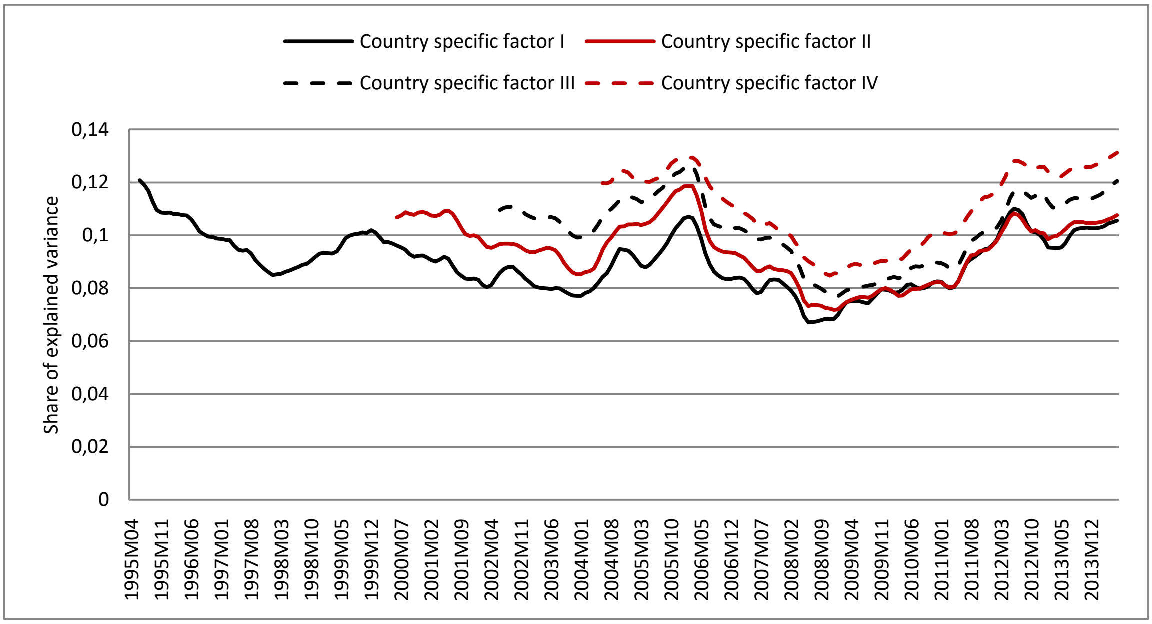
[71] We report summarized results for the IC_{p1} criterion in Appendix B, Table B15.

[72] Results for IC_{p1} and IC_{p2} criteria for country specific factors are reported in Appendix B, Table B16.

the periods (T=50) ending in 2004(4) – 2014(6), while the common EA factor explains 52 percent of the variance in the EA dataset for the same set of periods.

Since both common EU and sector specific factors explain the lower variance for the larger sets of EU countries, a higher importance of the country specific factors is expected for the larger sets (Figure 20). Country specific factors are at the highest levels in the last observed periods and decreasing trends can only be observed prior to 1999 and in the period 2006–2009.

Figure 20. Variance of output growth in manufacturing explained by country specific factors for four different subsets of countries.



Note. See Note in Figure 19.

Country specific factors exhibit a similar trend in all the groups of countries used in the analysis, however the gap between old member states in group I compared to group III and IV, broadened by mostly new member states, decreases over time.[73]

There is no clear cut evidence that the EU heterogeneity changed after the introduction of the euro. On the contrary, looking at the country specific factors, we can observe an increase in importance just at the point of when the euro was introduced and the 2004 enlargement for the group of the old member states (euro and non-euro), which could point to the enlargement of EU in 2004 having had asymmetric effects on the existing EU countries.[74]

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[73] A more thorough comparison between old and new member states is provided in the section B.6 of the Appendix B and in the next section, where we investigate business cycle synchronisation in the EU with euro area factors.

[74] We would have to control for other possible causes in order to confirm this effect.

New member states clearly contribute to more heterogeneity in the manufacturing sector as can be seen both in the decreasing of importance of EU factors and the increasing significance of country specific factors, by adding additional countries to the analysis. Before the start of the prolonged recession caused by the financial and the sovereign debt crisis that followed, the degree of synchronisation of the EU (including new member states) seemed to increase; however, in the recession period it decreased and in the latest periods, the heterogeneity in the EU manufacturing sectors is even more pronounced than before the EU enlargement in 2004.

3.6 Business cycle synchronisation of the EU countries with the EA

In this section we investigate the degree of synchronisation of EU countries with the euro area business cycle in the manufacturing sector. We start by extracting the common EA and sector specific factors from the euro area dataset and continue with country specific factors extraction from the residuals of the regression of EU countries' series on the common EA factor and sector specific factors. In this way we are also able to investigate some of the euro area countries that were excluded from the analysis in section 3.4 due to data availability.

This section is the most exhaustive regarding the quantity of the results reported. The setup enables us to look into the detailed results at the country and sector level for all the EU countries in our sample. We present the results for the groups of countries as well as for individual countries, for a rolling window analysis with T=50. A special subsection is dedicated to Slovenia, where we investigate the manufacturing sector's synchronisation with the EA in more detail. In this section we also present a more detailed disaggregated sector analysis and attempt to draw attention to sectors that are more prone to asymmetric shocks, i.e. those which present greater idiosyncratic risks.

Methodology

We use a similar setup as in the previous two sections, with one distinction. We start by imposing the factor structure on a euro area dataset (EA8):

$$x_{ijt} = \lambda_{ij} f_t + \mu_{ij} g_{jt} + \varepsilon_{ijt}. \qquad (3.6.1)$$

Following equations (3.3.2) – (3.3.4) we obtain estimates for the euro area common and sector specific factors, $\hat{f}_t$ and $\hat{g}_{jt}$. In the next step we perform a regression on all the variables in the EU dataset:

$$x_{ijt} = \lambda_{ij} \widehat{f_t} + \mu_{ij} \hat{g}_{jt} + v_{ijt}. \qquad (3.6.2)$$

Note that it applies for i in equation (3.6.1): $i = 1, \dots, N_{EA}$ and for equation (3.6.2) $i = 1, \dots, N_{EU}$, where N_{EA} is the number of countries in the EA sample and N_{EU} a number of the countries in the EU sample. [75]

We assume the following factor structure for the obtained estimates of the residuals for EU variables:

$$\hat{v}_{ijt} = \eta_{ij} h_{it} + \mathrm{e}_{\mathrm{ijt}}, \quad (3.6.3)$$

We estimate country specific factors for all EU countries in the dataset h_{it}. Using the OLS estimator in the regressions preserves the orthogonality of the estimated common, sector specific and country specific factors, and so the variance decomposition is as follows:

$$var(x_{ijt}) = (\hat{\alpha}_{ij})^2 var(\hat{f}_t) + (\hat{\mu}_{ij})^2 var(\hat{g}_{jt}) + (\hat{\eta}_{ij})^2 var(\hat{h}_{it}) + var(\widehat{e_{ijt}}). \quad (3.6.4)$$

In this way we exclude the impact of new member states on the variance of the dataset to which we impose a dynamic factors model structure in the first two steps.[76] The variance decomposition for the non-euro countries reflects only "pure" euro area common and sector specific factors. Note that the procedure does not change for the euro area countries included in the formation of EA factors.

The estimated factors allow us to calculate the contribution of each factor to the share of explained variance for each individual series. Their contribution to the share of explained variance of each individual measure of sectoral output thus measure the level of synchronisation of the variation in sectoral outputs across the countries. The evolution over time could then be traced by performing the steps described above recursively with a fixed rolling window.

3.6.1 Groups of countries

In this part we first present the results by groups of countries and then we turn our attention to individual countries and subsectors in the next subsections. When presenting the results for the groups of countries, we are limited by the country with the shortest series of data available. In the first disaggregation of countries we use three groups in order to make use of as much information as possible.

The groups of countries that are used in the presentation of results in Table 10 are:

- EA (BE, ES, DE, FI, FR, IE, IT, NL)[77],
- NMS (CZ, EE, HU, LT, LV, PL, SI, SK, BG, RO)[78],

[75] In a similar manner we could investigate the synchronisation of non-EU countries with the EA business cycle in manufacturing.

[76] Breitung and Eickmeier (2006) put more weight on the aggregate euro area series and the series for core euro area countries in constructing the factor model to investigate the synchronisation of CEEC countries with euro area.

[77] AT, EL and PT are omitted in order to increase the time span to 1995-2014 (data range is 1991-2014).

[78] New member states that acceded to the EU in 2004 and 2007, not including Cyprus and Malta.

- OMS (UK, SE, DK).

Table 10. Share of variance of output growth in manufacturing explained by the common EA factor, EA sector and country specific factors for EA, NMS and OMS. Annual averages.

	Common EA factor			EA sector specific factors			Country specific factors		
	EA	**NMS**	**OMS**	**EA**	**NMS**	**OMS**	**EA**	**NMS**	**OMS**
1995	0.43		0.44	0.16		0.03	0.10		0.17
1996	0.46		0.47	0.16		0.03	0.09		0.16
1997	0.49		0.52	0.15		0.02	0.08		0.14
1998	0.52		0.54	0.14		0.02	0.08		0.13
1999	0.51		0.51	0.13		0.03	0.08		0.16
2000	0.52		0.52	0.13		0.03	0.09		0.15
2001	0.52		0.52	0.12		0.03	0.08		0.15
2002	0.53		0.54	0.12		0.03	0.08		0.13
2003	0.53		0.56	0.11		0.03	0.08		0.11
2004	0.52	0.25	0.54	0.12	0.04	0.03	0.08	0.17	0.12
2005	0.51	0.26	0.51	0.12	0.04	0.03	0.09	0.16	0.14
2006	0.52	0.27	0.49	0.12	0.04	0.03	0.08	0.15	0.14
2007	0.54	0.31	0.50	0.12	0.04	0.03	0.07	0.13	0.13
2008	0.58	0.39	0.56	0.10	0.03	0.03	0.07	0.11	0.10
2009	0.57	0.41	0.55	0.11	0.03	0.03	0.07	0.12	0.10
2010	0.54	0.37	0.51	0.12	0.04	0.02	0.07	0.13	0.11
2011	0.52	0.34	0.48	0.13	0.04	0.03	0.08	0.14	0.13
2012	0.46	0.26	0.37	0.15	0.05	0.04	0.09	0.16	0.18
2013	0.46	0.26	0.38	0.15	0.05	0.05	0.09	0.16	0.17
2014	0.45	0.27	0.38	0.15	0.05	0.05	0.09	0.17	0.17
Δ14-95	0.03		-0.05	-0.01		0.02	-0.01		0.00
Δ14-08	-0.13	-0.13	-0.17	0.05	0.03	0.03	0.03	0.06	0.07
Δ08-95	0.16		0.12	-0.06		-0.01	-0.04		-0.07

The table above suggests two periods with clear distinctions. The first is a period of decreasing heterogeneity with the EA in all three groups of countries up to 2009, at which point the trend reverses and we observe increasing heterogeneity in the NMS and OMS, as well as among the EA countries. The NMS have exhibited decreased heterogeneity with the EA since the enlargement in 2004, which manifests itself mainly in the increased importance in the common EA factor and, to a lesser extent, in EA sector specific factors. The EA factors explained 44 percent of variance for the NMS in 2009 and closed the gap to the OMS to less than 15 p.p., while it was almost 30 p.p. in 2004.

After the beginning of the financial crisis the heterogeneity, measured in terms of the importance of common EA and sector specific factors, increased. The importance of the common EA factor for the NMS decreased by 14 p.p. and for the OMS by 17 p.p. This was partly offset by the increased importance of the sector specific factors, but the overall increase in heterogeneity still prevailed.

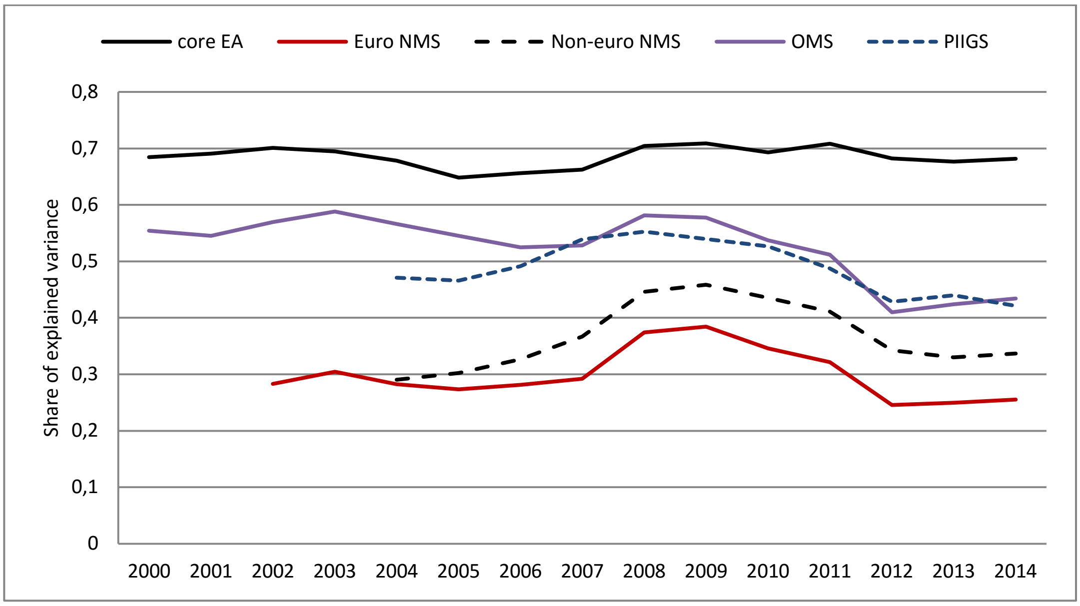
The other side of the story deals with the country specific factors effects that increased for the NMS and OMS in this second period, but declined in the first period. An increase in country specific factor importance can only be observed for the NMS and OMS, while for the EA countries there was no significant shift as they remained quite stable throughout both periods. The common EA factor has decreased in the EA countries, but it is mainly offset by an increase in the importance of sector specific factors.

The next disaggregation is based on the groups of countries according to membership of the EMU for new member states and on the division of EA countries between core EA countries and the periphery countries which have been worst affected by the recession.

- Core EA (AT, BE, DE, FR, NL),
- Periphery EA (PT, IE, IT, EL, ES),
- Euro NMS (EE, SI, SK),
- OMS (UK, SE, DK),
- Non-euro NMS (BG, HU, LT, PL, RO)

In Figure 21 we show the combined effects of common euro area and euro area sector specific factors, i.e. EA factors for these groups of countries. The inclusion of Greece in the sample of periphery EA countries limits the time interval, with the results for 2004 onwards, while the inclusion of Austria in the core EA sample limits the interval to 2000 and onwards.

Figure 21. Combined effects of common EA and sector specific factors on output growth in manufacturing for selected groups of countries.



Note. Annual averages of the share of explained variance.

As in the previous country aggregation, we can split the time interval of the results into two periods. In the first period, we observed a decreasing heterogeneity in the EU up to 2009 and increasing heterogeneity in the second period after 2009. The OMS and core EA, however, also experienced a decreasing trend in the importance of EA factors in part of the first period.

As one would expect, the degree of synchronisation between the manufacturing sectors in periphery countries with the EA is lower than that of the core EA countries in the sample. However, we should mention that this is mainly a consequence of the low degree of synchronisation of Ireland, Greece, and Portugal, whereas Spain and Italy are closer to the core EA countries. Periphery countries, as a group, are synchronised similarly with the EA to how the OMS are.

Surprisingly, Slovenia, Slovakia and Estonia, which entered the EA in 2007, 2009 and 2011, respectively, experienced a lower share of variance explained by EA factors than the other new member states. Poland and the Czech Republic are the countries among the new member states that have contributed to higher synchronisation with the EA. Up to 2009, the euro NMS seemed to close the gap with the EA; however, in the second period, the gap opened up even more. Estonia and Slovenia were among the countries with the highest GDP loss in the recession.

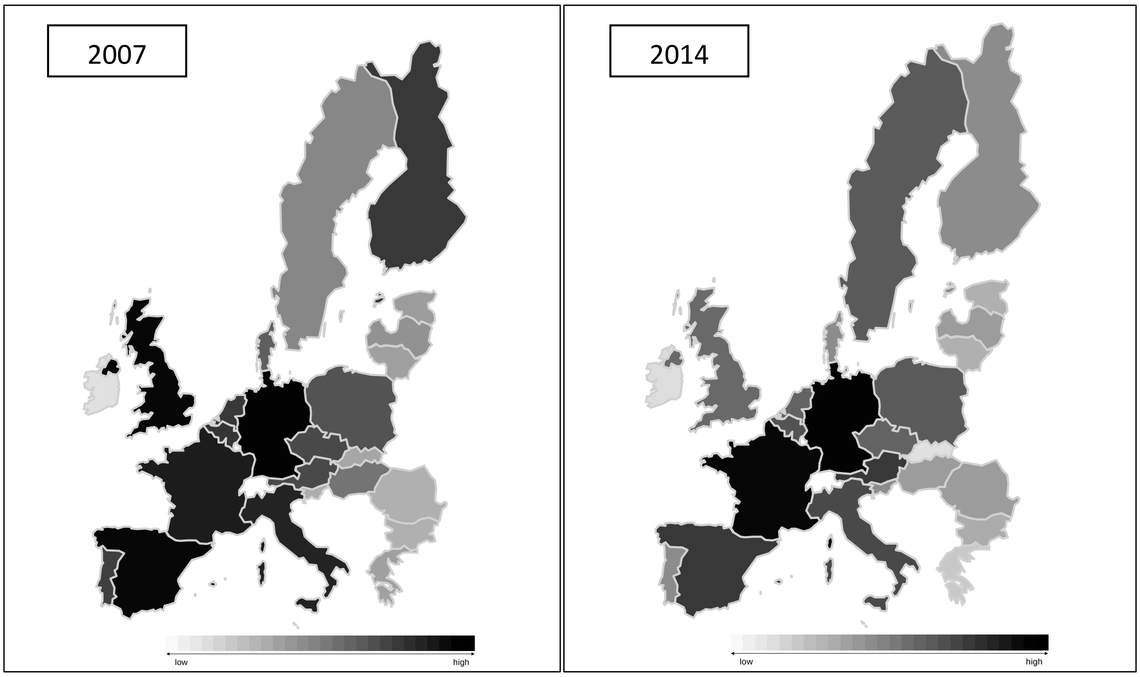
When comparing the euro NMS with the rest of the NMS, we find it difficult to see any effect resulting from the adoption of the euro on the synchronisation of the manufacturing sector's business cycles at this level of country aggregation. There may be signs in the 2007-2009 closing of the gap with the rest of the NMS, but this requires further, more detailed evaluation.

3.6.2 Geographical differences in factor importance – static view

In this section we present the results for individual countries for selected years.[79] In Figures 22 through 24 we show the proportion of the explained variance by common EA, sector specific and country specific factors for two periods, one year before the large recession and the last year of our observations, 2007 and 2014 respectively.

[79] Tables with complete results are provided in Appendix A, Tables A5–A7.

Figure 22. Share of variance of output growth in manufacturing explained by the common EA factor before and after the financial crisis.



Note. Annual averages, T=50. Maximum on the scale low to high is 70 %.

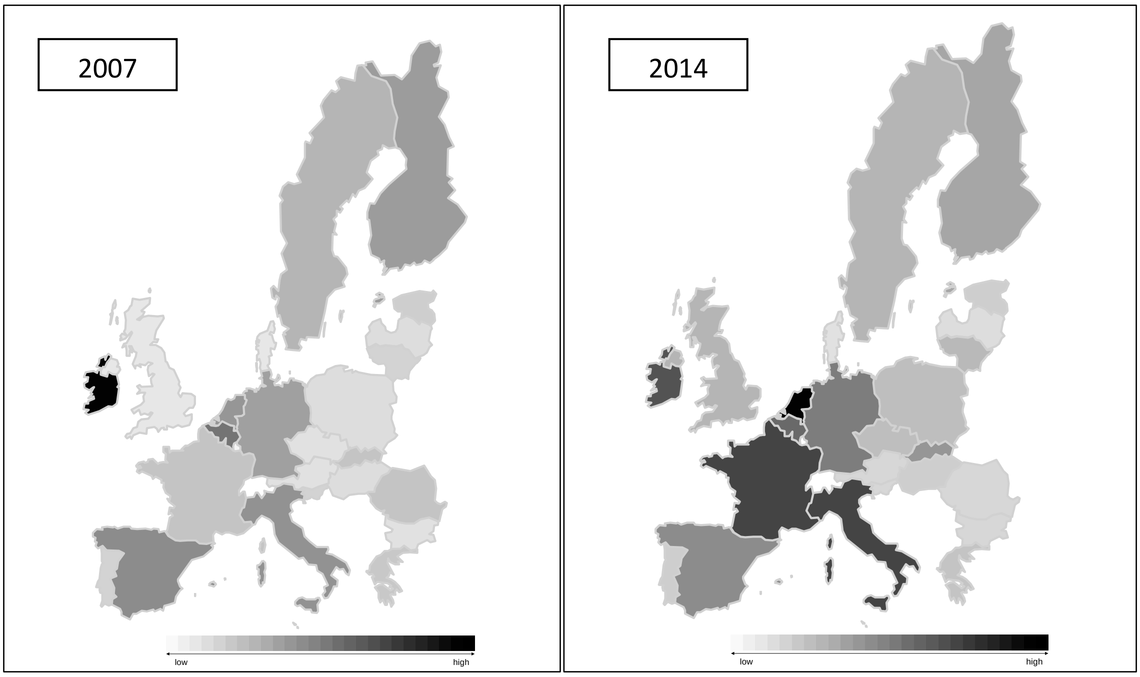
As can be seen from the figure above, the share of variance explained by the common EA factor has changed in the majority of countries.

In 2007 all the founding EA countries, apart from Ireland, exhibited a share of explained variance by the common EA factor of over 50 percent. Interestingly, among the OMS, the common EA factor is the most important for the UK, lagging only behind Germany in terms of variance explained. The common EA factor is less important for Denmark, while it is even lower for Sweden, with the factor's importance on the level of NMS. NMS have generally less important common EA factors. Only the Czech Republic and Poland are close to levels of the founding EA countries. Interestingly, Slovakia and Slovenia, members that joined the EA in 2007 and 2009, respectively, are among the countries which exhibit the lowest importance of the common EA factor.

In 2014 the proportion of variance explained by the common EA factor was lower in almost every country. The exceptions were Austria, Sweden, Romania and Slovenia. The "core" of the EA has been minimised to France and Germany, as the only countries with over 60 percent of the variance explained by the common EA factor.

Figure 23 also depicts the lower synchronisation of periphery countries, measured in terms of the importance of the common EA factor.

Figure 23. Share of variance of output growth in manufacturing explained by EA sector specific factors before and after the financial crisis.

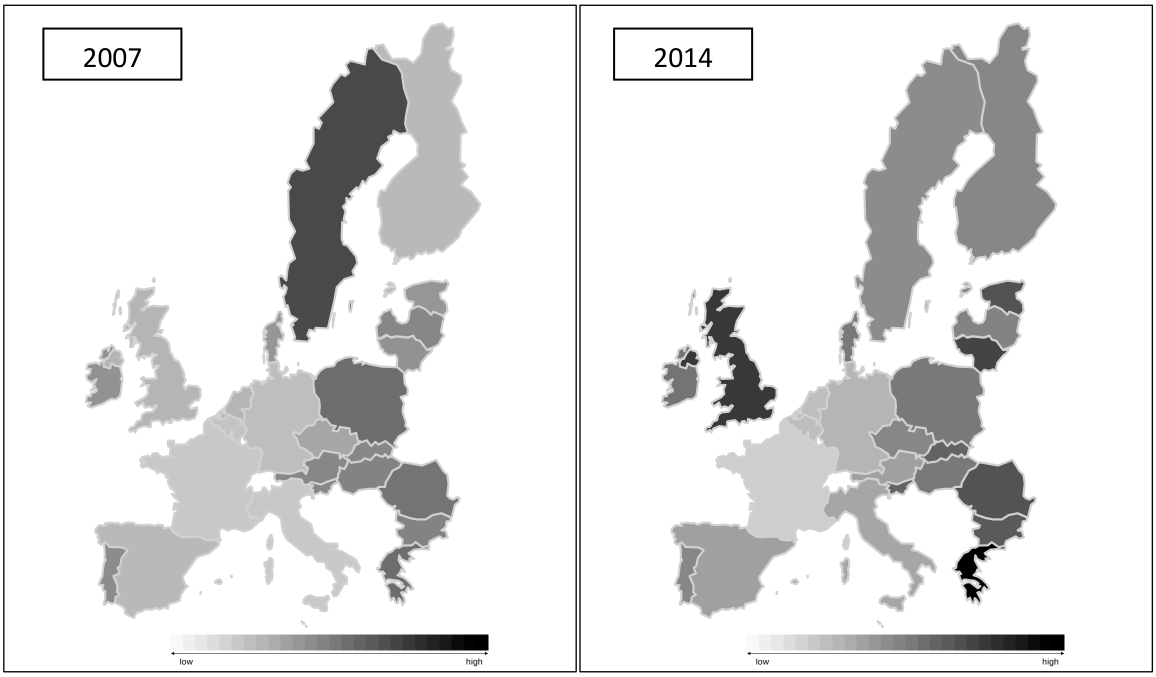


Note. Annual averages, T=50. Maximum on the scale low to high is 25 %.

Sector specific factors explain less variance than the common EA factor. In 2007, the average across all countries was only 6 percent, and 8 percent in 2014. For some countries, sector specific factors are more important in explaining variance in the industrial production index. The importance of the factors also changes over time. Ireland is practically the only country with a constant high importance of the factors, explaining around 20 percent of the variance throughout the observed period. A similar level of importance may be observed for Italy and the Netherlands, but only in the last couple of years. Among the NMS, sector specific factors are the most important for Slovakia, with 10 percent of explained variance, which is on the levels of some EA countries that were included in the calculation process of sector specific factors.[80]

[80] The lower importance of sector specific factors for countries that are not included in the factor calculations indicates that we must exercise caution when interpreting the results of this exercise, especially when comparing countries that are not in our EA sample to those in the sample. The results of this section can be compared to the results on a shorter time scale with Austria and Portugal included in the EA sample, which is reported in section B.5 in Appendix B.

Figure 24. Share of variance of output growth in manufacturing explained by the country specific factors before and after the financial crisis.



Note. Annual averages, T=50. Maximum on the scale low to high is 30 %.

In a way, the importance of country specific factors reflects the importance of EA factors. Countries with a smaller proportion of variance explained by EA factors generally exhibit a higher importance for country specific factors. Sweden and Poland stand out in the years prior to the major recession, since country specific factors in these countries are more important than for other countries with a similar importance of EA factors. The recession caused increases in the importance of country specific factors in almost all the countries. France, the Netherlands, Sweden, Lithuania and Poland are countries for which this importance decreased in absolute terms, while the UK and Greece are the countries with the highest absolute increase in the importance of country specific factors.

In the more detailed results (Tables A5–A7 in Appendix A) we can observe similarities between Sweden and Finland, which joined the EU in 1995, to the NMS that joined the EU in 2004 or 2007. The importance of the common EA factor increased after accession to the EU in the majority of the countries, apart from Slovakia and Slovenia. Prior to acceding to the EU, NMS from Central Europe were more synchronised with the EA than was the case with the Baltic countries, Romania and Bulgaria.

3.6.3 Sectoral differences

As stated in the previous sections, there are differences in the degree of synchronisation across manufacturing subsectors. There are differences in the dimensions of countries and groups of countries as well. Not surprisingly, the highest share of variance observed by the EA factors (the common EA factor and sector specific factors) can be observed for EA countries. The most heterogeneous subsector in the EA is the coke and refined fuel products subsector, for which EA factors explain only 25 percent of the variance in 2014. There are three subsectors, for which the EA factors explain more than 60 percent of the variance in a specific subsector; food, rubber and plastic, and furniture.

Old member states are more closely synchronised with EA countries than the new member states in all subsectors, with the exception of the textile and wood subsectors (Table 11). In the food sector, the EA factors account for a greater proportion of the explained variance in OMS (DK, SE and UK) than for the EA countries.

The new member states that joined the EU in 2004 (NMS 2004) have, on average, higher shares of variance explained by EA factors than those countries which joined the EU three years later (NMS 2007, BG and RO). However, on the disaggregated sector level, the NMS of 2007 have some of their sectors more closely synchronised with the EA than the NMS of 2004: textile, leather, rubber and plastic, machinery, and transport equipment.

Table 11. Proportion of variance of output growth in manufacturing explained by EA factors by groups of countries and subsector. Annual average for 2014 of the share of total variance.

Subsector	EA11	EA8	NMS 2004	NMS 2007	OMS
Food	0.70	0.71	0.60	0.35	0.76
Textile	0.51	0.59	0.31	0.38	0.22
Leather	0.45	0.50	0.17	0.27	0.29
Wood	0.58	0.63	0.45	0.20	0.20
Paper and printing	0.58	0.64	0.38	0.23	0.57
Coke	0.25	0.34	0.05	0.01	0.11
Chemicals and pharmaceuticals	0.54	0.61	0.24	0.16	0.40
Rubber and plastic	0.68	0.74	0.41	0.46	0.49
Other non-metallic	0.59	0.70	0.37	0.21	0.55
Metals	0.58	0.61	0.31	0.08	0.50
Electronic	0.53	0.62	0.31	0.24	0.41
Machinery	0.46	0.50	0.27	0.30	0.37
Transport	0.43	0.51	0.19	0.32	0.43
Furniture	0.60	0.72	0.39	0.39	0.53
Mean*	0.53	0.60	0.32	0.26	0.42
St.dev.	0.11	0.11	0.13	0.12	0.17

Note. EA11 (AT, BE, DE, EL, ES, FI, FR, IE, IT, NL, PT), EA8 (BE, DE, ES, FI, FR, IE, IT, NL), NMS2004 (CZ, EE, HU, LT, LV, PL, SI, SK), NMS2007 (RO, BG), OMS (DK, SE, UK).
*Unweighted mean

There are also differences in the evolution over time across the sectors and groups of countries. The main finding of the detailed subsector analysis was that the evolution of the degree of synchronisation was not uniform across the subsectors.[81] In more than half of the sectors, the degree of synchronisation of our EA-8 sample countries gradually increased prior to the establishment of the EMU in 1999. However, when we investigate the evolution of the degree of synchronisation of OMS with the EA business cycle in these subsectors, we also observed increased synchronisation. Exceptions to this are the following sectors: chemicals and pharmaceuticals, machinery, and furniture where the gap between EA and OMS synchronisation with EA business cycles opened after the introduction of the euro. There is therefore no uniform effect of the EMU on the heterogeneity of the EA countries. There is, however, a uniform effect that can be attributed to the euro in the periods after the financial crisis in 2008 and the subsequent sovereign debt crisis in 2011. In the majority of the subsectors, the degree of synchronisation in the EA countries decreased when compared to pre-crisis levels. Moreover, the gap with the OMS also opened up. The only exceptions were the food and transport subsectors.

3.6.4 Slovenia

There are a number of reasons for choosing Slovenia for broader analysis, one of which is that Slovenia has a relatively good dataset, compared to other new member states. Moreover, it underwent two major changes during the observed period. One was its accession to the EU in 2004 and the other was its adoption of the euro in 2007, the first new Member State to do so.

Our dataset for Slovenia consists of 13 sectors, with data beginning in 1998.[82] The first results are reported for 2002(2) in the case of a rolling window of size 50. This gives us over two years of results prior to Slovenia's accession to the EU in 2004(5).

We examine the proportion of variance for the Slovenian subsectors accounted for by EA factors and country specific factor. We also present the results for Slovenia using the EU series in constructing common EU and EU sector specific factors (section 3.5). As depicted in Figure 25, the evolution of the importance of common EA and common EU factors for Slovenia are very similar, with the EU common factor explaining slightly more of the variance in the Slovenian series. EU sector specific factors are also more important than those which are EA sector specific. Consequently, we find country specific factor to be less important, when obtained using EU factors in extracting the EU wide component from the series. Still, even in this case, country specific factors are more important than EU sector specific factors in most of the periods examined using rolling window with T=50.

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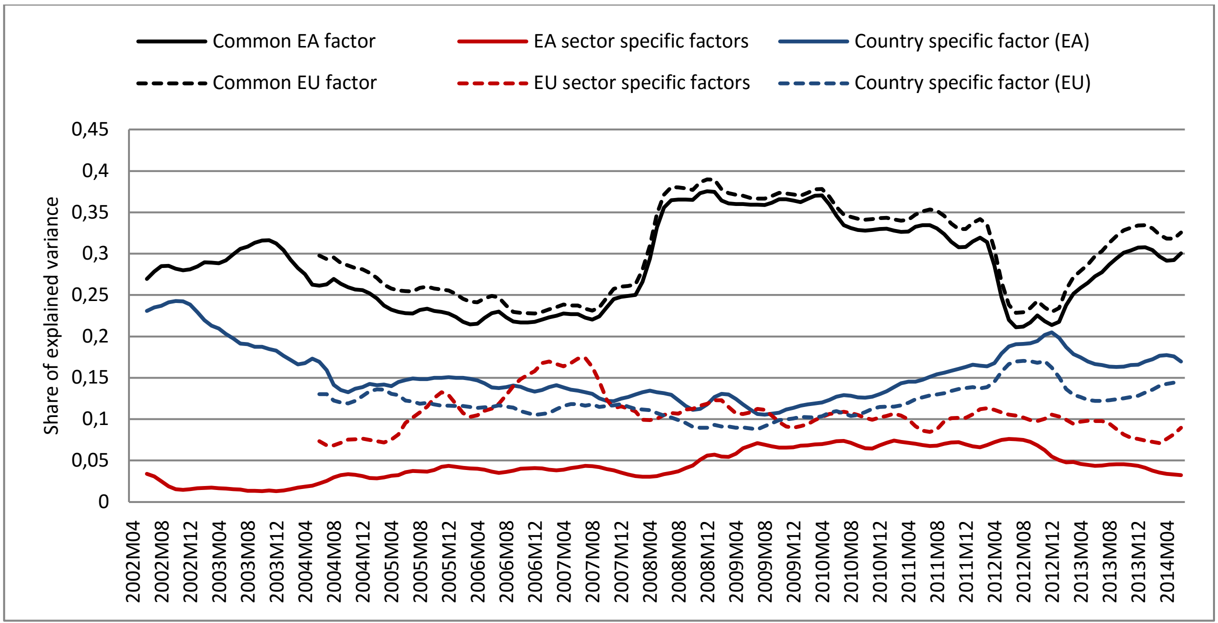
[81] This is, to a certain extent, in line with the findings of Herwartz and Weber (2010) who imply that the gradual and spread out adjustment of the currency union's effect on trade may simply be a consequence of different sectors adjusting at distinct times.

[82] We do not examine the sector of manufacture of coke and refined petroleum products for Slovenia due to missing data.

Figure 25. Share of variance of aggregate Slovenian manufacturing output growth explained by the common EA (EU), EA (EU) sector specific and the country specific factors.



Note. T=50.

If we examine the amount of variance of the Slovenian series panel explained by the common EA factor, and the EA sector specific factor for each subsector and country specific factor, we can observe that the importance of the country specific factor had steadily declined by 2008. However, from the levels of 10 percent in 2008, the variance explained by the country specific factor rose to 20 percent in 2012 and was above 15 percent in the latest observed periods.

The importance of the common EA factor increased prior to joining the EU in 2004 and mainly in the period after joining the euro area, peaking at over 35 percent of the explained variance. However, in just two years, this importance had declined by more than 15 p.p. from the levels above 35 percent in 2010, reaching its lowest point at just above 20 percent in 2012. In the last observed year the common EA factor again gained some importance, exceeding 30 percent of the explained variance for the Slovenian dataset in the last observed periods. This was still well below EA levels, and explained 45 percent of the variance of our EA dataset. This difference of 15 percentage points can be compared to that from the beginning of the time interval, in 2002, when the difference was 25 percentage points. The sector-specific factors had a relatively low explanatory power of around 5 percent, which is comparable to other non-EA countries. The share of unexplained variance for the last period showed almost 50 percent of unexplained variance for the Slovenian manufacturing sector dataset.

Sectors in Slovenia

As expected, there are considerable differences across subsectors. However, there seems to be a common trend in increasing the common EA factor influence and decreasing in the country specific effects in the period up to 2008. During the recession period, the common EA factor decreased, especially in the second dip after 2011, while the country specific effects increased. In recent periods, the common EA factor has gained some of its lost importance, while country specific factors persist at 15 percent.

The effects of EA sector specific factors are relatively low, accounting on average for less than 5 percent of the variance of a specific sector in Slovenia in the last year; however there are subsectors that show a higher effect of EA sector specific factors in some periods. For example, the food subsector has above 10 percent of variance explained after 2010, reaching even 24 percent in 2012 (Table B26 in Appendix B). Another example of a subsector with a high importance of sector specific factors is chemicals and pharmaceuticals with, on average, 15 percent of explained variance in the period 2009–2012.

Table 12. Variance of output growth in manufacturing explained by the EA common factor for subsectors in Slovenia, annual averages.

Subsector	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**Δ14-02**
Food	0.44	0.44	0.43	0.34	0.22	0.20	0.35	0.44	0.55	0.62	0.55	0.55	0.54	0.10
Textile	0.18	0.25	0.43	0.31	0.21	0.13	0.17	0.33	0.36	0.34	0.27	0.20	0.25	0.06
Leather	0.21	0.24	0.30	0.24	0.29	0.30	0.35	0.33	0.25	0.14	0.08	0.15	0.17	-0.05
Wood	0.33	0.33	0.22	0.26	0.29	0.42	0.60	0.56	0.47	0.42	0.29	0.25	0.34	0.00
Paper and printing	0.39	0.35	0.24	0.21	0.20	0.39	0.64	0.61	0.51	0.50	0.36	0.36	0.33	-0.06
Chemicals and pharmaceuticals	0.23	0.18	0.08	0.04	0.02	0.04	0.09	0.25	0.28	0.38	0.33	0.29	0.25	0.02
Rubber and plastic	0.31	0.33	0.35	0.33	0.40	0.42	0.60	0.69	0.67	0.52	0.31	0.19	0.22	-0.10
Other non-metallic	0.19	0.23	0.25	0.32	0.43	0.47	0.65	0.67	0.61	0.49	0.33	0.25	0.24	0.04
Metals	0.52	0.62	0.53	0.45	0.40	0.31	0.22	0.35	0.38	0.36	0.40	0.39	0.29	-0.24
Electronic	0.24	0.24	0.17	0.21	0.20	0.19	0.45	0.40	0.35	0.39	0.23	0.33	0.41	0.17
Machinery	0.30	0.36	0.30	0.39	0.29	0.20	0.26	0.24	0.27	0.31	0.41	0.61	0.60	0.30
Transport	0.23	0.23	0.23	0.16	0.15	0.15	0.22	0.14	0.15	0.20	0.17	0.36	0.39	0.15
Furniture	0.31	0.34	0.27	0.22	0.28	0.29	0.36	0.53	0.54	0.44	0.28	0.31	0.31	0.00
Mean*	0.30	0.32	0.29	0.27	0.26	0.27	0.38	0.43	0.41	0.39	0.31	0.33	0.33	0.03
St. dev.	0.10	0.12	0.12	0.11	0.11	0.13	0.19	0.17	0.16	0.13	0.12	0.13	0.13	0.02
Weighted mean**	0.32	0.39	0.40	0.39	0.36	0.30	0.27	0.42	0.48	0.45	0.36	0.33	0.34	0.01

Note. *Unweighted mean.
**Weighted with 2013 shares in value added for all periods.

In general we find EA sectors specific factors to be quite volatile on the level of individual subsectors for Slovenia. For this reason we show the variance explained by the common EA factor for subsectors in Table 12.[83] We find only four subsectors to exhibit a decrease of synchronisation with the euro area in the observed period, whereas nine subsectors exhibit an increase. On average, the degree of synchronisation only marginally increased.

The sectors that are most closely synchronised to our EA8 sample (measured by common EA factor importance) include the machinery and equipment, the manufacturing of food, beverages and tobacco, and electronic sectors.[84]

In Table 12 we also report change in the explained variance by the common EA factor from levels before the accession to the EU to levels in the most recent periods. We find four subsectors exhibiting a decrease in the degree of comovement with the euro area, whereas on average the degree of synchronisation increased for manufacturing subsectors in Slovenia.

Interesting years for observation are 2004, when Slovenia joins the EU, and 2007, when the euro is introduced in the country; however the synchronisation of the sectors might be a more gradual process and in some cases even subject to expectations.

As observed already with the aggregated results, the importance of the common EA factor decreased in the years after EU accession, and started to increase in 2007. On the subsector level, only the manufacture of rubber and plastic, and other non-metallic products, has increased the importance of the common EA factor in the years since EU accession. Since 2007, the EA common factor's importance has increased in the majority of subsectors; however, we cannot attribute this increase solely to the introduction of the euro, because synchronisation increased in the EU as a whole in these periods. The recession caused a loss of synchronisation with the EA in most of the subsectors in recent years. The subsectors that have stayed or even increased relative to pre-crisis levels include chemicals and pharmaceuticals, metals, machinery, and transport.

3.7 Heterogeneity of broader sectors in the EU

The manufacturing sector represents almost 20 percent of the total value added and employs about 14 percent of the workers in the EA17 economy, with noticeable differences across the countries. The economic importance of the manufacturing sector is higher, since it accounts for 75 percent of EU exports and each additional job in

[83] Tables B24 and B25 in section B.9 of Appendix B report the proportion of variance explained by EU and EA factors, respectively. We find EU sector specific factors to be more robust in importance for subsectors in Slovenia across different periods than EA sector specific factors.

[84] Burger and Rojec (2013) report the indices of inclusion in global supply chains for subsectors in Slovenia in 2012 and find the food and beverages subsector to be the least included in the global supply chains, while electronics, and machinery and equipment have high indices.

manufacturing creates 0.5–2 jobs in other sectors (Rueda-Cantuche, Sousa, Andreoni, & Arto, 2012).

The studies of business cycle synchronisation that are based on the analysis of a cyclical component generally use the cyclical component of industrial production, rather than GDP. This is supported by the close correlation of industrial production with GDP and the convenient monthly frequency of the data (EC, 2008).

However, even though the focus of the thesis is the manufacturing sector, we cannot neglect the importance of other sectors in the economy, especially in the context of the financial and subsequent sovereign debt crisis. Increased capital flows to periphery euro area countries in the pre-crisis period, as a consequence of divergence in the unit labour costs and consequently diverging trade balances in the euro area, stimulated economic growth across broader sectors of the economy.

In order to investigate the business cycle synchronisation for the overall economy, we perform an additional analysis using national accounts quarterly data on value added disaggregated to 10 sectors.[85] Quarterly data limit our ability to inspect output growth synchronisation in time by means of a rolling window methodology. Instead, we turn to investigating two distinct periods, the pre-crisis period, 2001 – 2007, and the period marked by financial and subsequent sovereign debt crisis, 2008 – 2014.

We apply the hierarchical DFM to estimate the common EA factor, sector specific factors and country specific factors for both periods. We report the proportion of explained variance by the factors in Table 13.

Table 13. Proportion of variance of value added growth explained by factors for the broad sectors for two distinct periods, by country and groups of countries.

	2001-2007				**2008-2014**			
	Common EA factor	**EA factors***	**Country specific factor**	**Unexplained variance**	**Common EA factor**	**EA factors***	**Country specific factor**	**Unexplained variance**
EA mean	*0.14*	*0.33*	*0.17*	*0.51*	*0.22*	*0.38*	*0.16*	*0.46*
Core mean	*0.15*	*0.40*	*0.16*	*0.44*	*0.28*	*0.46*	*0.14*	*0.40*
AT	0.09	0.19	0.20	0.61	0.23	0.28	0.15	0.57
BE	0.20	0.57	0.11	0.31	0.32	0.53	0.13	0.35
DE	0.13	0.48	0.16	0.37	0.30	0.58	0.10	0.32
FR	0.26	0.43	0.18	0.40	0.34	0.46	0.18	0.36
NL	0.08	0.32	0.14	0.54	0.22	0.45	0.13	0.42
FI	0.14	0.37	0.14	0.49	0.28	0.48	0.10	0.43
Periphery mean	*0.12*	*0.24*	*0.18*	*0.58*	*0.15*	*0.28*	*0.19*	*0.53*

(table continues)

[85] National accounts data in accordance with ESA2010 classification, disaggregated to 10 sectors according to NACE Rev. 2 classification of economic activity.

(continued)

	2001-2007				2008-2014			
	Common EA factor	**EA factors***	**Country specific factor**	**Unexplained variance**	**Common EA factor**	**EA factors***	**Country specific factor**	**Unexplained variance**
EL	0.07	0.14	0.19	0.67	0.13	0.18	0.21	0.60
ES	0.11	0.34	0.15	0.51	0.17	0.42	0.14	0.43
IT	0.22	0.40	0.15	0.45	0.24	0.51	0.11	0.38
PT	0.12	0.20	0.21	0.59	0.14	0.19	0.22	0.59
IE	0.06	0.14	0.19	0.67	0.05	0.08	0.25	0.67
NMS mean	*0.06*	*0.13*	*0.24*	*0.62*	*0.15*	*0.21*	*0.22*	*0.57*
NMS 2004 mean	*0.07*	*0.13*	*0.24*	*0.62*	*0.17*	*0.24*	*0.22*	*0.55*
CZ	0.03	0.09	0.25	0.67	0.14	0.20	0.23	0.57
HU	0.06	0.14	0.28	0.58	0.21	0.26	0.21	0.53
LV	0.09	0.12	0.24	0.64	0.27	0.33	0.24	0.43
SI	0.09	0.20	0.22	0.58	0.28	0.33	0.16	0.51
SK	0.04	0.11	0.23	0.66	0.12	0.16	0.25	0.59
EE	0.07	0.16	0.23	0.61	0.11	0.18	0.21	0.61
PL					0.11	0.20	0.21	0.59
NMS 2007 mean	*0.05*	*0.13*	*0.25*	*0.62*	*0.05*	*0.11*	*0.25*	*0.63*
RO	0.06	0.15	0.25	0.60	0.06	0.12	0.26	0.61
BG	0.04	0.11	0.24	0.65	0.04	0.10	0.24	0.66
OMS mean	*0.11*	*0.17*	*0.20*	*0.62*	*0.20*	*0.25*	*0.17*	*0.58*
DK	0.06	0.09	0.18	0.73	0.09	0.18	0.17	0.65
SE	0.14	0.22	0.24	0.54	0.22	0.26	0.17	0.57
UK	0.12	0.21	0.20	0.59	0.28	0.32	0.17	0.51

Note. *Combined effect of EA common and sector specific factors.

The obtained results confirm lower level of synchronisation of business cycles for the periphery countries in the euro area compared to the core countries. On average, the EA factors explain 40 percent of variance in the pre-crisis period and 46 percent in the depression period for the core euro area countries (average explained variation of the EA factors over respective periods in case of the manufacturing sector is 66 and 69 percent). The explained variance for the periphery countries is 24 percent for the pre-crisis period and 28 percent for the last period (49 and 44 percent for the manufacturing sector). However, among the periphery countries, Italy and Spain are closer to the core countries in terms of proportion of variance explained by the EA factors, as we also observe in the case of manufacturing sector.

We also find lower levels of synchronisation for the new member states and the old member states that are not a part of the euro area, with proportion of variance explained in the last period at 21 and 25 percent, respectively. In the case of manufacturing sector, the average proportion of variance explained for the OMS in the last period is 44 percent and for the new member states 32 percent. We find that both on the level of broader sectors as well as in the case of the manufacturing sector, the EA factors' importance for the OMS are at similar level as for the periphery countries, while the EA factors are less important for the NMS.

We further inspect sectoral differences for the core and periphery euro area countries. We observe industry, and wholesale and retail sector to exhibit the greatest importance of the common EA factor in the first time period for the core euro area countries, while in the second time period these sectors are joined by professional services sector.

Table 14. Proportion of variance of value added growth explained by factors for core euro area countries for two distinct periods, by broad sector.

	2001-2008			2008-2014		
	Common EA factor	**EA factors***	**Country specific factor**	**Common EA factor**	**EA factors***	**Country specific factor**
Agriculture	0.13	0.39	0.17	0.10	0.22	0.14
Industry	0.30	0.50	0.13	0.57	0.67	0.11
Construction	0.18	0.47	0.14	0.16	0.48	0.14
Wholesale and retail	0.22	0.45	0.10	0.53	0.64	0.14
ITC	0.17	0.37	0.13	0.22	0.49	0.08
Finance	0.08	0.31	0.19	0.10	0.35	0.17
Real estate	0.08	0.38	0.16	0.24	0.49	0.09
Professional services	0.15	0.35	0.21	0.52	0.61	0.12
Public services	0.10	0.37	0.20	0.05	0.21	0.26
Arts, entertainment and recreation	0.12	0.38	0.14	0.32	0.43	0.13
Mean**	0.15	0.40	0.16	0.28	0.46	0.14
St. dev.	0.07	0.06	0.03	0.20	0.16	0.05

Note. *Combined effect of EA common and sector specific factors. **Unweighted mean.

We find the proportion of explained variance by the EA factors to decrease only in the sectors of agriculture and public services in the second period compared to the pre-crisis period, while other sectors exhibit increasing importance of EA factors.

In the periphery euro area countries, we also find the sector of wholesale and retail to exhibit the greatest importance of the common factor in the pre-crisis period, while the common factor's importance for other sectors is considerably smaller than for the core euro area countries (Table 15). In the second period, the sector of industry has the greatest share of variance explained by the common factor.

In the periphery euro area countries, the increase in the proportion of variance explained by the EA factors in the second period is not as high as in the case of core euro area countries. Sectors of agriculture, finance, and real estate exhibit decreased importance, while the only sector with considerable increase of the EA factors' importance is the sector of industry.

Table 15. Proportion of variance of value added growth explained by factors for periphery euro area countries for two distinct periods, by broad sector.

	2001-2008			2008-2014		
	Common EA factor	**EA factors***	**Country specific factor**	**Common EA factor**	**EA factors***	**Country specific factor**
Agriculture	0.07	0.31	0.22	0.08	0.30	0.13
Industry	0.15	0.32	0.21	0.49	0.55	0.21
Construction	0.09	0.15	0.05	0.07	0.21	0.17
Wholesale and retail	0.30	0.42	0.05	0.39	0.42	0.13
ITC	0.06	0.16	0.13	0.03	0.17	0.15
Finance	0.18	0.25	0.22	0.11	0.23	0.16
Real estate	0.08	0.20	0.24	0.04	0.18	0.31
Professional services	0.03	0.19	0.22	0.12	0.24	0.13
Public services	0.04	0.17	0.24	0.03	0.21	0.19
Arts, entertainment and recreation	0.18	0.27	0.21	0.11	0.27	0.30
Mean**	0.12	0.24	0.18	0.15	0.28	0.19
St. dev.	0.08	0.09	0.08	0.16	0.12	0.07

Note. *Combined effect of EA common and sector specific factors. **Unweighted mean.

Apart from the qualitative difference of the data, the results are not directly comparable to the results of the previous sections due to different frequency of the data. As discussed before, the monthly frequency of the data contains more short term fluctuations than the quarterly national accounts data used in this section. However, if we compare the results to the results of the year-on-year industrial production output growth, we also find similar evolution in time.

Evidence from the broader sectors of the economy confirms the results obtained in the previous sections, using the data from the manufacturing sector. The main conclusions about the synchronisation of the manufacturing sector and economy wide business cycles in the euro area correspond. The degree of synchronisation in the core countries is higher than in the periphery euro area countries already in the pre-crisis period. The exceptions are Italy and, to some extent, Spain that reach the degree of synchronisation of the core euro area countries. These differences reflect the build-up of imbalances in the euro area in the pre-crisis period.

3.8 Summary

In this chapter we analyse heterogeneity in the EA and EU manufacturing sectors using data for 14 manufacturing subsectors for EA and EU countries. We show that the manufacturing sector business cycle is, to a large extent, connected to the GDP business cycle, thereby substantiating the importance of the analysis of the manufacturing sector. We point out some possible sources of heterogeneity in the manufacturing sectors. One which stands out is the composition of the manufacturing sector in the EA, the EU, and individual countries.

It is difficult to identify a specific underlying factor of output fluctuations as being country, or sector specific, or perhaps common in nature. For example, a change in the price of wheat can have symmetric effects on the countries (assuming they have the same manufacturing sector structures); however, at the level of subsectors, the food production sector is affected the most. Some underlying factors of output fluctuations can be linked to country specificities, such as the share of labour input and costs. In the absence of large scale labour mobility in Europe, this can also contribute to asymmetries. Differences in productivity levels and the cost of capital and intermediates are another source of heterogeneity, both for countries, and subsectors in a given country.

In terms of descriptive statistics we find that the founding EA countries are better synchronised with the euro area business cycle, measured using correlation coefficients. However, some of the new member states and old member states have a higher correlation to euro area output fluctuation than Ireland, Portugal and Greece. Variance analysis shows that the variability between countries is even more pronounced on a subsector level for the majority of the subsectors. It is more pronounced in the EU compared to the euro area.

Next, we use a DFM approach to decompose the output growth variation in a specific subsector in a given country into four source levels: common, sector specific, country specific, and an idiosyncratic component that is country-sector specific. We divide our research in three separate sections. In the first one we deal with 8 founding euro area countries[86], in the second with 24 EU countries and in the last we analyse 24 EU countries' synchronisation with the euro area business cycle.

Heterogeneity in the euro area

We find a substantial synchronisation of the manufacturing on the level of subsectors and countries in the euro area. The common EA factor accounts for around half of the variance in our euro area dataset.

Sector specific factors account, on average, for 13 percent of the variance in the euro area, thereby representing an important part in the formation of the symmetric part of the variance. In the last observed period they account for 15 percent of the variance. We must, however, exercise caution in interpreting sector specific factors as symmetric from a policy point of view. Even though sector specific factors are symmetric on the subsector level, on an aggregated level of manufacturing sector they can cause asymmetries due to the different composition of manufacturing sector across the countries.

[86] Excluding Austria, Luxembourg and Portugal.

Country specific factors prove not to be very important for output volatility as they explain less than 10 percent of the total variance in the EA, 9 percent in the last observed period.

We find that output fluctuations (a)symmetry is not constant over time. Contribution of the common EA factor had a rising trend in the period before the financial crisis in 2008 and a sharply declining trend afterwards. On the other hand, sector specific factors exhibited a reverse pattern thus partly offsetting the drop in the common EA factor. Combined, the two groups of factors, forming the symmetric part of output variation, had a slightly declining trend since 2008, while country specific factors, the asymmetric part of output variation, had a growing trend.

Based on the evidence from the manufacturing sector in EA countries, we cannot confirm the hypothesis that the EMU increased business cycle synchronisation. Our results do not show a uniform positive effect of euro adoption at a specific time in the degree of business cycle synchronisation in manufacturing. Instead, an increasing degree of synchronisation could already be observed in the years before the euro's introduction in 1999, reaching 65 percent of the explained variance by the EA factors in 1998. The proportion of explained variance stayed at around these levels up to 2006. Afterwards the degree of synchronisation increased, reaching 68 percent of the explained variance in 2008 and 2009. What followed was a huge drop in the degree of synchronisation in recent years, the period characterised by the major recession in the EA. In the last observed period, the synchronisation was still high, at 61 percent, but by historical standards, was on the level of the pre-euro period.

As the data on the relative size of subsectors on a country level shows, there are considerable differences in the importance of subsectors in the manufacturing across the countries. Thereby, sector specific factors are symmetric only conditionally, looking from a point of a given sector in a certain country. We have to be careful in interpreting the EA sector specific factors as symmetric in terms of an effect on the total output, especially for countries that have considerably different compositions of the manufacturing sector.

In the context of presenting idiosyncratic risks in the manufacturing sector which policy makers in the euro area should take into account, we find the four countries from Europe's periphery that pose the greatest challenge to common euro area policies. The idiosyncratic component, measured by the variance attributed to country specific factors and country-sector specific effects, was especially large for Finland, Portugal, Ireland and Greece for the last observed periods. We discuss the implications of the results more in detail later in our thesis, when we compare also the results obtained for other EU countries and we are able to put our results for the euro area in the broader perspective.

Heterogeneity in the EU

We continue our investigation with the EU countries. We have shorter series of industrial production indices for the EU countries, especially for NMS and Greece. We choose to perform four different analyses, grouping the countries by their data series lengths. For the largest group, which is composed of 24 EU countries, we have data available from 2000(1).

We find that adding more countries, especially NMS countries, to the analysis decreases the level of synchronisation, measured in terms of the importance of EU factors. This is mostly a consequence of decreasing importance of the common EU factor, while the importance of EU sector specific factors does not decrease substantially by adding additional countries to the sample. Similarly, the average country specific factors importance increases by adding more countries to the sample, but not enough to offset the lower EU factors' importance. The larger group also has, on average, larger country-sector specific effects.

For the narrowest group, EU factors explained 57 percent of variance in the last observed period of which 14 percent was accounted for by sector specific factors. A total of 47 percent of variance of the group with 24 countries was attributed to EU factors, of which 11 percent was by sector specific factors. The evolution over time of the EU factors was comparable to the evolution of EA factors discussed previously. EU factors exhibited an increasing trend until 2009, when the trend reversed and synchronisation in the last year was well below the average synchronisation before the major recession.

From the manufacturing sector business cycle perspective, our results show that the EU is less suitable for a currency area than founding euro area countries. This is despite, in comparison to the periods before 2004, the degree of synchronisation in the EU being closer to the degree of synchronisation in our EA dataset in the last periods observed. In fact, the importance of EU factors increased quite rapidly until 2009 and would have almost reached the levels of the EA factors if the trend had continued for the next five years. Instead, after the financial crisis and subsequent sovereign debt crisis, the EU factor's importance decreased even more than the importance of EA factors.

Synchronisation of EU countries with the euro area

Our next analysis attempts to estimate the synchronisation of EU countries with the euro area business cycle in manufacturing. We do this by decomposing the variance of a country dataset into common EA, EA sectors specific, country specific and country-sector specific effects. For the euro area components we use common EA and sector specific factors extracted from the euro area dataset (8 countries) and investigate the proportion of variance that these factors explain for individual EU countries. We use the same approach with a rolling window with T=50 to estimate the evolution of factors' importance over time.

The results of this exercise are consistent with the results we obtain in the EU factors analysis. The EA factors explain 4 percent less variance for the EU sample than EU factors, mainly due to less important EA sector specific factors.

Anylsis of the groups of countries shows that EA factors are most important in explaining variance for the EA countries, followed by the OMS and lastly the NMS. Synchronisation fell during the most recent recession for all groups of countries, but relatively more so for the OMS. Even though synchronisation also fell for the NMS, this group closed the gap to the EA levels of synchronisation over time. We find sector specific factors to be the least important in explaining the variance for the NMS and OMS, while the least important factors for the euro area are the country specific factors. When comparing the results for the importance of EA sector specific to EU sector specific factors for the NMS and OMS, we find that EU sector specific factors are more important. This might be a consequence of the euro area sectors' specificities or EA sector specific factors incorporating some country-sector properties due to the low number of series used in the construction of EA sector specific countries.

If we split the euro area into periphery and core euro area countries, we find even higher synchronisation of the core countries, with around 70 percent of the variance explained by EA factors. For the periphery countries, this is just over 40 percent during the recent major recession, but we identify Ireland and Greece to be the main contributors to the low EA factors' importance. Ireland, in particular, is a clear outlier, with less than 10 percent of the variance explained by the common EA factor. On the other hand, EA factors are as important in Spain and Italy as they are in the core countries.

We also find the NMS countries that joined the EMU to be less synchronised with the euro area than other NMS countries which still have their own currencies. This is partly a consequence of the below average synchronisation of Slovakia, and the relatively high synchronisation of Poland and the Czech Republic in the non-euro NMS group. When comparing the importance of EA factors for the periods prior to joining the EA, we find that only Portugal, Ireland and possibly Greece[87] had a comparable degree of synchronisation to Slovenia, Slovakia, Estonia and Latvia at the time of joining the euro area. According to our results, the NMS countries that would be more suitable as potential euro members are the Czech Republic, Poland and Hungary.[88]

When we shift our focus to the differences in subsectors' synchronisation, we find that the food subsector in the NMS and OMS is best synchronized with the euro area. In general, subsectors that are better synchronised in the euro area are also relatively more synchronised with the euro area for the non-EA countries. The subsectors differ more for NMS and OMS in terms of the degree of synchronisation, than in the EA. The main finding of the detailed subsector analysis over time is that the evolution of the degree of synchronisation is uneven across the subsectors.

Heterogeneity of broader sectors

[87] We have our first results for Greece for the period 2000-2004, which show a low degree of synchronisation with the EA.

[88] Our results are in line with the results obtained by Fidrmuc (2004).

In order to investigate the business cycle synchronisation for the overall economy, we perform an additional analysis using national accounts quarterly data on value added disaggregated to 10 sectors. We investigate two distinct periods, the pre-crisis period, 2001 – 2007, and the period marked by financial and subsequent sovereign debt crisis, 2008 – 2014. We apply the hierarchical DFM to estimate common EA factor, sector specific factors and country specific factors for both periods.

The main conclusions about the synchronisation of the manufacturing sector and economy wide business cycles in the euro area correspond. The degree of synchronisation in the core euro area countries is higher than in the periphery euro area countries already in the pre-crisis period. The exceptions are Italy and, to some extent, Spain that reach the degree of synchronisation of the core euro area countries. These differences reflect the build-up of imbalances in the euro area in the pre-crisis period.

Implications of the empirical results

We believe that our results provide compelling evidence that a variety of effects affect output fluctuation asymmetry.[89] Furthermore, the relative importance of these effects seems to vary over our observed time horizon. At the time of the formation of the EMU, and during its early years, the channels that decreased short term output fluctuations (more similar policies, knowledge spillovers, intra-industry trade) were more dominant. However, after the financial crisis in 2008, and especially after the sovereign debt crisis in 2011, the effects that increased asymmetry were dominant. Since trade within the euro area quickly regained pre-crisis levels, we are of the view that the divergence in national fiscal policies and the asymmetric transmission of monetary policies may suggest that the policy channel dominated in the most recent periods.

As observed from the results of our robustness check with year-on-year growth, the transformations of data for the analysis are important for variance decomposition. When we average out some of the variations in the monthly growths by using year-on-year data, we come to the conclusion that the main bulk of increases in the variance share explained by the area wide factors in the first period of the euro could be attributed to the increased comovement of short term fluctuations. Similarly, the decreases in the periods after the financial crisis and the subsequent sovereign debt crisis can also be only attributed to short term fluctuation.

Darvas et al. (2005) state that fiscal convergence seems to increase business cycle synchronisation by reducing volatile fiscal shocks even though, in the presence of an asymmetric shock, national fiscal policies are the only macroeconomic tool to smooth the business cycle in the EMU. With the financial crisis and the sovereign debt crisis, the ability of crisis countries to implement counter cyclical fiscal policies was hampered by the excessive fiscal burdens and constrained fiscal policies imposed by the Stability and

[89] The identification of specific channels is beyond the scope of this thesis.

Growth Pact. Our evidence from the manufacturing sector suggests that, in recent periods, the impact of fiscal consolidation has had negative effects on the degree of business cycle synchronisation.

A discussion of the policy implications, along with conclusions, is presented in the last chapter, where we also use the information from the next chapter in which we tackle the issue of heterogeneity in producer price inflation in the manufacturing sector.

How do our results compare to the literature?

It is difficult to relate our results to the literature since none of the existing studies is fully comparable to ours. We can attempt instead to compare our results for common factors and countries to some of the existing studies that use dynamic factor models as a tool for investigating the synchronisation of EU countries.

We can relate the results of our research of the variance decomposition for founding euro area members and Greece to a recent study by Lehwald (2013). She uses a quarterly dataset on output growth for the period 1991–2010, broken down into two sub-periods: 1991–98 and 2000–10. However, while we investigate output growth in the manufacturing sector, Lehwald instead investigates output growths in the whole economy. Moreover, we also use monthly data for output growth presenting us with more short term fluctuations. If we compare our results for the periods analysed by Lehwald (2013), we find 50 percent of the variance to be attributable to the common EA factor, while she finds 58 percent for the same set of countries. Our dataset is more disaggregated and so a lower share of variance explained in our case is expected. We find similar, although not equal, asymmetries in the common EA factor effects across the countries. For the same set of countries we find a less pronounced diversity of common EA factor effects across the countries (a standard deviation of 0.20 compared to 0.27 in Lehwald study). Both studies find common EA factors to have small effects on Ireland and Greece, but we find larger effects for the manufacturing sector in Portugal.

In her study, Lehwald (2013) claims that the euro has had a positive effect on the synchronisation of the core euro area countries, while it has had a negative impact on the synchronisation of the periphery countries, thereby fostering imbalances between the core and peripheral euro area countries. If we apply the same line of argument to our results for the importance of the common EA factor in the manufacturing sector for the same set of countries (core[90] vs PT, IE, ES[91]) and periods, we arrive at different conclusions. With regard to common EA factors for the manufacturing sector, we find that the degree of synchronisation had increased in both groups of countries. Furthermore, it had increased to a relatively greater extent in the periphery countries. Finally, if we add the effects of euro area sector specific factors, we obtain even more persuading results in favour of the

[90] Definition of core countries in Lehwald (2013): BE, FR, FI, DE, IT, NL.

[91] Lehwald (2013) includes Greece in the sample for the euro period, which further decreases her results for the importance of the common factor for periphery countries in the euro relative to pre-euro period.

periphery countries' degree of synchronisation with the euro area closing the gap to the core countries by 2010. However, the lower level of synchronisation of this group of countries compared to core euro area countries as the source of asymmetries in euro area is also confirmed in our study.

The other recent study that is interesting for our research is the study of quarterly GDP growth synchronisation by Lee (2012) for the period 1970–2010. He approaches the analysis of the evolution of output synchronisation in euro area countries by introducing time varying factor loadings in the dynamic factor model. His results are quite comparable to ours on an aggregate level for comparable time periods.[92] He finds modest increases in the euro area wide factor in the euro period for twelve EMU countries, however these increases are also observed in a control group consisting of additional five non-euro European countries. However, at the end of the sample, the degree of synchronisation in a larger group decreased more, which is also in line with our results. The study by Lee (2012) also indicates the low importance of the common world factor for our observed period.

A comparison of our results for the new member states is a more difficult task since there are few studies utilising dynamic factor models that cover these countries. We can compare our results to the results obtained by Eickmeier and Breitung (2006) for the period 1993–2003. They present the results of the variance decomposition of output growth (GDP) for CEE countries: CZ, EE, HU, LT, LV, PL, SI, and SK. If we compare our results based on the manufacturing sector data, we find similar variance shares for this group of countries over comparable time periods for both studies (28 percent of the variance explained by the common factor in our analysis compared to 27 percent in Eickmeier and Breitung (2006)). There are some differences in the rankings of the degree of synchronisation of these countries with the euro area. We both find Poland to be the country with the highest share of output growth variance explained by common euro area factor(s). The relative synchronisation compared to EA12 countries is also similar in both studies. We find the average variance share attributed to the common factor for the CEE countries to lag 18 percent behind EA12 average, while Eickmeier and Breitung (2006) find a 13 percent gap.

To the best of our knowledge there are no comparable studies which analyse sector specific effects of output growth comovements in a similar fashion to ours. Helg et al. (1995) investigate the manufacturing sector disaggregated to 11 subsectors for 11 EU countries for the period 1975–1992. The approach of their study is to model the output growths in a subsector in a given country using a vector error correction model (VECM). The estimated residuals (output innovations) of a VECM model are grouped first by subsector and then by country. The principal components for subsector and country groups are computed in the last steps. They find that principal components explain a larger share of variance in the country groups than in the subsector groups. There are some similarities in the relative

[92] Lee (2012) does not report results for individual countries.

shares of variance explained by subsector principal components when compared to our results for sector specific factors in the euro area.[93] Among the comparable subsectors, the subsector of other non-metallic products has the highest variance share explained by principal components or sector specific factors in both studies. Helg et al. (1995) also find that the correlation of the principal components of the subsector groups is higher, also in line with our result of a high variance share explained by the common factor.

Foerster et al. (2008) use a dynamic factor model to analyse US manufacturing sector data for the period 1972–2007, disaggregated to 117 subsectors. The variance share explained by two common factors that Foerster et al. obtain for the US for the period 1984–2007 is 50 percent for the monthly data, which is comparable to our results.[94] Our estimate for the period 1991–2007 is a 51 percent variance share explained by one common factor for our euro area sample. However, we find that, in the euro area, at least 8 percent of the variance is not attributable to subsectors, but rather countries. Our analysis shows that, on average, only 13 percent of the variance is attributable to euro area sector specific factors, while an additional 28 percent is country-sector specific.

[93] We use our results for the first observed period 1991-1995 for comparison.

[94] They apply a structural model to account for the comovements of sectoral growth rates that are generated by input-output linkages, using quarterly industrial production data and additional input-output table data.

4 HETEROGENEITY OF PRODUCER PRICE INFLATION IN THE MANUFACTURING INDUSTRY

The goal of this chapter is to contribute to the existing literature on producer price inflation differentials (or inflation differentials in general) in the euro area and the EU. Producer price inflation is an important input in the analyses of country competitiveness indices, where inflation differentials can serve as an equilibrating mechanism in a currency area. A part of the investigation of inflation differentials at the ECB is also disaggregated sectoral and country analysis, which enables the identification of the underlying trends and structural shocks that drive euro area developments (ECB, 2005). We propose an alternative method of analysing disaggregated country and sectoral information on producer prices for the manufacturing sector. We use a factor model approach to decompose inflation variation in a subsector in a certain country into four sources at different levels: area wide, sector specific, country specific, and an idiosyncratic component that is country-sector specific.

This part of the research also complements the research on output variability, especially in the context of the build-up of the euro crisis and how to exit it. The economic boom in the periphery countries after the euro's introduction led to a loss of competitiveness from 1999 to 2008 in countries such as Portugal, Spain, Ireland, Italy and Greece (De Grauwe, 2011 and Krugman, 2013). For the equilibrating process, the prices in these countries need to decrease relative to their competitors. However, in an environment of low inflation or even deflation, this process is deflationary in nature and causes recessions. Moreover, due to nominal rigidities such as downward labour costs rigidities, the process has additional limitations.

However, at the level of the manufacturing sector, we can observe producer price increases diverging not only in Greece, Spain and Portugal, but also in the Netherlands and Belgium, which are not among the countries with the highest unit labour costs increases (De Grauwe, 2011). There are more possible explanations as to why producer prices increase relatively more in the Netherlands and Belgium, e.g. higher productivity growth in these countries, increasing costs of capital or sectoral specialisation.

Using a hierarchical DFM in the analysis of the producer price inflation dataset, disaggregated to manufacturing subsectors and countries, we are able to quantify the symmetric and asymmetric parts of the inflation variability for each subsector in a given country in the euro area. We define the symmetric part as the variance of a given subsector in a country explained by a common and sector specific factor, while the asymmetric part is composed of the variance explained by country specific factor and country-sector specific effects. We interpret the relative size of the asymmetric part as the potential for inflation differentials, which could act as an equilibrating mechanism in the euro area.

For the empirical part of the analysis we use an identical setup that we use in the output fluctuation analysis in the previous chapter, which builds on the hierarchical DFM models. Our dataset consists of overlapping blocks of variables, since each variable belongs to a particular manufacturing subsector's block and a country block of variables. The overlapping blocks of variables are first examined by Beck, Hubrich and Marcellino (2012), where they investigate regional sectoral consumer prices inflation fluctuations for the period 1995–2004. Our dataset focuses on the manufacturing sector and spans from 1995–2014 and includes the periods of the financial crisis and subsequent sovereign debt crisis. Furthermore, we examine producer prices inflation that is of special relevance in the context of the increased divergence in the competitive positions of the euro area countries. We further expand the method by introducing the rolling window method of factor estimation to monitor the changes of heterogeneity over time.

For the euro area we find the common EA factor to explain over half of the variability in producer price inflation in recent periods, while the sector specific factors account for about a third of the total variance. Country specific factors are not as important for the area, with less than 10 percent of the explained variance. The remaining 15 percent of variance is country-sector specific. We further find that the importance of various contributors to variability changes over time.

As one would expect, when analysing a dataset consisting of EU countries, the share of variance explained by the common EU factor is smaller, but by no means negligible at around 40 percent in recent years. EU sector specific factors (one for each sector) are again very important, explaining around a 30 percent proportion of the total variance. Country specific factors (one for each country) also explain a substantial proportion of the variance, 15 percent.

Part of our research on the producer price inflation variability of the manufacturing sector in EU countries deals with an estimation of non-euro EU countries' synchronisation of inflation variability with euro area patterns. We find that these countries are, in general, less synchronised with the euro area.

We investigate also the synchronisation of the economy wide prices and wages inflation in the broader sectors. The main conclusions about the synchronisation of the manufacturing sector producer prices inflation and economy wide prices and wage inflation in the euro area correspond, even though the differences between core and periphery euro area countries are more substantial in the case of broader sectors.

The structure of the remainder of the chapter is as follows. In the first subsection we attempt to draw attention to the sources of heterogeneity in the manufacturing sectors across the countries and subsectors, and evaluate the heterogeneity using descriptive statistics. For the empirical part of our research, we use a similar methodological setup as in the chapter with industrial production heterogeneity. We present the results in three subsections, depending on the geographical area we examine. Firstly, we examine the euro area, more specifically the 1999 founding EA countries without Luxembourg, Ireland and Austria (EA8). Second, we examine the EU, conditional on the availability of data for the countries. Third, we use EA factors to examine all the EU countries' synchronisation with the euro area business cycle in manufacturing. Next, we investigate the price and wages growth heterogeneity in the broader sectors of the economy. Finally, we explore the linkages of price heterogeneity to the output synchronisation. The last subsection summarises the chapter.

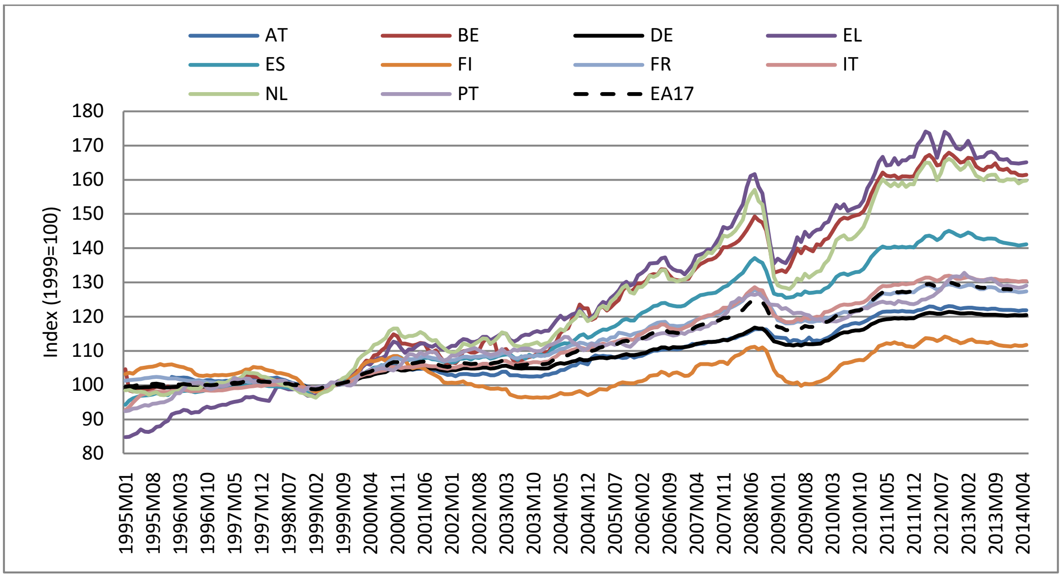
4.1 Sources of producer price heterogeneity

In this section we present descriptive statistics on the heterogeneity in manufacturing sector producer prices inflation in the EA and EU, both on the levels of individual subsectors and countries. Firstly, we try to point out some sources of heterogeneity. We then continue with the country differences on the level of the whole manufacturing sector. Then we deal with the differences between the subsectors on an aggregated EA and EU level. We also attempt to present heterogeneity in producer price inflation on a country-sector level, which is also the main objective of this part of research. In the final part of this section we briefly describe the data used in our research.

Before we continue with an examination of heterogeneity in more detail, we motivate the research by presenting the evolution of producer prices for the manufacturing sector in the EA17 (Figure 26). The figure shows rising prices after the 1999 euro introduction and a relatively stable price level afterwards in the period 2000–04. The period of high positive output gap (see Figure 4 in Chapter 3) prior to the financial crisis in 2008 is marked by a growth in prices, followed by a relatively sharp decline in late 2008 and the start of 2009. In 2010 the prices started to rise again, exceeding the pre-crisis level in recent years. However, the years since the sovereign debt crisis have been marked by stagnation and even deflationary processes.

We show the price developments for the founding euro area countries and Greece and see a similar picture for the development of relative unit labour costs across euro countries which is usually used in explaining the competitiveness problems of the periphery countries (e.g. De Grauwe, 2011). We observe an increased dispersion of price indices until 2008 and there are only small corrections in recent years. The inflation differentials that caused the dispersion from 2000–2008 have decreased in recent periods due in part to low inflation in all euro area countries. Note that the dispersion of prices can also reflect the convergence processes in the euro area if the prices in 1999 are not in equilibrium.

Figure 26. Evolution of producer prices in manufacturing for EA17 aggregate and 2002 euro member countries. Index 1999=100.



Note. Ireland and Luxembourg are excluded.

Source: Eurostat, *Short term business statistics*

There are some differences in the movements of unit labour cost and producer price indices on the country level. We can observe that the countries with the highest increases in producer prices in manufacturing in the pre-crisis period are Greece, Belgium and the Netherlands, followed by Spain. Portugal and Italy are very close to the EA17 average. Finland, Germany and Austria have decreased their relative prices in the manufacturing sector. On the other hand, relative unit labour costs for the same period have increased the most in Ireland[95], Italy, Spain and Greece, while Germany is the country with the highest decrease of the relative unit labour costs. However, Belgium and Netherlands increased the productivity relative to Italy, Spain and Greece in the pre-crisis euro period. Productivity increased in Ireland as well thus partly offsetting the increases in the unit labour costs. There are even more possible explanations for these differences, one of which is also the changing structure of the manufacturing sector (Table A1 in Appendix A); therefore we have a look at the possible sources of heterogeneity in more detail.

When discussing the determinants of producer price heterogeneity across the subsectors and countries, we follow the setup by Beck, Hubrich and Marcellino (2009), and Rogers (2007). We assume that producer price in country *i*, sector *j* and time *t*, denoted p_{ijt} is set by a monopolistic producer of a final good. The monopolist sets the price p_{ijt} with a mark-up over costs:

[95] The EC (2008) suggests that Ireland may have managed to sustain export driven growth due to its strong comparative advantages in mostly hi-tech industries. EC (2008) examines the 1999–2006 period.

$$p_{ijt} = \beta_{ijt}\alpha_{ijt}(w_{ijt})^{\phi_{ijt}}(q_{ijt})^{1-\phi_{ijt}}, \quad (4.1.1)$$

where β_{ijt} is the mark-up, α_{ijt} the total factor productivity in sector j and country i. w_{ijt} represents the costs of labour, which is non-tradable and q_{ijt} represents the costs of capital which is tradable. ϕ_{ij} measures the share of labour in the final output of item in sector j and country i.

The assumption that prices are set optimally by each producer in each period is quite strong, since there are nominal rigidities that prevent the prices from being adjusted continuously. As Beck et al. (2009) state, this can lead to the producer taking account of the expected marginal cost when setting the current prices. The response to economic shock in the presence of nominal rigidities is more gradual and inflation rates exhibit persistent behaviour which in turn can cause persistent inflation differentials across the countries and sectors. Using the evidence from U.S. product-level price data, Gilchrist, Schoenle, Sim and Zakrajšek (2014) show that firms react differently to an adverse demand shock, depending on the balance sheet position. Only those firms with sound balance sheets lowered their prices during the financial crisis in 2008, while the firms with problems increased their prices.[96]

If any of the variables or parameters on the right hand side of the equation (4.1.1) changes, the prices change. Heterogeneity in inflation across the subsectors and countries only arises if the changes are not equal. However, even a symmetric shock can have asymmetric effects. For example, a symmetric shock to the cost of capital across the countries and subsectors would cause the cost of capital to change; however, assuming that the share of labour in the final output ϕ_{ij} differs across the countries and subsectors, the changes in prices would be different across the subsectors and countries.

If there is convergence in producer prices, the convergence itself might be the cause of higher inflation differences. Rogers (2007) argues that the convergence in income can lead to the convergence of prices either through convergence in productivity (α_{ijt}) or factor endowments (ϕ_{ijt}).

The calculation of a proxy of ϕ_{ijt} from national accounts data[97] as a share of the compensation of labour in the total value added gives no conclusive answer as to whether this parameter is more country or sector dominated. The variance of labour compensation in the total value added is approximately the same across the subsectors and countries in the euro area.[98] This share does not change substantially over time, and so this term can be

[96] If we apply the findings of Gilchrist et al. (2014) to recent euro area developments, this might be another factor that prevents ”problematic” countries from improving their competitiveness (and output) by reducing relative producer prices.

[97] Source: Eurostat, August 2014.

[98] When using calculation, excluding Ireland and sector of coke and refined fuel as outliers.

considered not as a source of convergence but rather a source of different transmissions of capital or labour costs into the final producer price.

The productivity across subsectors and countries differs. From the calculated productivity changes we can assume that the differences in inflation arising from the productivity changes are mainly attributed to countries, or groups of countries.

The mark-up over costs (β_{ijt}) is inversely related to the elasticity of demand. We assume that products are specific to a subsector, so if the level of substitutability of products produced by a firm in the same subsector, but a different country, is high, we would expect this term to be mainly sector specific. We can proxy the mark-up from the national accounts data as the difference between the output and the consumption of fixed capital, compensation to employees, and the consumption of intermediate products disaggregated to sectoral and country level.

Labour costs (w_{ijt}) are determined locally and depend both on country and sector. However, we can assume that wage determination has a considerable country wide determinant. Messina, Duarte, Izquierdo, Du Caju, & Hansen (2010) also find some sectoral differences in the downward wage rigidity. However, the country component remains dominant for the downward wage rigidity, which has garnered much attention recently. Since inflation in the euro area has been too low in recent periods, not only countries with downward real wage rigidity[99] but also countries with downward nominal wage rigidity[100] are unable to utilise labour cost flexibility.

We could expect the costs of capital and intermediate products (q_{ijt}) to represent the most common of all the variables and parameters that affect the price changes, although significant sector effects can also be attributed to this variable. World prices of raw materials, including oil, should have symmetric effects on the subsectors if they are dependent on imports to the same extent. Nominal exchange rate effects are homogeneous inside a currency union. However, since the sectors are specific, a large part of this component is also expected to have a strong sector specific determinant, especially in the event that there are specific shocks in the world market for raw materials. If the price of wheat increases worldwide, for example, it affects the food production subsector the most, while the other sectors are not affected directly. Should an oil price shock occur, on the other hand, the increase of the energy prices might affect the manufacturing industry as a whole. Divergence in the real exchange rate reflects the different composition of sectors and trade partners. Further, countries which are not in the euro area are expected to have a

[99] Particularly strong in Belgium, Luxembourg, Spain, Slovenia and Finland (ECB, 2010).

[100] Above average in Netherlands, Portugal, Slovakia, Estonia, Lithuania and Czech Republic (ECB, 2010).

higher than average country specific determinant of this variable due to the additional idiosyncratic effect of the exchange rates.[101]

The costs of capital should become more homogeneous in a currency union with a common monetary policy.[102] However, transmission mechanism seems to be asymmetric as evidence from the interest rates for firms in euro area countries suggest.[103] The spreads that firms in periphery countries have to pay in comparison to the euro area average have only slowly come down since the maximums in 2011–2013. In fact, the cost of capital rose in the periphery countries in the period after financial crisis (Draghi, 2014), when a relative decrease in producer prices was needed in order to regain competitiveness. In our stylized model, this meant putting more pressure on labour costs and margins.

We first compare the heterogeneity of producer prices inflation across the countries in the EU for four different time periods, which are conditional on the availability of data. The first includes the pre-euro period. The second and third periods begin with the EMU formation and the introduction of the euro as a physical currency, respectively. The last period covers the period characterised by the major recession, caused by the financial crisis in 2008 and the subsequent sovereign debt crisis in 2011. In Table 16 we show the correlation coefficient of producer price inflation for a selected country with the Eurostat composed series for EA17. We also report the variance of the producer price inflation differential relative to EA17.

Table 16. Descriptive statistics of producer price inflation (π) for the manufacturing sector by selected country (i), for different time periods.

	Var (π_t^i- π_t^{EA})				**Corr(π_t^i,π_t^{EA})**			
	96-99	99-08	01-08	09-14	96-99	99-08	01-08	09-14
AT	0.12	0.39	0.49	0.31	0.83	0.75	0.71	0.86
BE				1.05				0.90
DE	0.01	0.17	0.20	0.15	0.96	0.97	0.97	0.97
FR	0.06	0.04	0.04	0.07	0.88	0.98	0.98	0.97
NL	0.68	2.41	2.59	2.63	0.93	0.97	0.97	0.98
FI	0.57	0.52	0.45	0.47	0.94	0.85	0.85	0.94
EL	1.12	2.46	2.99	1.67	0.59	0.92	0.93	0.85
ES			0.16	0.11			0.97	0.98
IE				0.90				0.52
IT			0.07	0.03			0.98	0.99

(table continues)

[101] More on exchange rate pass throughs for new member states in Corricelli, Jazbec and Masten (2006), for sectoral heterogeneity in the US in Yang (1997), for heterogeneity in the euro area in Bussiere (2007) and Comunale (2014).

[102] Boivin, Giannoni and Mojon (2008) argue that the EMU has contributed to greater homogeneity of transmission mechanisms across the countries.

[103] Draghi (2014) states that repairing the transmission mechanism is an important focus of ECB monetary policy.

(continued)

	Var (π_t^i- π_t^{EA})				Corr(π_t^i,π_t^{EA})			
	96-99	99-08	01-08	09-14	96-99	99-08	01-08	09-14
BG			3.61	3.57			0.83	0.95
CZ	0.74	1.93	1.38	2.01	0.59	0.39	0.29	0.18
EE				0.32				0.84
HU		3.65	3.65	7.05		-0.10	-0.19	-0.24
LT		12.73	13.11	8.02		0.88	0.92	0.96
LV		2.37	1.70	0.95		0.53	0.66	0.77
PL			1.76	2.27			0.32	0.21
RO			6.17	1.14			0.10	0.48
SI		0.69	0.74	0.49		0.54	0.51	0.74
SK				0.42				0.91
DK	0.40	0.15	0.16	0.35	0.68	0.91	0.92	0.85
SE	0.49	0.83	0.96	1.52	0.74	0.49	0.43	0.08
UK		0.89	0.84	4.42		0.56	0.64	0.21

Note. Selection of countries conditional on data availability. π_t^i represents producer prices inflation in manufacturing of a country *i* at time *t*, π_t^{EA} represents producer price inflation in manufacturing of EA17 at time *t*.

Source: Eurostat, *Short term business statistics*; Own calculations

Not surprisingly, the correlation of the EA countries with EA17 producer price inflation has increased in the euro period, while non-euro EU countries, Sweden and the UK did not experience such an increase. Germany's high level of correlation in the first period is to some extent due to the significant weight of this country in composing the aggregated EA17 indicator.

When we compare the correlation of producer price inflation with the EA17 in the manufacturing sector across all EU countries for the period 2008–2014, we find that founding EA countries are better correlated with EA17 price movements than the other countries. A notable exception among founding EA countries is Ireland; however, this may also be due to the specific composition of the manufacturing sector.[104]

A smaller correlation of non-euro EU countries is expected since exchange rates can influence pricing strategies: the appreciation or depreciation of a currency can reduce or increase competitiveness and so producers may change prices in response to exchange rate movements.

Countries that deserve our additional attention are the new member states that entered the EMU later.[105] Slovenia is a case where the correlation of producer prices inflation increased considerably after joining the monetary union. The correlation of Slovakia did not change

[104] Table A1 in Appendix A on the structural similarities of the manufacturing sector.

[105] Cyprus and Malta are not included due to country specificities and data availability. Latvia entered the EMU at the end of our data sample.

when comparing the periods before and after the euro but it had a relatively high correlation coefficient even before joining the EMU, when compared to Slovenia, for example. Estonia was the last of countries in our sample to enter the EMU in 2011; the correlation with the EA17 decreased after euro accession in the case of Estonia.

Shifting our attention to manufacturing sector heterogeneity across disaggregated subsectors, we find that the majority of the volatility in EA17 producer price inflation could be attributed to the sector of coke and refined fuel. Even though this subsector has a relatively small share of the value added in manufacturing as a whole, the volatility in price inflation greatly exceeds the volatility of other sectors.

Table 17. Descriptive statistics of producer price inflation for the EA17 across the manufacturing subsectors.

	Var (Δy_t^j- Δy_t^{MF})				**Corr(Δy_t^j,Δy_t^{MF})**				**VA^j/VA^{MF}**
Sector *(j)*	96-99	99-08	01-08	09-14	96-99	99-08	01-08	09-14	2011
Food	0.26	0.75	0.81	0.47	0.54	0.53	0.53	0.79	0.13
Textile			1.09	0.73			0.06	0.59	0.04*
Leather			1.30	1.43			0.09	0.29	
Wood	0.29	1.22	1.37	0.52	0.45	0.20	0.21	0.72	0.02
Paper and printing	0.91	0.96	0.97	0.70	0.47	0.39	0.28	0.63	0.05
Coke			67.75	32.86			0.91	0.86	0.01
Chemicals and pharmaceuticals	0.25	0.64	0.73	0.45	0.85	0.68	0.64	0.97	0.12
Rubber and plastic	0.16	0.76	0.86	0.34	0.65	0.40	0.35	0.84	0.05
Other non-metallic			1.01	1.12			0.28	0.12	0.04
Metals	0.39	1.26	1.46	1.20	0.82	0.78	0.78	0.90	0.15
Electronic	1.01	1.27	1.31	0.86	-0.28	0.00	-0.22	0.54	0.1
Machinery	0.25	0.90	1.01	1.04	0.29	0.12	0.07	0.21	0.12
Transport	0.21	0.94	1.10	0.98	0.49	0.03	-0.13	0.32	0.12
Furniture			1.06	1.01			0.06	0.26	0.05

Note. *Share of textile and leather combined in the total value added in manufacturing. π_t^j represents EA17 producer prices inflation in manufacturing of a subsector *j* at time *t*, π_t^{MF} represents producer price inflation in manufacturing of EA17 at time *t*.

Source: Eurostat, *Short term business statistics*; Own calculations

We compare the correlation coefficients of the producer price inflation series for the EA17 for each of the 14 disaggregated sectors with the composite indicator for aggregated manufacturing sector (*MF*). We find the coke and refined fuel subsector to have the largest correlation coefficient, while manufacture of transport equipment to have the smallest.

As Table 17 shows, the evolution of producer prices across the subsectors is quite heterogeneous across disaggregated subsectors. We would thus expect sector specific factors to have a large explanatory value for differences in inflation. However, when we look into specific subsectors, we find that heterogeneity across the countries is, on average, greater on the level of disaggregated subsectors than for the whole manufacturing sector, which is measured in terms of the correlation of the inflation of a country with EA17 composite within a specific sector.

Table 18. Dataset of producer prices indices for manufacturing used in the analysis. Dataset covers the period of 1995(1)–2014(6).

Country	Country code	Data starting point	EA membership	EU membership	Group*
Austria	AT	1996	1999	1995	II, III, IV
Belgium	BE	1995	1999	1957	I,II,III, IV
Bulgaria	BG	2000	/	2007	IV
Czech Republic	CZ	1996	/	2004	II, III, IV
Germany	DE	1995	1999	1957	I, II, III, IV
Denmark	DK	2000	/	1973	IV
Greece	EL	1995	2001	1981	I, II, III, IV
Spain	ES	1995	1999	1986	I, II, III, IV
Finland	FI	1995	1999	1995	I, II, III, IV
France	FR	1995	1999	1957	I, II, III, IV
Hungary	HU	1998	/	2004	III, IV
Ireland	IE	2000	1999	1973	IV
Italy	IT	1995	1999	1957	I, II, III, IV
Lithuania	LT	1998	/	2004	III, IV
Netherlands	NL	1995	1999	1957	I, II, III, IV
Poland	PL	2000	/	2004	IV
Portugal	PT	1995	1999	1986	I, II, III, IV
Romania	RO	2000	/	2007	IV
Sweden	SE	1995	/	1995	I, II, III, IV
Slovenia	SI	1998	2007	2004	III, IV
Slovakia	SK	1995	2009	2004	I, II, III, IV
United Kingdom	UK	1998	/	1973	III, IV

Note. HR, LU, MT, CY, LV are not included in the sample due to data availability and/or country particularities.
*Groups of countries by starting data point, used in section 4.3.

Source: Eurostat, *Short term business statistics*

Producer price data are scarcer than data on industrial production on a disaggregated sector level. We use Eurostat data on producer price indices with monthly frequency.[106] We transform the data by computing year-on-year inflation ($\pi_t = 100 * (\ln P_t - \ln P_{t-12})$). This transformation is useful since it removes seasonal effects from the monthly series and year-on-year inflation is the key variable for monetary policy. Further, the transformation averages out some of the idiosyncratic variation present in the month-on-month series. The factor structure is strengthened as a consequence (Beck et al., 2012).

[106] Data for Slovakia are obtained at Statistical office of the Slovak Republic.

4.2 Heterogeneity of producer price inflation in the euro area

This subsection presents the empirical results for the euro area. We begin by imposing a hierarchical DFM with overlapping blocks on the producer price inflation dataset and construction of the factors: common EA, sector specific and country specific factors. We discuss the formation of the factors in more detail, while focusing on the results in the remaining subsections. Common EA and sector specific factors represent the EA wide factors. We investigate the heterogeneity across the countries and sectors. The findings are first presented for the last observed periods[107]. We compare our results based on shorter time series due to rolling window methodology to a more usual approach by constructing factors from the dataset with the whole time horizon available.[108] In the part where we present the evolution of heterogeneity over time, we attempt to investigate the impact of the euro and the recession period on the heterogeneity.

We impose the following factor structure on the series of producer price inflation π_{ijt} for 8 EA countries *(i)* (BE, DE, ES, FI, FR, IT, NL, PT) [109] and 13 disaggregated manufacturing subsectors *(j)*:

$$\pi_{ijt} = \lambda_{ij} f_t + \mu_{ij} g_{jt} + \eta_{ij} h_{it} + e_{ijt} \qquad (4.2.1)$$

where f_t represents common euro area factors with factor loadings λ_{ij}, g_{jt} represents sector specific factors with loadings μ_{ij}, h_{it} country specific factors with loadings η_{ij} and e_{ijt} the idiosyncratic component.

We follow the procedure described in section 3.3 to estimate the factors and loadings for $t = T_{OP} - T, \dots T_{OP}$, where T is the size of the rolling window and T_{OP} runs from 1999(2)–2014(5) in the case of T=50.

This setup enables us to decompose the variance in the producer prices inflation into common, sector, country and idiosyncratic component.

4.2.1 Common EA factor

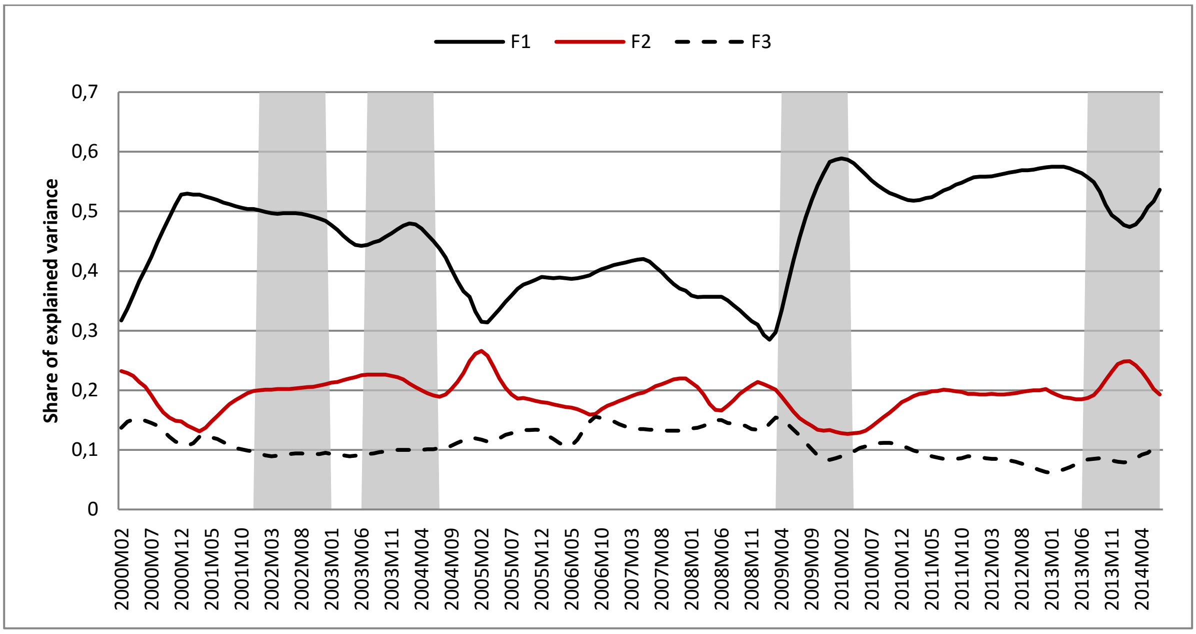
In the first step (equation 3.3.2), we extract common EA factors from our dataset of euro area producer price inflation for each period using a rolling window with T=50. Owing to the high volatility of the prices in the coke and refined fuel subsector, and the low coverage of this subsector by Eurostat data, we decide to construct common EA factors without the series for this subsector.

[107] We show the averages over five observed periods, all ending in 2014.

[108] Detailed results are reported in section C.1 in Appendix C.

[109] Luxembourg, Austria, and Ireland are exempt from the dataset of 11 founding EA countries due to shorter time series or other data issues. However, we also investigate Austria and Ireland in section 4.4, using the data available.

Figure 27. Share of variance of producer price inflation explained by common EA factors, average across the countries and manufacturing subsectors.



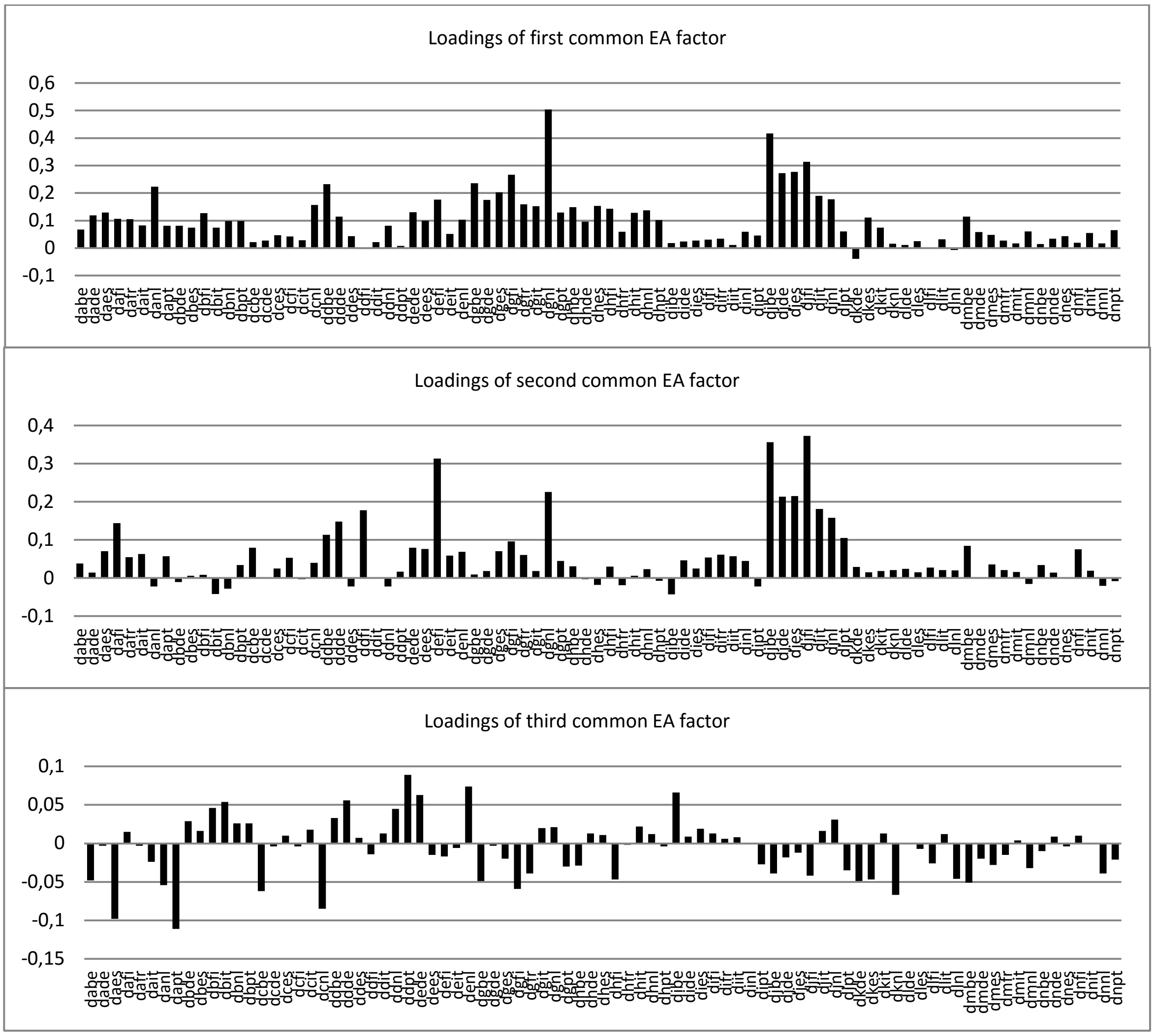
Note. Shaded areas indicate deflation periods. We define a deflation period as quarterly year-on-year producer prices deflation in the EA17 for more than two consecutive quarters.

Source: Own calculations; Eurostat, *Short term business statistics*

The first common EA factor explains, on average, about 43 percent of the total variability of the sample. The importance increased in the beginning of our sample after the implementation of the euro in 1999, while there was no sign of rising importance with the introduction of euro notes in 2002. Moreover, the importance of this factor had a decreasing trend until the beginning of the large recession period. The share of variance explained had been between 30 and 40 percent until the beginning of the crisis, when it suddenly jumped to almost 60 percent in 2009. It stays on levels above 50 percent, with a temporary decrease under 50 percent in the last months of 2013 and the beginning of 2014.

Above average loadings can be attributed to the metals (dj), and chemicals and pharmaceuticals (dg) sectors. If we compare the loadings from Figure 28 from our rolling window exercise with the loadings of the first factor obtained through the use of the entire time range of the dataset (Figure C1 in Appendix C), we find a very similar distribution of factor loadings across the sectors and countries.

Figure 28. Loadings of the common factors on the EA producer price inflation series for the last observed period.



Note. 2010(3)–2014(5), T=50.

Here, the second and third factors were much more important than the factors in the previous analysis of the industrial production indices. The second factor had the highest loadings on the basic metals.

Even though the factors are not interpretable as such, we show the correlation coefficients of the factors to some of the selected indicators (Table 19). The correlation coefficients reveal that the second factor is mostly correlated to non-energy commodity prices. The first factor has the highest correlation coefficients with all the other selected indicators.[110]

110 There are more approaches to giving economic meaning to the factors. Marcellino et al. (2000) use regressions on the other factors, Eickmeier (2005) rotates the factors, while Eickmeier (2006) identifies the shocks that drive the factors.

Table 19. Correlation coefficients of three common EA factors of producer price inflation in manufacturing to selected indicators, T=50.

Factor	Food prices	Non-food prices	Total non-energy commodity prices	Oil price	Effective exchange rate*	Short term interest rate
F1	0.68	0.53	0.60	0.91	-0.41	0.70
F2	0.56	0.77	0.71	0.24	-0.12	0.23
F3	0.22	0.30	0.27	-0.16	-0.22	-0.56

Note. *Euro area changing composition vis-a-vis the EER-12 group of trading partners (Source: ECB).

Source: ECB, Own calculations

We use statistical information criteria to determine the appropriate number of common EA factors for all of the observed periods. The Bai and Ng (2002) criterion IC_{p2}[111] suggests two common factors for the last observed period (2010(3)–2014(5), T=50, N=90), while the criterion IC_{p1} suggests the maximum of pre-determined number of factors. The rolling window approach brings additional uncertainty in determining the appropriate number of factors. The composition of factors changes over time, so for different time periods we obtain between 1 and maximum predetermined three common EA factors as an appropriate choice (Table A9 in Appendix A summarises the results). However, if we want to observe changes in the importance of the common EA factor over time, a constant setup is desirable.

The second and third factors have disproportionally high loadings in series in specific sectors; therefore one EA common factor would be sufficient, since the effect of commodity prices could be accommodated by sector specific factors.[112] Thus we decide to use only one common EA factor in the preferred setup of the rolling window analysis.[113]

As stated before, we further investigate the first three common factors in a static setup, where we use the same cross-section dimension of the dataset as for the rolling windows; however, the time series dimension covers the period of 1996(1)–2014(5). The proportion of the variance explained by the first common EA factor is 37 percent in this case. The second and third common EA factors explain an additional 8 and 7 percent of the variance, respectively. We examine the correlation of the obtained factors with the selected indicators (Table 20) and record similar results as in Table 19. The second and third factor have smaller correlation coefficients than in Table 19, where we examine the factors with smaller vertical dimension due to the rolling window setup.

[111] See eq. (2.2.2) in Chapter 2.

[112] One of the reasons to select only one EA wide factor is to prevent the possibility of including specific country's effects or the effects of a small group of countries in the common EA factor.

[113] We nevertheless perform also an analysis using 2 common EA factors. Results are reported in section C.2 in Appendix C.

Table 20. Correlation coefficients of three common EA factors of producer price inflation in manufacturing to selected indicators (1997–2014).

Factor	Food prices	Non-food prices	Total non-energy commodity prices	Oil price	Effective exchange rate**	Short term interest rate*
F1	0.65	0.40	0.55	0.41	-0.12	0.88
F2	0.09	0.59	0.47	0.33	-0.19	-0.19
F3	-0.06	0.24	0.15	-0.12	0.42	0.38

*Note.** Time period 2004-2014

**Euro area changing composition vis-a-vis the EER-12 group of trading partners (Source: ECB).

Source: ECB, Own calculations

We use statistical information criteria to determine the appropriate number of common EA factors in our static setup. The Bai and Ng (2002) criterion IC_{p2} suggests one common factor, while the criterion IC_{p1} suggests that two common factors are sufficient. We use this insight to confirm our choice of also using a single common EA factor for the setup with rolling window (T=50) in the next step, the extraction of sector specific factors.

4.2.2 Sector specific factors

We clean the series of producer price inflation disaggregated to countries and sectors from the common EA effects following equation (3.3.3). After grouping the series by sector we estimate the sector specific factors using equation (3.3.4). Even though we use one sector specific factor for each subsector, we examine three 3 sector specific factors for each of the 14 sectors.[114] The first sector specific factors account for more than a half of the remaining variability in the producer prices series in the EA (around a third of total variance of the sample). These results show that sector specific factors play an important role in explaining producer price inflation in sectors and countries.

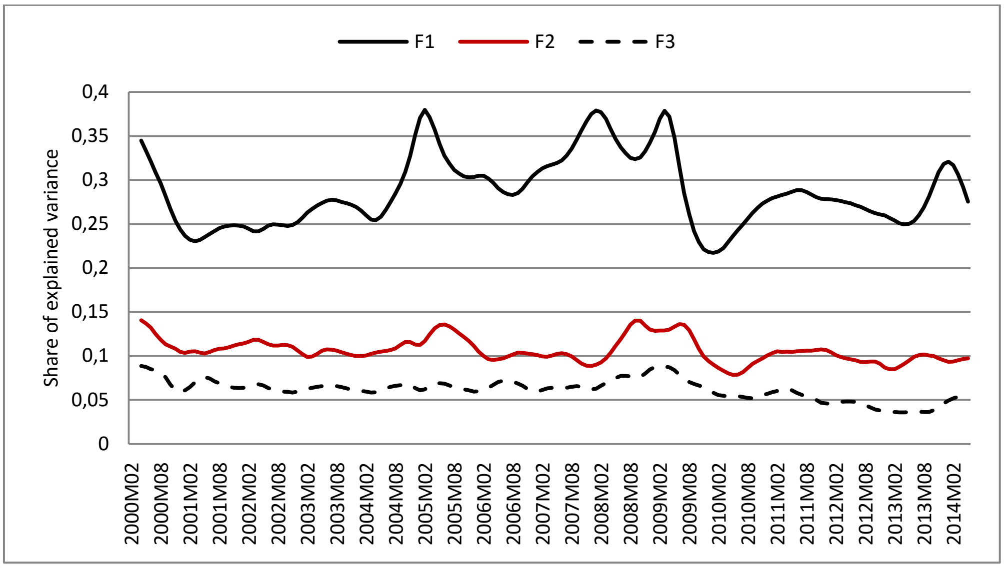
The second and third sector specific factors account for around 10 and 5 percent of the total variance of the sample, respectively. The Bai and Ng (2002) IC_{p2} criterion suggests one sector specific factor for the last observed period for six subsectors, two factors for another five subsectors and three factors for the last three subsectors. The number of factors according to the IC_{p2} criterion is not constant over different observed periods. We summarise the results of the Bai and Ng criteria in Table A.9 in Appendix A.[115]

Analysis of factor loadings (Figure C2 in Appendix C, setup with T=221) shows that the second and third sector specific factors by sectors have high loadings on the series of individual countries. We therefore decide to use one sector specific factor for each subsector.

[114] We use the same setup as in the section of industrial production heterogeneity.

[115] In a setup with T=221 we obtain one sufficient sector specific factor for 8 subsectors (Table C2 in Appendix C).

Figure 29. Share of total variance of producer price inflation in manufacturing explained by the sector specific factors.



Note. Three month moving averages.

The share of the variance explained by the first sector specific factor exhibits a decreasing trend prior to the formal introduction of the euro in 2002. In 2004, the level rises to over 30 percent of the explained variance and remains at levels close to or above 30 percent until 2009, when it decreases by 15 p.p. In 2013 a temporary upsurge in importance may be observed, raising the level by about 5 p.p. In 2014 there is another decline in the sector specific factors' importance.

4.2.3 Country specific factors

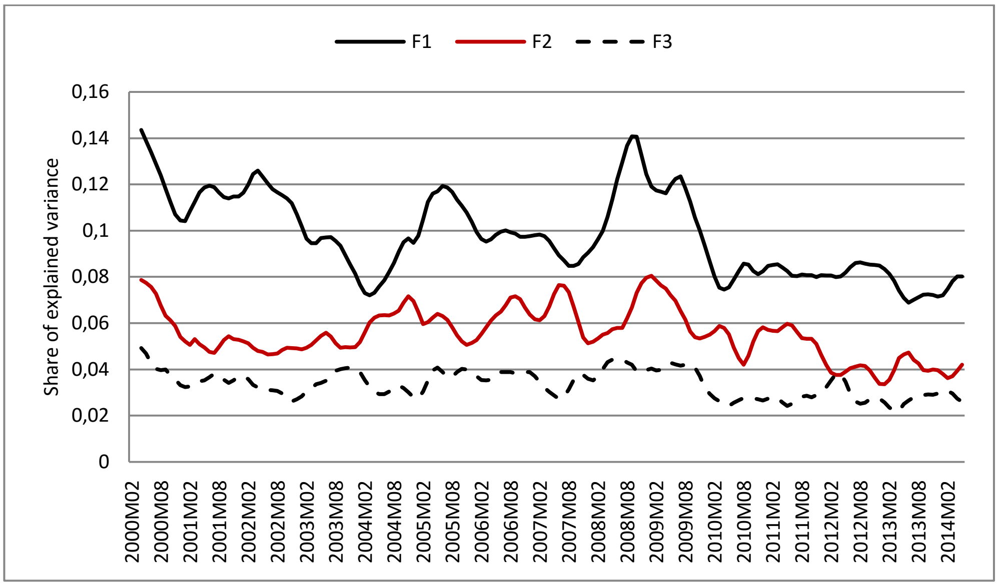
In the next step we extract the residuals for each series by regressing the producer price inflation series for each country and subsector on the common EA factor and EA sector-specific factor belonging to the particular series (equation (3.3.5)). Using principle components, we then extract the country-specific factors from the residuals of the series for each country (equation (3.3.7)).

The first country specific factors explains almost half of the remaining variance after the common EA and sector specific effects ware extracted. As the common EA and sector specific factors in the case of series of producer prices account for about three quarters (in the case of production indices, four fifths of the variance), the first country specific factors explain an average of approximately 10 percent of the variance in absolute terms (Figure 30). The second and third country specific factors only explain approximately one half and one third as much as the first factors, respectively.

The Bai and Ng (2002) IC_{p2} criterion suggests two country specific factors for Germany and Finland in the last observed period, while one factor is sufficient for the other countries. We also observe a changing number of sufficient factors for countries over different observed periods, and so the number of factors is not clear cut.[116] Since we strive for a constant factor setup, we use one country specific factor for each country in all the periods observed.

The importance of country specific factors has a similar evolution over time to that of sector specific factors. Their importance decreases prior to the formal introduction of the euro in 2002. It then slowly increases to 1999 levels. At the beginning of the recession, however, country specific factors start to lose importance and stabilise at around 8 percent of the explained variance in recent years.

Figure 30. Share of total variance of producer price inflation in manufacturing explained by three country specific factors.



Note. Three month moving averages.

There is considerable country heterogeneity in terms of the proportion of explained variance by country specific factors. For example, the share is 20 percent for France, while for Germany, Spain, and Italy it is 8 percent in the last observed year. We deal with the differences across the countries in more detail in the following subsections.

There is a share of variance not accounted for by either of the factors: common EA, sector specific or country specific. The proportion of unexplained variance is about 15 percent and is relatively stable over time. There are country differences, with France having only 8 and Finland 23 percent of variance specific to a country and subsector.

[116] We summarise the Bai and Ng (2002) IC_{p2} criterion results for different observed periods in Table A11 in Appendix A. In a setup with T=221 we get three sufficient factors for Italy, while one factor is sufficient for the other countries (Table C3 in Appendix C).

4.2.4 Geographical differences in variance decomposition

We are interested as to whether factors affect producer prices inflation symmetrically across the euro area. We demonstrate the differences among countries regarding the proportion of variance explained by the EA factors (common and sector specific), country specific factors and the country and sector specific component in Table 21.

Table 21. Proportion of total variance of producer price inflation in manufacturing explained by factors and countries. Average 2014.

	Common EA	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
BE	0.39	0.30	0.69	0.07	0.24
DE	0.59	0.31	0.90	0.05	0.06
EL	0.37	0.27	0.64	0.12	0.24
ES	0.61	0.29	0.89	0.04	0.06
FI	0.30	0.43	0.73	0.11	0.16
FR	0.47	0.24	0.71	0.04	0.25
IT	0.53	0.27	0.81	0.05	0.14
NL	0.52	0.24	0.76	0.10	0.14
PT	0.42	0.26	0.68	0.15	0.16
Mean*	0.47	0.29	0.76	0.08	0.16
St. dev.	0.10	0.06	0.09	0.04	0.07

Note. *Unweighted mean.

The table exhibits some country heterogeneity regarding the proportion of variance attributed to different factors. The EA factors (consisting of one common EA factor and a sector specific factor for each sector) account for 64 to 90 percent of the variance in producer price inflation in the observed countries.

Greece has the lowest share of explained variance by the EA factors at 64 percent. The main reason for this is the low contribution of the common EA factor. For Finland, with even smaller common EA factor contribution, sector specific factors explain the above average proportion of variance.

In this static view (containing information from 2010(3)) we do not find periphery countries to differ substantially from the core euro area countries in terms of the importance of EA factors. In fact, the proportion of variance explained by the EA factors for Spain is as high as in Germany. Italy is also among the countries with important euro area wide component. Greece does have a relatively lower share of explained variance by the EA factors, but similar to the case of Finland, mainly due to low importance of the common EA factor.

4.2.5 Sectoral differences in factor importance

As we find in the previous sections, the sector specific factors explain a considerable share of the variance in producer prices inflation. We are also interested to see whether the factors would affect producer prices inflation symmetrically across manufacturing subsectors. We show the differences across the subsectors regarding the proportion of variance explained by the EA factors (common and sector specific), country specific factors, and the country and sector specific component in Table 22.

Table 22. Proportion of total variance of producer price inflation explained by the factors, by manufacturing subsectors. Average, 2014.

	Common EA	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.41	0.40	0.81	0.07	0.12
Textile	0.63	0.12	0.75	0.06	0.19
Leather	0.38	0.23	0.60	0.11	0.28
Wood	0.42	0.22	0.65	0.18	0.17
Paper and printing	0.53	0.35	0.88	0.04	0.08
Coke, refined fuel	0.62	0.38	0.99	0.00	0.01
Chemicals and pharmaceuticals	0.66	0.22	0.88	0.01	0.11
Rubber and plastic	0.84	0.03	0.87	0.05	0.08
Other non-metallic	0.23	0.46	0.69	0.14	0.17
Metals	0.48	0.47	0.95	0.02	0.03
Electronic	0.42	0.27	0.69	0.07	0.24
Machinery	0.23	0.35	0.58	0.15	0.27
Transport	0.37	0.30	0.67	0.09	0.23
Furniture	0.36	0.30	0.66	0.10	0.25
Mean*	0.47	0.29	0.76	0.08	0.16
St. dev.	0.17	0.12	0.13	0.05	0.09

Note. *Unweighted mean.

Even in recent periods, with a high average variance share explained by EA factors, we find that these factors do not affect subsectors symmetrically. The standard deviation of the share of the variance explained by the EA factors is 0.13. The coke and metals subsectors exhibit the largest EA wide comovements, whereas the machinery subsector exhibits the least important EA wide factors.

4.2.6 Geographical differences in factors' importance – evolution over time

In previous sections where we show the formation of factors, we already indicate the evolution of the importance of these factors over time. One of the objectives of this research is to investigate the impact of the euro on the heterogeneity producer prices.

Although the convergence processes mainly occurred in the years preceding the euro launch, decreasing heterogeneity may still be observed, which manifests as an increased proportion of variance explained by EA factors. However, we are also interested if all euro area countries exhibit the same pattern. In Table 23 we show the evolution of EA factors importance, measured by the proportion of total variance explained by countries.

Table 23. Proportion of total variance of producer price inflation in manufacturing explained by the EA factors; by country and year. Annual averages.

	BE	**DE**	**EL**	**ES**	**FI**	**FR**	**IT**	**NL**	**PT**	**Mean***	**St. dev.**
2000	0.68	0.80	0.47	0.64	0.64	0.81	0.74	0.76	0.69	0.69	0.10
2001	0.67	0.85	0.48	0.63	0.67	0.84	0.79	0.87	0.73	0.73	0.13
2002	0.67	0.84	0.47	0.61	0.72	0.80	0.80	0.83	0.75	0.72	0.12
2003	0.61	0.83	0.64	0.59	0.65	0.74	0.81	0.83	0.81	0.72	0.10
2004	0.51	0.83	0.66	0.61	0.61	0.79	0.83	0.81	0.84	0.72	0.12
2005	0.55	0.81	0.51	0.61	0.49	0.76	0.81	0.77	0.80	0.68	0.14
2006	0.54	0.82	0.56	0.62	0.53	0.71	0.82	0.81	0.76	0.69	0.12
2007	0.62	0.82	0.57	0.68	0.62	0.70	0.82	0.83	0.68	0.70	0.10
2008	0.57	0.77	0.47	0.65	0.57	0.59	0.70	0.79	0.70	0.65	0.10
2009	0.56	0.76	0.50	0.80	0.64	0.64	0.77	0.72	0.73	0.68	0.10
2010	0.62	0.83	0.60	0.91	0.73	0.71	0.85	0.79	0.77	0.76	0.10
2011	0.60	0.81	0.62	0.90	0.68	0.80	0.85	0.77	0.86	0.77	0.11
2012	0.63	0.89	0.55	0.91	0.70	0.83	0.86	0.78	0.83	0.78	0.12
2013	0.66	0.90	0.56	0.89	0.78	0.77	0.85	0.77	0.78	0.77	0.11
2014	0.69	0.90	0.64	0.89	0.73	0.71	0.81	0.76	0.68	0.76	0.09
Δ2014-2000	0.01	0.10	0.16	0.26	0.09	-0.10	0.06	0.00	-0.01	0.06	-0.01
Δ2014-2008	0.13	0.13	0.17	0.25	0.16	0.11	0.10	-0.03	-0.01	0.11	-0.01

Note. *Unweighted mean.

The importance of EA factors increased in the euro period for five euro area countries in the sample. Only three countries exhibit decreased importance of EA factors comparing the first observed periods with the most recent periods. On average, for the euro area the importance of EA factors increased by 6 percentage points in terms of the variance explained.

Most of the countries exhibited increasing importance of EA factors between the introduction of the EMU in 1999 and the formal introduction of the euro in 2002. From 2002 (or 2001 for Spain and Portugal) to 2006, the EA synchronisation of the producer price inflation decreased. Since 2006 we note increases in the importance of EA factors for all the observed countries.

Even though the manufacturing sector in the Netherlands exhibited diverging producer prices in the period 2000–2011, we found an above-average variance share attributed to euro area factors on the subsector level. The same applied to Portugal, while producer price inflation variance was explained by euro area factors to a lesser degree for Belgium, Greece and Spain, which explains the persistent inflation differentials in these countries.

In the presence of a commodity price shock, the synchronisation of the sample EA countries increases. The importance of the EA factors fits well with the occurrence of price shocks in the commodity markets.

As we discuss before, in the last couple of years, in a period of deflation of producer prices the synchronisation of the EA countries' inflation may be higher for the wrong reasons, as far as the OCA criteria are concerned. The nominal rigidity of wages, especially when contraction is needed, could prevent faster adaptation of relative prices that are necessary in order to restore the equilibrium in the euro area, when other channels, such as labour mobility or fiscal transfers are either unimportant or missing.

4.2.7 Sectoral differences in factor importance – evolution over time

Sectoral evidence could provide some additional insight into the evolution of heterogeneity in the euro area. In Table 24 below, we present the evolution over time of the importance of EA factors by individual subsectors.

Table 24. Proportion of variance of producer price inflation explained by the EA factors, by manufacturing subsectors. Annual averages.

	Food	Text	Leath	Wood	Paper	Coke	Chem	Rubb	Non-m	Metals	Elect	Machin	Transp	Furn
2000	0.70	0.57	0.55	0.58	0.90	0.99	0.88	0.74	0.61	0.92	0.62	0.57	0.52	0.50
2001	0.72	0.68	0.70	0.52	0.88	0.98	0.88	0.79	0.76	0.93	0.70	0.48	0.54	0.55
2002	0.82	0.70	0.65	0.52	0.85	0.97	0.88	0.78	0.74	0.93	0.68	0.57	0.49	0.50
2003	0.78	0.71	0.71	0.63	0.86	0.96	0.82	0.75	0.74	0.90	0.65	0.65	0.47	0.53
2004	0.70	0.63	0.73	0.63	0.92	0.95	0.80	0.72	0.75	0.88	0.64	0.65	0.47	0.66
2005	0.66	0.56	0.62	0.58	0.69	0.95	0.74	0.80	0.64	0.92	0.49	0.68	0.49	0.51
2006	0.67	0.61	0.49	0.56	0.84	0.95	0.74	0.79	0.67	0.90	0.54	0.73	0.49	0.57
2007	0.62	0.59	0.51	0.74	0.83	0.96	0.74	0.75	0.84	0.87	0.50	0.82	0.49	0.59
2008	0.79	0.51	0.42	0.72	0.67	0.96	0.67	0.60	0.74	0.81	0.37	0.65	0.50	0.53
2009	0.77	0.50	0.51	0.82	0.77	0.98	0.74	0.72	0.75	0.92	0.55	0.53	0.45	0.49
2010	0.85	0.57	0.69	0.87	0.88	0.99	0.79	0.81	0.84	0.95	0.54	0.77	0.48	0.59
2011	0.87	0.72	0.71	0.77	0.90	0.99	0.75	0.84	0.83	0.95	0.45	0.78	0.49	0.65
2012	0.85	0.74	0.71	0.82	0.86	0.99	0.77	0.89	0.75	0.95	0.58	0.70	0.60	0.65
2013	0.86	0.75	0.69	0.79	0.90	0.99	0.83	0.89	0.70	0.93	0.63	0.61	0.71	0.59
2014	0.81	0.75	0.60	0.65	0.88	0.99	0.88	0.87	0.69	0.95	0.69	0.58	0.67	0.66
Δ14-00	0.11	0.18	0.05	0.07	-0.02	0.01	0.00	0.13	0.08	0.03	0.06	0.01	0.16	0.16
Δ14-08	0.02	0.24	0.18	-0.08	0.21	0.04	0.21	0.27	-0.05	0.14	0.32	-0.07	0.17	0.12

All the subsectors, with the exception of the paper subsector, exhibit increases in the variance shares explained by the EA factors in the euro period. The largest increases were observed in the subsectors of textiles, transport equipment, furniture, and rubber and plastic. The dispersion of EA factors' importance across the subsectors also decreased. The standard deviation of the variance share explained by EA factors fell from 0.17 to 0.13.

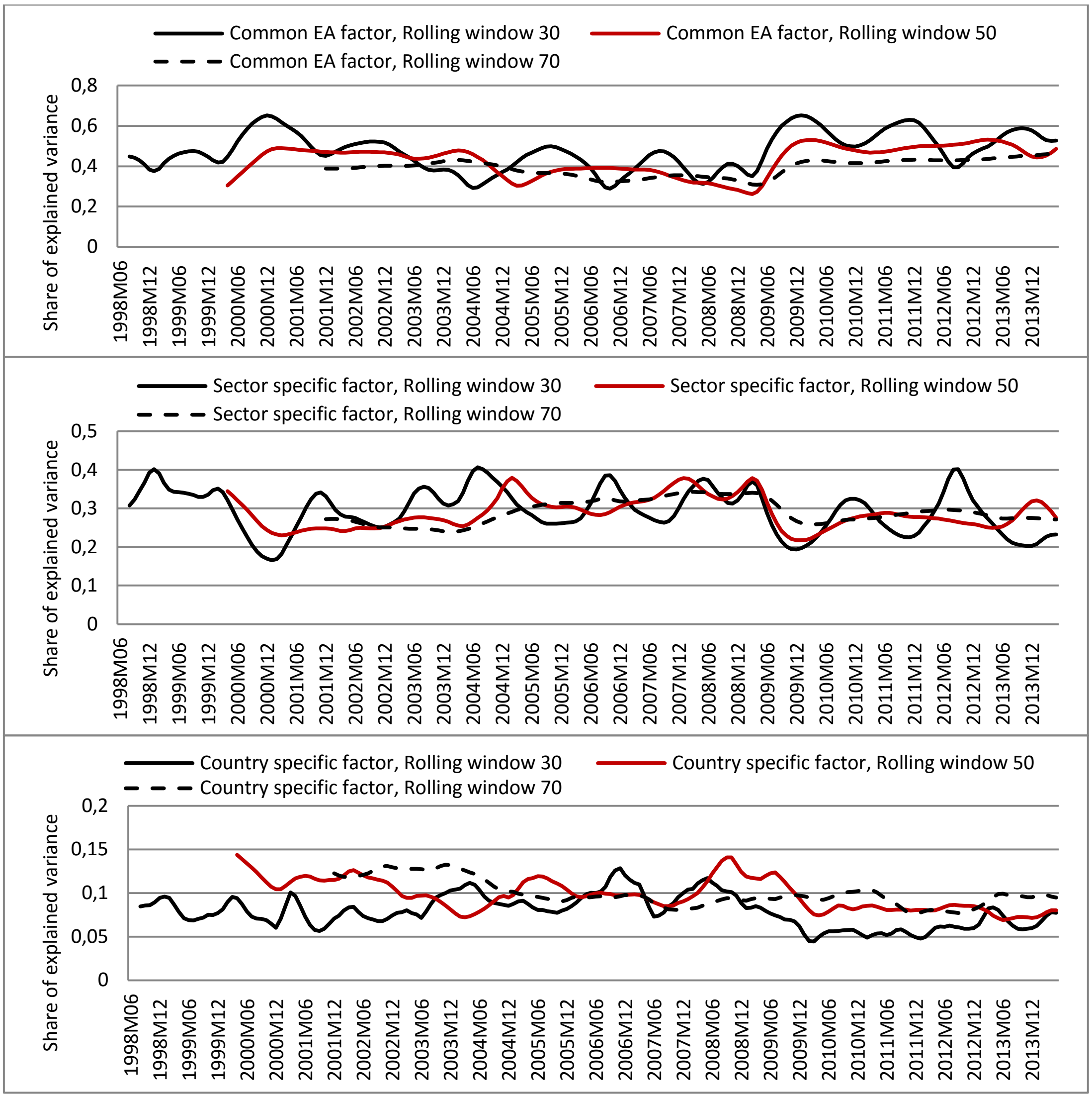
The coke and refined fuel subsector clearly has the most important EA component in terms of producer price inflation variation. The relatively lower contribution of EA factors in the periods observed in 2004–08 could also be attributed to less frequent larger shocks in oil prices.

4.2.8 Robustness check

Rolling window size

We examine the results using alternative sizes of rolling windows. As expected, the variance decomposition becomes more volatile with the decrease in the rolling window time interval. However, the overall evolution of the factors' importance over time shows the same picture, as depicted in Figure 31 below.

Figure 31. Proportion of explained variance of producer price inflation in manufacturing for different sizes of rolling windows.



4.3 Synchronisation of producer price inflation in EU

In this section we use the same methodology to estimate heterogeneity in the manufacturing sector producer price inflation for the EU countries. We expect EU countries to be more heterogeneous than the euro area countries for many reasons. The most obvious reason is that the monetary union does not include all EU countries and so exchange rates can influence pricing strategies: the appreciation or depreciation of a currency can reduce or increase competitiveness and so producers may change prices in response to exchange rate movements.

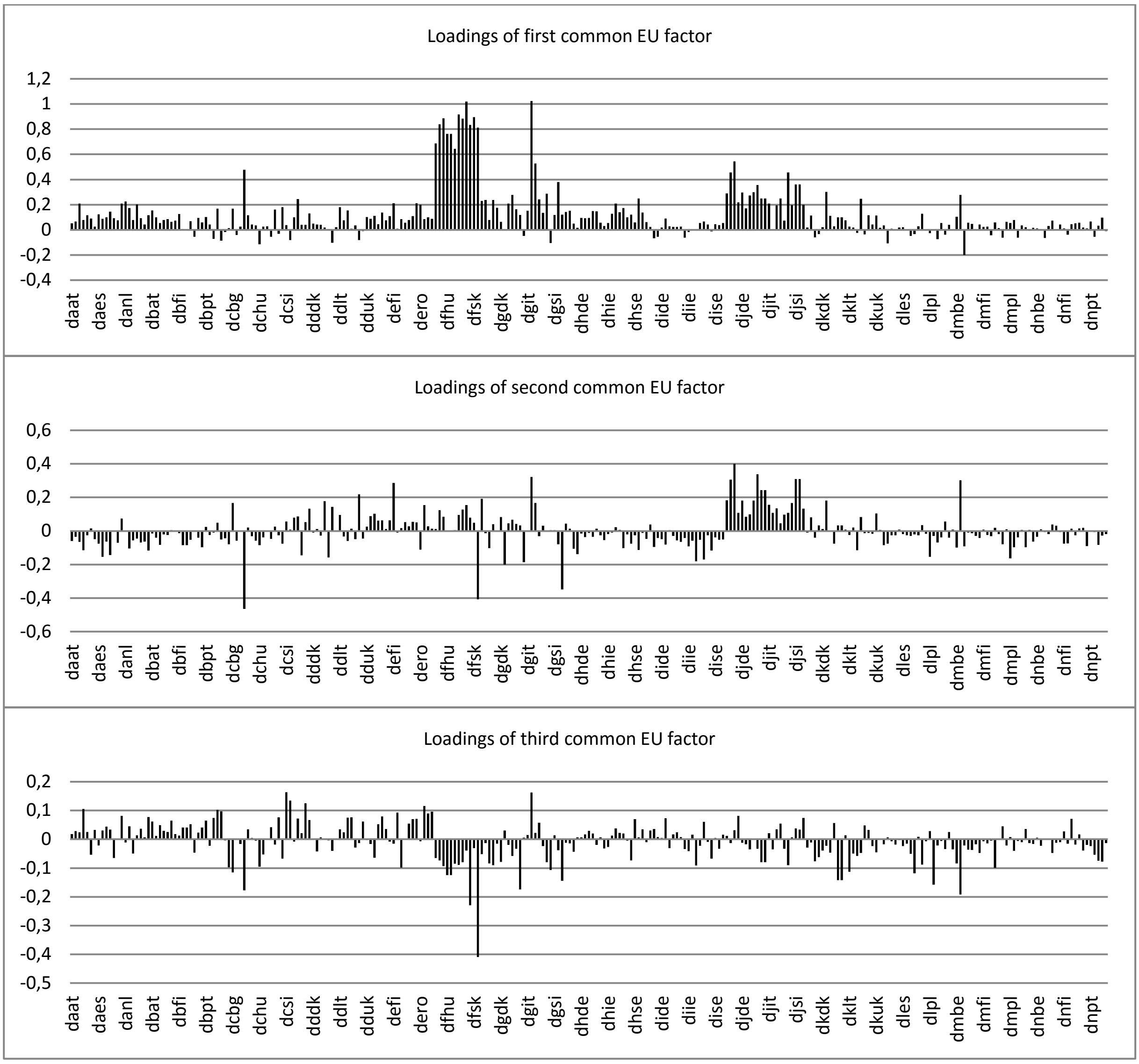
Further, non-euro EU member states have a smaller correlation to the euro area price movement than euro area countries (Table A8 in Appendix A). We therefore expect the common EU and sector specific factors to have less explanatory power for the EU data than the common EA factor in the case of the euro area dataset.

4.3.1 Heterogeneity in the EU in recent periods

In the last observed year with the series of all EU countries from our sample the first common EU factor explains 38 percent of the variance in EU producer price inflation volatility (T=50). The second common factor explains an additional 20 percent of variance.

The factor loadings for the common factors are reported in Figure 32 and exhibit a similar distribution to that observed in EA common factors from the previous section. The statistical information criteria by Bai and Ng (2002) suggest the maximum of predetermined factors, also due in part to the penalty term in the equation (2.2.2) being smaller owing to the larger N in the EU case. However, higher loadings of the third common factor on series of non-euro countries suggest that this factor has some country characteristics, which could be absorbed by the country specific factor in our setup. Further, since we want to compare the results of this exercise with the results for the euro area, we nevertheless use only one common EU factor in our analysis.

Figure 32. Loading of the common EU factors on the EU producer price inflation series in manufacturing subsectors for the last observed period.



Note. N=271, T=50.

Sector specific factors (a single factor for each subsector) explain 28 percent of the variance in our EU sample, which is comparable to the results obtained from our euro area sample (23 percent). Country specific factors (a single factor for each country) account for another 15 percent of the total variance, while 20 percent of the variance is country-sector specific.

Table 25 summarises the geographical differences in the factors' importance for the last observed periods. We find Germany, Spain and Italy to have the highest EU factors' importance (the proportion of variance explained by EU factors is over 80 percent), whereas Ireland and Hungary are the countries with the lowest importance of EU factors (below 50 percent).

Table 25. Average share of explained variance of producer price inflation in manufacturing by common EU, sector specific and country specific factors for EU countries, 2014 average.

	Common EU	Sector specific	EU factors	Country specific	Country-sector specific component
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
AT	0.39	0.31	0.70	0.08	0.23
BE	0.41	0.25	0.66	0.09	0.25
BG	0.29	0.32	0.61	0.15	0.25
CZ	0.29	0.35	0.63	0.20	0.17
DE	0.58	0.31	0.89	0.04	0.07
DK	0.34	0.22	0.56	0.11	0.33
EL	0.39	0.27	0.66	0.15	0.18
ES	0.60	0.26	0.86	0.08	0.06
FI	0.30	0.35	0.66	0.12	0.22
FR	0.45	0.26	0.71	0.04	0.25
HU	0.15	0.32	0.47	0.42	0.11
IE	0.19	0.24	0.43	0.28	0.29
IT	0.52	0.30	0.82	0.05	0.13
LT	0.37	0.20	0.56	0.11	0.33
NL	0.53	0.18	0.71	0.14	0.15
PL	0.38	0.33	0.71	0.15	0.15
PT	0.44	0.18	0.62	0.18	0.20
RO	0.45	0.22	0.67	0.17	0.16
SE	0.21	0.43	0.64	0.20	0.16
SI	0.41	0.26	0.67	0.11	0.22
SK	0.38	0.31	0.69	0.14	0.18
UK	0.31	0.19	0.50	0.24	0.26
Mean*	0.38	0.28	0.66	0.15	0.20
St. dev.	0.12	0.06	0.11	0.09	0.07

Note. *Unweighted mean

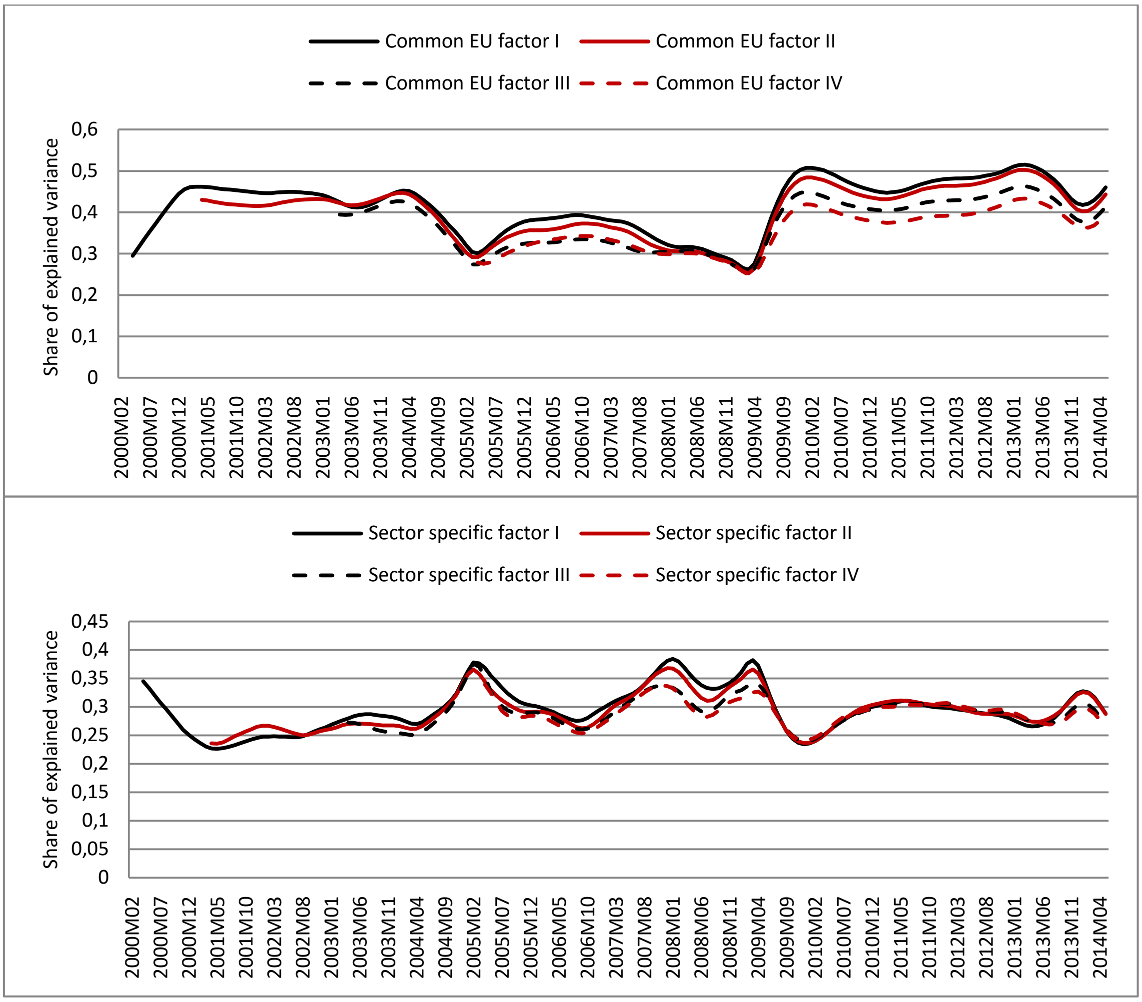
We can observe that the same factor structure imposed on the EU countries compared to the euro area exhibits, on average, smaller shares of explained variance for the common EU factors. Sector specific factors have, on average, almost the same effects in the EU as in the euro area, while the country specific factors are more important for the EU. The share of the variance explained by country specific factors is also more diverse across the countries, standard deviation is 9 percent, compared to 4 percent for the euro area case.

4.3.2 Evolution over time

We perform the analysis with four different samples of countries, based on the data availability and track the evolution of factors' importance over time using the rolling window approach.

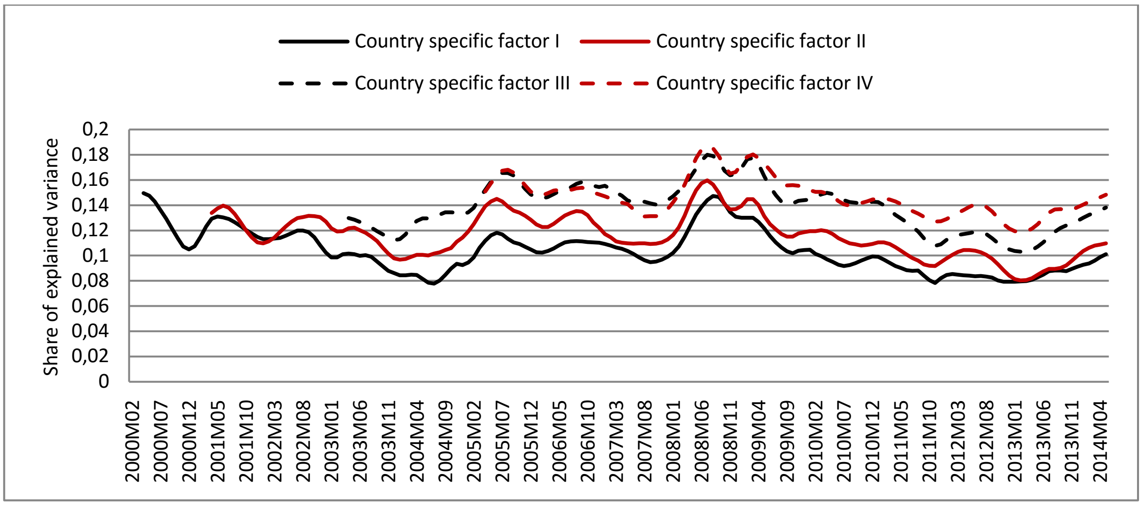
We can observe the diminishing importance of the common EU factor with the increasing number of countries in the sample. The factors' evolution over time is similar to that found in previous euro area analysis, indicating that euro area price movements determine the overall price movements in the EU.

Figure 33. Proportion of variance of producer price inflation in manufacturing explained by factors for four groups of countries. T=50.



(figure continues)

(continued)



Note: Group I: BE, DE, EL, ES, FI, FR, IT, NL, PT, SE, SK; Group II: Group I + AT, CZ; Group III: Group II + HU, LT, SI, UK; Group IV: Group III + BG, DK, IE, PL, RO.

4.4 Synchronisation of producer price inflation in EU with euro area

In this section we investigate the degree of synchronisation of producer prices inflation in manufacturing sector of EU countries with the EA. We start by extracting the common EA and sector specific factors from the EA dataset and continue with country specific factors extraction from the residuals of the regression of EU countries' series on the common EA factor and sector specific factors. In this way we also investigate some euro area countries that are excluded from the analysis in the section 4.2 due to data availability.

We present the results for groups of countries as well as for individual countries. This section is the most exhaustive regarding the quantity of results reported, since the setup enables us to look into detailed results at the country and sector level of all EU countries in our sample. In this section we present also a more detailed disaggregated sector analysis and try to point out sectors that are more prone to asymmetric shocks in prices. A special subsection is dedicated to Slovenia, where we investigate manufacturing sectors producer price inflation synchronisation with the euro area more in detail.

We use a similar setup as in the previous two sections, with one distinction; in the first two stages we operate with euro area dataset (dataset composed of 8 of the founding countries of euro). In this case we use the euro area (8 countries) dataset for the extraction of EA common factors f_t and sector specific factors g_{jt}. From the factor structure depicted in the equation (4.4.1) we extract EA common factors f_t and sector specific factors g_{jt}, which also represent the EA effect albeit on the sectoral level.

$$\pi_{ijt} = \lambda_{ij} f_t + \mu_{ij} g_{jt} + u_{ijt}, \qquad i = 1, \dots, 8 \qquad (4.4.1)$$

With estimates $\hat{f}_t$ and $\hat{g}_{jt}$ we can eliminate the effects of common EA factors and EA sector specific factors from the series in the EU sample by regressing the series on common EA and EA sector specific factors, thereby obtaining estimates of the residuals $\hat{v}_{ijt}$.

The last step is the estimation of country specific factors from the structure represented by the equation:

$$\hat{v}_{ijt} = \eta_{ij} h_{it} + \mathrm{e}_{\mathrm{ijt}}, \qquad (4.4.2)$$

Note that the following applies for i in equation (4.4.1): $i = 1, \ldots, N_{EA}$ and for equation (4.4.2) $i = 1, \ldots, N_{EU}$, where N_{EA} is the number of the countries in the EA sample and N_{EU} the number of the countries in the EU sample.

Estimated factors allow us to compute the contribution of each factor to the share of explained variance of each individual series. Their contribution to the share of explained variance for each individual series thus measure the level of synchronisation of the variation in sectoral producer price inflation across countries. The evolution over time is tracked by following the steps described above recursively with a fixed rolling window.

We first report the results for the latest observed period separately for a country and sectoral level. The evolution over time is reported for country groups. Finally, we report the results obtained for the Slovenian case.

4.4.1 Countries

Not surprisingly, the EA factors exhibit a high importance for euro area countries in our sample, explaining, on average, 72 percent of the variance in producer price inflation. The importance of EA factors for NMS and OMS is 55 and 51 percent, respectively.

An outlier in the euro area is Ireland with only 42 percent of the inflation variance explained by the EA factors. This may not come as such a surprise, since we obtain similar results even in the chapter on heterogeneity in industrial production.

On the other hand, the other countries in the periphery group seem to be as synchronised with the EA factor as the core euro countries. Greece and Portugal have a somewhat lower contribution of EA factors, below 70 percent, while Spain and Italy have variance of above 80 percent explained by the EA factors.

Country specific factors are important in the NMS and OMS without the euro, where they could also include the exchange rate shocks, presuming that companies in different subsectors react to exchange rate changes in the same manner.

Table 26. Contributions of EA and country specific factors to explained variance of producer price inflation in manufacturing for the sample countries. Annual average, 2014. T=50.

		Common EA	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
		(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
EA	BE	0.39	0.30	0.69	0.07	0.24
	AT	0.37	0.27	0.64	0.08	0.28
	DE	0.59	0.31	0.90	0.05	0.06
	FR	0.47	0.24	0.71	0.04	0.25
	NL	0.52	0.24	0.76	0.10	0.14
	FI	0.30	0.43	0.73	0.11	0.16
	EL	0.37	0.27	0.64	0.12	0.24
	ES	0.61	0.29	0.89	0.04	0.06
	IT	0.53	0.27	0.81	0.05	0.14
	PT	0.42	0.26	0.68	0.15	0.16
	IE	0.18	0.24	0.42	0.27	0.31
NMS	BG	0.27	0.29	0.56	0.16	0.28
	CZ	0.26	0.24	0.50	0.34	0.16
	HU	0.14	0.21	0.35	0.52	0.13
	LT	0.34	0.19	0.53	0.13	0.34
	PL	0.40	0.18	0.58	0.25	0.16
	RO	0.46	0.20	0.67	0.15	0.18
	SI	0.42	0.18	0.59	0.16	0.25
	SK	0.38	0.22	0.60	0.14	0.26
OMS	DK	0.35	0.23	0.58	0.11	0.32
	SE	0.21	0.30	0.50	0.28	0.21
	UK	0.32	0.15	0.46	0.24	0.30
Mean EA*		0.43	0.28	0.72	0.10	0.18
Mean NMS*		0.33	0.21	0.55	0.23	0.22
Mean OMS*		0.29	0.22	0.51	0.21	0.28
Mean core EA**		0.47	0.27	0.74	0.07	0.19
Mean periphery EA***		0.42	0.27	0.69	0.13	0.18
St. dev. EA		0.13	0.05	0.13	0.07	0.08
St. dev. NMS		0.11	0.04	0.09	0.14	0.07
St. dev. OMS		0.07	0.07	0.06	0.09	0.05

Note. EA includes also Austria, Greece and Ireland, that are not included in calculation of the EA factors *Unweighted means. **Core EA: AT, BE, DE, FR, NL. ***Periphery EA: EL, ES, IE, IT, PT.

Denmark is also an interesting case since we expect EA factors to be more important and country factors less important than in, for example, Sweden, since Denmark had an almost fixed exchange rate regime versus euro, while Swedish krona appreciated in the period covered in the results.[117] Our results confirm this fact as the EA factors explain more variability in producer price inflation in Denmark than in the other two OMS, Sweden and the UK. Likewise, the country specific factors are least important for Danish manufacturing sectors prices.

In the case of NMS volatility in exchange rates only partly explains differences among NMS synchronisation of producer price inflation with EA. Unexpectedly, besides Slovenia[118] and Slovakia that are part of the EA in the observed period[119], also Romania and Poland are highly synchronised with the EA. The Czech Republic, Hungary, Poland and Romania have a floating exchange rate but the importance of EA factors is relatively small only for Hungary and partly also Czech Republic. However, besides Hungary and Czech Republic, also Poland has a high share of country specific factor compared to countries that have an almost or completely fixed exchange rate to euro (Bulgaria, Lithuania, Slovakia, and Slovenia in our sample). Romania is a special case as it also has the largest share of variance explained by EA factors apart from the founding euro area countries.

4.4.2 Sectors

EA factors explain, on average, 72 percent of variance in the EA manufacturing subsectors producer price inflation in the last year, excluding sector of coke and refined fuel. EA factors in NMS and OMS account for 52 percent of the variance.

There are also notable differences across the subsectors. Apart from the coke and refined fuel subsector, EA factors also seem more important in the euro area also for the subsectors of basic metals, chemicals and pharmaceuticals, rubber and plastics, paper and printing, and food.

Table 27. Variance of producer price inflation explained by group of factors and groups of EU countries, disaggregated to 14 manufacturing subsectors. Annual average, 2014.

	Common EA			**Sector specific**			**EA factors**			**Country specific**		
	(1)			(2)			(3)=(1)+(2)			(4)		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
Food	0.41	0.46	0.42	0.37	0.31	0.23	0.78	0.77	0.65	0.09	0.09	0.13
Textile	0.60	0.30	0.34	0.13	0.14	0.12	0.73	0.44	0.46	0.09	0.29	0.26
Leather	0.31	0.17	0.30	0.22	0.20	0.12	0.53	0.38	0.41	0.12	0.26	0.27
Wood	0.39	0.25	0.43	0.24	0.28	0.20	0.63	0.53	0.63	0.17	0.25	0.08
Paper and printing	0.48	0.39	0.31	0.33	0.17	0.35	0.80	0.55	0.66	0.10	0.20	0.13
Coke, refined fuel	0.62	0.62	0.29	0.38	0.31	0.14	0.99	0.93	0.43	0.00	0.05	0.10

(table continues)

[117] Data on monthly exchange rates, ECB.

[118] Slovenia is discussed more in detail in the following section.

[119] The results in Table 26 are for year 2014; however they implicitly include information from 2009 onwards due to rolling window with T=50.

(continued)

	Common EA			Sector specific			EA factors			Country specific		
	(1)			(2)			(3)=(1)+(2)			(4)		
Chemicals and pharmaceuticals	0.57	0.59	0.09	0.28	0.08	0.20	0.85	0.67	0.29	0.02	0.14	0.26
Rubber and plastic	0.80	0.43	0.54	0.04	0.04	0.10	0.83	0.47	0.64	0.05	0.32	0.19
Other non-metallic	0.24	0.13	0.44	0.45	0.46	0.27	0.69	0.59	0.71	0.15	0.29	0.07
Metals	0.49	0.44	0.49	0.44	0.35	0.37	0.93	0.78	0.86	0.02	0.12	0.08
Electronic	0.36	0.31	0.09	0.31	0.13	0.24	0.66	0.44	0.33	0.08	0.31	0.23
Machinery	0.22	0.22	0.10	0.30	0.31	0.42	0.52	0.53	0.53	0.21	0.27	0.30
Transport	0.31	0.17	0.16	0.26	0.11	0.18	0.57	0.29	0.34	0.12	0.34	0.45
Furniture	0.33	0.24	0.13	0.28	0.11	0.10	0.60	0.35	0.23	0.12	0.35	0.30
Mean*	0.44	0.34	0.30	0.29	0.21	0.22	0.72	0.55	0.51	0.10	0.23	0.20
St. dev.	0.16	0.15	0.16	0.11	0.12	0.10	0.15	0.18	0.18	0.06	0.10	0.11

Note. *Unweighted mean

Importance of EA sector specific factors in the euro area sectors is between 20 and 45 percent of the explained variance, with two exceptions: rubber and plastics, and textile with less important EA sector specific factors at 4 and 13 percent, respectively.

The coke and refined fuel sector has almost 100 percent of explained variability by EA factors in the euro area. The UK is the only OMS to include this sector in the dataset. The lower synchronisation between the UK and the euro area in this subsector can only be observed in the last two years, and it was also highly synchronised until 2012. The high synchronisation of this subsector possibly reflects the world price shocks that have been quite symmetric across EU.

In general we find EA sector specific factors to also be quite important for the NMS and OMS. Chemicals and pharmaceuticals, and electronic products are subsectors where we observe less important sector specific factors for the NMS in recent periods. We could support the previous speculation that the sectors which are more dependent on the commodity prices have a higher than average importance of EA factors.

4.4.3 Evolution over time

In the case of producer prices data we are even more limited by the data availability than in the case of industrial production indices. In Table 28 below we show the evolution of the factors' importance for the groups of EU countries.

Table 28. Evolution of factors' importance over time for the EA, NMS and OMS. Share of explained variance of producer price inflation in manufacturing, annual averages.

	Common EA			**Sector specific**			**EA factors**			**Country specific**		
	(1)			(2)			(3)=(1)+(2)			(4)		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
2005	0.33	0.20	0.23	0.29	0.21	0.23	0.62	0.41	0.46	0.13	0.30	0.19
2006	0.38	0.24	0.32	0.26	0.18	0.16	0.63	0.42	0.48	0.11	0.30	0.23
2007	0.37	0.24	0.35	0.28	0.24	0.19	0.66	0.48	0.53	0.11	0.26	0.20
2008	0.31	0.27	0.25	0.28	0.20	0.21	0.60	0.46	0.46	0.14	0.29	0.27
2009	0.38	0.28	0.28	0.25	0.19	0.22	0.63	0.47	0.50	0.14	0.27	0.27
2010	0.49	0.32	0.25	0.21	0.20	0.27	0.71	0.53	0.52	0.10	0.27	0.31
2011	0.46	0.31	0.25	0.25	0.22	0.25	0.71	0.53	0.50	0.10	0.28	0.31
2012	0.48	0.33	0.26	0.24	0.23	0.27	0.73	0.56	0.52	0.10	0.25	0.27
2013	0.48	0.36	0.27	0.24	0.21	0.25	0.72	0.56	0.52	0.10	0.22	0.24
2014	0.43	0.32	0.29	0.28	0.21	0.23	0.71	0.52	0.52	0.10	0.25	0.21
Δ2014-2005	0.09	0.12	0.06	-0.01	-0.01	0.00	0.08	0.11	0.06	-0.03	-0.06	0.02

As observed in Table 28, the importance of the common EA factor increased in all groups of countries, when comparing the periods 2001–2005 and 2014–2010. The importance of sector specific factors did not change, whereas the importance of country specific factors decreased for the groups of euro area countries and NMS.

The synchronisation of the EA countries was relatively stable in terms of the variance explained by EA factors in the period before the prolonged recession. In the last couple of years, the synchronisation has increased, mostly due to the heightened importance of the common EA factor. The share of explained variance by sector specific factors, on the other hand, remains quite stable, but lost some of their explanatory power at the beginning of the crisis compared to pre-crisis levels. Country specific factors accounted for around 10 percent of the variance, with the lowest shares observed in the recession years following 2010.

The synchronisation of OMS with EA is lower, but EA factors still account for around half of the variance. We observe that the importance of sector specific factors is on the level of importance of the common EA factor for this group of countries. Sector specific factors explain almost as much variance as for the EA countries. Country specific factors form an important part, explaining more than 20 percent of the variance.

The importance of EA factors for the NMS is similar to that for the OMS countries, explaining around half of the total variance for this group of countries. Sector specific factors are again important, exceeding 20 percent of the explained variance in most of the observed periods. As is the case for OMS, country specific factors account for a substantial share of the variance, around 20 percent. Country specific factors are the most important in the periods ending in 2008–2012, with close to 30 percent of the explained variance.

A more detailed breakdown of the countries reveals that the EA factors are more important for the core countries than the periphery euro area countries throughout the observed period (Table C.5 in Appendix C.4). The difference is smallest in the periods around the start of the financial crisis, while it rises in the periods after the sovereign debt crisis, reflecting slow adjustment of the relative prices in the periphery countries.

In the group of NMS, countries that joined the EU in 2007 (BG, RO) on average exhibit greater synchronisation of price inflation than the countries that joined the EU in 2004. Moreover, the trend for these two countries is increasing in the periods after the financial crisis, reaching 60 percent of the explained variance in the last observed periods.

4.4.4 Slovenia

Slovenia has had quite a high degree of synchronisation with the EA relative to other NMS in recent years of observations, which is expected since it has been a member of the euro area since 2007. A high degree of synchronisation is already observable prior to its accession to the EU in 2004. It decreased in the first years of its EU membership, before increasing again after joining the EA in 2007.

Table 29. Contribution of EA and country specific factors for Slovenia. Share of explained variance of producer price inflation in manufacturing, annual averages.

	Common EA	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
2003	0.36	0.19	0.55	0.18	0.27
2004	0.48	0.15	0.62	0.14	0.23
2005	0.16	0.26	0.41	0.21	0.38
2006	0.18	0.21	0.39	0.22	0.40
2007	0.25	0.21	0.47	0.18	0.35
2008	0.28	0.22	0.49	0.20	0.31
2009	0.24	0.22	0.46	0.18	0.36
2010	0.31	0.24	0.56	0.15	0.30
2011	0.31	0.27	0.59	0.15	0.26
2012	0.39	0.26	0.65	0.13	0.22
2013	0.41	0.19	0.60	0.13	0.26
2014	0.42	0.18	0.59	0.16	0.25
Δ2014-2003	0.06	-0.01	0.04	-0.02	-0.02

Detailed analysis of the synchronisation of subsectors (Table 30) shows that, for some sectors, the importance of EA factors is on the level of EA countries, whereas EA factors are not that important for some. In the last observed periods, for four subsectors, the EA factors explain even more variance than for the EA countries; the food, metals, electronic and machinery subsectors. The metals subsector stands out with 97 percent of the variance in producer price inflation explained by EA factors. On the other hand, there were quite a few subsectors that contributed to lower synchronisation. The subsectors of leather, wood and transport are well below average euro area levels.

Table 30. Explained variance of producer price inflation by EA and country specific factors for manufacturing subsectors in Slovenia. Annual average, 2014.

Subsector	**Common EA**	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.20	0.64	0.84	0.01	0.15
Textile	0.54	0.16	0.70	0.01	0.29
Leather	0.05	0.08	0.13	0.42	0.45
Wood	0.01	0.12	0.13	0.63	0.24
Paper and printing	0.47	0.13	0.61	0.16	0.24
Chemicals and pharmaceuticals	0.73	0.01	0.73	0.00	0.27
Rubber and plastic	0.75	0.01	0.76	0.01	0.23
Other non-metallic	0.26	0.18	0.45	0.30	0.25
Metals	0.38	0.59	0.97	0.02	0.01
Electronic	0.82	0.03	0.85	0.10	0.05
Machinery	0.63	0.22	0.85	0.00	0.15
Transport	0.10	0.00	0.10	0.11	0.79
Furniture	0.48	0.10	0.58	0.28	0.14
Mean*	0.42	0.18	0.59	0.16	0.25
St.dev.	0.28	0.21	0.30	0.20	0.20
Min	0.01	0.00	0.10	0.00	0.01
Max	0.82	0.64	0.97	0.63	0.79

Note. *Unweighted mean

The evolution over time is also quite different across the sectors. Even though the manufacturing sector producer prices inflation in Slovenia exhibited an increased share of variance explained by EA factors, there were, on average, seven subsectors that showed decreased effects in terms of EA factors. The transport equipment and wood sectors showed the largest decreases, while the rubber and plastic sectors increased the most.

4.5 Heterogeneity of prices in broader sectors in the EU

In previous sections we deal with producer prices in the manufacturing sector that represents about 20 percent of the economy. Since divergence in unit labour costs is the prevalent explanation for surging trade imbalances in the euro area, and consequently divergence in growth across broader sectors of the economy, we are interested also in the economy wide prices development. In order to gain additional insight into economy-wide prices development we investigate broader sectors of the economy, examining both prices and wages across sectors and countries.

We perform an additional analysis using national accounts quarterly data on price deflators disaggregated to 10 sectors.[120] We investigate two distinct periods, the pre-crisis period, 2001 – 2007, and the period marked by financial and subsequent sovereign debt crisis, 2008-2014. Namely, quarterly data limit our ability to inspect inflation synchronisation in time by means of a rolling window methodology.

We apply the hierarchical DFM to estimate the common EA factor, sector specific factors and country specific factors for both periods. We report the proportion of explained variance by the factors in Table 31.

Table 31. Proportion of variance of price inflation explained by factors for the broad sectors for two distinct periods, by country and groups of countries.

	2001-2007				**2008-2014**			
	Common EA factor	**EA factors***	**Country specific factor**	**Unexplained variance**	**Common EA factor**	**EA factors***	**Country specific factor**	**Unexplained variance**
EA	*0.10*	*0.29*	*0.18*	*0.53*	*0.15*	*0.36*	*0.19*	*0.46*
Core	*0.11*	*0.33*	*0.17*	*0.49*	*0.19*	*0.43*	*0.15*	*0.42*
AT	0.07	0.18	0.20	0.61	0.17	0.30	0.18	0.52
BE	0.12	0.35	0.17	0.48	0.13	0.51	0.16	0.33
DE	0.08	0.40	0.20	0.40	0.30	0.41	0.17	0.43
FR	0.14	0.41	0.14	0.45	0.09	0.52	0.10	0.38
NL	0.13	0.31	0.15	0.53	0.27	0.42	0.15	0.43
FI	0.14	0.40	0.13	0.47	0.10	0.36	0.14	0.50
Periphery	*0.09*	*0.23*	*0.20*	*0.58*	*0.13*	*0.29*	*0.23*	*0.49*
EL	0.05	0.14	0.19	0.67	0.09	0.18	0.22	0.61
ES	0.14	0.35	0.17	0.49	0.12	0.36	0.27	0.37
IE	0.03	0.12	0.31	0.57	0.19	0.24	0.28	0.48
IT	0.14	0.36	0.14	0.50	0.16	0.49	0.11	0.40
PT	0.10	0.17	0.17	0.66	0.08	0.17	0.24	0.59
NMS	*0.06*	*0.11*	*0.34*	*0.55*	*0.13*	*0.21*	*0.31*	*0.48*
NMS 2004	*0.06*	*0.11*	*0.35*	*0.54*	*0.13*	*0.23*	*0.33*	*0.43*
CZ	0.06	0.12	0.45	0.44	0.09	0.25	0.45	0.30
EE	0.06	0.11	0.23	0.66	0.12	0.20	0.21	0.59
HU	0.06	0.10	0.53	0.37	0.16	0.22	0.55	0.23
LV	0.03	0.13	0.41	0.46	0.20	0.31	0.19	0.50
PL					0.24	0.35	0.49	0.17
SI	0.05	0.10	0.20	0.70	0.09	0.19	0.22	0.59
SK	0.07	0.11	0.25	0.65	0.03	0.10	0.25	0.65
NMS 2007	*0.07*	*0.11*	*0.34*	*0.55*	*0.10*	*0.15*	*0.22*	*0.64*
BG	0.04	0.10	0.23	0.67	0.07	0.12	0.20	0.68
RO	0.10	0.13	0.44	0.43	0.14	0.17	0.23	0.60

(table continues)

[120] National accounts data in accordance with ESA2010 classification, disaggregated to 10 NACE Rev. 2 classification of economic activity.

(continued)

	2001-2007				2008-2014			
	Common EA factor	**EA factors***	**Country specific factor**	**Unexplained variance**	**Common EA factor**	**EA factors***	**Country specific factor**	**Unexplained variance**
OMS	*0.09*	*0.14*	*0.45*	*0.42*	*0.13*	*0.21*	*0.44*	*0.34*
DK	0.06	0.11	0.23	0.66	0.08	0.13	0.21	0.66
SE	0.14	0.17	0.49	0.34	0.20	0.26	0.54	0.20
UK	0.06	0.15	0.61	0.24	0.12	0.25	0.58	0.17

Note. *Combined effect of EA common and sector specific factors.

On average, the EA factors explain 33 percent of variance in the pre-crisis period and 43 percent in the depression period for the core euro area countries (average explained variation of the EA factors over respective periods in case of the manufacturing sector is 68 and 76 percent). The explained variance for the periphery countries is 23 percent for the pre-crisis period and 29 percent for the last period (67 and 70 percent for the manufacturing sector). The results therefore confirm a lower level of synchronisation of prices measured by respective sectoral price deflators for the periphery countries in the euro area compared to the core countries, however the difference is higher in the case of broader sectors. On the other hand, among the periphery countries, Italy and Spain are even above the average level of the core countries in terms of proportion of variance explained by the EA factors in the pre-crisis period. In the second period, only Italy has above the core euro area average proportion of variance explained, while the importance of the EA factors for Spain is below core euro area countries' average.

Similarly to the case of the manufacturing sector in previous sections, we also find lower levels of synchronisation for the new member states and the old member states that are not a part of the euro area, with proportion of variance explained in the last period at 21 percent.[121]

We find all countries except Finland and Slovakia to increase the proportion of variance explained by the EA factors in the second period that is marked by depression and low inflation or deflationary pressures.

We further inspect sectoral differences for the core and periphery euro area countries. We observe real estate and construction sectors to exhibit the greatest importance of the EA factors in the first time period for the core euro area countries, while in the second time period the real estate and agriculture sectors exhibit the greatest importance in terms of proportion of explained variance (Table 32). The construction sector, on the other hand, is the only sector with decreased proportion of the variance explained by EA factors.

[121] For the manufacturing sector, the proportion of variance explained by the EA factors in the depression period is on average 57 and 52 percent for the new and old member states, respectively.

Table 32. Proportion of variance of price inflation explained by factors for the core euro area countries for two distinct periods, by broad sector.

	2001-2007			2008-2014		
	Common EA factor	**EA factors**	**Country specific factor**	**Common EA factor**	**EA factors**	**Country specific factor**
Agriculture	0.04	0.29	0.08	0.05	0.54	0.13
Industry	0.10	0.26	0.19	0.13	0.42	0.17
Construction	0.05	0.42	0.16	0.13	0.37	0.14
Wholesale and retail	0.14	0.34	0.16	0.20	0.40	0.14
ITC	0.11	0.28	0.13	0.09	0.28	0.18
Finance	0.11	0.31	0.20	0.36	0.49	0.11
Real estate	0.20	0.44	0.14	0.40	0.68	0.13
Professional services	0.09	0.35	0.18	0.13	0.36	0.11
Public services	0.11	0.33	0.27	0.17	0.41	0.23
Arts, entertainment and recreation	0.13	0.31	0.22	0.27	0.36	0.19
Mean*	0.11	0.33	0.17	0.19	0.43	0.15
St. dev.	0.04	0.06	0.05	0.12	0.11	0.04

Note. *Unweighted mean.

In the periphery euro area countries, we find the sector of agriculture to exhibit the greatest importance of EA factors in the pre-crisis period (Table 33), exceeding the average importance of the core euro area countries. The proportion of variance of the sector of industry explained by EA factors is on the same level as in the core euro area countries, while other sectors exhibit smaller importance of EA factors than the core euro area countries on average. In the second period, the sectors of real estate, and wholesale and retail have the greatest share of variance explained by the EA factors.

Table 33. Proportion of variance of price inflation explained by factors for the periphery euro area countries for two distinct periods, by broad sector.

	2001-2007			2008-2014		
	Common EA factor	**EA factors**	**Country specific factor**	**Common EA factor**	**EA factors**	**Country specific factor**
Agriculture	0.06	0.38	0.16	0.07	0.22	0.24
Industry	0.10	0.26	0.12	0.13	0.19	0.20
Construction	0.09	0.14	0.19	0.12	0.34	0.17
Wholesale and retail	0.15	0.27	0.23	0.13	0.42	0.23
ITC	0.12	0.21	0.17	0.03	0.25	0.33
Finance	0.06	0.23	0.15	0.16	0.33	0.14
Real estate	0.14	0.23	0.24	0.37	0.43	0.21
Professional services	0.07	0.17	0.27	0.06	0.22	0.28
Public services	0.06	0.20	0.14	0.06	0.12	0.22

(table continues)

(continued)

	2001-2007			2008-2014		
	Common EA factor	**EA factors**	**Country specific factor**	**Common EA factor**	**EA factors**	**Country specific factor**
Arts, entertainment and recreation	0.08	0.18	0.30	0.15	0.35	0.23
Mean*	0.09	0.23	0.20	0.13	0.29	0.23
St. dev.	0.03	0.07	0.06	0.10	0.10	0.05

Note. *Unweighted mean.

In the periphery euro area countries, the increase in the proportion of variance explained by the EA factors in the second period is smaller as in the case of core euro area countries. Sectors of agriculture, industry, and public services even exhibit decreased importance of the EA factors' importance.

Since the prevailing explanation for the surging trade imbalances in the euro area is divergence in unit labour costs (DeGrauwe, 2011), we also investigate the heterogeneity in wage growth on a country and sectoral level. We compute labour costs per hour worked, using Eurostat quarterly national accounts data, for each sector and country.

We report the results of variance explained by the factors for groups of countries in Table 34.[122]

Table 34. Proportion of variance of wage growth in broad sectors explained by factors for groups of EU countries for two distinct periods.

	2001-2007				2008-2014			
	Common EA factor	**EA factors***	**Country specific factor**	**Unexplained variance**	**Common EA factor**	**EA factors***	**Country specific factor**	**Unexplained variance**
EA	0.10	0.28	0.21	0.51	0.09	0.27	0.22	0.51
core	0.16	0.39	0.20	0.41	0.11	0.33	0.17	0.50
periphery	0.06	0.19	0.24	0.58	0.07	0.20	0.26	0.54
NMS	0.04	0.09	0.33	0.58	0.07	0.11	0.35	0.54
OMS	0.02	0.08	0.53	0.39	0.01	0.08	0.66	0.26

Note. *Combined effect of EA common and sector specific factors.

We find the degree of synchronisation to be higher for the core euro area countries also for the wage growth. The heterogeneity in wage growth could therefore be the decisive underlying factor in the divergence of the prices in the euro area.

122 Detailed results by country are in Appendix C.4, Table C11.

The importance of the EA factors has not increased in the second period. We can only observe a small increase in the group of periphery euro area countries and new member states.

The main conclusions about the synchronisation of the manufacturing sector producer prices inflation and economy wide prices and wage inflation in the euro area correspond, even though the differences between core and periphery euro area countries are more substantial in the case of broader sectors. The degree of synchronisation in the core countries is higher than in the periphery euro area countries already in the pre-crisis period. The exceptions are Italy and, to some extent, Spain that reach or even exceed the degree of synchronisation of the core euro area countries.

4.6 Exploring the linkages of price heterogeneity to the output synchronisation

This subsection deals with the price heterogeneity in relation to output synchronisation in the manufacturing sector.

We tackle this issue by analysing relationship between inflation and output synchronisation, using a panel regression method. We perform a regression analysis on a panel of country and sectoral shares of explained variance of inflation and output growth by the common factors. Thus, we investigate whether higher inflation synchronisation is associated to higher output growth synchronisation. To this end, we regress the share of output growth variance explained by the common EA factor on the corresponding explained share in inflation. The regressions control for country and sector fixed effects and are estimated over three periods. The first is the longest sample 2000-2014, but we also consider two sub-periods: before the crisis, 2000-2007, and post crisis, 2008-2014.

Table 35. OLS regression of proportion of output growth variance in manufacturing explained by common factor on proportion of producer price inflation variance explained by common factor, by groups of countries.

	2000-2014			**2000-2007**			**2008-2014**		
	EA	**OMS**	**NMS**	**EA**	**OMS**	**NMS**	**EA**	**OMS**	**NMS**
prices	-0.003	-0.037***	0.037***	0.000	-0.059***	0.013*	0.057***	-0.177***	0.044***
	(0.003)	(0.009)	(0.005)	(0.004)	(0.011)	(0.007)	(0.008)	(0.021)	(0.009)
constant	0.575***	0.527***	0.323***	0.590***	0.574***	0.315***	0.504***	0.497***	0.314***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.004)	(0.002)	(0.004)	(0.006)	(0.003)
observations	18047	4448	12008	10729	2368	5768	6009	1696	5088

Notes. Unit of observation is proportion of explained variance by the common EA factor for a time period of 50 months, by country and subsector. Fixed effects panel regressions. Significance at the 1/5/10 % level is indicated by ***/**/*. Standard errors in parentheses.

We find that higher inflation synchronisation is significant in explaining higher output growth synchronisation for new member states in both observed periods, pre and post crisis. For the euro area countries, the coefficient is significant and positive only in the post crisis period. On the other hand, the coefficient is negative and significant for the old member states outside of the euro area in both periods.

Since the unit of observation is on the subsector level, the results indicate that higher integration of a subsector results both in higher output growth and inflation synchronisation for the EA and the NMS in the post crisis period.

We further check the linkage of relative prices in manufacturing and output synchronisation on a country level. In contrast to the previous exercise, we deal with the levels of prices rather than inflation. The regressor is the relative producer price in manufacturing of a country compared to the euro area average. This type of analysis can provide some insights whether disproportionate relative prices lead to lower output growth synchronisation.

Table 36. OLS regression of proportion of output growth variance in manufacturing explained by common factor on relative producer prices, by groups of countries.

	2000-2014			**2000-2007**			**2008-2014**		
	EA	**OMS**	**NMS**	**EA**	**OMS**	**NMS**	**EA**	**OMS**	**NMS**
prices	0.011***	-0.038***	0.014***	0.025***	0.074***	0.011***	-0.075***	-0.251***	0.006
	(0.003)	(0.011)	(0.002)	(0.003)	(0.011)	(0.002)	(0.022)	(0.014)	(0.009)
constant	0.531***	0.487***	0.261***	0.543***	0.495***	0.261***	0.522***	0.484***	0.298***
	(0.002)	(0.004)	(0.006)	(0.001)	(0.004)	(0.006)	(0.004)	(0.004)	(0.036)
observations	1666	492	1074	1016	297	554	650	195	520

Notes. Unit of observation is proportion of explained variance of output growth by the common EA factor for a time period of 50 months for the dependent variable and average relative producer price for the same period, by country. Fixed effects panel regressions. Significance at the 1/5/10 % level is indicated by ***/**/*. Standard errors in parentheses.

We can observe that high relative prices were not associated with lower output growth synchronisation in any group of the EU countries prior to the crisis. This can also be a reflection of the credit fuelled growth in the periphery countries leading to divergence of the relative prices.

However, in the period after the financial crisis high relative prices are associated with lower output growth synchronisation for the euro area countries and old member states, while there is no significant effect for the new member states. For the euro area, this reflects both too high relative prices in the periphery countries (Figure 26) that experienced greater effects of the crisis on output and, on the other hand, low relative prices especially for Germany that is highly synchronised with the euro area.

The negative relationship between relative prices and output synchronisation for the euro area signals that the ability of countries to adjust the relative prices is crucial also in terms of OCA criteria for synchronised business cycles.

Next, we test the impulse response of producer prices and output on a country level to a common euro area wide shock in prices or output to determine whether common policies can contribute to adjustment of relative prices.

We use the factor-augmented VAR model (FAVAR) proposed by Bernanke, Boivin and Eliasz (2005) to determine the effect of a common euro area output or price shock on EU countries.[123]

The joint dynamics of factors is assumed to be defined by a VAR

$$\phi_0 \begin{bmatrix} F_t^o \\ F_t^p \end{bmatrix} = \phi(L) \begin{bmatrix} F_{t-1}^o \\ F_{t-1}^p \end{bmatrix} + \varepsilon_t, \qquad (4.6.1)$$

where F_t^o is an unobservable factor, representing the output in manufacturing and F_t^p is an unobservable factor, representing the producer prices in manufacturing. $\phi(L)$ is a lag polynomial with finite order and ε_t is a vector of shocks.

First, we analyse the transmission of a euro area price shock at the level of individual countries and we find important heterogeneity across countries in the effect of price shocks. We report aggregated results for groups of EU countries in Table 37.[124]

Table 37. FAVAR impulse response after 1 year to a shock in the EA common factor of the producer prices in manufacturing, for two distinct periods, by groups of countries.

	Industrial production		**Producer price index**	
	2000-2007	**2008-2014**	**2000-2007**	**2008-2014**
EA	0.13	0.45	1.38	3.23
core	0.22	0.55	1.58	3.73
periphery	0.02	0.14	1.14	2.54
NMS	-0.03	0.49	0.54	2.02
NMS 2004	-0.02	0.51	0.57	1.85
NMS 2007	-0.07	0.41	0.43	2.71
OMS	0.04	0.26	1.10	1.03

Notes. Percentage deviation from the baseline level. Shock size is 0.005 for both periods.

In the pre-crisis period, the effect of a shock in the PPI common EA factor on industrial production is more pronounced for the EA countries, especially the core euro area

[123] More on the monetary policy shock effects in the euro area countries before and after the creation of the euro in Boivin, Giannoni and Mojon (2008).

[124] Detailed results by country are in the Appendix C.4, Figures C5 and C6.

countries. The periphery euro area countries exhibit lower response relative to the core EA countries.

Apart from differences across groups of countries, we also find differences in the response between two distinct periods in time. The effects in the second observed period, after 2008, are more pronounced for all groups of EU countries.

The periphery EA countries exhibit the lowest effect on industrial production of the price shock. The difference between NMS and EA countries decreases in the post crisis period. The impulse response of the industrial production of the OMS countries increases less, but also gains relatively to the EA countries.

The response of producer prices differs across groups of countries as well. We observe considerable difference between the core and periphery EA countries; however the periphery countries on average still exhibit larger effect on producer prices than the NMS and OMS.

The effect of the shock on producer prices is more pronounced in the second observed period after the financial crisis. This period is marked by low inflation and deflationary pressures. Impulse responses for the second period show that a common positive shock in prices would cause the producer prices in the core EA countries to rise more, relatively to the periphery countries. However, the response of the producer prices would be strong and positive also for the periphery countries, thus partly offsetting the possibilities of a common policy to affect imbalances of the relative prices in the euro area countries. For the NMS, the increase of the impulse response in prices in the post crisis period is even more pronounced, indicating greater integration of the NMS in the post crisis period. On the other hand, the OMS impulse response in the post crisis period is lower both in absolute terms and relative to the EA countries.

Second, we analyse the transmission of a euro area shock in the production output at the level of individual countries. We find important heterogeneity across countries in the effect of output shocks in the depression period. We report aggregated results for groups of EU countries in Table 38.[125]

[125] Detailed results by country are in the Appendix C.4, Figures C7 and C8.

Table 38. FAVAR impulse response after 1 year to a shock in the EA common factor of the production output growth in manufacturing, for two distinct periods, by groups of countries.

	Industrial production		**Producer price index**	
	2000-2007	**2008-2014**	**2000-2007**	**2008-2014**
EA	0.07	0.46	0.00	0.47
core	0.07	0.55	0.00	0.51
periphery	0.08	0.34	0.00	0.37
NMS	0.06	0.41	-0.01	0.22
NMS 2004	0.07	0.43	0.00	0.20
NMS 2007	0.00	0.33	-0.03	0.27
OMS	0.08	0.57	-0.02	0.10

Notes. Percentage deviation from the baseline level. Shock size is 0.005 for both periods.

We find a relatively weak and uniform response of the industrial production to the shock across all groups of countries in the pre-crisis period. The response of producer prices is observable only for Romania, Bulgaria (NMS 2007) and the OMS; however, the response is quite weak.

The impulse response of prices and industrial production is much stronger in the depression period for all groups of countries. We find the response of industrial production to be the strongest for the core euro area countries, while the periphery euro area countries exhibit the weakest response, along with Romania and Bulgaria. The response of producer prices is also weaker for the periphery countries, compared to the core euro area countries.

The impulse response of industrial production to a euro area output shock is similar for the core and periphery countries in the pre-crisis period. In the depression period the impulse response increases for both groups of countries but relatively more for the core countries, signalling lower relative integration of the periphery countries. On the other hand the impulse responses of industrial production increase more for the NMS and the OMS.

The impulse response of the producer prices in the post crisis period also increases more for the core euro area countries compared to the increase for the periphery countries. The increases for the NMS and the OMS are noticeable but relatively smaller than for the EA countries, reflecting the fact that majority of these countries have their own currency.

Based on the insights of the FAVAR analysis we can conclude that the integration of the periphery countries decreases relatively to the core euro area countries after crisis. On the other hand the integration of the NMS after crisis increases, relatively to the core euro area countries. We have mixed signals for the OMS. While we observe increased integration in terms of output in the post crisis period relative to the EA countries, the relative difference in terms of response in prices increases.

4.7 Summary

In this chapter we analyse the heterogeneity in euro area and EU producer prices inflation in manufacturing. We use data for EU countries on the level of 14 disaggregated sectors. We show that producer price inflation heterogeneity in the euro area is relatively low and has even decreased after the financial crisis in 2008, which is undesirable from the OCA perspective in the current situation, since higher inflation differentials could help in the equilibrating process in the euro area. Furthermore, we demonstrate that a large part of the producer price variation is determined by sector specific effects, thereby justifying a sectoral approach in the analysis.

Evidence from the descriptive statistics

We draw attention to some possible sources of producer price inflation heterogeneity in the manufacturing sectors, such as labour costs, productivity, costs of capital and intermediates, labour share, and the exchange rates for the countries without the common currency. It is difficult to identify a specific underlying factor for producer price inflation fluctuations as being country, sector specific, or perhaps common in nature. For example, a change in the price of oil can have symmetric effects on the countries (assuming they have the same manufacturing sector structures); however, at the subsector level, they are affected by the proportion of oil or energy used in the manufacturing process. Some underlying producer price inflation fluctuation factors can be linked to country specificities, such as the share of labour input and costs. In the absence of large scale labour mobility in Europe, this can also contribute to asymmetries. Differences in productivity levels, and the costs of capital and intermediates are another source of heterogeneity, both for countries and sectors in a given country.

With regard to descriptive statistics, we find founding euro area countries (with the notable exception, of Ireland) to be better synchronised with the euro area aggregate, measured by the correlation of aggregate manufacturing sector producer price inflation. However, some of the new member states and old member states also have high correlation to EA inflation fluctuation. Surprisingly, the new member states that joined the euro area (Slovenia, Estonia, Slovakia) have lower correlations than some of the countries without euro. Nevertheless, the correlation of the new member states increased after the adoption of euro.

The correlation coefficients of inflation in the subsectors also revealed some possible sources for country heterogeneity on an aggregated sector level. Price inflation movements are quite heterogeneous across the sectors, thereby potentially causing heterogeneity on a country level due to different manufacturing sector compositions. We find that producer price inflation in manufacturing is dependent to a large extent on the price movements in the coke sector, especially at higher frequencies.

Empirical results

We then use a hierarchical DFM approach to decompose producer prices inflation variation in a subsector in a certain country into four source levels: common, sector specific, country specific, and the idiosyncratic component, which is country-sector specific. We divide our research into three separate sections. In the first one, we deal with eight founding euro area countries, in the second with the EU and in the last we analyse all the EU countries' degrees of synchronisation with the euro area.

We find a substantial synchronisation of the manufacturing producer price inflation on the level of subsectors and countries in the euro area. The common EA factor accounts for almost half of the variance in our euro area dataset. A rolling window analysis reveals a high increase in the importance of the common factor from levels at about 30 percent to well above 50 percent after the financial crisis.

Sector specific factors account for a quarter of the variance, thereby representing an important part in the formation of the symmetric part of the variance. In the analysis of evolution over time we find the sector specific factors varying in the range of between about 20 to 40 percent, to be the most important in the period 2004–2009.

Country specific factors prove not to be of great importance for inflation variance as they explain only about 10 percent of the total variance in the euro area dataset. Country specific factors have decreased in importance since 2008 to levels around 8 percent; however, even in the period 2000–2008, the proportion of variance explained by these factors is only slightly higher, at around 10 percent.

We demonstrate that the relative importance of the factors in explaining inflation variability is heterogeneous both across the countries and the subsectors. This implies that common euro area developments, for example, can also contribute to inflation differentials in countries and sectors. These differences can be related to sensitivity to shocks in world prices and the share of capital and intermediates in production with regard to subsectors and to the economic structures in the case of countries.

The increased importance of the symmetric part, i.e. common and sectors specific factors, in the last couple of years, in a period marked by deflation or low inflation of producer prices, the synchronisation of the EA countries inflation might be higher for the wrong reasons, as far as the OCA criteria are concerned. The nominal rigidity of wages, especially when contraction is needed, prevents faster adaptation of relative prices that are needed to restore the equilibrium in the EA, when other channels, such as labour mobility or fiscal transfers are either unimportant or missing. This can also be observed at the country level where we also find Portugal and Spain to have more important EA factors in the years following 2008 than in the pre-crisis period.

With regard to the producer price inflation differentials in the pre-crisis period, when the competitiveness of periphery countries decreased relative to the core euro area countries, we find that the EA factors affected inflation in the periphery countries to the same extent as the core euro area countries. The inflation differentials stemmed from the country specific factors and country-sector specific component, which contributed between 30 and 40 percent of the variance in inflation for both groups of countries. However, country specific factors accounted for less than 10 percent of the variance in the pre-crisis euro period, on average, for periphery countries, indicating important country-sector effects. On the other hand, we do find considerable differences in the importance of EA factors between core and periphery euro area countries beyond the confines of the manufacturing sector, on the level of economy-wide sectors.

In the second analysis where we extract factors from the EU dataset, we find common EU factor to explain a 13 percent proportion of the variance and sector specific factors another 37 percent.

In the last analysis with EA common and sector specific factors for the EU countries, we find that EA factors are less important for the NMS and OMS countries, while country specific factors seem to be the most important part of the inflation variation for most of these countries. We find countries with a floating exchange rate to have higher importance in country specific factors. However, when also taking into account the high importance of country specific factors in countries with fixed or relatively constant exchange rate relative to the euro, we can conclude that other underlying factors are also important, e.g. labour markets, financing costs, etc. We also find the variability stemming from the country-sector component very important.

The increased importance of the symmetric part in the recent years shows that the divergence of prices in the euro area, which could be observed in the pre-crisis periods, stopped. On the other hand, the increased importance of EA factors also reflects the absence of strong convergence of sectoral producer prices.

We explore the linkages of price heterogeneity to the output synchronisation to examine whether the ability of countries to adjust the relative prices is crucial also in terms of OCA criteria for synchronised business cycles. We find positive relation between the proportion of variance in the output growth and producer prices inflation explained by the respective common factors in the post-crisis period. We further find that high relative prices lead to lower output growth synchronisation for the euro area countries and old member states, while there is no significant effect for the new member states.

Next, using the FAVAR model, we test the impulse response of producer prices and output on a country level to a common euro area wide shock in prices to determine whether common policies can contribute to adjustment of relative prices. We find considerable differences across groups of countries as well as between two distinct periods in time. The effect of a shock in the PPI common EA factor on industrial production is more pronounced for the EA countries, especially the core euro area countries. The periphery euro area countries exhibit lower response relative to the core EA countries. The effects in the second observed period, after 2008, are more pronounced for all groups of EU countries. The periphery EA countries exhibit the lowest effect on industrial production of the price shock. The response of producer prices differs across groups of countries as well. We observe considerable difference between the core and periphery EA countries; however the periphery countries on average still exhibit larger effect on producer prices than NMS and OMS countries.

The transmission of a euro area shock in the production output at the level of individual countries also shows similar patterns. While the effects of a shock are relatively homogenous but weak in the pre-crisis period, the core euro area countries' response in both output and producer prices in manufacturing is the strongest in the depression period. The average response of the periphery euro area countries is weaker, however it still exceeds the average response in producer prices of NMS and OMS countries. The response of output in the case of the periphery countries is lower than in the NMS and OMS on average.

Last but not least, we investigate the heterogeneity of sectoral inflation and wage growth on a higher aggregation level, covering the whole economy of countries. We find a higher degree of synchronisation for the core euro area countries, compared to the periphery euro area countries in the pre-crisis period. While we did find a difference in the degree of synchronisation of the producer prices inflation in the manufacturing between core and periphery euro area countries, the differences in the degree of synchronisation are more pronounced in the case of prices growth across broader sectors. New member states and old member states outside of euro area have even lower degree of synchronisation, measured by the proportion of variance explained by the EA factors.

How do our results compare to the literature?

It is difficult to relate our results to the literature, since producer prices inflation differentials are usually investigated with a more aggregated approach. A study that we can relate to is the recent study of consumer price index (CPI) inflation differentials on a sectoral level by Beck et al. (2012). Even though their approach to decomposing the variance of the prices dataset is similar, they use CPI inflation on a sectoral (and regional) level. Their decomposition of 11 sectors also includes services sectors, while we concentrate on the manufacturing subsectors. Moreover, our dataset covers the period of the financial and sovereign debt crisis, while their dataset covers the period 1995–2004.

However, since one of the main objectives of this chapter is to show the evolution of variance decomposition over time, we can attempt to compare our results to the results of Beck et al. (2012) for the period up to 2004.[126] The average explained variance by the common euro area factors for the comparable period is much higher in our case (44 percent compared to 22 percent in Beck et al. (2012)), which is not surprising, given that we

[126] Year-on-year inflation results in Beck et al. (2012).

concentrate on the manufacturing sector and that additional country specific factors might affect consumer prices in comparison to producer prices (e.g. VAT, excises). The importance of the sectoral effects in our research is in line with Beck et al. (2012), but we do find a higher share of the variance explained by sector specific factors on the euro area level (27 percent compared to 13 percent). The importance of country specific factors is lower in our study, 10 percent of the explained variance, compared to 20 percent in Beck et al. (2012).

We can compare the results for individual countries with the results obtained by Breitung and Eickmeier (2006), including some of the new member states countries. The studies are not directly comparable since we analyse producer price inflation, while they investigate the variance shares of changes in consumer price inflation explained by the common factors for individual countries. If we compare the results for the common EA factors for approximately the same period, we find our results to be in the same range (43 percent share of the variance explained in our research compared to 38 percent in their analysis, for the same set of euro area countries). However, the results of Breitung and Eickmeier (2006) are more heterogeneous across the countries (the standard deviation of their results is 23 percent compared to 9 percent in ours). There are also differences in the rankings of individual countries. We both find Germany to be a country with an important common component, and Spain to be a country with one of the least important common components. On the other hand, we find the Netherlands to be the country with the most important common EA factor, while their study shows that the Netherlands' CPI inflation has a negligible common component.

The study of Breitung and Eickmeier (2006) also presents results for some new member states. Both studies show the lower importance of common factors for these countries, but our study presents higher results (an average of 33 percent compared to 22 percent in Breitung and Eickmeier (2006) for the same set of countries) and less country dispersion (a standard deviation of 6 percent compared to 14 percent), which is expected since we focus on a specific sector in the economy, while the CPI also comprises prices from non-tradable sectors to a large extent.

CONCLUSIONS

The aim of this research is to provide additional insight into the current situation and past developments regarding the heterogeneity of economies in the euro area, using the factor model methodology. The heterogeneity of the economic structures of member countries may lead to common policies having destabilising instead of stabilising effects on the economies of individual member states. This issue has recently gained in importance, since the financial crisis in 2008 and the subsequent sovereign debt crisis in 2011 revealed the large asymmetries in the euro area – asymmetries that existing mechanisms of adjustments have been unable to cope with.

One of the main impediments in dealing with the crises in the periphery countries is the euro itself. Asymmetries in the unit labour costs could be more easily offset by the devaluation of one’s own currency; for example, Krugman (2013) attributes the present situation in the euro area to the lack of appropriate adjustment mechanisms in his work entitled “The Revenge of the Optimum Currency Area”.

The optimum currency area (OCA) theory emphasises the importance of asymmetric shocks and mechanisms in their prevention or accommodation. One of the most important criteria in the OCA theory is the business cycle synchronisation of the participating countries. A special issue in this context is also the endogeneity of OCA criteria. No consensus seems to exist as to whether the establishment of the EMU contributed to a higher degree of business cycle synchronisation in the euro area.

Since one of the fundamental imbalances in the euro area is the increased divergence in the competitive positions of euro area countries (De Grauwe, 2011), we approach the problem by analysing the manufacturing subsectors’ industrial production and producer prices.

We tackle the issues by analysing the heterogeneity of the manufacturing sector in the euro area, given the emphasis devoted to the pattern of industry level economic activity in the literature as the key determinant in the endogenous evolution of the degree of business cycle synchronisation. In order to motivate our disaggregated analysis, we show that the variance in the manufacturing sector across the countries does not originate solely in the different composition of the sector, and that the heterogeneity across the countries and sectors also originates at the subsector level. We check the results by analysing the broader sectors of the economy, too.

One of the goals of this thesis is to present an alternative methodology for analysing disaggregated country and sectoral information for the manufacturing sector. We perform an analysis of the synchronisation of industrial production and producer price inflation in the manufacturing sector. We use a hierarchical DFM approach to decompose output growth and producer price inflation variation in a subsector in a certain country into four source levels: (i) common, (ii) sector specific, (iii) country specific, and (iv) an idiosyncratic component that is country-sector specific. We define common and sector specific components as the symmetric part of the variation, while country and country-sector specific components represent the asymmetric part of the variation. However, from a policy point of view, we must exercise caution when interpreting sector specific factors as symmetric. Even though sector specific factors are symmetric on the subsector level, they may cause asymmetries on an aggregated manufacturing sector level due to the different composition of the manufacturing sector across the countries.

With the factors obtained through DFM, we are able to quantify the relative importance of different components in explaining comovements. Using the rolling window method in our analysis, we manage to track the evolution of the relative importance of the symmetric and asymmetric components of output and producer price variation over time. The analysis allows a more detailed additional examination of the existing results in the literature through the identification of the synchronisation of specific manufacturing subsectors in the economy.

As well as analysing the euro area countries, we also extend the analysis to EU countries. The motivation for this is firstly to compare the results of the euro area to an area that is at a lower level of integration. Secondly, we are interested in the results of the countries that had adopted the euro after the creation of the EMU in 1999 or were potential candidates for euro adoption.

Main findings

For the euro area we find that there is a substantial comovement in output growths in the manufacturing subsectors on the euro area level. Almost 50 percent of the variation in the output growths on a country-sector level can be explained by a common EA factor for the period January 1991 – June 2014. The sectoral component, which also forms a symmetric part together with the common EA factor, explains, on average, an additional 8 percent of this variation. Country specific factors are also found to be relevant, explaining the additional 10 percent of the variation. The remaining 34 percent of the variation is attributed to the idiosyncratic country-sector specific component.

The comovement in country-sector inflation rates in the euro area is also relatively significant for the period January 1996 – May 2014. The euro area wide component accounts for 64 percent of the variance of producer price inflation on average. In the case of producer price inflation heterogeneity, we find the sector specific component to be very relevant, explaining 27 percent of the variance, while the common EA factor accounts for 37 percent. Country specific factors explain an additional 12 percent, and 24 percent of the variance is country-sector specific.

The relevance of the factors at the euro area level, the common EA and sector specific factors, as well as country specific factors, is heterogeneous across the countries and subsectors, implying that these factors affect output growth and producer price inflation asymmetrically across the countries and manufacturing subsectors. Furthermore, the importance of the factors is not constant over time.

In order to check the main hypothesis that business cycle synchronisation in the EA increased after the introduction of the euro, we perform a hierarchical DFM analysis of the output growth variation in manufacturing subsectors for eight founding euro area countries. The method of tracking the evolution of the factors' importance is approached by introducing a rolling window estimation of the DFM. This enables us to see how the symmetric part, the proportion of variation explained by common and sector specific factors, changes in respect to the asymmetric part, which is made up of country specific and idiosyncratic country-sector specific components.

We find no conclusive evidence for the *main hypothesis* that synchronisation had increased after the euro's introduction. Instead, we find that synchronisation measured by the contribution of the symmetric part of the variation in output growths, explained by common and sector specific factors, increased prior to the euro's introduction in 1999. We further find a decrease in the degree of synchronisation after the financial crisis in 2008 and especially after the sovereign debt crisis in 2011; however, the degree of synchronisation of manufacturing business cycles was still above the degree in the first half of the 1990s.

We confirm our *first sub hypothesis* that the level of synchronisation of manufacturing business cycles is higher for euro area countries than it is for EU countries. We find that EU wide factors explain about 8 percent less variance for the EU countries than euro area wide factors do for euro area countries. The main contribution of the higher explained variance for the euro area is the higher importance of the common EA factor relative to the common EU factor, while the euro area and EU sector specific factors are more similar in importance for the euro area and EU, respectively. This suggests that the euro area consists of countries with highly synchronised business cycles, without implying the effects of the euro on synchronisation.

We also confirm our *second sub hypothesis* that new member states increased the degree of synchronisation with the euro area, but only for the period up to 2009. After the financial crisis and sovereign debt crisis, the comovements of output growth for manufacturing subsectors in new member states with the euro area began to decrease and were barely above the pre-accession period in the last observed period. Further, among the new member states that adopted euro, an increase in the degree of synchronisation with the euro area after joining it can only be observed for Slovenia. However, even this increase can hardly be attributed to the euro's effects, since synchronisation also increased for other euro and non-euro countries during the same period.

With regard to our *second hypothesis* that heterogeneity in the euro area increased in the last period after the sovereign debt crisis, we find that the degree of synchronisation decreased for euro area countries in comparison to pre-crisis levels. This holds both for short term fluctuation comovements and for the comovements of year-on-year growth. We observe a huge drop in synchronisation in recent years, the period characterised by the major recession in the EA. In the last observed period, synchronisation was still high, at 61 percent but, in terms of historical standards, it is now at the level of the pre-euro period. Furthermore, we find an increased divergence between the core euro area countries and the periphery countries. Finally, we also find a decreased degree of synchronisation with the euro area in the manufacturing sectors of other EU countries, new member states and non-euro old member states.

The lower degree of synchronisation in euro area countries after the sovereign debt crisis, and especially the differences in the relative importance of area wide factors, indicate that common shocks in the euro area or EU result in asymmetrical effects in individual countries. Using the FAVAR model, we find that a common shock in the production output results in an asymmetric impulse response across the EU countries especially in the post-crisis period. The impulse response is more pronounced for the core euro area countries, relative to the periphery and non-euro EU countries.

The countries most severely hit by the crisis could increase their output by improving their competitive positions. However, without the option of a country to devalue its own currency, internal devaluation is the only option. We should observe increasing producer prices differentials if this adjusting mechanism is taking place. In an environment of low inflation, inflation differentials are limited by the nominal rigidities. When analysing sectoral producer price data, we find that the heterogeneity of producer price inflation has indeed even decreased in the post crisis period. Thereby, we confirm our *sub hypothesis of the second hypothesis*. In fact, the higher synchronisation of producer price inflation as a result of (too) low inflation in the EA in recent years is one of the reasons why "problematic" countries were unable to regain their competitiveness and increase the output growth.

We explore the linkages of price heterogeneity to the output synchronisation to examine whether the ability of countries to adjust the relative prices is crucial also in terms of OCA criteria for synchronised business cycles. We find positive relation between the proportion of variance in the output growth and producer prices inflation explained by the respective common factors in the post-crisis period. We further find that high relative prices lead to lower output growth synchronisation for the euro area countries and old member states, while there is no significant effect for the new member states.

Next, using the FAVAR model, we test the impulse response of producer prices on a country level to a common euro area wide shock in prices to determine whether common policies can contribute to adjustment of relative prices. We find considerable differences across groups of countries as well as between two distinct periods in time. The effect of a shock in the PPI common EA factor on industrial production is more pronounced for the EA countries, especially the core euro area countries. The periphery euro area countries exhibit lower response relative to the core EA countries. The effects in the second observed period, after 2008, are more pronounced for all groups of EU countries. The periphery EA countries exhibit the lowest effect on industrial production of the price shock. The response of producer prices differs across groups of countries as well. We observe considerable difference between core and periphery EA countries; however the periphery countries on average still exhibit larger effect on producer prices than NMS and OMS countries, thus partly offsetting the possibilities of a common policy to affect imbalances of the relative prices in the euro area countries.

The geographical component, which can be associated with national sources of price convergence or divergence, only accounts for 8 percent of the variance share in the most recent periods. Together with the idiosyncratic country sector specific component, the asymmetric part of the inflation variance account for 24 percent of the variance share. The effects of the differences in the countries' unit labour costs, which are often associated with losses and gains in competitiveness, are therefore limited since a large part of the price changes is determined by the common, symmetric component.

We find similar country patterns of the degree of synchronisation of business cycles in the manufacturing and for the whole economy. However, the analysis of the prices in the broader sectors, and especially wage inflation reveals an even greater gap in the degree of synchronisation between the core euro area countries and other groups, the periphery euro area countries, new member states and the old member states outside of the euro area.

We also check the effect of the euro on the synchronisation of producer price inflation. We do find some increased synchronisation of producer price inflation rates at the time of the introduction of the euro. The importance of EA wide factors increased in the periods that covered the time after the euro's introduction compared to the first observed period of 1996–2000. The variance explained by common EA and sector specific factors increased by 10 p.p. Unfortunately, the span of our dataset on producer prices is not long enough to draw definite conclusions.

Policy implications

We find differences of the degree of synchronisation of output fluctuations with the euro area across the countries and subsectors, thereby demonstrating that common factors affect the manufacturing sectors in euro area countries asymmetrically, even if we take into account the sectoral comovements represented by sector specific factors. Furthermore, the degree of synchronisation with the euro area has decreased considerably in the recent period for the periphery countries and the new member states that joined the euro area subsequently. This represents a challenge for the euro area's common policies.

Detailed results show that the degree of synchronisation since the financial crisis in 2008 has decreased in the periphery countries, but has remained at pre-crisis levels for the core euro area countries. However, the sovereign debt crisis in 2011 had a more significant impact on the euro area as a whole, decreasing the degree of synchronisation for the core euro area countries. The results therefore reflect the decreasing scope of common policies in the euro area, if we interpret the symmetric part of the variance to be the target of common policies.

Nonetheless, even at the present level of synchronisation of the output fluctuations in the euro area, the fiscal policies in the core euro countries which are focused on investment and demand stimuli could also positively affect the manufacturing sectors in periphery countries, even though the scope has diminished owing to the decreasing degree of synchronisation in recent years. A positive fiscal stimulus, accompanied by inflation, would help the ECB to reach the euro area inflation target, thereby making room for producer price inflation differentials. The manufacturing subsectors in periphery countries would be able to gain competitiveness without the need for deflationary processes. The process could even be accelerated if the inflation target for the euro area were set higher. The resulting increase in the heterogeneity of producer prices would, in this case, be favourable, in contrast to the observed pre-crisis heterogeneity.

On the other hand, policy makers should take note of the decreasing business cycle synchronisation of the euro area countries in recent years. We find a substantial share of the variance in the output to be country and country-sector specific for specific countries, highlighting the importance of policies at the national level. Coupled with increased comovements in producer price inflation, this directly implies that the ECB should devote more focus to sectoral and country information. We find sectoral information important by demonstrating the importance of sector specific factors for the producer price inflation variance. Further, since this analysis also tackles the evolution of the importance of the specific components of the price changes, we can suggest that the increase in the symmetric part in the periods since the financial crisis and the sovereign debt crisis has been a consequence of nominal rigidities and an aggregate euro area inflation (target) that was set too low.

Our results show that there are significant differences in the importance of common factors across the countries and sectors. This suggests that even symmetric shocks can have asymmetric effects in the euro area, and that the effects of common euro area policies differ across the countries and sectors, which is confirmed by the FAVAR analysis of the impulse responses to a common euro area shock. As the recent crisis has revealed, the stabilising mechanisms at the country level are not sufficient in themselves in the presence of large shocks. Therefore, future adjustment mechanisms need to encompass, or at least allow, sufficient measures at the country level.

Our results indicate that the periphery countries that were most severely hit by the sovereign debt crisis exhibit a low degree of synchronisation of their manufacturing as well as economy-wide business cycles with the euro area, even in the pre-crisis period. On the other hand, the new member states exhibit even lower degrees of synchronisation with the euro area, thus posing an even greater challenge. The future enlargement of the euro area should follow only after the appropriate adjustment mechanisms have been put in place.

Scientific contribution

The approach of this study with disaggregated sectoral data is relatively new in the literature. Beck, Hubrich and Marcellino (2012) present a very similar approach for an analysis of consumer price inflation on the sectoral level in specific euro area regions. In comparison with this study, their approach includes an additional regional level and proposes a new iterative method of principal components rather than the Stock and Watson (2002a, 2002b) method used in this research.

However, this study still presents novel results in the literature on inflation differentials and business cycle synchronisation. We investigate producer price inflation and output fluctuations for the euro area and EU countries. Furthermore, we use the rolling window approach as a tool to track the evolution of heterogeneity over time. Next, our dataset covers the periods of the global financial crisis and the sovereign debt crisis in the euro area. Finally, we compare the synchronisation of the manufacturing sector to the synchronisation of broader sectors and explore the linkages between the inflation and business cycle synchronisation.

The sectoral approach to producer price inflation differentials contributes to the present debate on inflation differentials in the euro area. While the persistent inflation differentials in the pre-crisis euro period might have been the cause of rising asymmetries in the euro area (Krugman, 2013), they could also act as an equilibrating mechanism in the post-crisis period in the absence of other adjustment mechanisms. For the manufacturing sector, we demonstrate that not only are the aggregate comovements of producer prices of great importance, but also comovements on the subsectoral level. Furthermore, we show that the ability of countries to adjust the relative prices is crucial also in terms of the OCA criteria for synchronised business cycles.

As we demonstrate in this research, the degree of synchronisation is different both across the countries and the subsectors. Moreover, the degree of synchronisation also evolves over time. Future developments in business cycle synchronisation and inflation differentials are dependent to a large extent on the future developments of the euro area monetary, banking and fiscal mechanisms. The proposed methodology allows the very recent developments in the heterogeneity to be tracked on a sectoral and country level. We argue that not only the degree of synchronisation but also the trends in synchronisation evolution, which our proposed methodology is able to evaluate, present valuable information for the policy makers.

Limitations and future research

One of the characteristics of OCA theory is that it gives no definite answer as to the suitability of countries to form a currency union. This theory gives some insights into the trade-offs regarding the currency union, but the process of determining the suitability of candidates for a currency union is more qualitative (Krugman, 2013). The same can be applied to the question of business cycle synchronisation. We do not know precisely what a sufficient degree of synchronisation would be for members of the currency union. One of the objectives of this analysis of EU countries was also to put the results for the euro area countries into perspective. However, similar research on, for example, US data, using the same methodological approach would also give additional insight into the heterogeneity of the manufacturing sector for the euro area.

The empirical setup may be used for similar, but more detailed analyses, for further sectoral disaggregation. We perform an additional analysis on 20 disaggregated sectors and find greater importance in the underlying sector specific factors than those for the 14 disaggregated sectors. Similarly, we would expect the importance of the sector specific factors to increase further with more disaggregation, but this has yet to be proven.

Similarly, the empirical setup could be used in an analysis that goes beyond the confines of the manufacturing sector, covering instead a larger part of the economy. We perform an additional analysis on 10 broader sectors of the economy and find similar results. Richer data sources would provide even more opportunities for detailed research.

As observed from the results of our robustness check against year-on-year growth, the transformations of the data for the analysis are important for the variance decomposition. When we average out some of the variation in the monthly growths by using year-on-year data, we come to the conclusion that the main bulk of increases in the variance share in the first period of the euro could be attributed to the increased comovement of short-term fluctuations. An alternative approach to deseasonalizing the monthly series could also be applied to further check the results.

Our approach is unweighted, meaning we did not distinguish between sectors and countries in terms of their size and importance. A weighted approach that takes the importance of individual subsectors into account could represent an improvement to our empirical setup, especially when interpreting the results.

The issues with the small number of countries used in estimating the sector specific factors may result in inconsistencies, thereby presenting bias problems in subsequent OLS estimations. Beck et al. (2011) propose an iterative method of factor extraction by principal component in order to overcome these issues. They assess a small sample performance of the iterative method compared to the standard principal components based factor estimation (Stock & Watson, 2002a, 2002b) that is used in our research. They find significant improvements which manifest as a reduction in the bias of the results. The explanatory value of sectoral factors in our analysis could thus be overestimated. We do find evidence that sectoral factors' importance decreases if we estimate the country specific factors first. However, we find that the evolution of variance decomposition over time stays more or less the same, and so does the relative importance of factors across the countries and subsectors. However, a similar analysis with the new method proposed by Beck et al. (2012) could potentially improve our results considerably.

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APPENDICES

LIST OF APPENDICES

Appendix A: Additional tables

Table A1. Indicator of structural similarities in the composition of manufacturing sector

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011-2000
AT	23.8	25.3	25.4	24.2	22.4	23.2	22.4	22.8	22.4	21.6	24.0	24.0	0.3
BE	30.7	29.3	30.3	31.9	33.0	34.5	34.6	35.5	34.7	33.7	39.3	35.3	4.6
DE	24.0	25.8	28.1	28.6	27.9	28.0	27.9	29.3	29.2	28.8	29.4	29.3	5.3
EL	68.7	62.3	60.7	61.2	57.4	61.9	66.6	65.1	65.1	71.0	78.3	85.2	16.5
ES	24.3	22.2	23.6	24.2	23.0	25.6	25.9	26.3	26.4	23.0			-1.3
FI	68.8	62.1	66.2	64.6	61.1	57.0	59.9	58.9	51.1	42.9	47.2	40.3	-28.5
FR	22.9	24.7	25.1	25.6	24.9	26.4	29.7	28.5	27.3	27.3	28.8	31.6	8.8
IE	94.5	100.2	105.2	96.8	99.9	93.0	95.8	95.2	100.7	103.6	112.9	114.4	19.9
IT	26.7	27.9	28.6	28.6	28.2	27.5	28.0	28.5	28.0	27.1	27.7	28.0	1.3
NL	40.3	42.2	45.9	47.1	46.4	48.5	48.0	47.4	47.4	44.5	46.7	47.8	7.5
PT	44.9	44.7	46.0	46.7	46.1	48.2	49.7	47.8	48.9	48.0	49.3	49.7	4.8
BG	69.4	62.4	58.7	55.5	57.3	61.7	60.0	56.8	50.2	52.7	54.0	57.4	-12.0
CY	82.2	82.4	82.4	82.7	82.9	86.6	82.0	78.1	79.7	78.2	79.1	81.1	-1.1
CZ	26.0	26.9	27.4	24.9	28.4	29.6	30.9	31.2	31.0	32.5	34.0	34.5	8.5
EE	69.9	71.5	71.0	68.1	60.1	56.3	54.6	53.5	48.1	52.3	52.3	52.0	-17.9
HU	39.7	37.4	38.0	40.6	43.4	49.9	50.3	46.3	47.8	45.1	44.0	45.9	6.2
LT	76.5	76.1	74.9	72.3	63.4	66.0	67.4	71.2	68.7	70.3	70.9	74.5	-2.0
LV*	73.9	73.0	76.8	72.6	69.6	67.5	67.4	64.1	61.7	102.2	99.1		25.2
MT	79.5	75.0	73.5	73.9	68.2	70.8	75.3	79.8	81.7	82.0	85.0	90.1	10.5
PL	38.2	42.7	37.5	34.5	33.3	32.1	30.8	33.6	34.5	29.5	36.0	34.3	-3.9
RO	64.8	66.0	64.0	62.1	57.2	58.5	55.3	52.0	56.6	57.6	66.9	68.4	3.6
SI	32.0	32.4	34.3	34.9	34.8	36.9	37.2	37.1	37.1	36.7	35.9	37.0	5.0
SK	37.3	38.7	34.0	38.7	41.3	38.9	34.8	41.9	40.6	41.9	40.7	42.7	5.3
DK	41.4	43.2	43.8	43.3	43.2	46.2	44.8	46.3	39.9	41.0	45.2	42.6	1.2
SE*	38.2	38.9	35.3	34.3	37.9	38.2	36.4	35.2	31.8	45.7	47.5	43.9	5.7
UK	21.5	23.7	23.0	24.4	24.2	24.1	25.0	25.9	27.5	28.5	31.2	32.4	10.9
EU15	3.7	3.7	3.5	3.7	4.0	3.9	3.9	3.8	3.7	4.2	4.4	4.4	0.7
EU27	4.0	4.2	4.2	4.1	4.6	4.2	4.2	4.1	4.4	4.9	5.0	5.0	1.0

*not all sectors are included

Table A2. Number of common EA factors for output growth in manufacturing, according to Bai and Ng (2002) criteria (ICp1, ICp2); T=50, N=99. 12 results for each year.

	IC_{p2}	IC_{p1}		
	Average	Average	Min	Max
1995*	1	2.0	2	2
1996	1	3.0	3	3
1997	1	3.0	3	3
1998	1	3.0	3	3
1999	1	2.7	2	3
2000	1	3.0	3	3
2001	1	2.8	1	3
2002	1	1.5	1	3
2003	1	1.7	1	3
2004	1	2.8	2	3
2005	1	2.5	2	3
2006	1	2.3	1	3
2007	1	2.9	2	3
2008	1	2.7	1	3
2009	1	1.9	1	3
2010	1	2.4	2	3
2011	1	3.0	3	3
2012	1	2.0	1	3
2013	1	1.0	1	1
2014**	1	1.0	1	1

*10 observations

**6 observations

Table A3. Results of regression of aggregate industrial production index in EA-17 manufacturing sector on common EA factors. T=50.

	$F>F_{crit}$ (F2 vs F1)*	$F>F_{crit}$ (F3 vs F2)*	Average of R^2 F1	Average of R^2 F2	Average of R^2 F3
1995	9	9	0.01	0.24	0.42
1996	12	0	0.00	0.25	0.28
1997	12	0	0.09	0.15	0.15
1998	11	0	0.06	0.10	0.11
1999	0	0	0.03	0.02	0.03
2000	7	0	0.03	0.09	0.15
2001	6	0	0.06	0.12	0.29
2002	1	1	0.05	0.08	0.29
2003	0	0	0.08	0.11	0.26
2004	0	0	0.09	0.13	0.32
2005	0	0	0.07	0.08	0.27
2006	0	0	0.14	0.15	0.21
2007	12	2	0.12	0.21	0.30
2008	11	2	0.24	0.35	0.42
2009	12	2	0.26	0.39	0.44
2010	6	3	0.25	0.32	0.46
2011	0	0	0.24	0.26	0.32
2012	1	0	0.17	0.20	0.32
2013	0	0	0.06	0.07	0.17
2014	0	0	0.07	0.11	0.17

*No of occurrences

Figure A1. Loadings of EA sector specific factors on the EA output growth manufacturing series, 2014M06. T=50, N_{max}=8. 14 factors for 14 subsectors represented in one figure, first two letters of series stand for a subsector, last two for a country.

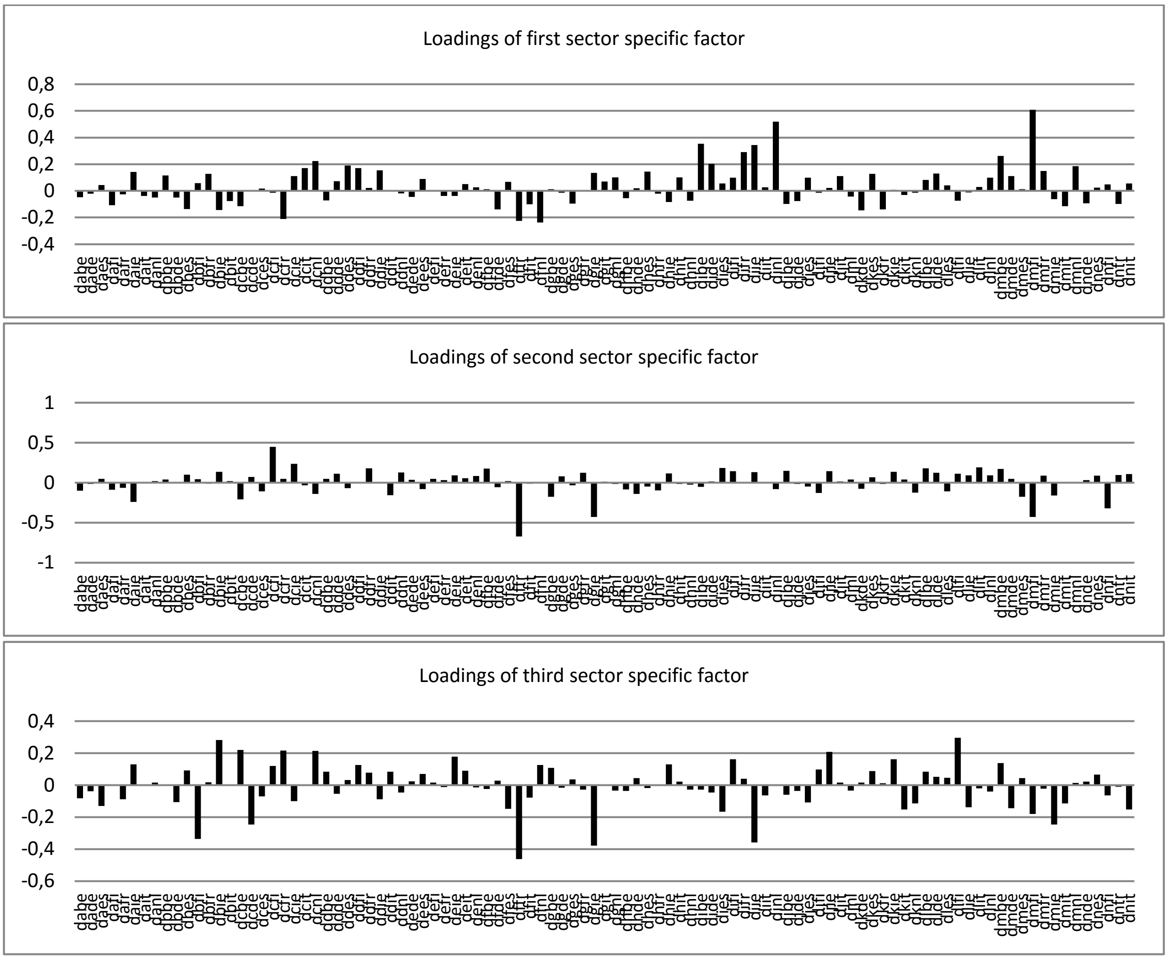


Table A4. Results of regression of aggregate industrial production index in EA-17 manufacturing subsectors on common EA and up to three sector specific factors. T=50.

	$F>F_{crit}$ (F2 vs F1)													
	da	db	dc	dd	de	df	dg	dh	di	dj	dl	dk	dm	dn
1995	0	0	4	0	2	11	6	5	11	0	0	3	11	7
1996	6	0	0	0	7	12	9	7	12	5	3	1	12	7
1997	6	4	1	5	12	12	7	0	12	1	5	10	12	4
1998	2	8	0	12	12	5	9	7	10	0	7	11	10	5
1999	1	11	8	12	11	12	11	1	12	3	3	9	5	12
2000	12	4	9	6	9	12	0	0	7	0	3	5	6	9
2001	1	7	7	9	12	12	9	9	1	0	6	0	6	12
2002	0	10	4	0	11	8	12	2	1	2	12	5	3	5
2003	1	6	0	1	2	12	12	0	0	1	12	0	4	9
2004	10	3	1	9	7	12	11	6	0	1	0	3	5	11
2005	12	12	0	12	1	12	12	11	9	12	9	1	12	0
2006	12	12	9	12	5	10	6	0	0	8	6	0	8	8
2007	12	12	12	12	4	12	8	0	12	0	0	0	0	8
2008	2	12	2	0	12	12	1	3	12	7	2	9	3	11
2009	2	12	2	2	8	12	0	3	11	6	0	5	12	7
2010	0	12	5	0	4	12	0	0	3	3	0	11	12	12
2011	0	3	7	1	1	11	12	7	5	8	0	3	12	9
2012	0	9	12	4	6	12	12	11	0	11	0	11	12	9
2013	0	4	6	6	12	12	3	4	4	0	1	7	9	7
2014	0	6	0	1	0	5	2	0	4	2	2	0	4	6

Note. No. of instances with more than 1 sector specific factor as the best model.

Table A5. Proportion of variance of output growth in manufacturing explained by the common EA factor for EU countries. T=50. Annual averages.

	AT	**BE**	**DE**	**EL**	**ES**	**FI**	**FR**	**IE**	**IT**	**NL**	**PT**	**DK**	**SE**	**UK**	**BG**	**CZ**	**EE**	**HU**	**LT**	**LV**	**PL**	**RO**	**SI**	**SK**
1995		0.36	0.57		0.34	0.32	0.49	0.04	0.61	0.59		0.32	0.40	0.56										
1996		0.35	0.62		0.39	0.44	0.52	0.06	0.63	0.58		0.32	0.46	0.61										
1997		0.35	0.68		0.48	0.54	0.53	0.07	0.66	0.55		0.38	0.54	0.61										
1998		0.38	0.70		0.55	0.61	0.55	0.07	0.66	0.54		0.44	0.56	0.61										
1999		0.40	0.71		0.52	0.62	0.54	0.08	0.63	0.52		0.35	0.54	0.61										
2000	0.47	0.49	0.74		0.52	0.62	0.60	0.05	0.62	0.51	0.35	0.40	0.54	0.62							0.41			
2001	0.50	0.51	0.73		0.48	0.57	0.63	0.06	0.61	0.53	0.33	0.35	0.51	0.66							0.36			
2002	0.54	0.52	0.74		0.50	0.57	0.67	0.07	0.58	0.54	0.33	0.40	0.52	0.67				0.34	0.20		0.40		0.28	0.20
2003	0.54	0.56	0.71		0.53	0.58	0.66	0.06	0.58	0.52	0.33	0.48	0.54	0.64				0.31	0.20		0.43		0.30	0.23
2004	0.50	0.55	0.68	0.24	0.57	0.55	0.66	0.06	0.57	0.48	0.35	0.46	0.49	0.64	0.12	0.35	0.22	0.30	0.17	0.22	0.40	0.17	0.27	0.26
2005	0.46	0.53	0.66	0.25	0.59	0.57	0.62	0.04	0.54	0.47	0.36	0.47	0.40	0.63	0.16	0.37	0.23	0.30	0.19	0.26	0.39	0.18	0.23	0.24
2006	0.48	0.55	0.67	0.22	0.63	0.55	0.61	0.05	0.58	0.50	0.44	0.46	0.32	0.66	0.19	0.43	0.25	0.33	0.19	0.27	0.41	0.19	0.22	0.23
2007	0.51	0.56	0.70	0.25	0.67	0.54	0.62	0.06	0.61	0.54	0.54	0.44	0.33	0.67	0.22	0.50	0.26	0.38	0.26	0.30	0.47	0.21	0.23	0.24
2008	0.58	0.57	0.75	0.28	0.72	0.58	0.67	0.04	0.67	0.57	0.56	0.47	0.44	0.72	0.24	0.60	0.38	0.42	0.41	0.37	0.58	0.27	0.34	0.28
2009	0.61	0.58	0.73	0.29	0.71	0.58	0.68	0.02	0.66	0.53	0.54	0.46	0.45	0.71	0.27	0.61	0.40	0.39	0.45	0.39	0.61	0.26	0.36	0.25
2010	0.58	0.51	0.73	0.28	0.68	0.50	0.66	0.02	0.63	0.52	0.48	0.37	0.45	0.69	0.28	0.58	0.34	0.36	0.38	0.36	0.58	0.26	0.34	0.19
2011	0.58	0.48	0.73	0.21	0.63	0.43	0.69	0.02	0.60	0.48	0.42	0.36	0.43	0.62	0.26	0.55	0.31	0.34	0.31	0.33	0.54	0.25	0.32	0.15
2012	0.54	0.45	0.68	0.16	0.50	0.34	0.64	0.04	0.50	0.44	0.33	0.26	0.35	0.48	0.21	0.45	0.23	0.28	0.21	0.27	0.40	0.21	0.24	0.08
2013	0.54	0.41	0.70	0.17	0.51	0.31	0.64	0.06	0.49	0.45	0.31	0.27	0.43	0.43	0.21	0.42	0.21	0.26	0.19	0.26	0.41	0.25	0.28	0.07
2014	0.52	0.45	0.67	0.14	0.52	0.30	0.64	0.07	0.48	0.41	0.30	0.30	0.45	0.40	0.21	0.41	0.21	0.25	0.20	0.25	0.44	0.25	0.30	0.06

Table A6. Proportion of variance of output growth in manufacturing explained by the EA sector specific factors (one for each sector). T=50. Annual averages.

	AT	**BE**	**DE**	**EL**	**ES**	**FI**	**FR**	**IE**	**IT**	**NL**	**PT**	**DK**	**SE**	**UK**	**BG**	**CZ**	**EE**	**HU**	**LT**	**LV**	**PL**	**RO**	**SI**	**SK**
1995		0.19	0.12		0.22	0.13	0.13	0.20	0.15	0.14		0.03	0.05	0.02										
1996		0.19	0.12		0.24	0.13	0.14	0.19	0.15	0.12		0.03	0.06	0.02										
1997		0.17	0.11		0.21	0.10	0.11	0.17	0.14	0.15		0.03	0.04	0.01										
1998		0.19	0.09		0.16	0.07	0.13	0.19	0.12	0.14		0.02	0.03	0.02										
1999		0.17	0.09		0.16	0.04	0.12	0.16	0.13	0.15		0.03	0.03	0.02										
2000	0.05	0.13	0.08		0.13	0.07	0.12	0.18	0.13	0.18	0.03	0.02	0.03	0.04							0.04			
2001	0.05	0.14	0.07		0.14	0.08	0.10	0.16	0.13	0.19	0.03	0.03	0.03	0.03							0.04			
2002	0.04	0.14	0.07		0.15	0.09	0.09	0.17	0.13	0.16	0.05	0.04	0.02	0.04				0.03	0.04		0.06		0.02	0.05
2003	0.03	0.11	0.10		0.15	0.07	0.08	0.14	0.11	0.14	0.04	0.04	0.02	0.04				0.03	0.03		0.05		0.01	0.06
2004	0.02	0.16	0.11	0.04	0.10	0.07	0.08	0.18	0.11	0.15	0.03	0.04	0.02	0.03	0.05	0.04	0.03	0.03	0.02	0.06	0.04	0.02	0.03	0.05
2005	0.02	0.15	0.12	0.05	0.11	0.08	0.07	0.18	0.11	0.14	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.03	0.04	0.04	0.04	0.03	0.04	0.06
2006	0.02	0.17	0.10	0.06	0.11	0.08	0.06	0.19	0.11	0.13	0.02	0.02	0.06	0.02	0.03	0.03	0.04	0.03	0.05	0.02	0.04	0.05	0.04	0.07
2007	0.02	0.13	0.09	0.05	0.11	0.10	0.05	0.25	0.11	0.10	0.04	0.02	0.07	0.02	0.02	0.03	0.04	0.03	0.04	0.03	0.03	0.05	0.04	0.06
2008	0.03	0.10	0.09	0.04	0.11	0.11	0.05	0.21	0.06	0.10	0.03	0.02	0.04	0.02	0.03	0.02	0.03	0.03	0.03	0.03	0.02	0.05	0.04	0.04
2009	0.02	0.09	0.10	0.03	0.12	0.13	0.06	0.18	0.06	0.14	0.06	0.02	0.04	0.02	0.03	0.03	0.02	0.03	0.02	0.03	0.01	0.04	0.06	0.04
2010	0.02	0.12	0.09	0.04	0.13	0.15	0.07	0.22	0.05	0.15	0.07	0.03	0.03	0.02	0.04	0.04	0.02	0.03	0.03	0.03	0.03	0.04	0.07	0.05
2011	0.02	0.12	0.09	0.04	0.11	0.09	0.11	0.22	0.08	0.22	0.06	0.02	0.04	0.03	0.04	0.06	0.03	0.03	0.03	0.03	0.03	0.05	0.07	0.05
2012	0.02	0.16	0.11	0.04	0.12	0.06	0.17	0.21	0.14	0.20	0.06	0.03	0.05	0.04	0.06	0.07	0.04	0.03	0.04	0.04	0.05	0.05	0.07	0.06
2013	0.02	0.17	0.10	0.05	0.12	0.09	0.18	0.23	0.17	0.18	0.04	0.03	0.05	0.06	0.04	0.06	0.04	0.04	0.05	0.02	0.05	0.03	0.05	0.08
2014	0.03	0.14	0.12	0.05	0.11	0.08	0.18	0.16	0.18	0.24	0.04	0.02	0.07	0.07	0.03	0.06	0.04	0.04	0.06	0.03	0.06	0.03	0.03	0.10

Table A7. Proportion of variance of output growth in manufacturing explained by country specific factors (one for each country). T=50. Annual averages.

	AT	**BE**	**DE**	**EL**	**ES**	**FI**	**FR**	**IE**	**IT**	**NL**	**PT**	**DK**	**SE**	**UK**	**BG**	**CZ**	**EE**	**HU**	**LT**	**LV**	**PL**	**RO**	**SI**	**SK**
1995		0.15	0.12		0.09	0.11	0.07	0.18	0.07	0.05		0.23	0.11	0.16										
1996		0.15	0.09		0.08	0.08	0.05	0.17	0.06	0.06		0.25	0.10	0.12										
1997		0.15	0.07		0.06	0.07	0.05	0.15	0.05	0.06		0.23	0.08	0.11										
1998		0.13	0.08		0.06	0.07	0.05	0.15	0.06	0.07		0.19	0.10	0.10										
1999		0.10	0.08		0.07	0.09	0.05	0.17	0.06	0.08		0.26	0.11	0.11										
2000	0.14	0.09	0.07		0.09	0.08	0.05	0.17	0.06	0.09	0.20	0.23	0.10	0.11							0.19			
2001	0.11	0.06	0.06		0.10	0.08	0.05	0.17	0.06	0.06	0.19	0.25	0.11	0.09							0.21			
2002	0.10	0.08	0.06		0.10	0.06	0.04	0.13	0.08	0.07	0.16	0.19	0.10	0.11				0.11	0.19		0.18		0.24	0.16
2003	0.11	0.07	0.06		0.09	0.07	0.05	0.16	0.09	0.07	0.16	0.11	0.09	0.12				0.14	0.18		0.16		0.20	0.15
2004	0.15	0.04	0.06	0.21	0.11	0.08	0.04	0.14	0.10	0.09	0.15	0.12	0.12	0.13	0.23	0.20	0.16	0.15	0.18	0.15	0.15	0.15	0.15	0.16
2005	0.18	0.05	0.07	0.19	0.11	0.08	0.05	0.15	0.11	0.10	0.17	0.12	0.18	0.14	0.18	0.18	0.14	0.15	0.14	0.15	0.17	0.16	0.15	0.17
2006	0.16	0.05	0.07	0.18	0.09	0.09	0.05	0.14	0.08	0.10	0.17	0.12	0.21	0.10	0.20	0.14	0.12	0.15	0.13	0.15	0.18	0.15	0.14	0.15
2007	0.13	0.06	0.07	0.16	0.07	0.08	0.06	0.12	0.06	0.08	0.13	0.12	0.21	0.08	0.14	0.10	0.11	0.14	0.12	0.13	0.16	0.16	0.13	0.13
2008	0.11	0.07	0.05	0.14	0.06	0.07	0.05	0.15	0.04	0.06	0.14	0.09	0.16	0.06	0.14	0.07	0.10	0.11	0.08	0.13	0.11	0.15	0.12	0.11
2009	0.09	0.06	0.05	0.16	0.05	0.07	0.05	0.18	0.07	0.05	0.11	0.09	0.15	0.07	0.16	0.08	0.09	0.11	0.09	0.13	0.09	0.15	0.12	0.18
2010	0.09	0.06	0.05	0.16	0.04	0.07	0.05	0.15	0.08	0.06	0.12	0.12	0.16	0.07	0.15	0.09	0.12	0.13	0.11	0.15	0.09	0.16	0.13	0.17
2011	0.08	0.06	0.05	0.21	0.07	0.09	0.04	0.14	0.11	0.05	0.11	0.12	0.16	0.11	0.18	0.10	0.15	0.14	0.13	0.16	0.10	0.14	0.15	0.16
2012	0.09	0.06	0.06	0.24	0.09	0.12	0.04	0.14	0.13	0.06	0.13	0.16	0.19	0.18	0.19	0.12	0.16	0.13	0.19	0.16	0.13	0.16	0.19	0.18
2013	0.09	0.08	0.06	0.25	0.10	0.13	0.05	0.15	0.10	0.06	0.12	0.17	0.14	0.19	0.17	0.11	0.17	0.14	0.20	0.14	0.14	0.18	0.17	0.17
2014	0.10	0.07	0.08	0.28	0.10	0.13	0.05	0.15	0.10	0.07	0.13	0.15	0.13	0.22	0.19	0.13	0.19	0.15	0.21	0.14	0.15	0.19	0.17	0.17

Producer prices in manufacturing

Table A8. Correlation coefficients of series of producer price inflation for sector of manufacturing between EA-17 and selected country, for two time periods.

	1991-2001	2002-14
AT		0.71
BE	0.61	0.80
DE	0.89	0.94
EL	0.55	0.87
ES	0.84	0.95
FI		0.85
FR		0.92
IT	0.76	0.96
LU	0.22	0.58
NL	0.79	0.94
PT	0.46	0.83
SE	0.62	0.70
UK	0.57	0.55

*Source: Eurostat, Own calculations

**Countries without data available for the whole period 2002-14 are not shown in the table.

Table A9. Number of common EA factors for producer price inflation in manufacturing, according to Bai and Ng (2002) criterion (IC_{p2}); T=50, N=90. 12 results for each year.

	Average	Min	Max
2000*	2.8	1	3
2001	3.0	3	3
2002	2.4	2	3
2003	2.2	2	3
2004	2.0	2	2
2005	1.8	1	2
2006	1.1	1	2
2007	2.0	2	2
2008	2.6	1	3
2009	2.2	1	3
2010	2.6	2	3
2011	2.8	2	3
2012	2.5	2	3
2013	2.5	2	3
2014**	2.2	2	3

*10 observations

**5 observations

Table A10. Results of regression of aggregate producer price inflation in EA17 manufacturing sector on common EA factors. T=50.

	$F>F_{crit}$ (F2 vs F1)*	$F>F_{crit}$ (F3 vs F2)*
2000	4	3
2001	9	0
2002	12	0
2003	4	0
2004	12	0
2005	3	0
2006	0	0
2007	0	0
2008	0	0
2009	0	0
2010	8	3
2011	12	8
2012	12	2
2013	12	0
2014	3	0

*No of occurrences

Table A11. Average number of sufficient factors according to Bai and Ng IC_{p2} criterion for sectors depending on the last year of the data in observed period. T=50. N_{max}=8.

	da	**db**	**dc**	**dd**	**de**	**df**	**dg**	**dh**	**di**	**dj**	**dl**	**dk**	**dm**	**dn**
2000	2.7	2.3	1.7	2.0	2.5	2.6	2.4	1.0	1.0	3.0	2.3	1.0	1.8	1.5
2001	2.8	1.7	1.9	2.5	2.8	3.0	2.4	1.0	2.2	2.5	1.9	2.2	2.0	2.5
2002	1.1	2.0	2.7	2.1	2.9	2.6	2.8	1.0	1.0	2.0	3.0	3.0	1.8	1.8
2003	1.0	2.7	2.0	1.8	3.0	2.9	1.2	2.5	1.6	2.0	3.0	2.1	2.7	2.3
2004	2.2	1.3	1.9	1.8	2.8	3.0	1.7	2.7	2.3	2.7	3.0	1.8	2.3	1.9
2005	2.1	1.0	2.8	1.3	3.0	2.8	1.2	2.8	1.9	2.6	3.0	2.1	2.0	2.2
2006	1.7	1.7	3.0	1.3	2.3	2.3	1.7	1.7	1.5	2.2	1.7	1.2	2.3	1.4
2007	2.1	2.0	1.8	1.0	1.3	1.8	3.0	1.9	1.0	1.7	2.5	1.0	1.3	1.5
2008	2.8	1.6	1.6	1.3	2.8	1.0	2.5	1.3	1.3	2.8	3.0	2.2	1.0	1.2
2009	3.0	1.2	1.9	1.9	2.7	1.2	2.9	2.0	1.8	2.3	3.0	2.7	1.1	1.2
2010	3.0	1.0	2.2	1.9	2.5	3.0	2.7	3.0	2.2	3.0	2.5	2.8	1.2	1.4
2011	3.0	2.2	1.0	2.2	2.6	3.0	3.0	2.5	1.4	3.0	3.0	2.0	1.0	2.0
2012	3.0	3.0	2.5	1.2	2.0	3.0	2.8	1.5	1.1	3.0	2.5	1.5	1.0	2.0
2013	2.8	3.0	2.9	1.3	2.0	2.7	1.6	1.0	2.4	2.9	2.8	2.0	1.0	2.2
2014	3.0	3.0	1.8	2.0	2.0	2.2	1.0	1.0	2.0	2.6	3.0	2.4	1.0	1.0

Table A12. Results of regression of aggregate producer price inflation in EA17 manufacturing subsectors on common EA and up to three sector specific factors. No. of instances with more than 1 sector specific factor as the best model (F-statistics). T=50.

	$F>F_{crit}$ (F2 vs F1)*													
	da	**db**	**dc**	**dd**	**de**	**df**	**dg**	**dh**	**di**	**dj**	**dl**	**dk**	**dm**	**dn**
2000					6		0	8			10	0	11	
2001	5			11	2		12	8		12	12	0	12	
2002	10			12	0		12	11		12	10	8	12	
2003	5			8	11		12	6		12	0	10	12	
2004	6			12	8		9	10		5	2	10	11	
2005	11	9	10	1	6	12	7	6	10	5	12	6	12	12
2006	4	5	5	8	9	12	0	11	12	12	5	10	12	4
2007	10	11	4	2	8	12	1	5	9	10	8	11	12	0
2008	3	10	7	9	8	8	11	11	8	12	6	12	12	0
2009	6	6	9	12	9	8	10	12	12	12	10	11	10	0
2010	12	4	12	12	12	4	12	4	12	12	12	6	11	6
2011	12	6	9	12	3	2	6	10	0	12	12	10	10	12
2012	8	10	0	12	9	12	10	9	4	11	12	10	11	7
2013	0	12	11	12	12	5	12	1	12	11	6	12	12	12
2014	0	5	5	5	5	0	2	1	5	4	3	5	5	5

*No. of observations

Table A13. Sufficient number of EU sector specific factors for producer price inflation in manufacturing, Bai and NG IC_{p2} criterion. Averages over observed periods in a year. T=50.

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Food	2.8	2.7	3.0	2.7	3.0	3.0	3.0	2.7	2.8	3.0
Textile	1.1	2.0	1.1	1.5	2.3	2.5	2.1	2.8	2.1	1.8
Leather	1.0	1.0	1.2	1.3	1.5	2.2	1.2	2.0	2.1	1.4
Wood	3.0	2.4	2.1	2.1	1.6	3.0	3.0	1.8	1.2	2.4
Paper	2.6	1.8	1.1	1.0	1.8	2.8	3.0	2.8	2.8	3.0
Coke	1.0	1.0	1.5	2.2	1.5	2.4	1.8	1.5	3.0	3.0
Chemicals and pharmaceuticals	2.8	2.7	2.2	2.9	2.8	3.0	3.0	2.3	1.3	2.0
Rubber and plastic	1.9	2.8	2.6	2.7	2.9	2.0	2.8	1.7	1.8	1.0
Other non-metallic	2.5	2.8	2.4	1.4	2.3	2.4	2.4	2.6	1.8	1.4
Metals	2.8	2.7	2.9	3.0	3.0	3.0	3.0	2.9	2.3	1.6
Electronic	1.7	1.7	2.0	1.8	2.0	3.0	2.2	2.0	1.1	2.0
Machinery	2.6	1.8	1.7	2.4	2.4	2.5	3.0	2.7	1.8	2.0
Transport	2.0	2.3	1.3	1.9	1.7	3.0	3.0	2.8	2.3	1.0
Furniture	2.5	2.0	2.3	2.8	2.2	2.8	2.0	2.2	1.5	3.0

Table A14. Sufficient number of country specific factors for producer price inflation in manufacturing for the EU sample, Bai and NG IC_{p2} criterion. Averages over observed periods in a year. T=50.

	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
AT	1.1	1.0	1.3	1.0	1.2	1.3	1.3	1.9	1.2	1.0
BE	1.0	1.2	1.4	1.0	1.0	1.0	1.1	1.0	1.0	1.0
BG	1.5	1.5	1.2	1.6	1.5	1.8	2.6	2.3	1.0	1.4
CZ	1.7	1.8	2.4	2.9	2.3	2.3	2.6	2.3	2.3	2.6
DE	1.0	1.4	1.7	2.0	1.9	2.0	2.0	2.2	1.8	1.2
DK	1.0	1.0	1.0	1.0	1.0	1.3	1.5	1.2	1.5	1.8
EL	1.0	1.0	1.3	1.5	1.0	1.4	1.8	1.0	1.2	2.0
ES	1.0	1.0	1.0	1.0	1.3	2.2	2.3	1.2	2.2	2.2
FI	1.0	1.1	1.0	1.5	2.0	2.0	1.1	1.0	1.1	2.0
FR	2.0	1.5	1.4	1.0	1.7	1.0	1.2	1.4	1.0	1.0
HU	2.7	1.6	1.4	1.8	2.0	2.8	2.3	2.8	1.5	1.6
IE	1.9	1.5	2.0	1.9	1.8	1.4	1.8	1.0	1.3	3.0
IT	1.9	1.0	1.0	1.0	1.3	1.6	1.0	1.0	1.4	1.0
LT	1.3	1.3	1.3	1.3	2.0	1.4	1.6	1.6	1.3	1.0
NL	1.0	1.0	1.0	1.2	1.9	2.0	1.7	2.8	1.6	1.0
PL	1.7	1.9	1.6	1.5	2.2	2.5	2.8	2.5	2.3	1.4
PT	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
RO	1.5	2.3	1.8	1.8	1.1	1.2	1.8	2.3	1.3	1.6
SE	2.1	1.5	1.8	2.3	2.8	2.0	1.2	1.7	2.0	1.2
SI	1.5	1.0	1.0	1.0	1.8	1.5	2.2	1.3	1.0	1.0
SK	1.9	1.8	2.7	1.7	1.1	1.8	1.3	1.0	1.0	1.0
UK	1.0	1.0	1.9	2.0	2.0	1.4	3.0	2.2	2.8	3.0

Table A15. Proportion of explained variance of producer price inflation in manufacturing by EU factors and sectors. EU, annual average 2014. T=50.

	Common EU	Sector specific	EU factors	Country specific	Country-sector specific component
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.38	0.41	0.79	0.08	0.13
Textile	0.44	0.20	0.64	0.14	0.22
Leather	0.25	0.24	0.50	0.17	0.33
Wood	0.35	0.28	0.63	0.17	0.20
Paper and printing	0.47	0.24	0.71	0.11	0.18
Coke, refined fuel	0.64	0.29	0.93	0.03	0.05
Chemicals and pharmaceuticals	0.54	0.19	0.73	0.08	0.19
Rubber and plastic	0.61	0.13	0.75	0.12	0.13
Other non-metallic	0.20	0.48	0.68	0.16	0.17
Metals	0.56	0.31	0.87	0.06	0.07
Electronic	0.31	0.24	0.55	0.15	0.30
Machinery	0.19	0.35	0.54	0.24	0.22
Transport	0.23	0.26	0.49	0.25	0.26
Furniture	0.26	0.24	0.50	0.25	0.25

Appendix B: Results of additional analyses of output growth synchronization

B.1 Dataset for 8 euro area countries for time interval 1991(1)–20014(6)

Figure B1. Loadings of the EA common factors on the EA output growth manufacturing series. T=282, N=99.

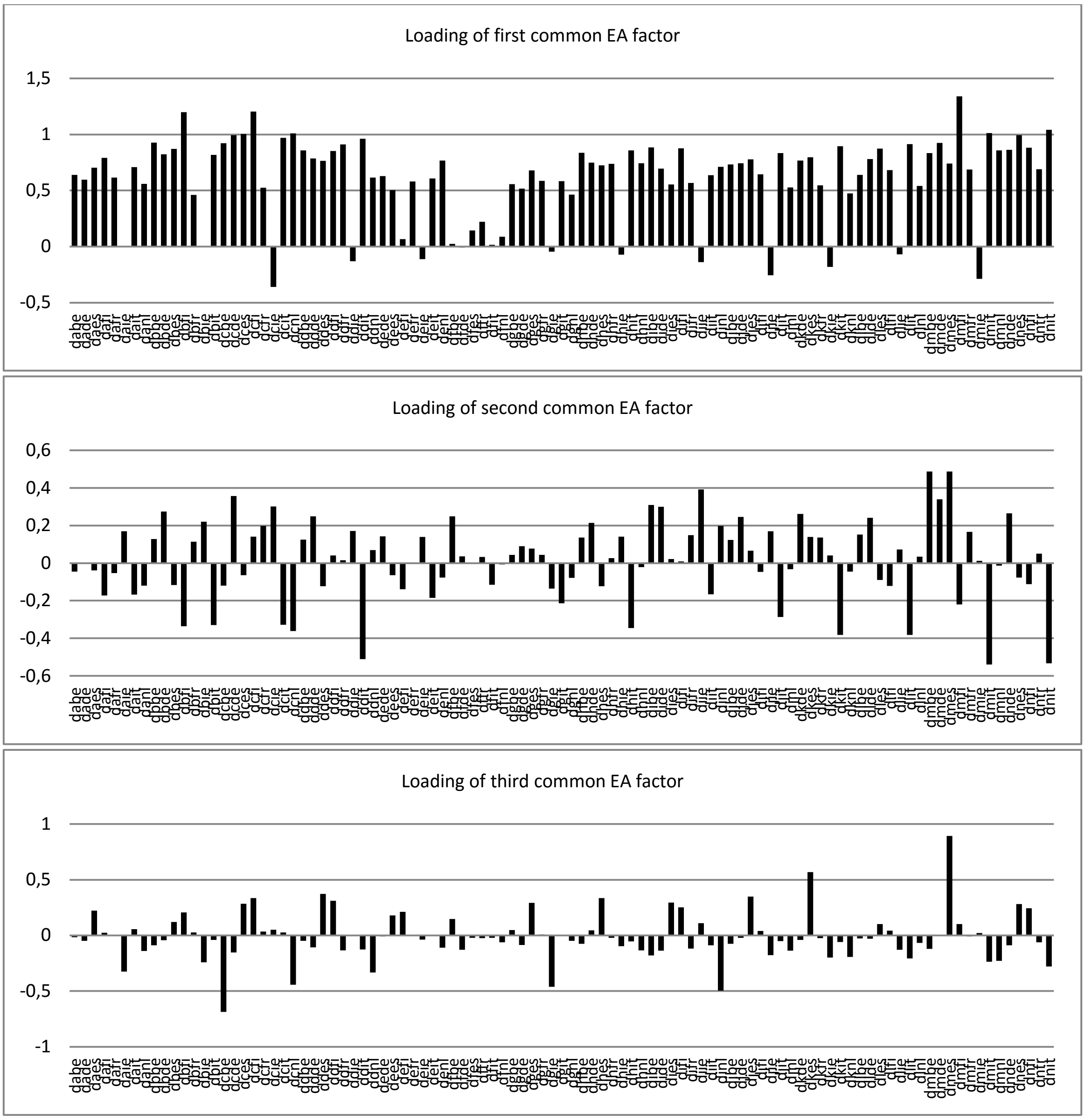


Table B1. Results of the OLS regression of aggregate industrial production index in EA-17 manufacturing sector on common EA factors. 1991M03-2014M06.

	Coeff	StdError	t-value	t-prob			
F1	0.05689	0.0103	5.521	0			
F2	0.03641	0.0103	3.534	0.0005			
F3	-0.04194	0.01031	-4.067	0.0001			
RSS	0.02942	sigma	0.01031	R^2	0.17448	Radj^2	0.16852
LogLik	1282.538	AIC	-9.13956	HQ	-9.12394	SC	-9.10062
T	280	p	3	FpNull	0	FpConst	0
	value	prob					
Chow(2002:11)	1.1783	0.1679					
Chow(2012:3)	0.5977	0.9447					
normality test	9.0543	0.0108					
AR 1-4 test	9.1067	0					
ARCH 1-4 test	19.5095	0					
hetero test	2.3091	0.0343					

Figure B2. Loadings of EA sector specific factors on the EA series, 2014M06. T=282, N_{max}=8. 14 factors for 14 subsectors represented in one figure, first two letters of series stand for a subsector.

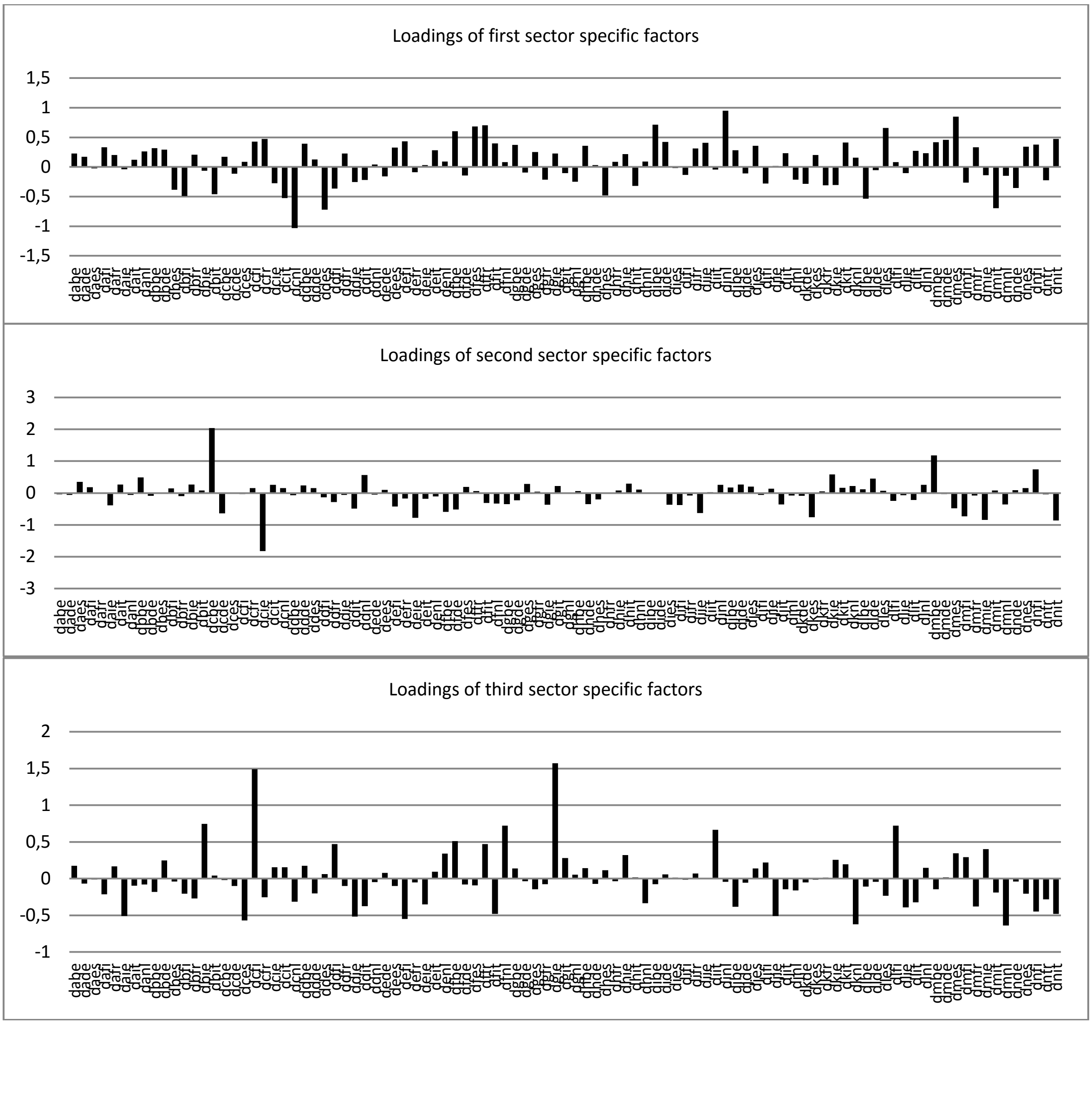


Table B2. Proportion of explained variance of output growth in manufacturing by factors and countries; 2014M06. T=282, N=99.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
BE	0.46	0.15	0.61	0.06	0.33
DE	0.68	0.07	0.75	0.08	0.18
ES	0.51	0.16	0.67	0.08	0.25
FI	0.47	0.06	0.53	0.09	0.38
FR	0.65	0.10	0.74	0.05	0.21
IE	0.02	0.04	0.06	0.17	0.77
IT	0.56	0.11	0.67	0.08	0.25
NL	0.49	0.12	0.61	0.08	0.31

Table B3. Proportion of explained variance of output growth by factors and manufacturing subsectors; 2014M06. T=282, N=99.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.63	0.07	0.69	0.07	0.24
Textile	0.50	0.09	0.59	0.09	0.32
Leather	0.38	0.12	0.49	0.07	0.44
Wood	0.50	0.09	0.59	0.15	0.26
Paper and printing	0.60	0.07	0.68	0.07	0.25
Coke	0.01	0.22	0.22	0.01	0.77
Chemicals and pharmaceuticals	0.50	0.08	0.58	0.04	0.38
Rubber and plastic	0.62	0.08	0.70	0.10	0.19
Other non-metallic	0.47	0.18	0.64	0.12	0.24
Metals	0.59	0.06	0.66	0.12	0.22
Electronic	0.45	0.10	0.55	0.06	0.39
Machinery	0.44	0.10	0.54	0.11	0.35
Transport	0.40	0.09	0.48	0.07	0.45
Furniture	0.61	0.09	0.70	0.08	0.23

B.2 Dataset for 8 euro area countries for the period 1992(1)–20014(6), y-o-y series

Table B4. Proportion of explained variance of output growth in manufacturing by factors and countries. T=270, N=99.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
BE	0.37	0.12	0.50	0.12	0.39
DE	0.55	0.15	0.69	0.09	0.21
ES	0.47	0.15	0.63	0.09	0.28
FI	0.41	0.10	0.51	0.11	0.38
FR	0.54	0.16	0.69	0.04	0.27
IE	0.16	0.17	0.33	0.15	0.52
IT	0.51	0.14	0.65	0.06	0.28
NL	0.40	0.18	0.58	0.07	0.35

Table B5. Proportion of explained variance of output growth by factors and manufacturing subsectors. T=270, N=99.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.24	0.25	0.49	0.13	0.38
Textile	0.38	0.13	0.52	0.11	0.37
Leather	0.19	0.20	0.39	0.10	0.51
Wood	0.49	0.14	0.63	0.06	0.31
Paper and printing	0.46	0.14	0.61	0.11	0.29
Coke	0.04	0.22	0.26	0.01	0.73
Chemicals and pharmaceuticals	0.39	0.13	0.52	0.05	0.44
Rubber and plastic	0.66	0.07	0.73	0.10	0.17
Other non-metallic	0.55	0.14	0.69	0.09	0.22
Metals	0.69	0.09	0.78	0.08	0.14
Electronic	0.50	0.15	0.65	0.12	0.22
Machinery	0.47	0.17	0.64	0.11	0.25
Transport	0.46	0.11	0.57	0.06	0.37
Furniture	0.50	0.12	0.63	0.11	0.27

B.3 Results for EA factors. T=282. 23 subsectors.

Table B6. List of manufacturing subsectors in a 23 subsectors sample.

Eurostat code	Description	Short label
C10	Manufacture of food products	Food
C11	Manufacture of beverages	Beverages
C12	Manufacture of tobacco products	Tobacco
C13	Manufacture of textiles	Textiles
C14	Manufacture of wearing apparel	Wearing apparel
C15	Manufacture of leather and related products	Leather
C16	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Wood
C17	Manufacture of paper and paper products	Paper
C18	Printing and reproduction of recorded media	Printing
C19	Manufacture of coke and refined petroleum products	Coke
C20	Manufacture of chemicals and chemical products	Chemicals
C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	Pharmaceuticals
C22	Manufacture of rubber and plastic products	Rubber and plastic
C23	Manufacture of other non-metallic mineral products	Other non-metallic
C24	Manufacture of basic metals	Metals
C25	Manufacture of fabricated metal products, except machinery and equipment	Fabricated metals
C26	Manufacture of computer, electronic and optical products	Electronic
C27	Manufacture of electrical equipment	Electrical eq
C28	Manufacture of machinery and equipment n.e.c.	Machinery
C29	Manufacture of motor vehicles, trailers and semi-trailers	Transport
C30	Manufacture of other transport equipment	Other transport
C31	Manufacture of furniture	Furniture
C32	Other manufacturing	Other
C33	Repair and installation of machinery and equipment	Repair

Source: Eurostat

Table B7. Proportion of explained variance of output growth in manufacturing by factors and countries. T=282, N=99.

	Common EA factor	Sector specific factor	EA factors	Country specific factor	Unexplained variance
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
BE	0.41	0.16	0.57	0.06	0.38
DE	0.64	0.10	0.73	0.07	0.20
ES	0.43	0.16	0.60	0.07	0.33
FI	0.36	0.09	0.45	0.06	0.49
FR	0.53	0.10	0.64	0.04	0.32
IE	0.03	0.07	0.10	0.13	0.77
IT	0.49	0.14	0.63	0.06	0.31
NL	0.43	0.12	0.55	0.08	0.37

Table B8. Proportion of explained variance of output growth by factors and manufacturing subsectors. T=282, N=99.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.59	0.08	0.67	0.06	0.27
Beverages	0.37	0.15	0.52	0.05	0.43
Tobacco	0.32	0.16	0.48	0.04	0.49
Textiles	0.49	0.11	0.60	0.08	0.32
Wearing apparel	0.30	0.11	0.41	0.05	0.55
Leather	0.37	0.12	0.49	0.06	0.45
Wood	0.49	0.09	0.59	0.14	0.28
Paper	0.71	0.06	0.78	0.06	0.16
Printing	0.44	0.12	0.56	0.07	0.37
Coke	0.01	0.21	0.22	0.00	0.77
Chemicals	0.46	0.11	0.57	0.08	0.35
Pharmaceuticals	0.36	0.13	0.48	0.02	0.50
Rubber and plastic	0.62	0.09	0.70	0.10	0.20
Other non-metallic	0.46	0.18	0.64	0.11	0.25
Metals	0.36	0.14	0.50	0.06	0.44
Fabricated metals	0.56	0.07	0.63	0.12	0.24
Electronic	0.32	0.14	0.46	0.04	0.51
Electrical eq	0.52	0.12	0.64	0.04	0.32
Machinery	0.44	0.08	0.51	0.11	0.38
Transport	0.41	0.17	0.57	0.06	0.36
Other transport	0.46	0.11	0.57	0.02	0.41
Furniture	0.57	0.09	0.66	0.11	0.24
Other	0.44	0.11	0.56	0.03	0.41
Repair	0.30	0.13	0.43	0.04	0.52

B.4 Results for EA factors. T=50. 23 subsectors.

Table B9. Share of variance of output growth in manufacturing explained by the common EA factor, EA sector and country specific factors for EA, NMS and OMS. Annual averages.

	Common EA factor			EA sector specific factors			Country specific factors		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
1995	0.37		0.40	0.18		0.02	0.10		0.16
1996	0.41		0.43	0.17		0.03	0.09		0.15
1997	0.45		0.47	0.16		0.03	0.07		0.14
1998	0.48		0.50	0.15		0.02	0.08		0.12
1999	0.46		0.46	0.15		0.03	0.08		0.14
2000	0.48		0.47	0.14		0.03	0.08		0.14
2001	0.48		0.46	0.14		0.02	0.07		0.14
2002	0.49		0.47	0.14		0.03	0.07		0.12
2003	0.49		0.47	0.14		0.03	0.07		0.11
2004	0.47	0.20	0.46	0.15	0.04	0.03	0.07	0.14	0.12
2005	0.45	0.21	0.44	0.15	0.04	0.03	0.08	0.13	0.13
2006	0.46	0.22	0.42	0.15	0.03	0.03	0.08	0.13	0.13
2007	0.48	0.25	0.43	0.14	0.03	0.03	0.07	0.12	0.12
2008	0.53	0.33	0.50	0.13	0.03	0.03	0.06	0.10	0.10
2009	0.52	0.34	0.50	0.14	0.04	0.03	0.06	0.10	0.09
2010	0.50	0.30	0.46	0.14	0.04	0.03	0.07	0.10	0.10
2011	0.48	0.28	0.43	0.15	0.04	0.04	0.07	0.11	0.11
2012	0.42	0.21	0.32	0.16	0.05	0.04	0.08	0.13	0.15
2013	0.41	0.22	0.32	0.16	0.04	0.04	0.08	0.13	0.14
2014	0.41	0.22	0.32	0.16	0.03	0.04	0.08	0.14	0.14

Figure B3. Combined effects of common EA and sector specific factors for selected groups of countries. Annual averages.

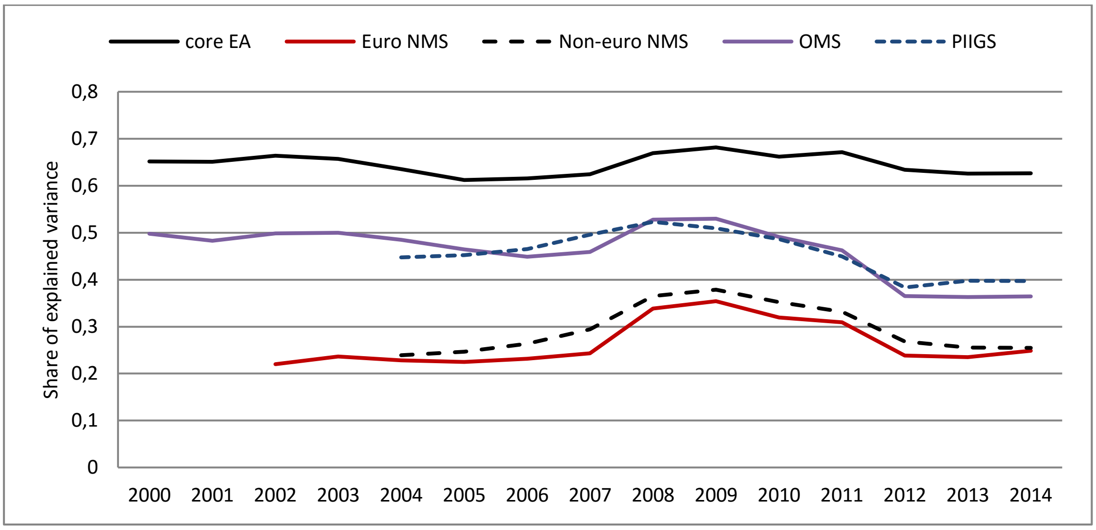


Table B10. Variance of output growth in manufacturing explained by EA factors (common EA and EA sector specific factors) by groups of countries and subsectors. Annual average for year 2014.

Subsector	**EA**	**NMS 2004**	**OMS**	**NMS 2007**
Food	0.62	0.60	0.78	0.29
Beverages	0.48	0.13	0.23	0.20
Tobacco	0.40	0.04	0.10	0.02
Textiles	0.60	0.33	0.43	0.29
Wearing apparel	0.28	0.20	0.03	0.31
Leather	0.46	0.17	0.32	0.26
Wood	0.58	0.44	0.20	0.19
Paper	0.59	0.36	0.57	0.21
Printing	0.50	0.31	0.41	0.16
Coke	0.25	0.04	0.11	0.01
Chemicals	0.50	0.24	0.36	0.07
Pharmaceuticals	0.44	0.17	0.34	0.17
Rubber and plastic	0.68	0.41	0.48	0.45
Other non-metallic	0.59	0.36	0.54	0.21
Metals	0.46	0.18	0.45	0.09
Fabricated metals	0.60	0.37	0.47	0.04
Electronic	0.46	0.14	0.35	0.15
Electrical eq	0.56	0.30	0.23	0.25
Machinery	0.46	0.30	0.36	0.31
Transport	0.42	0.18	0.42	0.32
Other transport	0.43	0.09	0.14	0.19
Furniture	0.62	0.44	0.58	0.37
Other	0.48	0.17	0.25	0.17
Repair	0.48	0.11	0.21	0.07

B.5 Results for EA factors. T=50, EA10.

Note: In this part we report results using the EA10 sample, where we include also series for AT and PT in constructing the EA factors. This reduces the sample to 1996M01-2014M06.

Table B11. Proportion of explained variance of output growth in manufacturing by factors and countries; Average 2014. T=50.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factor**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
AT	0.54	0.09	0.63	0.08	0.29
BE	0.46	0.14	0.60	0.06	0.34
DE	0.68	0.11	0.80	0.07	0.13
EL	0.14	0.04	0.18	0.29	0.54
ES	0.50	0.12	0.62	0.11	0.26
FI	0.30	0.10	0.40	0.13	0.47
FR	0.65	0.13	0.79	0.06	0.16
IE	0.07	0.03	0.11	0.18	0.71
IT	0.47	0.19	0.65	0.09	0.26
NL	0.40	0.22	0.63	0.09	0.29
PT	0.30	0.12	0.42	0.12	0.46
BG	0.21	0.04	0.25	0.19	0.57
CZ	0.40	0.06	0.46	0.13	0.41
EE	0.20	0.06	0.25	0.19	0.55
HU	0.25	0.05	0.30	0.15	0.56
LT	0.19	0.06	0.25	0.22	0.53
LV	0.24	0.04	0.28	0.14	0.58
PL	0.43	0.06	0.49	0.16	0.35
RO	0.25	0.05	0.30	0.19	0.51
SI	0.29	0.04	0.33	0.17	0.50
SK	0.06	0.10	0.17	0.17	0.66
DK	0.30	0.02	0.31	0.15	0.54
SE	0.44	0.07	0.50	0.14	0.36
UK	0.39	0.09	0.48	0.22	0.30

Table B12. Proportion of explained variance of output growth in manufacturing by factors and groups of countries. Annual averages. T=50.

	Common EA factors			**EA sector specific factors**			**Country specific factors**		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
2000	0.51		0.52	0.11		0.04	0.10		0.15
2001	0.51		0.51	0.11		0.03	0.09		0.15
2002	0.52		0.53	0.11		0.04	0.09		0.13
2003	0.52		0.55	0.10		0.04	0.09		0.11
2004	0.51	0.25	0.53	0.10	0.04	0.04	0.09	0.17	0.13
2005	0.49	0.25	0.51	0.10	0.04	0.04	0.11	0.16	0.14
2006	0.52	0.27	0.49	0.10	0.04	0.04	0.10	0.15	0.14
2007	0.54	0.31	0.50	0.10	0.03	0.03	0.08	0.13	0.13
2008	0.58	0.39	0.56	0.09	0.03	0.03	0.08	0.11	0.10
2009	0.57	0.41	0.55	0.09	0.03	0.03	0.08	0.12	0.10
2010	0.54	0.37	0.51	0.10	0.04	0.03	0.08	0.13	0.11
2011	0.52	0.34	0.48	0.11	0.04	0.04	0.08	0.14	0.13
2012	0.46	0.26	0.36	0.12	0.05	0.05	0.09	0.17	0.18
2013	0.46	0.26	0.37	0.12	0.05	0.05	0.09	0.16	0.17
2014	0.45	0.26	0.37	0.13	0.05	0.06	0.10	0.17	0.17

Figure B4. Combined effects of common EA and sector specific factors for selected groups of countries. Annual averages.

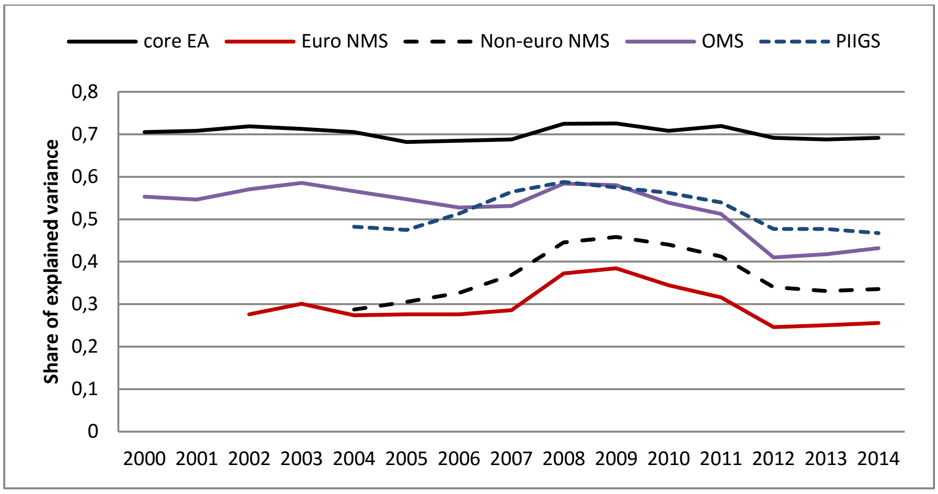


Table B13. Proportion of explained variance of output growth by factors and manufacturing subsectors for 10 EA countries included in the extraction of EA factors. Average 2014.

	Common EA factor	**Sector specific factor**	**EA factors**	**Country specific factors**	**Country-sector specific effects**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.64	0.17	0.81	0.05	0.14
Textile	0.52	0.11	0.63	0.06	0.31
Leather	0.34	0.16	0.50	0.08	0.42
Wood	0.60	0.09	0.69	0.12	0.19
Paper and printing	0.60	0.07	0.67	0.09	0.24
Coke	0.03	0.25	0.29	0.06	0.66
Chemicals and pharmaceuticals	0.51	0.12	0.63	0.06	0.30
Rubber and plastic	0.65	0.11	0.76	0.11	0.13
Other non-metallic	0.39	0.28	0.67	0.12	0.21
Metals	0.61	0.09	0.70	0.09	0.20
Electronic	0.51	0.11	0.62	0.11	0.27
Machinery	0.48	0.08	0.56	0.08	0.36
Transport	0.36	0.16	0.52	0.11	0.37
Furniture	0.57	0.11	0.67	0.07	0.26

Table B14. Proportion of variance of output growth explained by EA factors by groups of countries and manufacturing subsectors. Annual average 2014.

	EA	**NMS 2004**	**NMS 2007**	**OMS**
Food	0.70	0.62	0.33	0.77
Textile	0.52	0.31	0.40	0.22
Leather	0.42	0.15	0.40	0.43
Wood	0.57	0.44	0.20	0.19
Paper and printing	0.57	0.37	0.25	0.53
Coke	0.25	0.05	0.01	0.11
Chemicals and pharmaceuticals	0.53	0.22	0.17	0.40
Rubber and plastic	0.66	0.41	0.45	0.47
Other non-metallic	0.58	0.35	0.20	0.53
Metals	0.61	0.30	0.09	0.50
Electronic	0.52	0.34	0.21	0.42
Machinery	0.46	0.27	0.30	0.37
Transport	0.43	0.18	0.30	0.42
Furniture	0.61	0.38	0.39	0.53

B.6 Results for EU factors. T=50.

Figure B5. Loadings of the 3 common EU factors on the EU series of manufacturing output growth for the last observed period 2009M04-2014M06. T=50. N=310.

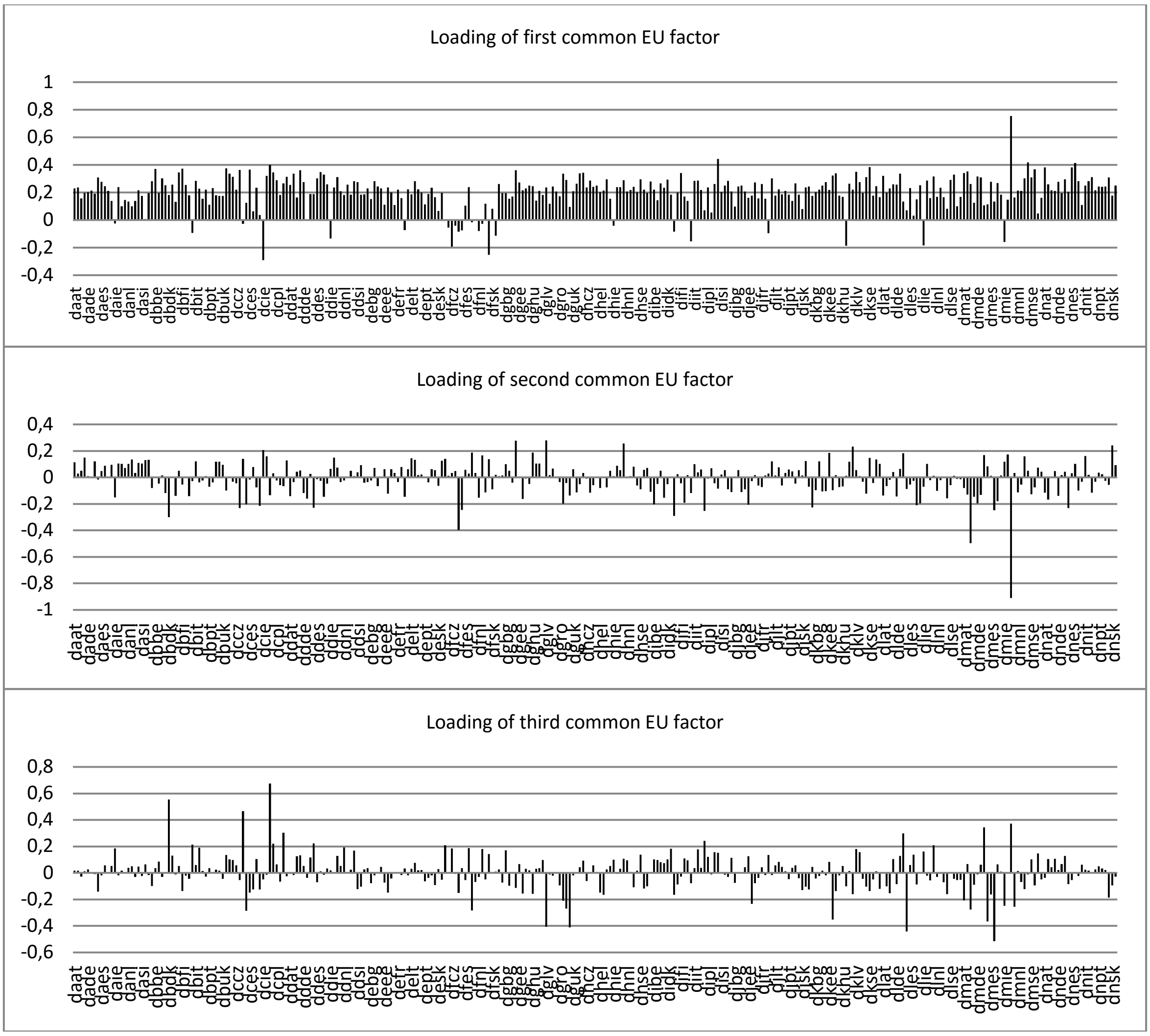


Figure B6. Loadings of sector specific factors on EU series of manufacturing output growth for the last observed period 2009M04-2014M06. T=50. $N \leq 24$. 14 factors depicted in one figure.

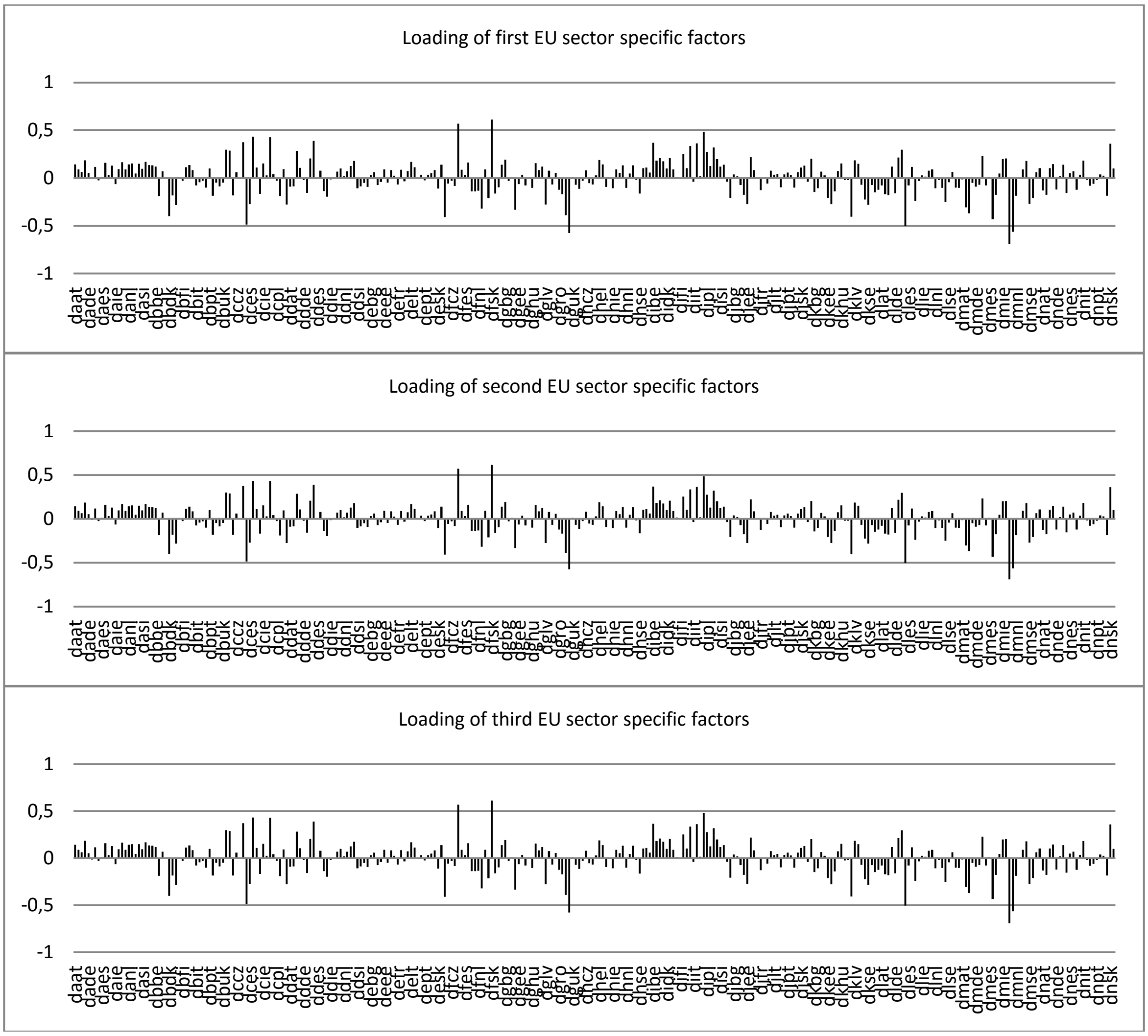


Table B15. Sufficient number of EU sector specific factors according to Bai and Ng IC_{p1} criterion. Averages for 12 periods ending in given year. T=50.[1]

	N	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Food	23	1.0	1.0	1.0	1.4	1.0	1.1	2.0	2.3	2.6	2.7	3.0
Textile	22	2.9	1.2	1.0	2.5	2.2	2.8	2.7	2.2	1.0	1.5	2.0
Leather	19	1.3	1.5	2.1	1.7	2.2	1.5	1.4	2.1	2.7	2.9	3.0
Wood	22	1.3	1.0	1.0	1.0	1.0	2.0	1.1	1.0	1.0	1.5	2.8
Paper and printing	24	1.3	1.1	2.4	1.9	2.5	1.3	1.0	1.0	1.0	1.0	1.0
Coke	16	1.0	1.0	1.7	1.0	1.8	1.0	1.0	1.0	1.2	1.8	2.0
Chemicals and pharmaceuticals	23	1.0	1.0	2.1	2.6	1.7	2.9	1.4	1.0	1.0	1.1	1.0
Rubber and plastic	22	1.4	1.0	1.0	1.0	1.0	1.9	1.0	1.0	1.0	2.0	2.0
Other non-metallic	23	1.0	1.0	1.5	2.0	2.0	1.0	1.0	1.2	1.1	1.5	2.0
Metals	24	1.0	1.0	1.0	1.6	1.8	1.0	1.0	1.0	1.0	1.2	1.0
Electronic	22	1.5	1.8	1.5	1.5	1.2	1.3	1.2	1.5	1.6	1.2	1.0
Machinery	24	1.0	1.4	1.2	1.2	1.0	1.0	1.8	1.8	1.0	1.3	1.0
Transport	24	1.9	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Furniture	22	1.0	1.5	2.8	1.4	1.8	1.5	3.0	1.3	1.0	1.0	1.0

[1] Note that criterion IC_{p2} suggests one sector specific factors for all subsectors in every observed period.

Table B16. Sufficient number of country specific factors according to the Bai and Ng criteria. Averages for 12 periods ending in a given year. T=50.

	N	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
IC_{p2}												
AT	14	1.0	1.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BE	11	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BG	13	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
CZ	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
DE	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
DK	12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
EE	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
EL	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
ES	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
FI	10	1.0	1.0	1.0	1.0	1.0	1.8	1.0	1.0	1.0	1.0	1.0
FR	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.3
HU	12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
IE	12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
IT	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LT	13	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LV	12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
NL	12	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PL	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PT	9	1.0	1.1	1.8	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
RO	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SE	11	1.0	1.0	1.2	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SI	13	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
SK	10	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
UK	14	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
IC_{p1}												
AT	14	2.2	2.0	1.3	1.7	1.9	1.9	1.5	1.3	3.0	1.9	1.0
BE	11	1.0	2.8	2.4	1.6	2.4	1.5	2.7	2.2	2.5	2.4	1.3
BG	13	2.2	2.0	1.0	1.3	1.2	2.8	2.3	1.9	2.1	2.7	2.0
CZ	14	1.0	1.4	1.2	1.3	1.3	2.0	2.2	1.7	2.3	2.7	2.7
DE	14	1.2	1.3	2.8	3.0	2.8	3.0	2.7	1.7	1.0	1.6	2.5
DK	12	2.0	1.8	1.0	1.2	1.2	2.4	2.5	3.0	3.0	2.6	2.5
EE	14	1.5	1.5	1.0	1.0	1.1	2.3	1.3	1.8	1.1	2.2	3.0
EL	14	1.6	2.3	2.0	2.3	1.8	2.2	1.5	3.0	2.9	3.0	3.0
ES	14	1.3	2.0	1.8	1.4	1.2	1.7	1.3	1.6	1.9	3.0	2.8
FI	10	2.5	2.8	2.4	2.6	3.0	3.0	3.0	2.3	1.7	2.6	2.3
FR	14	1.6	2.1	3.0	2.8	2.8	3.0	3.0	2.2	2.0	2.5	2.0
HU	12	2.7	2.1	2.0	1.2	2.3	1.0	1.0	1.8	2.0	2.9	3.0
IE	12	1.1	2.2	2.3	1.9	1.5	1.6	1.0	2.1	1.1	1.1	1.5
IT	14	1.4	1.8	1.8	2.3	1.9	1.1	1.0	1.4	1.0	1.3	1.0
LT	13	1.1	1.8	2.2	2.7	1.0	1.2	1.1	1.6	1.7	1.1	1.0
LV	12	1.5	1.0	2.3	2.4	1.5	2.3	2.2	1.8	2.3	3.0	3.0
NL	12	3.0	2.7	1.8	2.5	1.7	1.0	1.0	1.0	1.0	1.0	2.0
PL	14	2.5	2.7	2.2	2.0	2.5	1.2	1.8	2.0	1.6	1.8	1.8
PT	9	2.5	2.2	2.6	2.8	1.2	1.3	1.3	1.0	2.3	2.3	3.0
RO	14	2.7	1.3	1.7	1.4	1.2	1.0	1.0	2.0	2.3	1.3	2.0
SE	11	2.5	2.5	3.0	2.4	2.6	3.0	2.8	2.5	1.9	1.5	2.7
SI	13	2.3	2.1	1.7	1.3	1.2	1.3	1.3	1.1	2.4	1.3	1.5
SK	10	1.2	1.6	1.1	2.5	2.5	1.9	2.1	2.0	1.3	2.0	1.7
UK	14	2.5	1.8	1.5	2.5	2.4	2.0	2.7	2.2	1.3	2.7	2.0

Table B17. Share of variance of output growth in manufacturing explained by the common EU factor, EU sector and country specific factors for EA, NMS and OMS. Annual averages.

	Common EU factor			Sector specific factors			Country specific factors		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
2004	0.47	0.27	0.54	0.09	0.10	0.07	0.11	0.14	0.10
2005	0.46	0.27	0.53	0.08	0.11	0.08	0.12	0.13	0.11
2006	0.48	0.29	0.51	0.08	0.11	0.08	0.12	0.12	0.11
2007	0.51	0.32	0.51	0.08	0.11	0.07	0.10	0.11	0.10
2008	0.55	0.40	0.56	0.07	0.10	0.05	0.09	0.09	0.08
2009	0.54	0.42	0.56	0.07	0.10	0.06	0.09	0.09	0.08
2010	0.51	0.39	0.53	0.08	0.10	0.06	0.09	0.10	0.09
2011	0.48	0.36	0.50	0.09	0.09	0.08	0.11	0.11	0.10
2012	0.42	0.28	0.40	0.10	0.12	0.10	0.12	0.13	0.14
2013	0.42	0.28	0.40	0.10	0.12	0.10	0.12	0.13	0.14
2014	0.41	0.29	0.41	0.10	0.12	0.11	0.13	0.13	0.13

Figure B7. Combined effects of common EU and sector specific factors on selected groups of countries. Annual averages of share of explained variance.

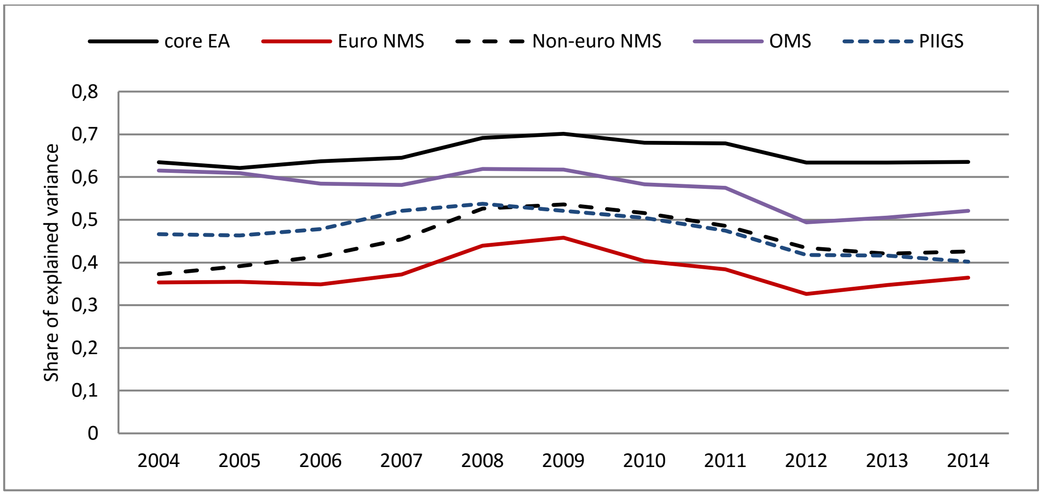


Figure B8. Share of variance of output growth in manufacturing explained by the common EU factor before and after the financial crisis

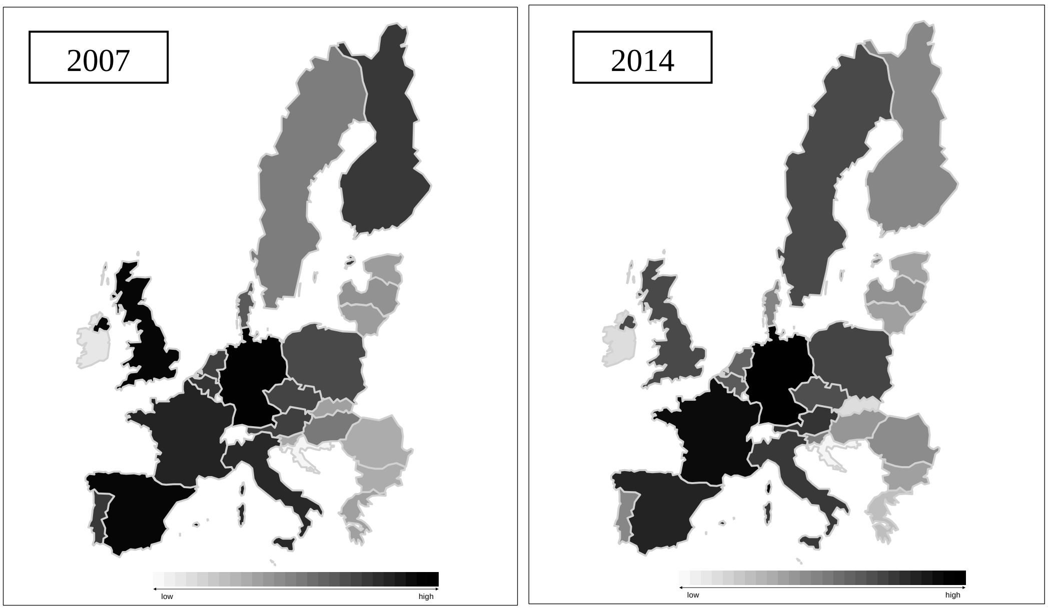


Figure B9. Share of variance of output growth in manufacturing explained by the EU sector specific factors before and after the financial crisis

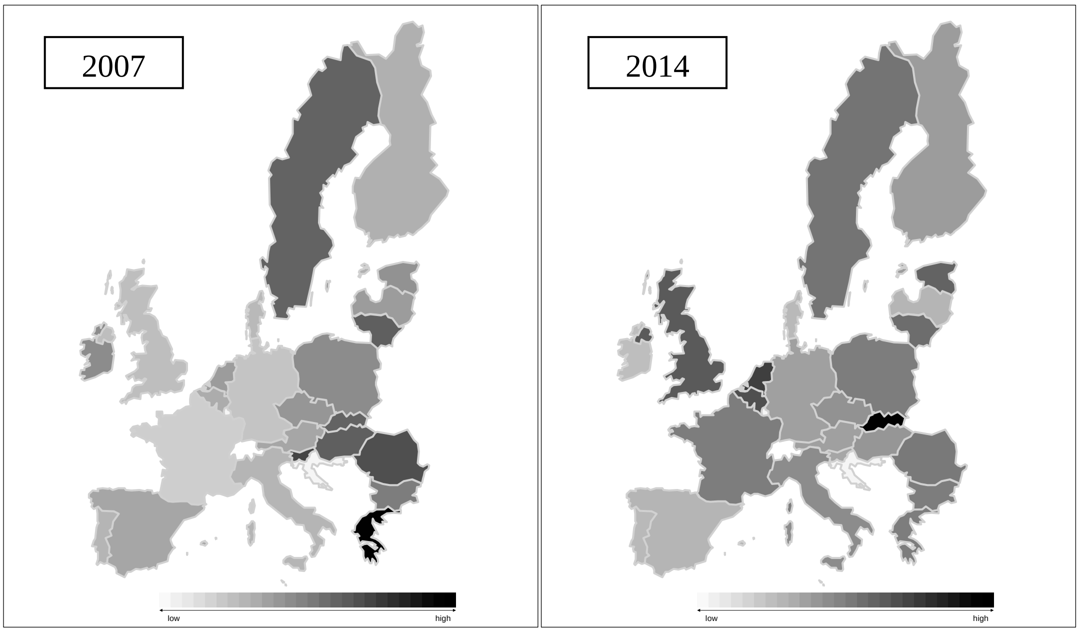


Figure B10. Share of variance of output growth in manufacturing explained by the country specific factors before and after the financial crisis

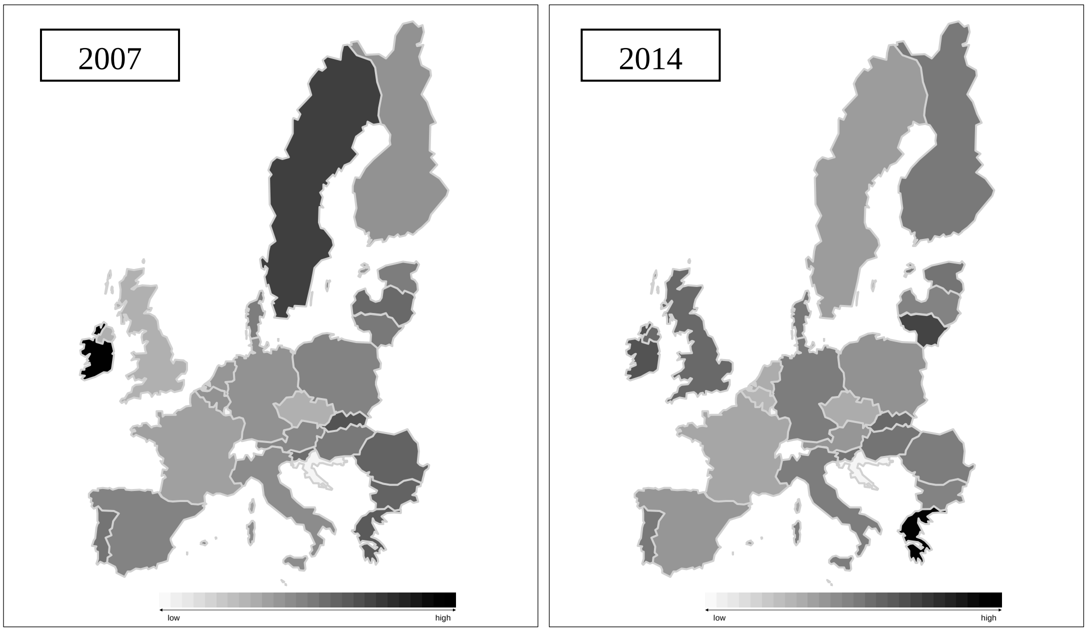


Table B18. Variance of output growth explained by factors for EU countries (24) by manufacturing subsectors. Share of total variance. Annual average for year 2014.

	Common EU factor	**Sector specific factor**	**EU factors**	**Country specific factors**	**Unexplained variance**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.48	0.20	0.67	0.07	0.25
Textile	0.37	0.09	0.46	0.13	0.41
Leather	0.24	0.12	0.37	0.10	0.53
Wood	0.42	0.09	0.51	0.14	0.35
Paper and printing	0.45	0.06	0.52	0.12	0.36
Coke	0.03	0.15	0.18	0.05	0.77
Chemicals and pharmaceuticals	0.33	0.08	0.42	0.12	0.46
Rubber and plastic	0.49	0.08	0.57	0.17	0.26
Other non-metallic	0.32	0.20	0.52	0.17	0.30
Metals	0.40	0.08	0.48	0.17	0.35
Electronic	0.35	0.10	0.45	0.16	0.39
Machinery	0.31	0.10	0.41	0.14	0.45
Transport	0.25	0.11	0.36	0.12	0.52
Furniture	0.45	0.09	0.53	0.11	0.36

B.7 Results for EU factors. T=174, N=310.

Figure B11. Loadings of common EU factors on EU output growth manufacturing series. T=174, N=310.

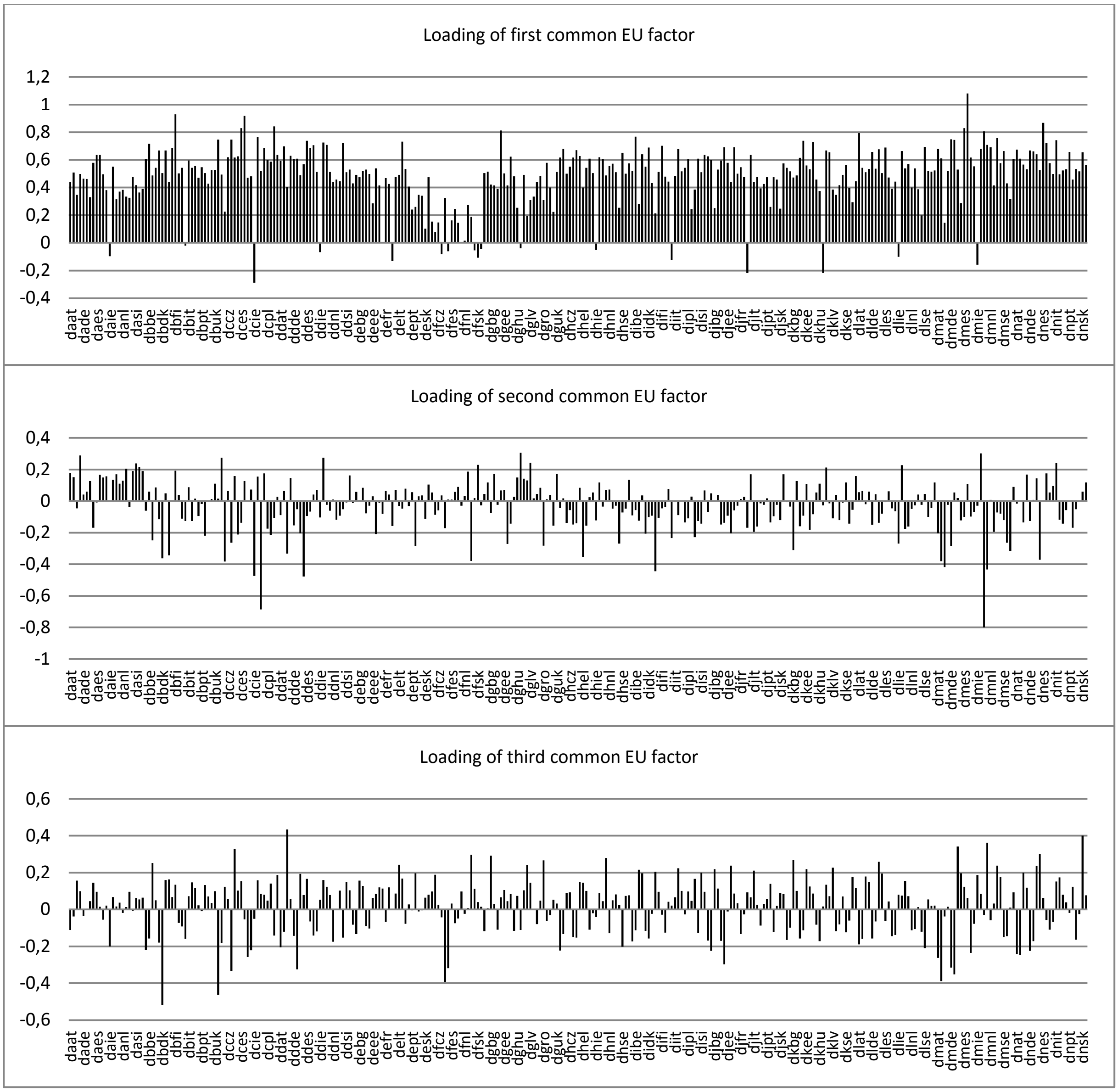


Figure B12. Loadings of EU sector specific factors on EU output growth manufacturing series. T=174. N_{max}=24.

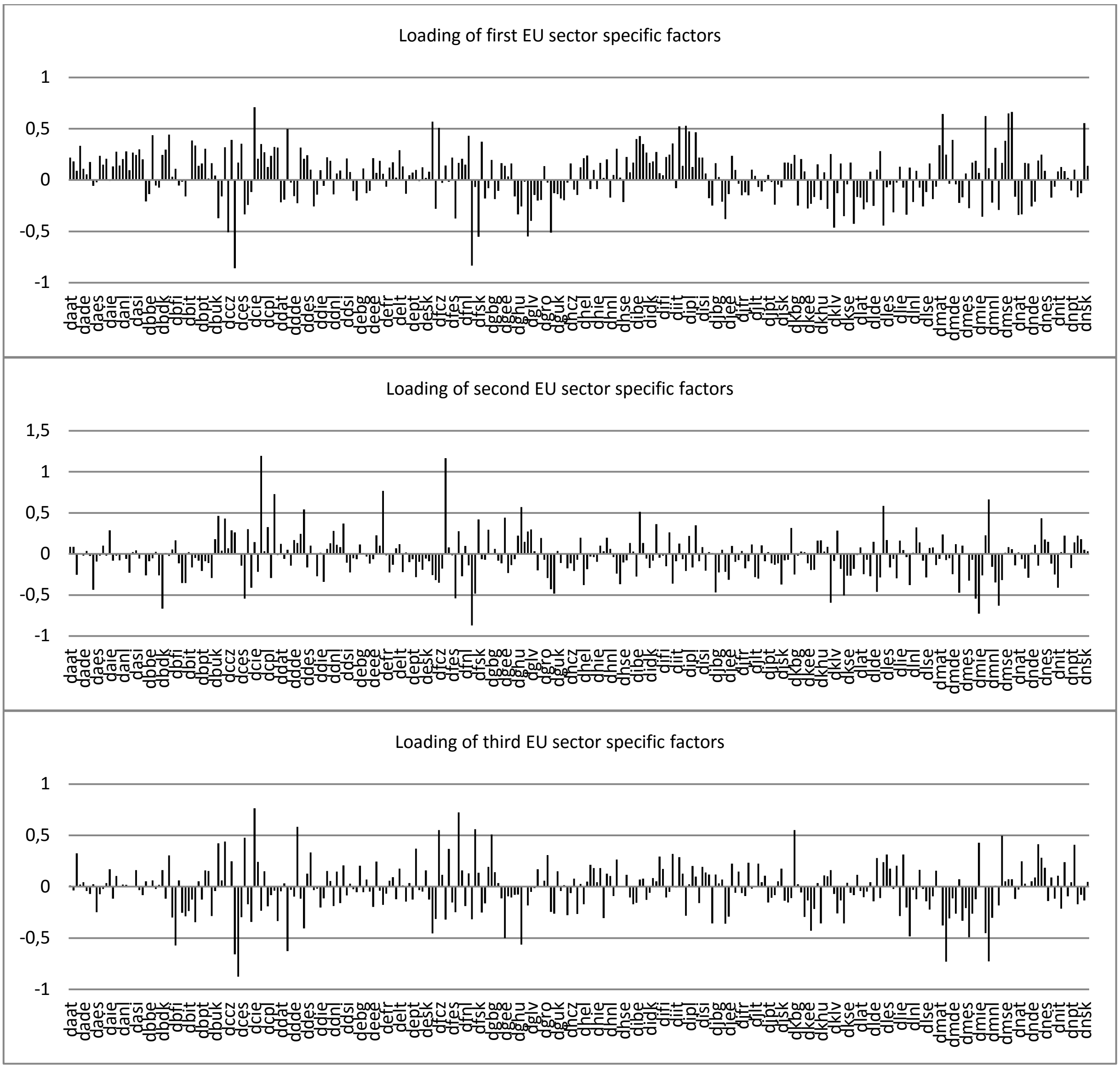


Table B19. Number of sufficient factors according to Bai and Ng criteria. T=174.

Level of factors	Factor	N	No. of sufficient factors	
			IC_{p2}	IC_{p1}
Common EU factors	Common EU factor	310	1	1
Sector specific factors	Food	23	1	1
	Textile	22	1	1
	Leather	19	1	1
	Wood	22	1	1
	Paper and printing	24	1	1
	Coke	16	1	1
	Chemicals and pharmaceuticals	23	1	1
	Rubber and plastic	22	1	1
	Other non-metallic	23	1	1
	Metals	24	1	1
	Electronic	22	1	1
	Machinery	24	1	1
	Transport	24	1	1
	Furniture	22	1	1
Country specific factors	AT	14	1	1
	BE	10	1	1
	BG	13	1	2
	CZ	14	1	1
	DE	14	1	1
	DK	12	1	2
	EE	14	1	1
	EL	14	1	3
	ES	14	1	1
	FI	10	1	3
	FR	14	1	2
	HU	12	1	1
	IE	12	1	1
	IT	14	1	1
	LT	13	1	1
	LV	12	1	2
	NL	12	1	3
	PL	14	1	1
	PT	9	1	1
	RO	14	1	1
	SE	11	1	2
	SI	13	1	1
	SK	10	1	1
	UK	14	1	1

Table B20. Proportion of variance of output growth in manufacturing explained by factors for EU countries. T=174.

	Common EU factor	**Sector specific factors**	**EU factors**	**Country specific factor**	**Country-sector specific effects**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
AT	0.53	0.08	0.61	0.07	0.32
BE	0.48	0.08	0.56	0.06	0.37
DE	0.68	0.08	0.75	0.08	0.16
EL	0.19	0.05	0.24	0.19	0.57
ES	0.61	0.05	0.66	0.10	0.25
FI	0.47	0.02	0.49	0.08	0.43
FR	0.66	0.06	0.72	0.06	0.22
IE	0.02	0.04	0.06	0.17	0.77
IT	0.55	0.04	0.59	0.12	0.28
NL	0.46	0.09	0.54	0.09	0.36
PT	0.39	0.04	0.43	0.12	0.45
BG	0.19	0.08	0.27	0.14	0.59
CZ	0.48	0.08	0.56	0.09	0.35
EE	0.26	0.06	0.32	0.09	0.59
HU	0.32	0.04	0.36	0.10	0.55
LT	0.26	0.08	0.34	0.10	0.56
LV	0.29	0.05	0.34	0.10	0.56
PL	0.48	0.08	0.57	0.10	0.34
RO	0.21	0.07	0.27	0.11	0.61
SI	0.30	0.08	0.38	0.11	0.51
SK	0.15	0.10	0.25	0.11	0.64
DK	0.38	0.03	0.41	0.09	0.50
SE	0.44	0.06	0.49	0.11	0.39
UK	0.61	0.07	0.68	0.10	0.22

Table B21. Proportion of variance of output growth in manufacturing explained by factors for subsectors by groups of countries. T=174.

	Common EU factor			**Sector specific factor**			**Country specific factors**		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
Food	0.63	0.40	0.61	0.07	0.15	0.13	0.07	0.09	0.03
Textile	0.51	0.40	0.37	0.05	0.10	0.01	0.09	0.11	0.10
Leather	0.29	0.22	0.50	0.06	0.08	0.12	0.08	0.09	0.05
Wood	0.51	0.42	0.42	0.04	0.07	0.01	0.17	0.08	0.16
Paper and printing	0.58	0.36	0.57	0.04	0.04	0.01	0.08	0.09	0.07
Coke	0.02	0.03	0.00	0.08	0.12	0.17	0.00	0.05	0.02
Chemicals and pharmaceuticals	0.48	0.16	0.45	0.04	0.07	0.02	0.08	0.08	0.04
Rubber and plastic	0.58	0.42	0.61	0.06	0.02	0.03	0.13	0.18	0.23
Other non-metallic	0.42	0.31	0.59	0.10	0.14	0.03	0.18	0.12	0.20
Metals	0.57	0.30	0.56	0.05	0.01	0.11	0.15	0.11	0.16
Electronic	0.44	0.24	0.49	0.05	0.08	0.03	0.09	0.12	0.06
Machinery	0.44	0.27	0.46	0.05	0.04	0.01	0.12	0.12	0.12
Transport	0.37	0.15	0.43	0.07	0.08	0.06	0.09	0.08	0.06
Furniture	0.55	0.40	0.56	0.05	0.04	0.04	0.09	0.13	0.03

B.8 Results for EU factors. T=50. Y-o-y series.

Figure B13. Proportion of variance of output growth in manufacturing explained by common EU and EU sector specific factors for 4 groups of EU countries, y-o-y series used. T=50.

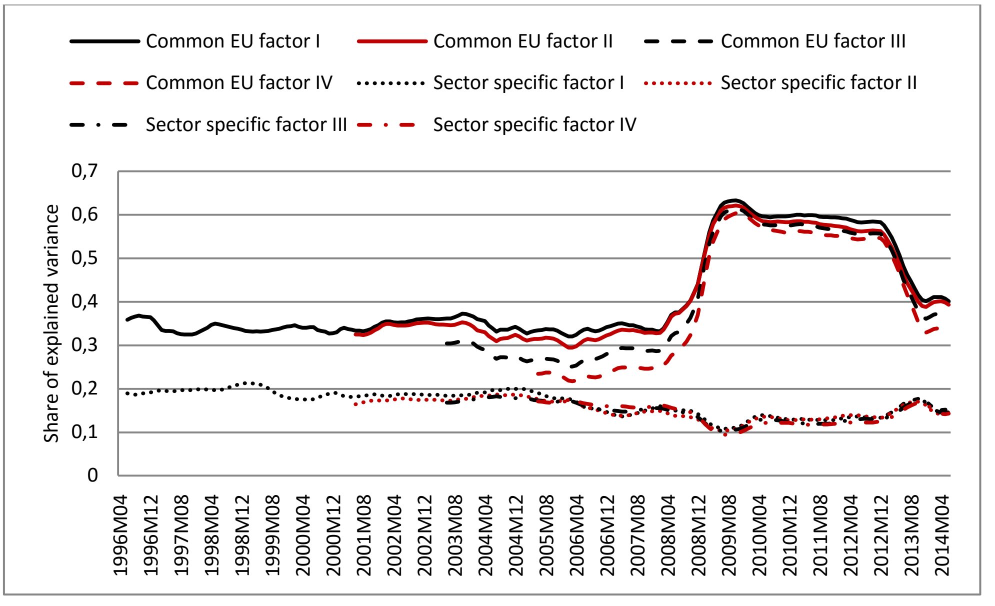


Figure B14. Proportion of variance of output growth in manufacturing explained by country specific factors for 4 groups of EU countries, y-o-y series used. T=50.

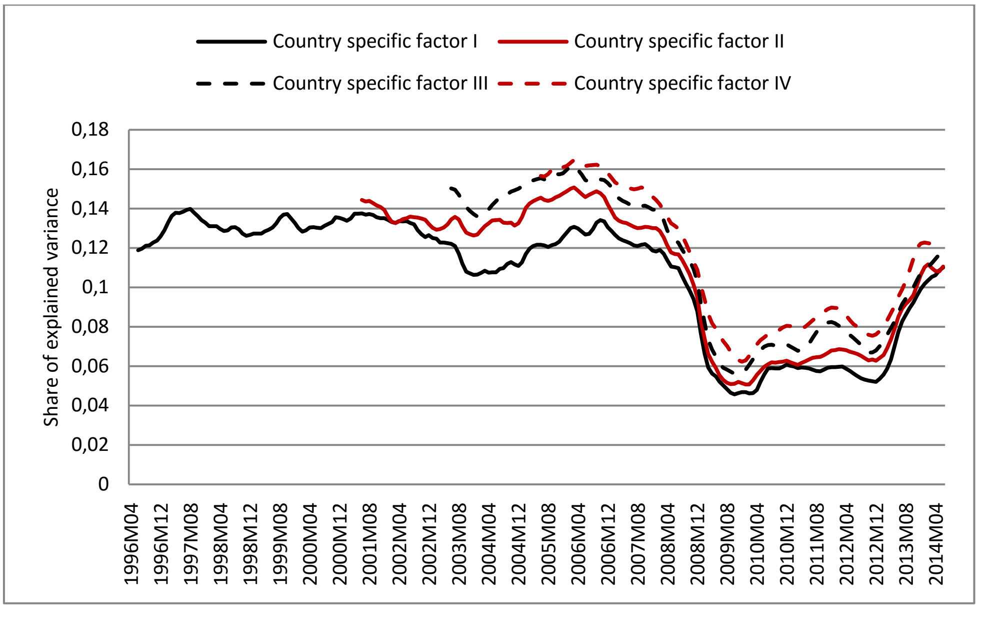


Table B22. Share of variance of output growth in manufacturing explained by the common EU factor, EU sector and country specific factors for EA, NMS and OMS. Annual averages.

	Common EU factor			EU sector specific factors			Country specific factors		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
2005	0.30	0.15	0.28	0.14	0.20	0.14	0.15	0.17	0.17
2006	0.30	0.13	0.28	0.13	0.22	0.12	0.15	0.17	0.17
2007	0.32	0.16	0.28	0.12	0.21	0.12	0.13	0.16	0.17
2008	0.36	0.23	0.33	0.12	0.19	0.11	0.12	0.13	0.14
2009	0.58	0.56	0.56	0.10	0.11	0.09	0.07	0.08	0.07
2010	0.57	0.57	0.55	0.13	0.12	0.11	0.07	0.08	0.08
2011	0.56	0.56	0.54	0.12	0.12	0.10	0.08	0.09	0.10
2012	0.54	0.56	0.52	0.13	0.12	0.12	0.08	0.08	0.08
2013	0.43	0.40	0.40	0.15	0.17	0.14	0.11	0.10	0.09
2014	0.39	0.29	0.31	0.14	0.15	0.13	0.11	0.13	0.13

Figure B15. Combined effects of common EU and sector specific factors on selected groups of countries. Annual averages of share of explained variance.

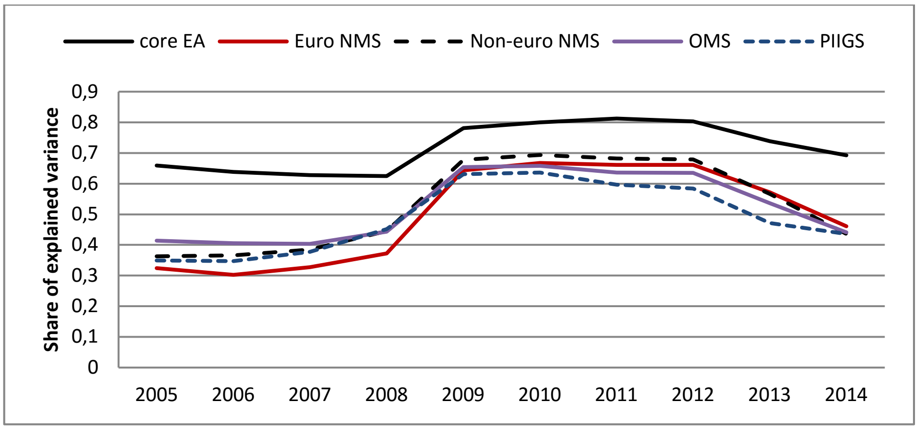


Table B23. Variance of output growth in manufacturing explained by factors for EU countries by subsectors. Share of total variance. Annual average for year 2014.

	Common EA factor	Sector specific factor	EA factors	Country specific factor	Unexplained variance
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.20	0.26	0.46	0.14	0.40
Textile	0.32	0.14	0.47	0.13	0.41
Leather	0.31	0.18	0.48	0.09	0.43
Wood	0.38	0.11	0.49	0.14	0.37
Paper and printing	0.39	0.12	0.50	0.13	0.37
Coke	0.09	0.15	0.24	0.07	0.69
Chemicals and pharmaceuticals	0.26	0.12	0.38	0.13	0.49
Rubber and plastic	0.48	0.10	0.58	0.17	0.25
Other non-metallic	0.36	0.18	0.54	0.13	0.33
Metals	0.53	0.09	0.62	0.12	0.26
Electronic	0.35	0.14	0.49	0.12	0.40
Machinery	0.36	0.14	0.50	0.11	0.40
Transport	0.35	0.13	0.48	0.08	0.44
Furniture	0.26	0.16	0.41	0.13	0.46

B.9 Results for Slovenia

Table B24. Proportion of variance of output growth explained by EU factors for manufacturing subsectors in Slovenia. T=50.

	2004	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Food	0.56	0.46	0.31	0.26	0.36	0.44	0.54	0.63	0.58	0.59	0.60
Textile	0.54	0.48	0.37	0.21	0.21	0.29	0.32	0.32	0.29	0.20	0.27
Leather	0.31	0.34	0.52	0.50	0.45	0.40	0.36	0.22	0.15	0.13	0.09
Wood	0.31	0.36	0.37	0.60	0.64	0.58	0.47	0.42	0.30	0.29	0.41
Paper and printing	0.30	0.31	0.24	0.42	0.62	0.63	0.55	0.55	0.45	0.46	0.46
Chemicals and pharmaceuticals	0.16	0.07	0.05	0.21	0.37	0.40	0.42	0.45	0.41	0.44	0.45
Rubber and plastic	0.35	0.35	0.43	0.47	0.65	0.73	0.68	0.55	0.36	0.25	0.30
Other non-metallic	0.47	0.50	0.42	0.44	0.63	0.64	0.75	0.63	0.48	0.37	0.33
Metals	0.54	0.47	0.47	0.42	0.34	0.36	0.36	0.30	0.39	0.45	0.35
Electronic	0.27	0.33	0.45	0.41	0.49	0.48	0.42	0.49	0.24	0.44	0.40
Machinery	0.32	0.44	0.35	0.29	0.29	0.33	0.35	0.38	0.49	0.68	0.68
Transport	0.28	0.34	0.47	0.54	0.58	0.35	0.16	0.21	0.17	0.42	0.46
Furniture	0.30	0.23	0.30	0.34	0.40	0.55	0.59	0.55	0.43	0.42	0.46

Table B25. Proportion of variance of output growth explained by EA factors for manufacturing subsectors in Slovenia. T=50.

Subsector	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Food	0.44	0.44	0.43	0.34	0.22	0.20	0.35	0.44	0.55	0.62	0.55	0.55	0.54
Textile	0.18	0.25	0.43	0.31	0.21	0.13	0.17	0.33	0.36	0.34	0.27	0.20	0.25
Leather	0.21	0.24	0.30	0.24	0.29	0.30	0.35	0.33	0.25	0.14	0.08	0.15	0.17
Wood	0.33	0.33	0.22	0.26	0.29	0.42	0.60	0.56	0.47	0.42	0.29	0.25	0.34
Paper and printing	0.39	0.35	0.24	0.21	0.20	0.39	0.64	0.61	0.51	0.50	0.36	0.36	0.33
Chemicals and pharmaceuticals	0.23	0.18	0.08	0.04	0.02	0.04	0.09	0.25	0.28	0.38	0.33	0.29	0.25
Rubber and plastic	0.31	0.33	0.35	0.33	0.40	0.42	0.60	0.69	0.67	0.52	0.31	0.19	0.22
Other non-metallic	0.19	0.23	0.25	0.32	0.43	0.47	0.65	0.67	0.61	0.49	0.33	0.25	0.24
Metals	0.52	0.62	0.53	0.45	0.40	0.31	0.22	0.35	0.38	0.36	0.40	0.39	0.29
Electronic	0.24	0.24	0.17	0.21	0.20	0.19	0.45	0.40	0.35	0.39	0.23	0.33	0.41
Machinery	0.30	0.36	0.30	0.39	0.29	0.20	0.26	0.24	0.27	0.31	0.41	0.61	0.60
Transport	0.23	0.23	0.23	0.16	0.15	0.15	0.22	0.14	0.15	0.20	0.17	0.36	0.39
Furniture	0.31	0.34	0.27	0.22	0.28	0.29	0.36	0.53	0.54	0.44	0.28	0.31	0.31

Table B26. Proportion of variance of output growth explained by EA sector specific factors for manufacturing subsectors in Slovenia. T=50.

	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Food	0.01	0.02	0.07	0.12	0.08	0.04	0.03	0.05	0.12	0.16	0.24	0.19	0.13
Textile	0.00	0.00	0.01	0.02	0.00	0.00	0.02	0.05	0.07	0.03	0.01	0.00	0.00
Leather	0.00	0.01	0.04	0.02	0.03	0.04	0.08	0.11	0.06	0.01	0.00	0.05	0.10
Wood	0.00	0.02	0.02	0.06	0.08	0.07	0.01	0.01	0.02	0.03	0.03	0.00	0.00
Paper and printing	0.03	0.00	0.02	0.01	0.02	0.06	0.04	0.02	0.01	0.03	0.07	0.05	0.01
Chemicals and pharmaceuticals	0.00	0.01	0.01	0.01	0.01	0.03	0.04	0.13	0.14	0.19	0.15	0.07	0.05
Rubber and plastic	0.07	0.03	0.03	0.02	0.00	0.00	0.02	0.19	0.21	0.22	0.18	0.02	0.02
Other non-metallic	0.00	0.01	0.02	0.03	0.05	0.04	0.04	0.09	0.11	0.10	0.11	0.07	0.03
Metals	0.03	0.00	0.02	0.02	0.04	0.03	0.03	0.12	0.12	0.10	0.02	0.00	0.00
Electronic	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.02	0.02	0.02	0.01	0.02	0.03
Machinery	0.07	0.06	0.05	0.03	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Transport	0.06	0.01	0.04	0.11	0.15	0.15	0.18	0.05	0.02	0.02	0.05	0.11	0.05
Furniture	0.02	0.01	0.00	0.02	0.04	0.04	0.00	0.00	0.01	0.00	0.00	0.00	0.00

Table B27. Proportion of variance of output growth explained by EA factors (EA10 sample) for manufacturing subsectors in Slovenia. T=50.

	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Food	0.44	0.43	0.46	0.38	0.24	0.21	0.34	0.44	0.55	0.62	0.57	0.56	0.55
Textile	0.16	0.25	0.45	0.37	0.30	0.24	0.24	0.33	0.34	0.31	0.24	0.19	0.27
Leather	0.20	0.23	0.26	0.25	0.27	0.27	0.32	0.28	0.31	0.20	0.11	0.11	0.08
Wood	0.32	0.34	0.21	0.24	0.26	0.37	0.60	0.56	0.47	0.41	0.29	0.25	0.35
Paper	0.37	0.34	0.22	0.20	0.21	0.36	0.63	0.62	0.53	0.50	0.36	0.40	0.37
Chemicals and pharmaceuticals	0.26	0.16	0.12	0.09	0.06	0.09	0.13	0.32	0.36	0.37	0.34	0.27	0.23
Rubber and plastic	0.28	0.31	0.33	0.31	0.39	0.42	0.59	0.64	0.60	0.51	0.35	0.20	0.23
Other non-metallic	0.18	0.22	0.27	0.36	0.39	0.44	0.64	0.66	0.62	0.49	0.35	0.27	0.24
Metals	0.51	0.63	0.51	0.43	0.36	0.28	0.20	0.24	0.26	0.29	0.38	0.38	0.28
Electronic	0.27	0.25	0.20	0.28	0.24	0.25	0.47	0.41	0.36	0.40	0.25	0.38	0.42
Machinery	0.26	0.33	0.27	0.40	0.30	0.21	0.26	0.28	0.29	0.33	0.42	0.60	0.58
Transport	0.28	0.24	0.26	0.17	0.11	0.16	0.25	0.26	0.22	0.24	0.17	0.33	0.36
Furniture	0.30	0.36	0.30	0.23	0.27	0.28	0.37	0.54	0.56	0.47	0.30	0.32	0.32

Table B28. Proportion of variance of output growth explained by EA factors for manufacturing subsectors (23 subsectors disaggregation) in Slovenia. T=50.

	2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Food	0.46	0.44	0.43	0.34	0.24	0.25	0.36	0.48	0.60	0.65	0.63	0.66	0.65
Beverages	0.50	0.47	0.36	0.23	0.14	0.19	0.34	0.25	0.26	0.29	0.15	0.13	0.12
Textiles	0.29	0.34	0.46	0.45	0.37	0.22	0.28	0.26	0.25	0.29	0.17	0.21	0.24
Wearing apparel	0.11	0.12	0.28	0.21	0.11	0.06	0.04	0.15	0.16	0.16	0.18	0.06	0.04
Leather	0.19	0.23	0.28	0.23	0.29	0.28	0.30	0.26	0.26	0.14	0.09	0.16	0.16
Wood	0.32	0.32	0.21	0.26	0.28	0.41	0.60	0.56	0.47	0.41	0.29	0.24	0.32
Paper	0.11	0.21	0.16	0.12	0.15	0.20	0.27	0.23	0.26	0.28	0.19	0.15	0.13
Printing	0.32	0.23	0.13	0.12	0.09	0.23	0.51	0.51	0.41	0.42	0.38	0.36	0.40
Chemicals	0.25	0.18	0.08	0.05	0.09	0.19	0.42	0.52	0.42	0.44	0.35	0.26	0.34
Pharmaceuticals	0.23	0.21	0.09	0.03	0.02	0.02	0.09	0.13	0.13	0.24	0.19	0.17	0.16
Rubber and plastic	0.30	0.31	0.34	0.32	0.40	0.42	0.60	0.70	0.67	0.53	0.34	0.20	0.23
Other non-metallic	0.19	0.22	0.25	0.34	0.43	0.47	0.65	0.67	0.61	0.48	0.33	0.24	0.23
Metals	0.41	0.51	0.41	0.29	0.19	0.21	0.08	0.17	0.17	0.16	0.28	0.27	0.18
Fabricated metals	0.39	0.53	0.56	0.60	0.62	0.47	0.58	0.53	0.49	0.50	0.37	0.48	0.49
Electronic	0.09	0.04	0.01	0.03	0.16	0.25	0.52	0.36	0.32	0.42	0.17	0.27	0.31
Electrical eq	0.18	0.29	0.30	0.35	0.23	0.17	0.32	0.34	0.33	0.33	0.12	0.21	0.36
Machinery	0.29	0.36	0.31	0.43	0.30	0.21	0.26	0.26	0.28	0.32	0.41	0.62	0.60
Transport	0.53	0.37	0.22	0.05	0.02	0.01	0.04	0.19	0.26	0.31	0.18	0.28	0.31
Other transport	0.04	0.05	0.04	0.08	0.05	0.09	0.07	0.05	0.05	0.06	0.05	0.04	0.03
Furniture	0.31	0.39	0.37	0.25	0.26	0.30	0.38	0.54	0.44	0.36	0.23	0.23	0.21
Other	0.28	0.21	0.18	0.13	0.12	0.07	0.09	0.11	0.13	0.21	0.21	0.30	0.26
Repair	0.23	0.26	0.23	0.32	0.26	0.24	0.33	0.28	0.29	0.26	0.18	0.16	0.15

Table B29. Proportion of variance of output growth in manufacturing explained by EU factors for subsectors in Slovenia. T=174. EU24 sample.

	Common EU factor	**Sector specific factor**	**EU factors**	**Country specific factor**	**Country-sector specific effects**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.37	0.13	0.50	0.01	0.49
Textile	0.25	0.00	0.25	0.14	0.61
Leather	0.20	0.03	0.23	0.00	0.77
Wood	0.38	0.06	0.45	0.01	0.54
Paper and printing	0.39	0.05	0.45	0.10	0.45
Chemicals and pharmaceuticals	0.11	0.18	0.29	0.08	0.63
Rubber and plastic	0.36	0.07	0.43	0.18	0.39
Other non-metallic	0.40	0.07	0.48	0.02	0.50
Metals	0.34	0.00	0.35	0.14	0.52
Electronic	0.29	0.05	0.35	0.24	0.42
Machinery	0.35	0.03	0.38	0.24	0.39
Transport	0.13	0.30	0.43	0.12	0.45
Furniture	0.35	0.02	0.37	0.15	0.48

Appendix C: Results of additional analyses of producer price inflation heterogeneity

C.1 Results for EA factors. T=221.

Table C1. Variance of producer price inflation in manufacturing explained by factors, depending on the number of factors used in the setup. 1995M1-2014M5. T=221.

	1	**2**	**3**
Common EA factors	0.37	0.08	0.07
Sector specific factors*	0.27	0.11	0.08
Country specific factors**	0.12	0.06	0.05

*Using setup with one common EA factor.

**Using setup with one common and one sector specific factor for each sector.

Figure C1. Factor loadings of common EA factors on the EA producer price inflation in manufacturing series. 1995M1-2014M5. T=221.

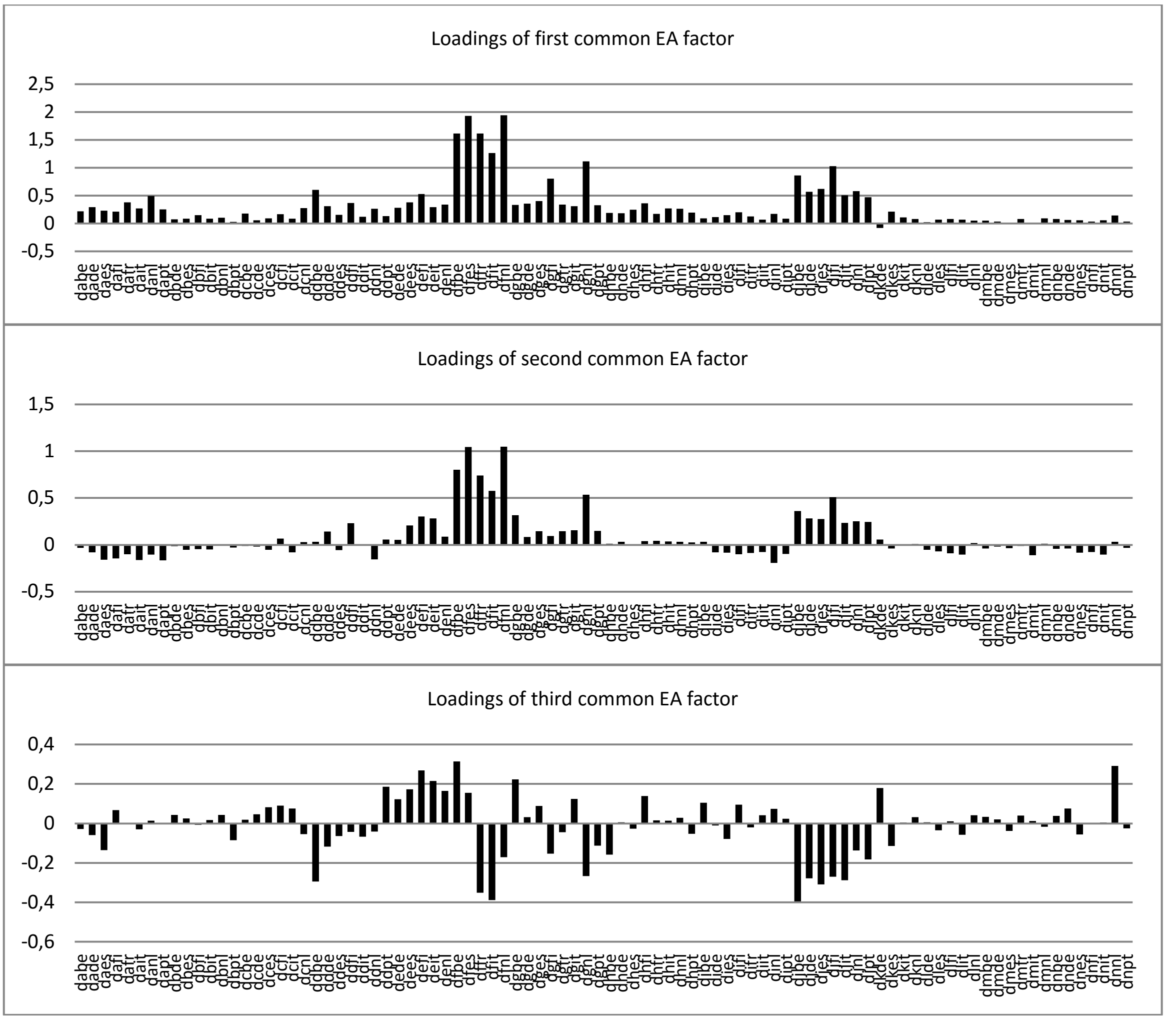


Figure C2. Loadings of EA sector specific factors on the EA producer price inflation series, 1995M1-2014M5. T=221, N_{max}=8. 14 factors for 14 manufacturing subsectors represented in one figure, first two letters of series stand for a subsector, last two for a country.

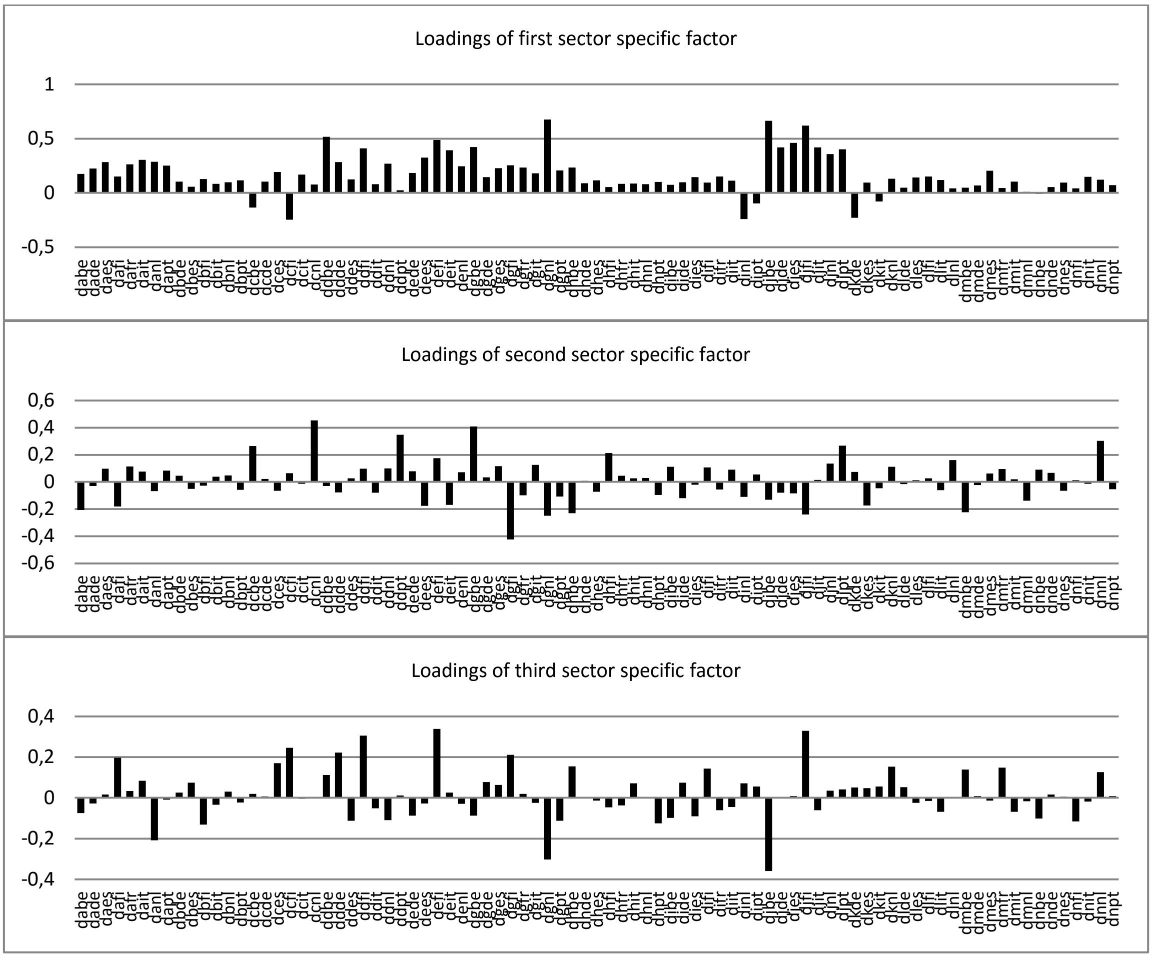


Table C2. Number of EA sector specific factors for producer price inflation, according to Bai and Ng (2002) criteria (ICp1, ICp2); 1995M1-2014M5. T=221.

	IC_{p2}	IC_{p1}	N
Food	1	3	8
Textile	1	3	7
Leather	3	3	5
Wood	1	3	7
Paper	3	3	5
Coke	3	3	7
Chemicals and pharmaceuticals	2	3	8
Rubber and plastic	1	3	8
Other non-metallic	1	3	8
Metals	3	3	7
Electronic	1	3	4
Machinery	1	2	5
Transport	1	3	6
Furniture	2	3	7

*Setup with one common EA factor.

Table C3. Number of EA country specific factors for producer price inflation, according to Bai and Ng (2002) criteria (ICp1, ICp2); 1995M1-2014M5. T=221.

	IC_{p2}	IC_{p1}	N
BE	1	3	13
DE	1	3	14
ES	1	1	14
FI	1	1	13
FR	1	2	14
IT	3	3	14
NL	1	3	14
PT	1	1	8

*Setup with one common and one sector specific factor for each subsector.

Table C4. Proportion of variance of producer price inflation in manufacturing explained by factors for EA countries. 1995M1-2014M5. T=221.

	Common EA	Sector specific	EA factors	Country specific	Country-sector specific component
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
BE	0.24	0.22	0.46	0.11	0.43
DE	0.39	0.35	0.74	0.08	0.18
EL	0.12	0.11	0.22	0.33	0.44
ES	0.36	0.34	0.70	0.06	0.23
FI	0.33	0.18	0.52	0.08	0.41
FR	0.43	0.30	0.73	0.10	0.16
IT	0.34	0.38	0.73	0.06	0.21
NL	0.39	0.24	0.63	0.12	0.25
PT	0.29	0.26	0.56	0.13	0.31

Table C5. Proportion of variance of producer price inflation explained by factors for 14 manufacturing subsectors. 1995M1-2014M5. T=221.

	Common EA	Sector specific	EA factors	Contry specific	Country-sector specific component
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.35	0.29	0.65	0.08	0.27
Textile	0.22	0.21	0.43	0.22	0.35
Leather	0.15	0.30	0.45	0.12	0.43
Wood	0.26	0.26	0.52	0.16	0.31
Paper and printing	0.43	0.32	0.76	0.05	0.19
Coke, refined fuel	0.29	0.63	0.92	0.02	0.05
Chemicals and pharmaceuticals	0.48	0.16	0.64	0.12	0.24
Rubber and plastic	0.53	0.11	0.64	0.16	0.21
Other non-metallic	0.22	0.29	0.51	0.19	0.30
Metals	0.53	0.29	0.82	0.06	0.12
Electronic	0.19	0.15	0.34	0.13	0.53
Machinery	0.11	0.30	0.41	0.31	0.27
Transport	0.12	0.17	0.29	0.21	0.50
Furniture	0.11	0.26	0.37	0.19	0.45

C.2 Results for EA factors. 2 common EA factors. T=50

Table C6. Proportion of variance of producer price inflation in manufacturing explained by EA factors for EU countries. Average 2014. T=50.

	Common EA	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
AT	0.68	0.07	0.75	0.06	0.19
BE	0.60	0.15	0.75	0.04	0.21
DE	0.80	0.13	0.93	0.04	0.04
EL	0.64	0.12	0.76	0.11	0.12
ES	0.78	0.16	0.94	0.01	0.05
FI	0.73	0.06	0.79	0.05	0.15
FR	0.69	0.13	0.83	0.02	0.15
IE	0.37	0.18	0.55	0.21	0.23
IT	0.77	0.11	0.88	0.04	0.08
NL	0.65	0.17	0.83	0.10	0.07
PT	0.57	0.21	0.78	0.07	0.15
BG	0.69	0.10	0.78	0.05	0.16
CZ	0.52	0.14	0.66	0.22	0.12
HU	0.31	0.13	0.44	0.47	0.09
LT	0.52	0.11	0.64	0.08	0.28
PL	0.70	0.06	0.77	0.15	0.08
RO	0.63	0.12	0.76	0.13	0.11
SI	0.58	0.11	0.69	0.10	0.21
SK	0.66	0.10	0.76	0.11	0.14
DK	0.51	0.11	0.62	0.10	0.28
SE	0.46	0.14	0.60	0.24	0.16
UK	0.49	0.09	0.57	0.23	0.20

Table C7. Proportion of variance of producer price inflation in manufacturing explained by EA factors for groups of countries in time. Annual averages. T=50.

	Common EA factors			**Sector specific factors**			**Country specific factors**		
	EA	NMS	OMS	EA	NMS	OMS	EA	NMS	OMS
2001	0.64			0.15			0.07		
2002	0.66			0.14			0.07		
2003	0.68			0.11			0.07		
2004	0.63			0.14			0.06		
2005	0.55	0.45	0.46	0.19	0.15	0.13	0.08	0.20	0.15
2006	0.54	0.44	0.50	0.19	0.15	0.12	0.07	0.21	0.15
2007	0.56	0.44	0.50	0.19	0.16	0.14	0.07	0.20	0.15
2008	0.50	0.46	0.48	0.22	0.15	0.14	0.10	0.20	0.17
2009	0.55	0.46	0.55	0.21	0.17	0.13	0.08	0.20	0.16
2010	0.65	0.51	0.55	0.17	0.16	0.17	0.05	0.20	0.15
2011	0.69	0.52	0.52	0.16	0.15	0.18	0.04	0.20	0.17
2012	0.71	0.58	0.59	0.13	0.12	0.14	0.05	0.17	0.14
2013	0.71	0.61	0.51	0.13	0.10	0.12	0.05	0.16	0.18
2014	0.70	0.57	0.49	0.13	0.11	0.11	0.05	0.17	0.19

Table C8. Proportion of variance of producer price inflation explained by EA factors for manufacturing subsectors, for EU sample. 2014, annual averages. T=50.

	Common EA	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.66	0.20	0.86	0.05	0.09
Textile	0.58	0.13	0.71	0.13	0.16
Leather	0.44	0.11	0.55	0.15	0.30
Wood	0.62	0.13	0.75	0.12	0.14
Paper and printing	0.64	0.16	0.80	0.10	0.10
Coke, refined fuel	0.72	0.22	0.94	0.03	0.04
Chemicals and pharmaceuticals	0.72	0.06	0.78	0.08	0.13
Rubber and plastic	0.73	0.04	0.78	0.12	0.10
Other non-metallic	0.66	0.06	0.72	0.13	0.15
Metals	0.86	0.02	0.88	0.05	0.07
Electronic	0.47	0.20	0.66	0.14	0.20
Machinery	0.49	0.15	0.63	0.20	0.17
Transport	0.45	0.14	0.59	0.20	0.21
Furniture	0.51	0.15	0.66	0.15	0.19

C.3 Results for EU factors. 2 common factors. T=161

Figure C3. Loadings of EU common factors on EU series of producer price inflation in manufacturing. T=161.

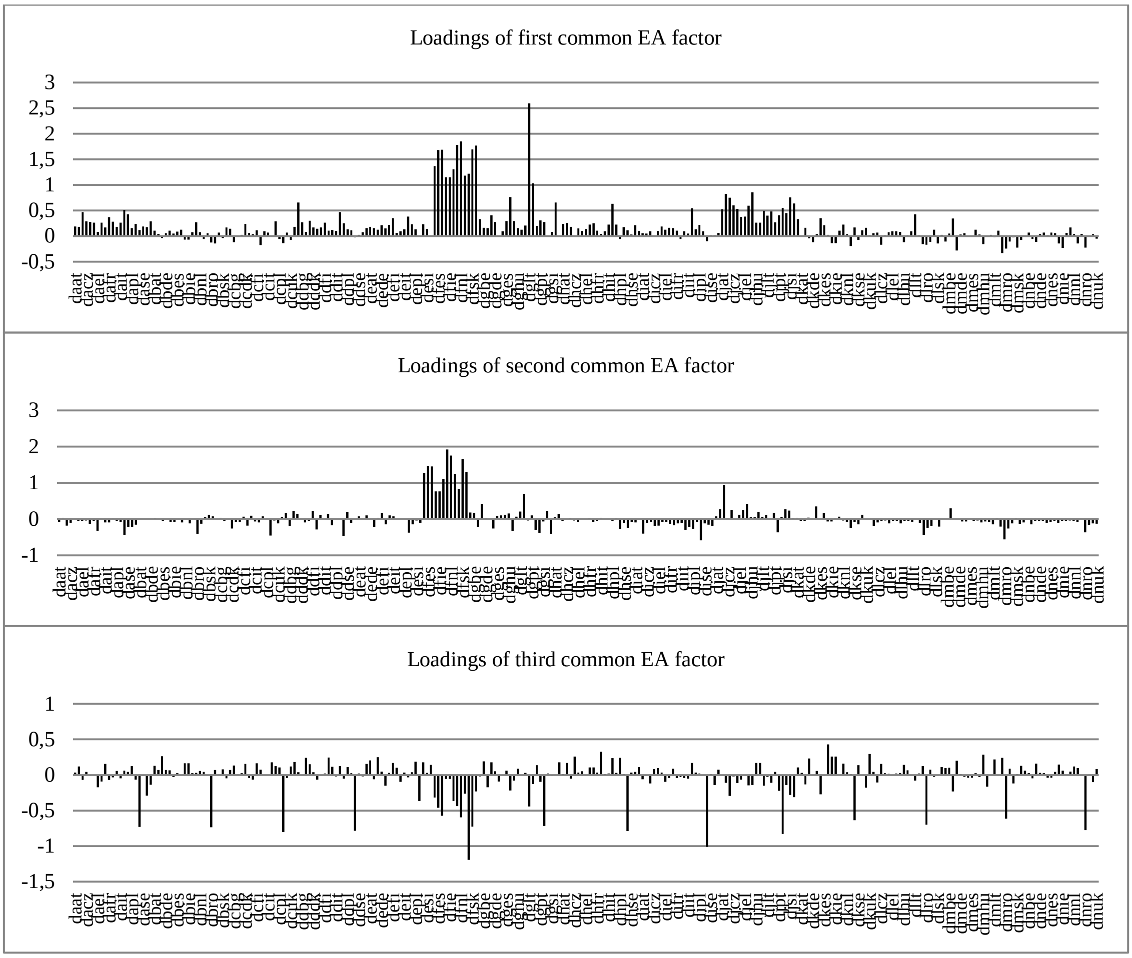
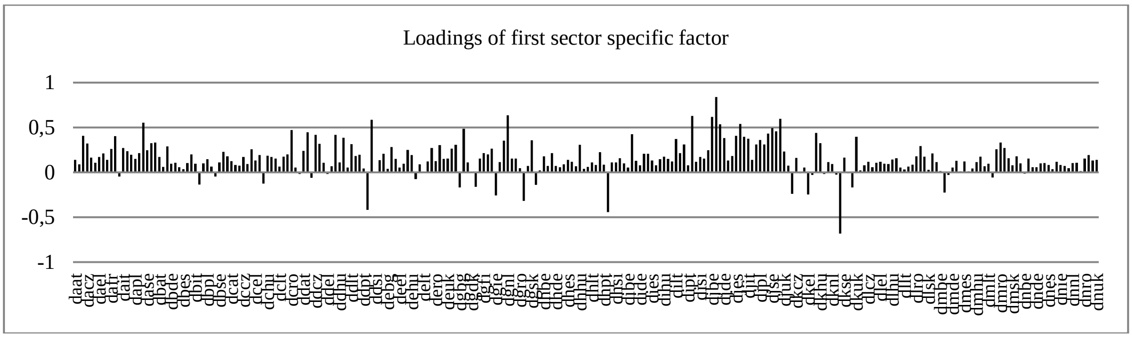


Figure C4. Loadings of EU sector specific factors on EU series of producer price inflation in manufacturing. T=161.



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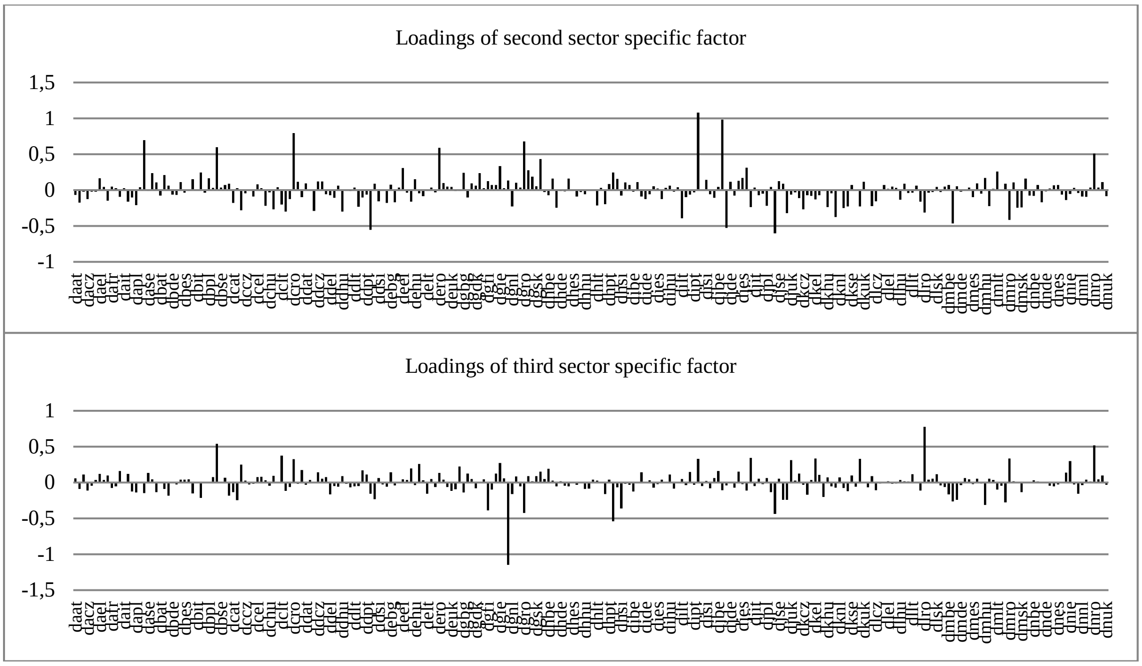


Table C9. Proportion of variance of producer price inflation in manufacturing explained by EU factors for EU countries. T=161.

	Common EU	**Sector specific**	**EU factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
AT	0.41	0.21	0.62	0.12	0.27
BE	0.30	0.18	0.48	0.12	0.40
DE	0.50	0.25	0.75	0.09	0.17
EL	0.39	0.11	0.50	0.13	0.38
ES	0.53	0.20	0.73	0.07	0.20
FI	0.43	0.21	0.65	0.09	0.26
FR	0.57	0.18	0.75	0.04	0.21
IE	0.18	0.18	0.35	0.19	0.46
IT	0.57	0.18	0.75	0.06	0.19
NL	0.49	0.20	0.68	0.14	0.17
PT	0.46	0.15	0.61	0.10	0.29
BG	0.32	0.09	0.40	0.14	0.46
CZ	0.22	0.29	0.52	0.32	0.17
HU	0.25	0.22	0.46	0.37	0.17
LT	0.46	0.09	0.55	0.10	0.35
PL	0.25	0.20	0.46	0.33	0.22
RO	0.22	0.22	0.44	0.45	0.11
SI	0.33	0.21	0.53	0.13	0.34
SK	0.37	0.21	0.58	0.09	0.33
DK	0.34	0.13	0.47	0.09	0.44
SE	0.38	0.20	0.58	0.20	0.22
UK	0.30	0.22	0.51	0.28	0.21

Table C10. Proportion of variance of producer price inflation explained by EU factors for manufacturing subsectors, for EU sample. T=161.

	Common EA	**Sector specific**	**EA factors**	**Country specific**	**Country-sector specific component**
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=1-(3)-(4)
Food	0.46	0.23	0.69	0.12	0.20
Textile	0.21	0.26	0.47	0.21	0.32
Leather	0.14	0.20	0.34	0.20	0.46
Wood	0.36	0.24	0.60	0.15	0.25
Paper and printing	0.38	0.21	0.60	0.16	0.24
Coke, refined fuel	0.63	0.28	0.91	0.04	0.05
Chemicals and pharmaceuticals	0.48	0.12	0.59	0.17	0.24
Rubber and plastic	0.44	0.15	0.59	0.18	0.23
Other non-metallic	0.49	0.12	0.61	0.13	0.25
Metals	0.54	0.22	0.76	0.12	0.12
Electronic	0.19	0.20	0.39	0.21	0.39
Machinery	0.38	0.14	0.52	0.23	0.25
Transport	0.25	0.16	0.40	0.22	0.38
Furniture	0.32	0.15	0.47	0.18	0.35

C.4 EA factors' importance for groups of countries

Table C11. Proportion of explained variance of producer price inflation in manufacturing by the EA factors.

	Core EA	**Periphery EA**	**NMS 2004**	**NMS 2007**	**OMS**
2005	0.66	0.62	0.42	0.39	0.46
2006	0.65	0.64	0.40	0.46	0.48
2007	0.68	0.64	0.45	0.55	0.53
2008	0.63	0.58	0.46	0.48	0.46
2009	0.63	0.63	0.47	0.48	0.50
2010	0.71	0.70	0.53	0.52	0.52
2011	0.73	0.70	0.53	0.53	0.50
2012	0.76	0.69	0.56	0.58	0.52
2013	0.75	0.68	0.55	0.59	0.52
2014	0.73	0.68	0.50	0.60	0.52

C.5 Price heterogeneity of the broader sectors

Table C12. Proportion of variance of the wage growth explained by factors for the broad sectors for two distinct periods, by country and groups of countries.

	Common EA factor	EA factors	Country specific factor	Common EA factor	EA factors	Country specific factor
		2000-2007			2008-2014	
EA	*0.10*	*0.28*	*0.49*	*0.09*	*0.27*	*0.49*
core	*0.16*	*0.39*	*0.59*	*0.11*	*0.33*	*0.50*
AT	0.07	0.36	0.52	0.04	0.29	0.46
DE	0.47	0.59	0.72	0.24	0.41	0.55
FR	0.04	0.20	0.54	0.11	0.30	0.48
NL	0.06	0.40	0.58	0.07	0.32	0.51
FI	0.07	0.30	0.43	0.13	0.37	0.54
periphery	*0.06*	*0.19*	*0.42*	*0.07*	*0.20*	*0.46*
ES	0.07	0.33	0.53	0.03	0.24	0.51
IT	0.09	0.32	0.48	0.17	0.52	0.60
PT	0.03	0.12	0.49	0.03	0.06	0.48
EL	0.07	0.11	0.36	0.02	0.07	0.39
IE	0.03	0.06	0.26	0.08	0.11	0.32
NMS	*0.04*	*0.09*	*0.42*	*0.07*	*0.11*	*0.46*
NMS 2004	*0.04*	*0.09*	*0.43*	*0.06*	*0.10*	*0.47*
CZ	0.04	0.08	0.56	0.06	0.09	0.71
SK	0.09	0.12	0.41	0.10	0.17	0.46
HU	0.03	0.11	0.48	0.04	0.06	0.59
LV	0.01	0.09	0.41	0.10	0.15	0.40
EE	0.03	0.08	0.31	0.04	0.05	0.25
SI	0.03	0.08	0.40	0.03	0.09	0.41
NMS 2007	*0.05*	*0.12*	*0.36*	*0.13*	*0.18*	*0.42*
BG	0.05	0.12	0.36	0.13	0.18	0.42
OMS	*0.02*	*0.08*	*0.61*	*0.01*	*0.08*	*0.74*
SE	0.02	0.06	0.63	0.00	0.06	0.86
UK	0.02	0.10	0.59	0.02	0.10	0.64

C.6 FAVAR impulse responses

Figure C5. Impulse response functions to a common euro area price shock in manufacturing for the period 2000 – 2007.

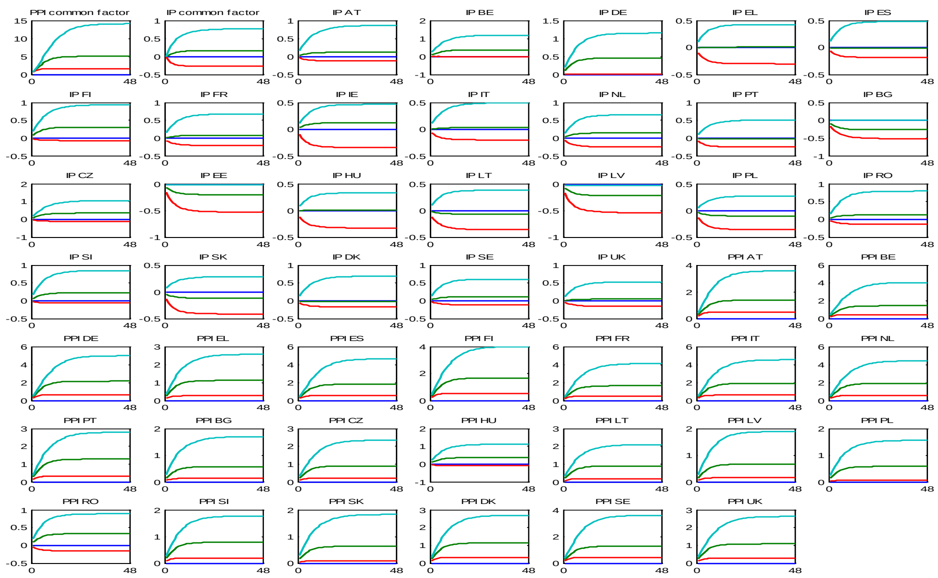


Figure C6. Impulse response functions to a common euro area price shock in manufacturing for the period 2008 – 2014.

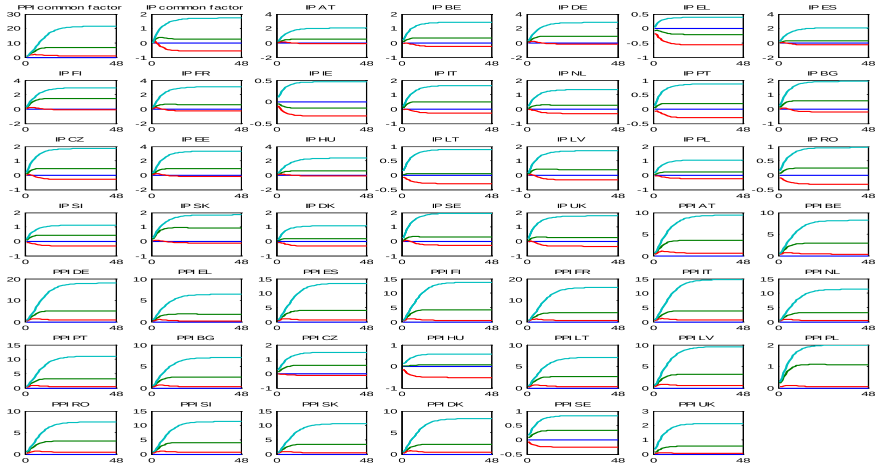


Figure C7. Impulse response functions to a common euro area industrial production shock in manufacturing for the period 2000 – 2007.

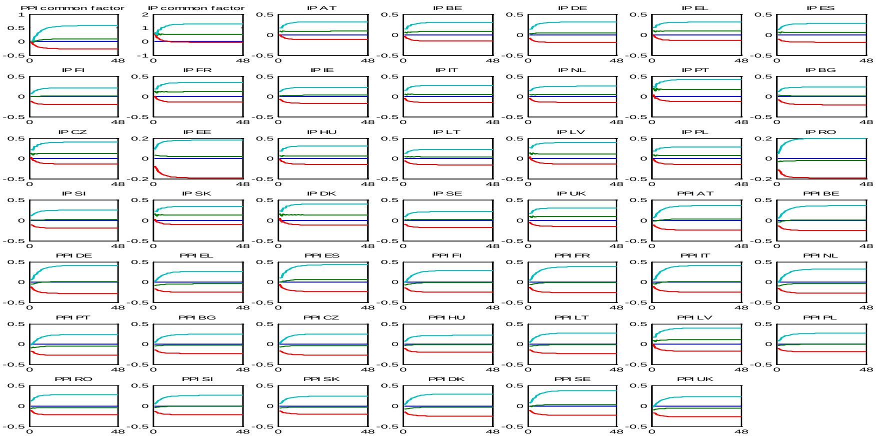
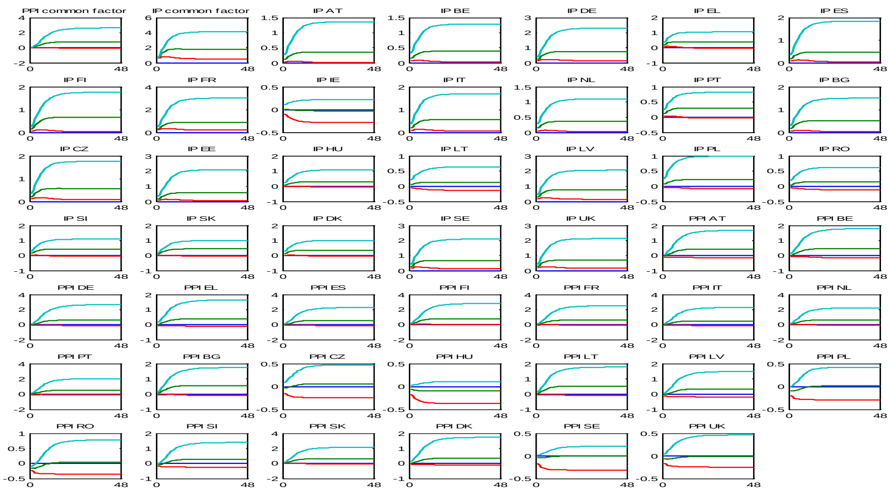


Figure C8. Impulse response functions to a common euro area industrial production shock in manufacturing for the period 2008 – 2014.



Appendix D: SUMMARY IN SLOVENIAN LANGUAGE (DALJŠI POVZETEK V SLOVENSKEM JEZIKU)

Analiza heterogenosti gospodarstev v EMU z dinamičnim faktorskim modelom

Namen raziskave je dodatno osvetliti trenutno situacijo in preteklo dogajanje na področju heterogenosti gospodarstev v evrskem območju, in sicer z uporabo metodologije faktorskih modelov. Heterogenost v strukturi gospodarstev držav članic lahko pripelje do razmer, v katerih imajo skupne politike v nasprotju s pričakovanji destabilizacijske učinke na gospodarstva posameznih držav članic. V zadnjem času je ta problem še posebej pomemben, saj sta finančna kriza v letu 2008 in dolžniška kriza v letu 2011 razkrili velike asimetrije med gospodarstvi evrskega območja. Pokazalo se je, da se uveljavljeni mehanizmi evrskega območja s tovrstnimi asimetrijami ne morejo spopadati.

Uvedba evra v 1999 je povzročila tok kapitala iz centralnih v periferne države evrskega območja, kar je privedlo do višje rasti cen in rasti BDP v državah kot sta Španija in Portugalska. Evropska centralna banka (ECB) se na zvišanje inflacije v posameznih državah ni odzvala, saj je njena glavna naloga vzdrževanje ciljne inflacije za evrsko območje kot celoto. Odziv na razlike v inflaciji je bil deljen. Medtem ko so nekateri ekonomisti opozarjali na vztrajnost razlik in s tem povečevanja asimetrij v evrskem območju, je bilo na drugi strani mnenje, da so razlike v inflaciji le posledica konvergenčnega procesa znotraj evrskega območja. Finančna kriza v 2008 je prekinila te toke kapitala in periferne države so se znašle v položaju s previsokimi relativnimi cenami in stroški dela na enoto proizvoda. S temi asimetrijami v evskem območju se obstoječi sistemi Evrosistema niso dovolj uspešno spopadli. Ker mobilnost dela v Evropi ni na dovolj visoki stopnji, je fleksibilnost plač edini način, da se kratkoročno izboljša relativno konkurenčnost držav. V razmerah nizke inflacije pa to predstavlja deflacijske pritiske, ki vodijo v recesijo. Države so bile namreč omejene pri uporabi fiskalnih ukrepov, saj so hkrati reševale tudi bančne sisteme. Vse to je privedlo do izbruha dolžniške krize v evro območju.

V državah na robu evrskega območja je ena izmed večjih ovir pri spopadanju s krizo skupna valuta. Asimetrije v stroških dela na enoto proizvoda bi bilo tem državam namreč lažje odpraviti z devalvacijo lastne valute. Krugman (2013) tako v svojem delu Maščevanje optimalnega denarnega območja (angl. *The Revenge of the Optimum Currency Area*) sedanjo situacijo v evrskem območju pripisuje prav pomanjkanju primernega mehanizma za prilagajanje.

Teorija optimalnega valutnega območja (angl. *Optimum Currency Area*, OCA) poudarja pomen asimetričnih šokov in mehanizmov za njihovo preprečevanje ali premostitev. Eden najpomembnejših kriterijev v teoriji OCA je usklajenost poslovnih ciklov med sodelujočimi državami. Poseben problem v tem kontekstu je tudi endogenost OCA

kriterija, ki sta ga prva predstavila Frankel in Rose (1998, 2000). Vendar konsenza o tem, ali naj bi nastanek EMU dejansko doprinesel k višji stopnji usklajenosti poslovnih ciklov v evrskem območju, ni.
Teoriji endogenosti namreč nasprotuje teorija specializacije (Krugman, 1993), ki predvideva znižanje stopnje usklajenosti poslovnih ciklov kot posledico uvedbe monetarne unije.

Eno osnovnih neravnovesij v evrskem območju predstavlja povečana divergenca konkurenčnih pozicij držav v evrskem območju (De Grauwe, 2011). Zato se med potrebnimi ukrepi za izhod iz krize in ponovno vzpostavitev rasti v gospodarstvih evrskega območja pogosto omenja tudi zvišanje inflacije, ki je daleč pod ciljno inflacijo ECB. Za vzpostavitev prostora za izboljšanje relativne konkurenčnosti v krizi najbolj prizadetih držav brez deflacijskih pritiskov, je namreč nujna višja inflacija v centralnih državah evrskega območja. Zato sem k problemu pristopil dodatno tudi z analizo proizvodnih cen v podsektorjih predelovalnih dejavnosti.

Opisane probleme v raziskavi rešujem z analizo heterogenosti sektorja predelovalnih dejavnosti v evrskem območju, saj strokovna literatura poudarja vzorec gospodarske aktivnosti na ravni industrijske proizvodnje kot ključno determinanto endogenega razvoja stopnje sinhronizacije poslovnih ciklov. Kot potrditev pravilnosti izbora razčlenjene analize pokažem, da varianca rasti industrijske proizvodnje in proizvodnih cen v sektorju predelovalnih dejavnosti med državami ne izhaja le iz različne sestave sektorja ter da heterogenost med državami in sektorji obstaja tudi na ravni posameznih predelovalnih dejavnosti.

Cilj raziskave je razčleniti rast industrijske proizvodnje in proizvodnih cen v posameznem oddelku predelovalnih dejavnosti in državi na (i) skupno komponento, značilno za evrsko območje, (ii) komponento, značilno za posamezen oddelek v področju predelovalnih dejavnosti – sektorsko komponento, (iii) komponento, značilno za državo, in (iv) idiosinkratično komponento, značilno za sektor in državo.

Metodologija

Eden izmed ciljev disertacije je predstaviti alternativno metodologijo za analizo razčlenjenih podatkov po državah in posameznih oddelkov predelovalnih dejavnosti. Osnovna znanstvena metoda, ki je uporabljena v raziskavi, je metoda z dinamičnimi faktorskimi modeli (DFM). DFM so se v zadnjem času uveljavili na področju makroekonomskih analiz in napovedovanja, uspešno pa so bili uporabljeni tudi v raziskavah usklajenosti poslovnih ciklov.

Glede na to, da je bil cilj raziskave razčlenitev variance (angl. *variance decomposition*) rasti industrijske proizvodnje in proizvodnih cen na simetrični in asimetrični del, smo uporabili pristop s hierarhičnim DFM, ki ga ponazarja spodnja enačba:

$$x_{ijt} = \lambda_{ij} f_t + \mu_{ij} g_{jt} + \eta_{ij} h_{it} + e_{ijt}.$$

V primeru analize usklajenosti poslovnih ciklov v predelovalnih dejavnosti enačba prikazuje razčlenitev rasti industrijske proizvodnje v posameznem oddelku predelovalnih dejavnosti za posamezno državo evrskega območja (leva stran enačbe), in sicer na: prispevke skupnega faktorja (f_t), sektorskega faktorja (g_{jt}), državnega faktorja (h_{it}) in idiosinkratično komponento, značilno za sektor in državo (e_{ijt}).

Hierarhični DFM modeli so relativna novost v literaturi o usklajenosti poslovnih ciklov. Ena prvih raziskav, ki uporablja tak pristop, je v Kose, Otrok in Whiteman (2003). Metodologija moje raziskave se razlikuje v tem, da v hierarhični DFM uvajam medsebojno prepletene sklope (angl. *overlapping blocks*). Sklop spremenljivk za določeno državo namreč vsebuje spremenljivke iz vseh sklopov, razporejenih po sektorjih, in nasprotno. Beck, Hubrich in Marcellino (2012) so predstavili podoben problem z medsebojno prepletenimi sklopi v hierarhičnem DFM v raziskavi cen življenjskih potrebščin na regionalni in sektorski ravni v evrskem območju.

Pristop k reševanju problema v moji raziskavi temelji na uporabi metode glavnih komponent za ocenjevanje faktorjev v zgornji enačbi (podrobnosti v Stock in Watson, 1998, 2002a, 2002b) in ocenjevanju faktorjev v posameznih korakih. V prvem koraku ocenim skupne faktorje, nato pa z regresijo še ostanke, ki predstavljajo zadnje tri člene v zgornji enačbi. V naslednjem koraku združim ostanke po sektorjih, ocenim sektorske faktorje in z regresijo ponovno ocenim ostanke, ki tokrat predstavljajo zadnja dva člena v enačbi. V zadnjem koraku združim ostanke po državah in ocenim državne faktorje. Z linearnimi regresijami z metodo navadnih najmanjših kvadratov (OLS) ocenim tudi faktorske uteži (angl. *factor loadings*) λ_{ij}, μ_{ij}, η_{ij}.

Ker so tako ocenjeni faktorji pravokotni (angl. *orthogonal*), je razčlenitev variance za posamezno spremenljivko naslednja:

$$var(x_{ijt}) = (\hat{\propto}_{ij})^2 var(\hat{f}_t) + (\hat{\mu}_{ij})^2 var(\hat{g}_{jt}) + (\hat{\eta}_{ij})^2 var(\hat{h}_{it}) + var(\widehat{e_{ijt}}).$$

Prva dva člena na desni strani enačbe definiram kot simetrični del. Predstavljata ga deleža variance, pojasnjena s skupnim in pripadajočim sektorskim faktorjem. Zadnja dva člena pa definiram kot asimetrični del in ga predstavljata delež pojasnjene variance s pripadajočim državnim faktorjem in nepojasnjena varianca, ki je značilna za sektor in državo. Relativna pomembnost simetričnega dela po moji definiciji torej določa stopnjo usklajenosti posameznega sektorja v dani državi z gibanji v evrskem območju.

Stopnjo usklajenosti poslovnih ciklov na agregatni ravni držav, sektorjev oz. evrskega območja predstavim kot povprečje simetrične pojasnjene variance po sektorjih, državah ali sektorjih in državah.

Glavni cilj raziskave je spremljanje sprememb usklajenosti poslovnih ciklov in proizvodnih cen v času. V ta namen ocenjujem razčlenitev variance z rekurzivno metodo z drsečim oknom stalne velikosti. V temeljnem izračunu uporabljam časovno okno velikosti štirih let, kar predstavlja približno polovico trajanja celotnega poslovnega cikla, ki naj bi bilo prevladujoče v državah evrskega območja.

Analize z držav evrskega območja razširim tudi na vse države EU, s čimer pridobim možnost primerjave dobljenih rezultatov za evrsko območje in območje, ki je na nižji stopnji integracije. Nadalje me zanimajo tudi rezultati za države, ki so potencialne kandidatke za uvedbo evra ali so uvedle evro po nastanku EMU leta 1999.

Podatki

V analizi uporabim podatke Evropskega statističnega urada o industrijski proizvodnji v predelovalnih dejavnostih (indeks industrijske proizvodnje) za države članice EU ter podatke o indeksih cen industrijskih proizvodov pri proizvajalcih za posamezne predelovalne dejavnosti in države EU. Uporabim razčlenitev na 14 oddelkov (sektorjev) področja predelovalnih dejavnosti po Standardni klasifikaciji dejavnosti 2008.

Podatki o industrijski proizvodnji za osem držav evrskega območja in tri stare članice EU, ki niso v Evrosistemu, so razpoložljivi za obdobje 1991(1)−2014(1). Podatki za ostale države evrskega območja in nove članice EU so na voljo le za krajše obdobje. Ker me zanima vpliv uvedbe evra, ocenjujem usklajenost poslovnih ciklov v evrskem območju le za države z najdaljšimi razpoložljivimi serijami: Belgija, Finska, Francija, Irska, Italija, Nemčija, Nizozemska in Španija.

V naslednjem delu ocenjujemo tudi sinhronizacijo poslovnih ciklov v EU državah, rezultati za države so odvisni od razpoložljivosti časovnih serij. Za nekatere nove članice EU so podatki dostopni šele od 2000(1), zato razdelim države v glede na dolžino časovnih serij. Za analizo najširšega nabora EU držav (24 držav) je torej obravnavano obdobje 2000(1)–2014(6).

Podatki o letnih rasteh proizvodnih cen pri proizvajalcih so za osem držav evrskega območja na voljo le za krajše časovno obdobje, 1996(1)−2014(5).

Dobljeni sektorski rezultati za ostale države EU so posledično omejeni na krajše obdobje, odvisno od razpoložljivosti časovnih serij.

Glavne ugotovitve

Rezultati analize pokažejo, da za evrsko območje obstaja precejšnje sočasno gibanje rasti proizvodnje v predelovalnih dejavnosti na ravni evrskega območja za celotno opazovano obdobje 1991(1)−2014(6). Skoraj 50 odstotkov variance v rasti proizvodnje na ravni države in sektorja lahko pojasnim z enim skupnim faktorjem evrskega območja (angl. *euro area*, EA) za obdobje 1991(1)−2014(6). Sektorska komponenta, ki skupaj z enotnim EA faktorjem predstavlja simetrični del, pojasni v povprečju še nadaljnjih osem odstotkov variance. Ugotavljam, da so pomembni tudi faktorji, specifični za države, ki pojasnjujejo nadaljnjih 10 odstotkov variance. Preostalih 34 odstotkov variance predstavlja idiosinkratično, za posamezno državo in sektor specifično komponento.

Vzporedno gibanje stopenj inflacije po državah in sektorjih v evrskem območju je za opazovano obdobje 1996(1)−2014(5) prav tako precej pomembno. Enotna komponenta evrskega območja v povprečju pojasni 64 odstotkov variance inflacije proizvodnih cen. V primeru heterogenosti inflacije proizvodnih cen ugotovim velik pomen sektorsko specifične komponente, ki pojasni 27 odstotkov variance, medtem ko skupni EA faktor pojasni 37 odstotkov. Državni faktorji pojasnijo nadaljnjih 12 odstotkov, preostalih 24 odstotkov pa predstavlja varianco, ki je specifična za posamezno državo in sektor.

Pomembnost faktorjev na ravni evrskega območja, skupnih EA faktorjev, sektorsko specifičnih faktorjev in tudi državnih faktorjev je heterogena po državah in podsektorjih. To nakazuje, da ti faktorji na rast proizvodnje in proizvodnih cen vplivajo asimetrično po državah in podsektorjih predelovalnih dejavnosti.

Za preverjanje glavne hipoteze, da se sinhronizacija poslovnih ciklov v evrskem območju poveča po uvedbi evra, izvedem analizo s hierarhičnim DFM na ravni posameznih sektorjev predelovalnih dejavnosti na osem ustanovnih držav evrskega območja. K spremljanju sprememb v pomembnosti posameznih faktorjev pristopim z uporabo rekurzivne metode razčlenjevanja variance z drsečim oknom stalne velikosti. To omogoči vpogled v časovno dimenzijo pomembnosti simetričnega in asimetričnega dela variance za posamezno spremenljivko.

Rezultati analize ne pokažejo, da bi se sinhronizacija med državami evrskega območja po uvedbi evra dejansko povečala. Sinhronizacija, merjena s povprečnim doprinosom simetričnega dela variance v rasti industrijske proizvodnje, ki je pojasnjena s skupnim in sektorsko specifičnimi faktorji, se je namreč povečala v obdobju pred uvedbo evra v letu 1999. Analiza pokaže tudi padanje stopnje sinhronizacije po finančni krizi v letu 2008 in še posebej po nastopu dolžniške krize v letu 2011. Vendar je tudi v tem obdobju sinhronizacija poslovnih ciklov v predelovalnih dejavnostih presegala tisto v prvi polovici 90-ih let. Pomembna je tudi ugotovitev, da vpliv faktorjev ni konstanten skozi čas. Vendar v nasprotju s teorijo endogenosti OCA (Frankel in Rose, 1998, 2000) ugotavljam, da se lahko stopnja usklajenosti poslovnih ciklov tudi zmanjšuje.

Potrjujem torej prvo podhipotezo, da je stopnja sinhronizacije poslovnih ciklov v predelovalnih dejavnostih višja med državami evrskega območja kot med državami EU. Ugotavljam, da skupni faktorji na ravni EU za območje EU pojasnijo okoli osem odstotkov variance manj, kot je pojasnijo skupni faktorji evrskega območja za to območje. Pri pojasnjeni varianci za evrsko območje najvišje stopnje dosega skupni EA faktor v primerjavi s skupnim faktorjem za EU, medtem ko so si sektorsko specifični faktorji za obe obravnavani območji po relativni pomembnosti bolj podobni. Iz tega lahko sklenem, da evrsko območje sestavljajo države z relativno usklajenimi poslovnimi cikli, vendar pri tem ne morem trditi, da ima skupna valuta na to kakršenkoli vpliv.

Potrjujem tudi drugo podhipotezo, da se v novih državah članicah stopnja usklajenosti poslovnih ciklov v predelovalnih dejavnostih z evrskim območjem po uvedbi evra poveča, vendar le za obdobje do leta 2009. Po začetku finančne in dolžniške krize se vzporedno gibanje rasti proizvodnje v podsektorjih predelovalnih dejavnosti v novih državah evrskega območja začenja zmanjševati, tako da v zadnjem obdobju (2010(4)−2014(6)) komaj presega raven iz obdobja pred vstopom v EU. Nadalje ugotavljam, da lahko med novimi državami članicami, ki so uvedle evro, rast stopnje usklajenosti z evrskim območjem po vstopu v evrsko območje ugotovim le na primeru Slovenije. Vendar tudi v tem primeru to povečanje težko pripišem učinkom evra, saj se usklajenost v istem obdobju poveča tudi v drugih državah.

Druga hipoteza je, da se je sinhronizacija poslovnih ciklov v evrskem območju zmanjšala v zadnjem obdobju po nastopu dolžniške krize evrskega območja v 2011, v primerjavi s predkriznim obdobjem. Rezultati analize to hipotezo potrjujejo, saj opažam zmanjšanje stopnje sinhronizacije tako v kratkoročnih gibanjih industrijske proizvodnje, merjeno z mesečno rastjo, kot pri rasti industrijske proizvodnje na medletni ravni. Nadalje, zmanjšano stopnjo sinhronizacije opažam tako v perifernih kot v centralnih državah evrskega območja. Stopnja sinhronizacije z evrskim območjem pa se zmanjša tudi za ostale EU države, nove članice in stare članice, ki niso sprejele evra.

Zmanjšana stopnja sinhronizacije v evrskem območju po nastopu dolžniške krize ter še posebej razlike v relativni pomembnosti skupnih faktorjev med posameznimi državami kažejo, da skupne politike v evrskem območju nimajo enakega vpliva na vse države.

Države, ki jih je kriza najbolj prizadela, bi lahko povišale rast z izboljšanjem konkurenčnosti. Ker v monetarni uniji tega ni mogoče doseči z devalvacijo valute, je edina možnost notranja devalvacija. V tem primeru bi morali opažati večje razlike v inflaciji proizvodnih cen na ravni evrskega območja in posledično zmanjšano usklajenost gibanja cen, merjeno s prispevkom EA faktorjev k varianci inflacije proizvodnih cen. Vendar je v okolju nizke inflacije notranja devalvacija v državah otežena, saj jo omejujejo nominalne rigidnosti, predvsem na trgu dela. Moja podhipoteza druge hipoteze se glasi, da se usklajenost gibanja proizvodnih cen v pokriznem obdobju ne zmanjšuje. Rezultati to podhipotezo potrjujejo, saj se usklajenost gibanja cen celo poveča in je v zadnjih obdobjih na zgodovinsko visokih ravneh. To pomeni, da gospodarstva v okolju nizke inflacije oz. deflacije ne zmorejo izboljševanja konkurenčnosti in zvišanja rasti, kar se kaže v povečani usklajenosti gibanja cen v naših rezultatih.

V disertaciji preverjam tudi vpliv uvedbe evra na usklajenost gibanja proizvodnih cen v sektorju predelovalnih dejavnosti. Analiza pokaže večjo usklajenost gibanja cen v evrskem območju po uvedbi evra, saj se delež pojasnjene variance v obdobjih po uvedbi evra v primerjavi z obdobjem 1996−2000 poviša za 10 o. t. Žal je časovna dimenzija podatkov o proizvodnih cenah prekratka, da bi lahko podrobneje preveril učinek evra na usklajenost gibanja cen.

Pomen rezultatov za ekonomsko politiko

Ugotavljam, da skupni faktorji nimajo simetričnih učinkov na področje predelovalnih dejavnosti v državah evrskega območja. Ta ugotovitev velja tudi, če upoštevam skupne sektorske učinke, ki odražajo usklajenost gibanj rasti na ravni posameznih sektorjev predelovalnih dejavnosti. V nasprotju z nekaterimi drugimi študijami ugotavljam, da se je usklajenost poslovnih ciklov v perifernih državah po uvedbi evra sicer zviševala, vendar ni dosegla stopnje usklajenosti v centralnih državah evrskega območja, kar nakazuje, da evrsko območje ni OCA po kriteriju usklajenosti poslovnih ciklov. Nadalje ugotavljam, da se usklajenost v zadnjih obdobjih še znižuje za periferne države evrskega območja in nove članice EU, ki so naknadno pristopile tudi v evrsko območje. To predstavlja izziv pri oblikovanju skupnih politik evrskega območja, gledano s perspektive predelovalnih dejavnosti.

Podrobni rezultati kažejo, da se je usklajenost poslovnih ciklov z evrskim območjem v perifernih državah začela zniževati že po izbruhu finančne krize v 2008, medtem ko je v centralnih državah evrskega območja ostala približno na predkrizni ravni. Vendar se je z nastopom dolžniške krize v 2011 začela zniževati tudi usklajenost poslovnih ciklov predelovalnih dejavnosti v centralnih državah evrskega območja. Rezultati torej nakazujejo zmanjševanje vpliva enotnih ekonomskih politik za celotno evrsko območje, če interpretiram simetrični delež variance kot potencialni doseg teh politik.

Rezultati torej kažejo, da obstajajo pomembne razlike v pomenu skupnih faktorjev med državami in sektorji. To pomeni, da imajo lahko celo simetrični šoki asimetrične učinke v okviru evrskega območja ter da bi bili učinki skupnih politik evrskega območja različni za posamezne države in sektorje. Zadnja kriza je pokazala, da stabilizacijski mehanizmi na ravni države niso zadostni v primeru velikih šokov. Zato bi morali prihodnji mehanizmi prilagajanja zajemati ali vsaj dopuščati zadostne ukrepe na ravni držav.

Oblikovalci politik bi torej morali upoštevati zmanjšano usklajenost držav evrskega območja v zadnjih letih. Skupaj s povečanjem vzporednega gibanja rasti proizvodnih cen to pomeni, da bi bili potrebni dodatni mehanizmi za primere asimetričnih šokov v evrskem območju. Ugotavljam, da je velik del variance v proizvodnji za posamezne države specifičen na ravni države ter države in sektorja, kar nakazuje pomen politik na nacionalni ravni. Vendar so te politike omejene s Paktom za stabilnost in rast ter posledično omejeno fiskalno politiko držav evrskega območja. Strukturne reforme pa težko kratkoročno pripomorejo k vzpostavljanju ravnovesja v evrskem območju in zagotovijo potrebno rast.

Analiza kaže visoko usklajenost gibanja proizvodnih cen, ki je z vidika povečevanja konkurenčnosti s krizo najbolj prizadetih držav nezaželeno. Zvišanje inflacije v evrskem območju bi zato moralo biti med prvimi kratkoročnimi prioritetami ECB, saj bi se tako ustvaril prostor za dvig konkurenčnosti podjetij v predelovalnih dejavnostih v državah, ki so v predkriznem obdobju na konkurenčnosti relativno izgubljale. To je pomembno predvsem z vidika, da notranja devalvacija zaradi deflacijskih pritiskov upočasnjuje gospodarsko rast.

Rezultati tudi nakazujejo, da so imele države na obrobju evrskega območja, ki so bile najbolj prizadete v dolžniški krizi, nizko stopnjo usklajenosti poslovnih ciklov v predelovalnih dejavnostih z evrskim območjem tudi v obdobju pred krizo. Na drugi strani nove države članice izkazujejo celo še nižje stopnje usklajenosti z evrskim območjem, kar predstavlja še večji izziv. Prihodnja širitev evrskega območja bi tako morala biti izvedena šele po uvedbi ustreznih prilagoditvenih mehanizmov. Med predlaganimi mehanizmi, ki bi morali delovati v evrskem območju, so bančna in fiskalna unija ter vloga Evropske centralne banke (ECB) kot posojilodajalca v skrajni sili (ang. *lender of last resort*). Nenazadnje rezultati analize, ki kažejo nizko stopnjo usklajenosti poslovnih ciklov z evrskim območjem v novih članicah EU, opominjajo, da je v raziskave o potrebnih spremembah ogrodja Evrosistema treba vključiti tudi gospodarstva novih članic EU.

Znanstveno-raziskovalni prispevek

Pristop v raziskavi, kjer uporabim razčlenjene sektorske podatke, je v literaturi razmeroma nov. Beck, Hubrich in Marcellino (2012) so predstavili zelo podoben pristop za analizo rasti potrošnih cen na ravni sektorjev v izbranih regijah evrskega območja. Njihov pristop v primerjavi z mojim vključuje dodatni regijski nivo ter predlaga novo iterativno metodo ocenjevanja faktorjev z metodo glavnih komponent v nasprotju z mojo raziskavo, kjer uporabim metodo Stocka in Watsona (1998, 2002a, 2002b).

Vendar moja raziskava prinaša nove rezultate na področju usklajenosti gibanja cen in poslovnih ciklov. Raziščem namreč rast proizvodnih cen in gibanje proizvodnje v državah evrskega območja in EU. Nadalje uporabim rekurzivno metodo ocenjevanja hierarhičnega DFM z drsečim oknom za sledenje razvoja heterogenosti skozi čas. Poleg tega s podatki zajamem obdobji globalne finančne krize in dolžniške krize v evrskem območju.

V raziskavi predstavim tudi rezultate za nove države članice EU, ki so v literaturi prepogosto zapostavljene. Ugotavljam, da te predstavljajo še večji izziv za delovanje EMU, kot je to primer s perifernimi ustanovnimi državami evrskega območja, z vidika usklajenosti poslovnih ciklov z evrskim območjem. Usklajenost poslovnih ciklov novih držav članic je namreč pod ravnjo usklajenosti perifernih držav evrskega območja pred uvedbo evra.

Razvoj v usklajenosti poslovnih ciklov in gibanja cen v evrskem območju je v veliki meri odvisen od sprememb v zasnovi in delovanju institucij EMU. Usklajenost poslovnih ciklov je pomemben pokazatelj tako za oceno velikosti potrebnih ukrepov kot za naknadno vrednotenje vpliva ukrepov. Uporaba mesečnih podatkov in drsečega časovnega okna v moji raziskavi omogoča spremljanje nedavnih sprememb v usklajenosti poslovnih ciklov na sektorski in državni ravni.

Omejitve disertacije in možnosti za nadaljnje raziskave

Ena od značilnosti teorije OCA je, da ne daje končnega odgovora glede primernosti, da izbrane države tvorijo valutno unijo. Teorija daje določen vpogled v koristi in slabosti denarne unije, vendar je določanje primernosti držav za denarno unijo bolj kvalitativen proces. Podobno lahko rečem za usklajenost poslovnih ciklov, saj ni znano, kakšna stopnja usklajenosti poslovnih ciklov je še primerna, da države tvorijo OCA. Eden od razlogov, da v raziskavo vključujem tudi države EU, ki (še) niso v evrskem območju, je tudi primerjava rezultatov za evrsko območje z območjem, ki je na nižji stopnji integracije. Vendar bi raziskava s predlagano metodologijo na podatkih za ZDA lahko doprinesla k razumevanju heterogenosti v evrskem območju.

S podrobnejšo razčlenitvijo področja predelovalnih dejavnosti in/ali vključitvijo dodatnih področij gospodarstva bi lahko dodatno razširili vedenje o heterogenosti gospodarstev. V dodatni analizi razčlenjujem področje predelovalnih dejavnosti na 24 sektorjev in ugotavljam zvišanje pomembnosti sektorskih faktorjev pri pojasnjevanju skupne variance rasti industrijske proizvodnje. Z dodatno razčlenitvijo bi dosegli še dodatno zvišanje pomembnosti sektorskih faktorjev, vendar bo to moralo biti potrjeno z novimi raziskavami.

Nazadnje, ugotavljam, da je izračun pomembnosti sektorskih in državnih faktorjev odvisen od vrstnega reda ocenjevanja. Zaradi pomembnosti med-industrijske specializacije in učinkov na posamezne sektorje, v osnovnem izračunu najprej ocenjujem sektorsko specifične faktorje. Za natančnejše rezultate bi bila primernejša uporaba iteracijskega načina ocenjevanja faktorjev, ki so ga predlagali Beck in ostali (2012). Vendar analiza pokaže, da je ocenjevanje sprememb usklajenosti poslovnih ciklov v času v veliki meri neodvisno od izbire vrstnega reda ocenjevanja faktorjev, tako da glavne ugotovitve raziskave ostanejo enake v obeh primerih. Vseeno pa bi metoda, ki jo predlagajo Beck in ostali (2012), potencialno izboljšala dobljene rezultate.