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Abstract

This dissertation aims to analyse the economic growth determinants in four Central Eastern European countries (CEE-4) - Hungary, Poland, Slovakia and the Czech Republic - since their transition from centrally planned to free market economies. The time span of research encompasses the years from 1995 (when these countries passed beyond their lowest output levels since the economic transformation) till 2018. The CEE-4 countries have been chosen based on their direct geographical proximity with Western Europe, in particular with its most advanced economy - Germany, and their adoption of different approaches to conducting market reforms. The thesis closely examines the linkages between geographical location, trade and financial flows in the region prior to and after the accession to the European Union (EU), and the outcome of complex reforms for economic growth in the CEE-4.

Following the introduction in Chapter 1, in order to obtain a general overview of the sources of economic growth in the CEE-4 countries the Solow growth accounting and the non-parametric approach have been presented in Chapter 2. The findings obtained from the above decomposition methods provide support for a hypothesis that technological progress together with strong capital accumulation were the dominant factors behind the economic growth and convergence process in the CEE-4 countries in the post-transition years. Chapter 3 investigates financial interlinkages of the CEE-4 with Western Europe. It provides a valuable assessment of a distinctive "development model" pursued by the CEE-4 region since the transition, of which financial integration - in the form of large capital inflows and an increasing presence of foreign banks - has been an integral part. It has allowed the CEE-4 economies to enter a growth path driven by domestic demand financed substantially by foreign savings. The study provides an assessment of the impact of the global financial crisis and European debt crisis on capital flows into the CEE-4 region. The main contribution of this chapter has been an in-depth empirical study of factors affecting credit growth in Central Eastern and South-Eastern Europe (CESEE) in the years 2012-2016 based on the Bank Lending Survey (BLS) of the European Investment Bank. It allows to account for cross-border effects, namely home-host country macroeconomic conditions and parent-subsidiary banks' characteristics and health, while controlling systematically for the answers from the BLS. The purpose of Chapter 4 has been an analysis of the business cycles synchronisation of the CEE-4 countries with economic cycles of Germany

and the Euro area. The analysis of the interdependencies between the business cycles is important in monitoring the effectiveness of pursued economic policies in the CEE-4 region since the transition. Studying the degree of synchronization of the CEE-4 business cycles is also vital in connection with the future introduction of the Euro in Hungary, Poland and the Czech Republic. To this end, the time series analysis methods have been introduced in this study, which focus on an analysis in the domain of both time (cross-correlation analysis) and frequency (cross-spectral analysis). This allows obtaining a more comprehensive picture of the dependencies between the business cycles of the CEE-4 countries and the economic cycle of Germany and the Euro zone. The analysis shows that fluctuations in economic activity in the CEE-4 countries have become over time, to a relatively large extent, synchronized with the business cycles of Germany and the whole Euro area. Chapter 5 examines the impact of macroeconomic and institutional factors on economic growth in the CEE-4 countries since the transition. The building of a market economy in the region required deep macroeconomic reforms and the creation of a wide range of institutions and business practices needed to support those reforms. To examine significant changes which have occurred in the last two decades in the region, a wide range of macroeconomic and demographic variables as well as key institutional indicators have been analysed. For this purpose, a new approach has been employed based on the Bayesian Model Sampling (BMS), which implements Bayesian Model Averaging for linear regression models. This comprehensive study also provides an empirical analysis of growth determinants in the CEE-4 region in comparison to the Euro area-12 group as well as within the EU-28 block.

Zusammenfassung

Ziel dieser Dissertation ist es, die Determinanten des Wirtschaftswachstums in vier mittel- und osteuropäischen Staaten (MOE-4) - Ungarn, Polen, der Slowakei und der Tschechischen Republik, seit ihrer Wende von einer zentralen Planwirtschaft zu einer freien Marktwirtschaft zu analysieren. Der zeitliche Rahmen der Studie umfasst die Jahre von 1995 (als diese Länder ihren niedrigsten Produktionsstand seit der wirtschaftlichen Transformation überschritten) bis 2018. Die MOE-4-Staaten wurden aufgrund ihrer unmittelbaren geografischen Nähe zu Westeuropa, insbesondere zu dessen fortschrittlichsten Volkswirtschaft, der Bundesrepublik Deutschland, und ihrer unterschiedlichen Ansätze zur Durchführung von Marktreformen ausgewählt. In dieser Dissertation werden die Zusammenhänge zwischen der geografischen Lage, den Handels- und Finanzströmen in der Region vor und nach ihrem Beitritt zur Europäischen Union (EU) sowie die Auswirkungen breit angelegter Reformen auf das Wirtschaftswachstum in den MOE-4-Staaten eingehend untersucht.

Nach der Einführung in Kapitel 1 wurden in Kapitel 2 Berechnungen zum Wirtschaftswachstum nach dem Solow-Modell und der nichtparametrische Ansatz vorgestellt, um einen allgemeinen Überblick über die Quellen des Wirtschaftswachstums in den MOE-4-Staaten zu erhaltenen. Die aus den oben genannten Dekompositionsmethoden gewonnenen Erkenntnisse stützen die Hypothese, dass der technologische Fortschritt zusammen mit einer starken Kapitalakkumulation die beherrschenden Triebkräfte des Wirtschaftswachstums und des Konvergenzprozesses in den MOE-4-Staaten in den Jahren nach der wirtschaftlichen Transformation waren. In Kapitel 3 werden die finanziellen Verbindungen der MOE-4-Staaten mit Westeuropa untersucht. Es liefert eine wertvolle Bewertung des besonderen „Modells der wirtschaftlichen Entwicklung“, das die MOE-4-Region seit der Transformation verfolgt, und dessen fester Bestandteil die finanzielle Integration in Form großer Kapitalzuflüsse und der wachsenden Präsenz ausländischer Banken war. Dies hat es den Volkswirtschaften der MOE-4-Region dazu verholfen, einen Wachstumspfad einzuschlagen, der von der Inlandsnachfrage angetrieben und weitgehend durch ausländische Spareinlagen finanziert wird. In der Studie werden auch die Auswirkungen der globalen Finanzkrise und der europäischen Schuldenkrise auf die Kapitalströme in der MOE-4-Region einer Bewertung unterzogen. Der wichtigste Beitrag dieses Kapitels ist eine im Rahmen des Bank Lending Survey (BLS) der Europäischen Investitionsbank durchgeführte, fundierte empirische Untersuchung der Faktoren,

die das Wachstum der in Mittel-, Ost- und Südosteuropa (MOE) zwischen 2012 und 2016 gewährten Kredite beeinflussen. Auf dieser Grundlage können grenzüberschreitende Effekte, d. h. die makroökonomischen Bedingungen des Herkunfts- und des Aufnahmelandes sowie die Merkmale und die finanzielle Gesundheit der Mutterbanken und ihrer Tochterunternehmen, berücksichtigt und gleichzeitig die Antworten auf die BLS-Erhebung systematisch kontrolliert werden. Das Ziel von Kapitel 4 war es, die Synchronisation der Konjunkturzyklen der MOE-4-Staaten mit denen Deutschlands und der Eurozone zu analysieren. Die Analyse der Wechselbeziehung zwischen den Konjunkturzyklen hat für die Überwachung der Wirksamkeit der in der MOE-4-Region seit der Transformation verfolgten Wirtschaftspolitik eine große Relevanz. Die Untersuchung, inwieweit die Konjunkturzyklen in der MOE-4-Region synchronisiert wurden, ist auch im Hinblick auf die künftige Einführung des Euro in Ungarn, Polen und der Tschechischen Republik von Bedeutung. Dazu wurden in der Studie Methoden der Zeitreihenanalyse eingeführt, die sowohl auf die Analyse im Bereich der Zeit (Kreuzkorrelationsanalyse) als auch der Frequenz (Kreuzspektralanalyse) fokussiert sind. Dies erlaubt, ein vollständigeres Bild der Beziehung zwischen den Konjunkturzyklen der MOE-4-Staaten sowie den Konjunkturzyklen Deutschlands und der Eurozone zu gewinnen. Aus der Analyse ist ersichtlich, dass sich die Konjunkturschwankungen in den MOE-4-Staaten mit der Zeit relativ weitgehend mit den Konjunkturzyklen Deutschlands und der gesamten Eurozone synchronisiert haben. In Kapitel 5 wurden die Auswirkungen makroökonomischer und institutioneller Faktoren auf das Wirtschaftswachstum in den MOE-4-Staaten seit der Transformation untersucht. Der Aufbau einer Marktwirtschaft in der Region erforderte tiefgreifende makroökonomische Reformen und die Schaffung eines breiten Spektrums von Institutionen und Geschäftspraktiken, die zur Förderung dieser Reformen notwendig waren. Um die relevanten Veränderungen zu untersuchen, die in den letzten zwei Jahrzehnten in der Region stattgefunden haben, wurde eine ganze Breite an makroökonomischen und demografischen Variablen sowie wichtige institutionelle Indikatoren analysiert. Zu diesem Zweck wurde ein neuer Ansatz auf der Grundlage von Bayesian Model Sampling (BMS) verwendet, der Bayesian Model Averaging für lineare Regressionsmodelle implementiert. Diese umfassende Studie ermöglicht auch einen Vergleich der Determinanten des Wirtschaftswachstums in der MOE-4-Region sowohl vor dem Hintergrund der Eurozone-12-Gruppe als auch innerhalb des Länderblocks der Europäischen Union (EU-28).

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List of Abbreviations

ADF	Augmented Dickey-Fuller
ARIMA	Autoregressive Integrated Moving Average
ASEAN	Association of Southeast Asian Nations
BACE	Bayesian Averaging of Classical Estimates
BERD	Business enterprise expenditure on R&D
BIS	Bank for International Settlements
BK	Baxter-King
BLS	Bank Lending Survey
BMA	Bayesian Model Averaging
BMS	Bayesian Model Sampling
BvD	Bureau van Dijk
CEE	Central Eastern Europe
CESEE	Central Eastern and South-Eastern Europe
CF	Christiano-Fitzgerald
CIS	Commonwealth of Independent States
CL	Civil liberties
DEA	Data Envelopment Analysis
e.g.	Exempli gratia (for example)
EBRD	European Bank for Reconstruction and Development
EC	European Commission
ECB	European Central Bank
EF	Economic freedom
EFF	Efficiency change
EIB	European Investment Bank
EIS	European Innovation Scoreboard
EMU	Economic and Monetary Union
et al.	Et alii (and others)
EU	European Union
FDI	Foreign direct investment

GDP	Gross Domestic Product
GDR	German Democratic Republic
GERD	Gross domestic expenditure on R&D
GGDC	Groningen Growth and Development Centre
GMM	Generalized Method of Moments
HACC	Human capital accumulation
HF	Hodrick-Prescott
i.a.	Inter altere (among others)
i.e.	Id est (that is)
ICT	Information and communications technology
ID	Identification number
IID	Independent and identically distributed
IMF	International Monetary Fund
IPR	Intellectual property rights
KACC	Physical capital accumulation
KPSS	Kwiatkowski–Phillips–Schmidt–Shin
LTRO	Long term refinancing operation
NPL	Non-performing loans
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
PIP	Posterior inclusion probability
PMP	Posterior model probability
PPP	Purchasing power parity
PR	Political rights
PWT	Penn World Table
R&D	Research and Development
SOE	State-owned enterprise
TECH	Technological change
TFP	Total factor productivity
TRAMO/SEATS	Time Series Regression with ARIMA Noise, Missing Observations, and Outliers/Signal Extraction in ARIMA Time Series

UIP	Unit information prior
US	United States
USPTO	United States Patent and Trademark Office
WDI	World Development Indicators
WEF	World Economic Forum
WEF- GCI	World Economic Forum - Global Competitiveness Index

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Chapter 1

Introduction

The main purpose of this dissertation is to provide a comprehensive examination of the economic growth determinants in four Central Eastern European countries (henceforth the CEE-4) - Hungary, Poland, Slovakia and the Czech Republic - since their transition from centrally planned to free market economies. The choice of those countries has been determined by their direct geographical proximity with Western Europe, in particular with its most advanced economy - Germany, and their adoption of different approaches to conducting market reforms. This allows to closely examine the linkages between geographical location, trade and investment patterns in the region prior to and after the accession to the European Union (EU), and the outcome of complex reforms for economic growth in the CEE-4. While all four countries under discussion followed a set of economic policy prescriptions promoted by international institutions (the so called Washington Consensus) aimed at macroeconomic stabilization, trade liberalization and privatisation, the reform paths differed among the countries. Poland and the former Czechoslovakia adopted a more radical reform program while Hungary opted for a more gradual approach to reforms.

The time span of research encompasses the years from 1995 (when these countries passed beyond their lowest output levels since the economic transformation) till 2018. Over two decades provide already a framework for studying growth factors in the region, as well as the impact of EU membership on economic growth in the CEE-4 which were in the first group of transition countries chosen for the accession. The recent global financial and economic crisis of 2008 has revealed many serious vulnerabilities of the Central Eastern European economies, and provides a ground for rethinking the growth strategies in the region which should focus even more on growth-enhancing economic and structural policies.

Chapter 2 presents an overview of the sources of economic growth in Hungary, Poland, Slovakia and the Czech Republic obtained by applying the Solow growth accounting and the non-parametric approach. The results obtained from the above decomposition methods provide support for a hypothesis that technological progress together with strong capital accumulation were the dominant factors behind the economic growth and convergence process in the CEE-4 countries in the post-transition years. Since the CEE-4 countries have a limited capacity for

knowledge-based total factor productivity (TFP) growth and a systemic disadvantage relative to advanced economies, the study has focused on examining their potential to develop frontier technologies. The CEE-4 have been assessed based on their performance in areas that have been identified in the literature as prerequisites for knowledge-based growth: technology-acquisition (‘technology-buy') and technology-creation ('technology-make') strategies. In the end, trade and financial integration of the region with the European Union have also been discussed.

Afterwards, Chapter 3 focuses on examining financial interlinkages of the CEE-4 with Western Europe and capital flows into the region in the years preceding and following the global crisis of 2008 and European sovereign debt crisis. A distinctive feature of this financial integration process was the accession process of the CEE-4 countries to the European Union and the dominance of Western European banks in the region. Foreign banks were attracted by the growth prospects in the CEE-4 economies as interest margins were generally higher in those countries than in their saturated home markets in Western Europe (Gill and Raiser (2012), p. 135). The chapter analysis the accumulation of vulnerabilities in the CEE-4 countries in the pre-crisis years with a particular attention to the cross-border loans to banks and to the non-bank sector in the region. The main contribution of this chapter is an in-depth empirical study of factors affecting credit growth in the Central Eastern and South-Eastern Europe (CESEE) in the years 2012-2016, following the global financial and European sovereign debt crises, based on the Bank Lending Survey (BLS) of the European Investment Bank. It allows to account for cross-border effects, namely home-host country macroeconomic conditions and parent-subsidiary banks’ characteristics and health, while controlling systematically for the answers from the BLS.

Chapter 4 then analysis the degree of synchronization of the CEE-4 countries’ business fluctuations with economic cycles of Germany and the Euro area. This allows to assess the effectiveness of pursued economic policies in the CEE-4 region since the transition, and is also vital in connection with the future introduction of the euro in Hungary, Poland and the Czech Republic. To this aim, the time series analysis methods have been employed in the study, which focus on an analysis in the domain of both time (cross-correlation analysis) and frequency (cross-spectral analysis). This allows to obtain a more comprehensive picture of the dependencies between the business cycles of the CEE-4 countries and the economic cycle of Germany and the Euro zone. The main contribution of the study has been an approach based on introducing the spectral methods and a band-pass filter, to estimate components illustrating the GDP fluctuations.

This analysis shows that fluctuations in economic activity in the CEE-4 countries has become over time, to a relatively large extent, synchronized with the business cycles of Germany and the whole Euro area.

In the last chapter, the examination of the main factors driving economic growth in the CEE-4 countries since the transition has been conducted with the main focus on macroeconomic policies and institutions. To detect significant changes which have occurred in the last two decades in the region, a wide range of macroeconomic, demographic variables as well as key institutional indicators have been analysed. To avoid a model uncertainty in explaining variation of the response variable - economic growth - a new approach has been employed based on the Bayesian Model Sampling (BMS), which implements Bayesian Model Averaging (BMA) for linear regression models. The BMS allows to sample data according to different g-priors and model priors, and leaves the choice of different samplers. Another contribution of this comprehensive study has been an empirical analysis of growth determinants in the CEE-4 region in comparison to the Euro area-12 group as well as within the EU-28 block.

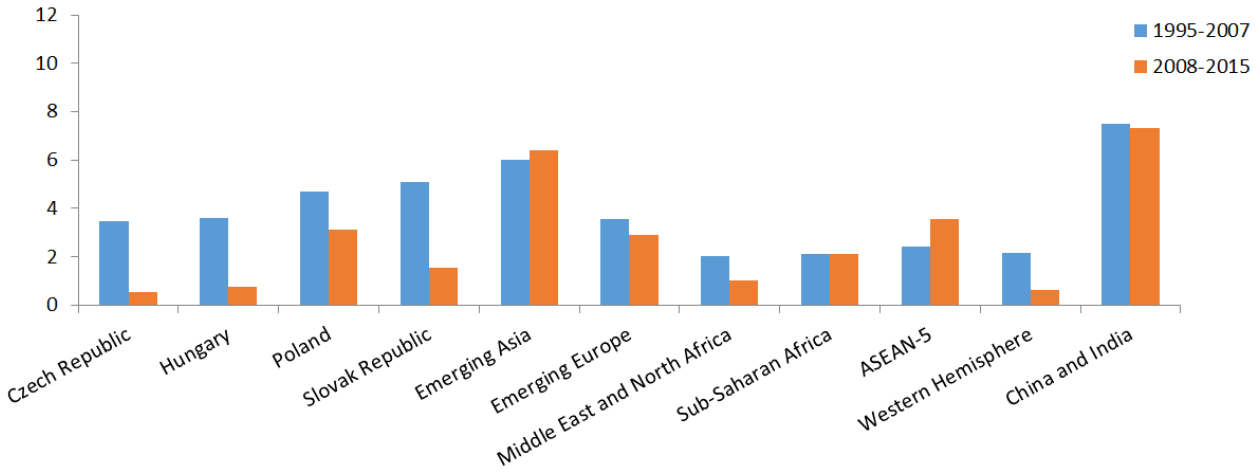
Chapter 2

Growth Accounting

2.1 Introduction

Since the beginning of its transition in the early 1990s, Central Eastern European (CEE) countries have seen impressive progress. In a span of less than two decades, the region went from centrally-planned economies to fully-fledged market economies (Åslund (2007)). This economic transformation accompanied by extensive structural changes boosted growth, and after an initial decline in output, emerging Europe before the global crisis of 2008-2009 grew faster than almost all other emerging market regions, allowing it to display real convergence. Per capita income expanded by 3.6 per cent annually from 1995 to 2007 - exceeded only by Emerging Asia. This rapid growth also allowed the CEE countries to increase their share in the world's economic output, which has been increasing from about 1.5 per cent in the early 1990s to an estimated 2.1 per cent in 2008.[1]

Figure 2.1 Emerging Europe and Selected Regions: Real Per Capita GDP Growth, 1995-2007 and 2008-2015 (annual percentage change in purchasing power parity terms)



Note: ASEAN-5 = Five of the members countries of the Association of Southeast Asian Nations, including Indonesia, Malaysia, the Philippines, Thailand and Vietnam
Emerging Europe excludes Slovakia and the Czech Republic
Emerging Asia includes China and India
Source: Author's calculations based on IMF World Economic Outlook database

[1] Bakker and Klingen (2012), Čihák and Fonteyne (2009). Analysing economies' shares in the world economic output is useful, because - unlike the GDP growth rates - these shares are not affected by the global economic cycle.

Having followed their economic transformation - marked by the accession to the European Union (EU) in 2004 - the CEE countries recorded, however, heterogeneous growth paths. The focus is to analyse the main growth determinants in four Central Eastern European countries: Hungary, Poland, Slovakia and the Czech Republic since 1995 till today. While all four countries under discussion followed a set of economic policy prescriptions promoted by international institutions (the so-called Washington Consensus), Poland and the former Czechoslovakia pursued more radical reform programs while Hungary opted for a more gradual approach to reforms.

The radical reforms were aimed at putting to a halt hyperinflation by tightening monetary policy and at a swift reduction of large budget deficit. The program also envisaged the convertibility of currency on the current account to allow for free trade and for the breaking up of monopolies to avoid monopolistic pricing. Restrictions on the private sector had to be abolished and new private entrepreneurs were offered a maximum of freedom. On the other hand, the proponents of more gradual economic reforms favored state intervention and retained a strong belief in social engineering. Also, gradualists wanted to stimulate output through demand management (whereas radical reformers saw a systemic lack of supply as the prime problem). Therefore, they defended the Hungarian policies against the Polish shock therapy (Åslund (2007), p. 32, 37).

The chapter is structured as follows. Section 2 contains the results of the Sollow growth accounting as well as the non-parametric approach, which has been employed to shed more light on the ultimate sources of economic growth in the region. Section 3 then examines the CEE-4 countries' potential for knowledge-based growth while section 4 discusses trade and financial linkages of the region with the European Union. Section 5 then concludes.

2.2 Solow Growth Accounting

At the beginning of the analysis, in order to obtain a general overview of the sources of economic growth in Hungary, Poland, Slovakia and the Czech Republic since 1995, the Solow growth accounting has been conducted based on the standard neoclassical production function:[2]

[2] Solow growth accounting is a framework developed to test empirically the neoclassical growth model introduced by Solow (1956) and Swan (1956). The methodology has been presented in Appendix.

$$Y_t = A_t F(K_t, L_t) \tag{2.1}$$

where output of period t, Y_t, is produced by a combination of capital K_t and labor L_t while A_t ("Total Factor Productivity", TFP) represents the level of "technology" in the economy. It decomposes the growth rate of output into contributions from changes in the quantity of the physical capital stock, the amount of labor input and some other unexplained factor commonly interpreted as reflecting technological progress and called the "Solow residual" or "Total Factor Productivity (TFP)":[3]

$$\frac{Y_{t+1} - Y_t}{Y_t} = \left(\frac{A_{t+1} - A_t}{A_t}\right) + (1 - \alpha_{t+1})\left(\frac{K_{t+1} - K_t}{K_t}\right) + \alpha_{t+1}\frac{L_{t+1} - L_t}{L_t} \tag{2.2}$$

and allows for variations in the factor income shares: labor share α_{t+1} and capital share $(1 - \alpha_{t+1})$. The aim has been to obtain an insight into the general importance of physical capital accumulation and technological progress in the production process in the CEE-4 before analyzing in detail by what factors this process was driven. A hypothesis has been tested that technological progress together with strong capital accumulation were the dominant factors behind the economic growth and convergence process in Central Eastern European countries in the post-transition years.

The standard model of Solow growth accounting has been estimated using 'the total amount of working hours' as a more accurate measure of labor input instead of 'total employment'.[4] The aggregate amount of working hours in the economy is the number of hours worked by all self- and dependently employed persons. The Solow growth decomposition has been conducted for the CEE-4 countries as well as for Germany as the leading economy of the European Union and the most important trading partner of CEE-4 countries, for the US and the Euro area-12 as the benchmark advanced economies, for comparative purpose. The data for estimations has been taken from the OECD Economic Outlook, Eurostat, IMF, Penn World Table (PWT) 9.0 and Total Economy Database - Output, Labor and Labor Productivity, 1950-2018. Since data on the remuneration payable by enterprises to employees provided by the OECD is only available for the dependently employed, the figures had to be scaled up accordingly. For this purpose, data on self-employed workers as a percentage of total employment has been retrieved from Eurostat and the total compensation for all employed persons has been computed.

[3] TFP is measured as the 'residual' part of total output growth. It includes all other sources driving economic growth except for changes in the quantity of capital and labor. Neuhaus (2006), p. 10.

[4] A model measuring labor as the total number of people in employment underestimates the amount of labor contribution because it does not consider the increase in working hours. Neuhaus (2006), p. 22.

2.2.1. Model: Labor Measured as 'Total Number of Hours Worked'

The model points to significant contributions of capital accumulation and technological progress in the production process of the CEE-4 countries since 1995, both in absolute values and compared to Germany, the US and the Euro area-12.[5] From 1995 to 2014, the average annual capital contribution in the four Central and Eastern European countries under discussion was between 2.4 per cent (in Hungary) and 2 per cent (in the Czech Republic), and it was higher than in the reference group of advanced western economies. A high level of capital contribution to economic growth in the whole observation period has been associated with an extension of the physical capital stock.[6] A more stable macroeconomic and political environment in the post-transition years resulted in capital inflows to the emerging CEE-4 region. Foreign long-term loans raised domestic investment together with foreign direct investment (FDI) inflows, which generated substantial greenfield investments and spillover effects in the host economies, thus significantly increasing the physical capital stock. The CEE-4 countries have also recorded higher figures for the total factor productivity input compared to the advanced economies of the Euro area-12 and the USA, with Poland leading the rank with an average TFP growth of 2.2 per cent. High TFP figures capture a more efficient use of production inputs and better managerial practices introduced with the transition process involving privatization, deregulation in product and labor markets, opening to international trade, foreign direct investment inflows and transfer of technologies.[7] Therefore, the CEE-4 region has been benefiting from a structural transformation of their economies. The opposite results, however, have been obtained for the labor input factor. The labor contribution in the CEE-4 since 1995 was very weak or negative, which is a distinctive characteristic of the growth path in Central Eastern Europe since the beginning of its economic transformation. Average annual labor contribution in 1995-2014 was between 0 per cent (in the Czech Republic) and 0.2 per cent (in Poland), and it was a decelerating factor in the growth process.

To obtain additional insight into the sources of economic growth, the whole observation period has been divided into three sub-periods: the late transition period of 1995-2000, the pre-

[5] The findings are in line with other studies. See Arratibel et al. (2007) and Dombi (2013).
[6] The total capital contribution consists of the change in the physical capital stock and the change in the capital income share. Neuhaus (2006), p. 18.
[7] In the examined countries the TFP growth rate in some years is negative due to a very high pace of capital growth. The capital and labor shares have been calculated here based on data from economic statistics. Meanwhile, many studies use arbitrary shares - often 0.3 or 0.5 for capital, i.e. the role of capital in those studies is smaller.

crisis years 2001-2007 when the CEE-4 countries experienced economic booms, and the years 2008-2014 of the global financial crisis and of the post-crisis recovery period. The average annual capital contribution in the CEE-4 countries in the examined intervals exhibited a hump-shaped pattern - with low figures in the early transition years, high contributions in the 2000s before the global crisis and their decrease in the post-crisis years (with the exception of Poland).[8] Similar results also hold for the growth in TFP. The average TFP contribution was much lower in the years 2008-2014 due to the global crisis (with Poland being again an outlier). After the crisis, the contribution of TFP growth has been less significant in the sample countries coinciding with generally weak output growth. It was higher, however, in the second half of the 1990s (on average 2.2 per cent in the CEE-4) and in the pre-crisis years 2001-2007. There are several reasons which may explain this. First, TFP is the residual of the Solow decomposition, so its value depends on labor and capital, the other two factor inputs. The labor contribution to growth in 1995-2000 was negative in Slovakia and the Czech Republic, only slightly positive in Poland and Hungary. In the 1990s labor was substituted by capital and, at the same time, the slackness of labor force - which was inherited under the centrally-planned economies - was gradually removed. These developments made the production process much more efficient and boosted the TFP contribution in the 2000s. A second argument to explain the high TFP growth was a more stable macroeconomic and political environment due to the EU accession of the CEE-4 in 2004, which attracted foreign investors and, thus, increased the capital stock. European integration played a supporting role in the catching-up process of the CEE-4 economies.[9] This anchoring certainly contributed to substantial trade flows and FDI inflows, which facilitated technology transfer. Low unit labor costs combined with a relatively high human capital endowment also made the region attractive to foreign investors. This led to know-how transfer, access to high-income markets and the possibility of integrating into cross-border production networks. Furthermore, the four economies showed evidence of significant qualitative upgrading of their industrial and export structures (Landesmann and Stehrer (2009), Fabrizio et al. (2007)). Other

[8] Poland was among the CEE-4 countries that suffered least from the world economic crisis, and the only one which recorded positive GDP growth in 2009. Gradzewicz et al. (2014).

[9] The benefits included the accession to the common market and free trade, financial assistance via EU transfers, and labor force mobility. Equally important were benefits from closer institutional and financial integration with Western Europe. They were seen in growing trade volumes, low risk premia, larger capital inflows and the increasing use of foreign savings in the CEE-4. Čihák and Fonteyne (2009).

factors contributing to the capital deepening in the CEE-4 region included changes in sectoral and regional economic structures (Römisch (2007)).

With regard to the labor input, its negative growth contribution was most significant in the second half of the 1990s and in the post-crisis years. The downward trend in 1995-2000 can be explained with the disorganization argument by Blanchard and Kremer (1997). Employment rates fell sharply during the 1990s with the privatization of state-owned enterprises, weak job-search incentives and retraining for the new market economy due to social benefits and disability pensions (Estevão (2003), Schiff et al. (2006)). In the four countries under examination one could also observe an ongoing process of sectoral transformation from agriculture and heavy industry to higher productivity industries and services. This was accompanied by increasing mismatches between labor supply and job vacancies, and created labor market bottlenecks in many sectors.[10] In the second half of the 1990s, the average labor contribution was negative in Slovakia and the Czech Republic. The negative developments in the labor market were further aggravated by increased east-west migration after the EU accession.[11] Labor contribution in 2001-2007 was negative in Hungary and the Czech Republic, and only slightly positive in the remaining two countries: Poland and Slovakia. After the global crisis the contribution of labor growth has been negative or close to zero in all CEE-4 countries coinciding with generally weak output growth. This was due to a diminishing labor force and rising to double-digit unemployment rate in the region. Overall, the input labor factor in the whole examined period of 1995-2014 was a decelerating factor in the growth process of the CEE-4 region with an average value of 0.1 per cent.

With respect to the growth contributions over time, in the years 1995-2000 only Poland (5 per cent) exhibited the growth rates of output above the average of 3.4 per cent for the whole CEE-4 region, with the Czech Republic (0.7 per cent) much below the average as a result of the recession caused by the Asian crisis in 1997. The CEE-4 countries were, however, on the climbing growth path till the global financial crisis, with Slovakia achieving in 2001-2007 the highest on average growth rate (5.7 per cent) in the region since the transition. When the global

[10] The indicators on educational attainment confirm that the adaptability of the workforce has not been sufficient to meet the changed labor requirements resulting from the rapid sectoral shift, i.e. the higher demand for skilled workers. Arratibel et al. (2007), p. 36.

[11] Along with the international flows of capital, the movement of labor across the borders of the European Union's new member states has been perceived as a feature of their income convergence process. International Monetary Fund (2008), p. 67.

crisis began, all the four countries, however, experienced in the years 2008-2014 a sharp contraction in growth rates - with the exception of Poland which recorded the highest growth rate above the average of the advanced western economies. In sum, the average annual growth rate in the examined period of 1995-2014 for all CEE-4 countries was higher than in advanced western economies pointing to the catching up process of the CEE-4 region in the last two decades.

Table 2.1 Solow Growth Accounting (Model: Total Hours Worked)

		1995-2000	2001 - 2007	2008- 2014	1995 - 2014
Czech Republic	GDP %	0.68	4.42	1.49	2.34
	Capital contribution %	0.37	2.71	1.30	2.00
	Labor contribution %	-0.22	-0.03	0	0
	TFP %	0.53	1.74	0.19	0.34
	Labor income share	0.36	0.43	0.51	0.44
	Capital income share	0.64	0.57	0.49	0.56
Hungary	GDP %	2.80	3.21	2.47	2.83
	Capital contribution %	0.46	3.74	2.83	2.53
	Labor contribution %	0.69	-0.27	-0.19	0.01
	TFP %	1.65	-0.26	-0.17	0.29
	Labor income share	0.50	0.56	0.55	0.54
	Capital income share	0.50	0.44	0.45	0.46
Poland	GDP %	5.03	3.67	5.18	4.58
	Capital contribution %	1.86	1.30	3.22	2.15
	Labor contribution %	0.23	0.30	0.16	0.23
	TFP %	2.94	2.07	1.80	2.20
	Labor income share	0.49	0.51	0.50	0.50
	Capital income share	0.51	0.49	0.50	0.50
Slovak Republic	GDP %	1.54	5.74	2.98	3.58
	Capital contribution %	-1.15	3.93	3.12	2.27
	Labor contribution %	-0.47	0.41	0.02	0.03
	TFP %	3.16	1.40	-0.16	1.28
	Labor income share	0.38	0.43	0.49	0.44
	Capital income share	0.62	0.57	0.51	0.56

		1995-2000	2001 - 2007	2008- 2014	1995 - 2014
CEE-4	GDP %	3.35	3.94	3.81	3.74
	Capital contribution %	1.06	2.85	3.23	2.51
	Labor contribution %	0.09	0.17	0.06	0.11
	TFP %	2.20	0,92	0.52	1.12
	Labor income share	0.38	0.43	0.49	0.44
	Capital income share	0.62	0.57	0.51	0.56
Germany	GDP %	3.20	2.75	1.61	2.45
	Capital contribution %	0.22	2.14	1.74	1.48
	Labor contribution %	-0.01	-0.07	0.12	0.02
	TFP %	2.99	0.68	-0.25	0.95
	Labor income share	0.51	0.52	0.56	0.53
	Capital income share	0.49	0.48	0.44	0.47
USA	GDP %	4.3	2.44	1.01	2.39
	Capital contribution %	2.15	2.23	0.39	1.53
	Labor contribution %	0.90	0.19	-0.02	0.30
	TFP %	1.25	0.02	0.64	0.56
	Labor income share	0.46	0.52	0.58	0.52
	Capital income share	0.54	0.48	0.42	0.47
Euro area-12	GDP %	4.47	2.75	0.82	2.00
	Capital contribution %	0.42	3.21	1.74	2.00
	Labor contribution %	0.58	0.48	-0.46	0.16
	TFP %	3.47	-0.94	-0.46	-0.16
	Labor income share	0.45	0.52	0.58	0.52
	Capital income share	0.55	0.48	0.42	0.48

Note: Period averages computed using the geometric mean. The sum of the contributions may not add up to output growth due to rounding. The CEE-4 and Euro area-12 averages are the unweighted average.
Source: Author's calculations based on the OECD Economic Outlook, Eurostat, IMF, Penn World Table 9.0 and Total Economy Database-Output, Labor and Labor Productivity, 1950-2018

2.2.2. Non-parametric approach

As the Solow growth accounting does not reveal the driving forces behind the technological progress and, thus, a large part of the growth decomposition remains unexplained in the CEE-4 economies, the non-parametric approach has been employed to shed more light on the ultimate sources of economic growth in the region. The non-parametric (production-frontier) method enables the further decomposition of changes in total factor productivity into changes in

the efficiency of production and technological changes. Furthermore, it allows accounting for human capital accumulation since improvements in quality of labor are also reflected in TFP growth. As the stock of human capital (proxied by school enrollment ratios) inherited from the centrally-planned economies was very high in Central Eastern Europe, it is important to account for this factor. For a given level of initial per capita income, a higher initial stock of human capital tends to generate higher economic growth through at least two channels. First, more human capital facilitates the absorption of superior technologies from developed countries. Secondly, countries which start with a high ratio of human to physical capital - such as the transition economies in the aftermath of the sharp drop in output and physical capital in the early 1990s - tend to grow rapidly by adjusting upward the quantity of physical capital (Iradian (2007), p. 21).

Labor productivity growth is decomposed into technological change (shifts in the world production frontier), efficiency change (movements toward or away from the frontier), and physical and human capital accumulation (movements along the frontier). This quadripartite decomposition is carried out based on data envelopment analysis (DEA) introduced by Farrell (1957) and exposited by Färe et al. (1994), and on methodology developed by Kumar and Russell (2002) and Henderson and Russell (2005).[12] The authors construct a deterministic frontier for the sample, and compare each country's distance from the frontier in a framework of constant returns to scale. They use distance functions to calculate the Malmquist index as an alternative measure of TFP. During the time of writing this chapter, there have been no studies conducted for the former transition economies of Central Eastern Europe using the quadripartite decomposition. Therefore, this research has been precursory is this regard as the sample consisting of 35 countries - aside from advanced and developing economies - included 11 post-transition countries mainly from Central Eastern Europe. The choice of countries and time frame was conditioned on the availability of data. The study has been conducted for the CEE-4 countries as well as for Germany, the US, the Euro area-12 and OECD countries as a benchmark for the time frame of 1995-2014. The data for estimations has been taken from the Penn World Table 9.0.

The quadripartite decomposition has been conducted for three sub-periods: 1995-2000, 2001-2007 and 2008-2014 to obtain a comparative basis with the results from the Solow growth accounting. It appears that productivity growth has been driven primarily by technological

[12] The methodology is presented in the Appendix.

change and physical capital accumulation in the CEE-4 countries. This might indicate that the emerging economies of Central Eastern Europe still have not passed the phase common for developing countries, in which productivity growth is attributed mainly to technological change and physical capital accumulation. Contribution to productivity growth from efficiency change in the examined period 1995-2014 has been negative in Hungary and the Czech Republic, neutral in Poland and only slightly positive in Slovakia. Higher efficiency in the use of inputs can be achieved by investing in "knowledge," which can be defined as investment in R&D and higher education (Arratibel et al. (2007), p. 29). With regard to the growth contributions from human capital accumulation, the CEE-4 countries recorded positive yet single-digit figures over the span of two decades.

Table 2.2 Percentage change of quadripartite decomposition indexes, 1995-2014

		1995-2000	2001 - 2007	2008- 2014	1995 - 2014
Czech Republic	Productivity change%	8.9	22.6	15.6	56.6
	(EFF-1) x 100	-2	3.7	-3.9	-7.3
	(TECH-1) x 100	4.9	15.8	19.5	56.1
	(KACC-1) x 100	0	1	0	0
	(HACC-1) x 100	5.9	1.1	0.7	8.2
Hungary	Productivity change%	8.6	16.9	13.5	64.9
	(EFF-1) x 100	0	-3.3	-8.7	-9.4
	(TECH-1) x 100	6.6	11.8	19.5	40.9
	(KACC-1) x 100	-0.3	2.1	0	20
	(HACC-1) x 100	2.1	5.9	4	7.6
Poland	Productivity change%	25.4	19.4	36.8	109.7
	(EFF-1) x 100	0	0	0	0
	(TECH-1) x 100	10.5	10.4	9.9	29
	(KACC-1) x 100	12.2	6.4	22.3	51.8
	(HACC-1) x 100	1.1	1.6	1.8	7.1
Slovak Republic	Productivity change%	12.7	30.4	16.1	87.4
	(EFF-1) x 100	5.8	4.6	-6.7	3.6
	(TECH-1) x 100	5.6	12.3	19.5	47.1
	(KACC-1) x 100	0	3.8	0	14.6
	(HACC-1) x 100	0.9	7	4.2	7.3
CEE-4	Productivity change%	17.2	20.5	26.7	87.3
	(EFF-1) x 100	0	0	0	0
	(TECH-1) x 100	11.1	4	9.7	25.2
	(KACC-1) x 100	3.7	13.4	13.7	40.6
	(HACC-1) x 100	1.7	2.3	1.6	6.5
Germany	Productivity change%	11.7	18.4	5.3	41.4
	(EFF-1) x 100	0	0	0	0
	(TECH-1) x 100	11.9	0.9	-3.2	8.5
	(KACC-1) x 100	-1.2	16.5	8.4	27.3
	(HACC-1) x 100	1	0.7	0.4	2.3

		1995-2000	2001 - 2007	2008- 2014	1995 - 2014
USA	Productivity change%	11.7	18.4	5.3	41.4
	(EFF-1) x 100	0	0	0	0
	(TECH-1) x 100	11.9	0.9	-3.2	8.5
	(KACC-1) x 100	-1.2	16.5	8.4	27.3
	(HACC-1) x 100	1	0.7	0.4	2.3
Euro area-12	Productivity change%	14.8	10.6	8.4	39.3
	(EFF-1) x 100	0	0	0	0
	(TECH-1) x 100	15.5	-11.2	-5.9	-4.7
	(KACC-1) x 100	-2.1	22.4	13.2	38.4
	(HACC-1) x 100	1.5	1.7	1.7	5.7
OECD	Productivity change%	14.4	11.4	5.9	36.1
	(EFF-1) x 100	0	0	0	0
	(TECH-1) x 100	9.4	-5.7	-3.7	-2.5
	(KACC-1) x 100	2.8	16.2	8.2	32.3
	(HACC-1) x 100	1.6	1.6	1.6	5.5

Note: Productivity change% is calculated as a percentage change in GDP per capita, while Efficiency change, Technological change, Physical capital accumulation and Human capital accumulation are computed as indices.
Period averages computed using the arithmetic mean. The CEE-4, Euro area-12 and OECD averages are the unweighted average.
Source: Author's calculations based on the Penn World Table 9.0 database

2.3 The CEE-4 countries' potential for knowledge-based growth

The non-parametric approach provides a valuable insight into human capital accumulation process in the economy and its contribution to growth. As the theoretical background for this study is the endogenous growth theory, which emphasises the quality of factor inputs and introduces the notion of human capital pointing to the importance of knowledge-based economy, the CEE-4 countries' potential for knowledge-based growth has been examined. A knowledge-based growth path gives a country a greater ability to adapt to technological change and globalization and, thus, the analysis may shed some light on the CEE-4 countries' post-crisis prospects as they try to follow more sustainable and robust growth paths.

Recent studies have pointed to the fact that the countries of Central Eastern Europe have limited potential for knowledge-based TFP growth and a systemic disadvantage relative to the United States, Euro area and Japan (Veugelers (2010), Piech and Radosevic (2006)). In the 1990s the CEE-4 lacked the capability to develop frontier technologies. This implied that technological progress in these countries took place mainly through the adoption and imitation of technologies developed elsewhere.[13] When judged by the level of investment into human capital, the CEE-4

[13] Verspagen (1991) identifies three phases in the technological development process. During the first or pre-catch-up phase, technological progress does not contribute to growth. At best, countries in this phase are laying the foundations for knowledge-based growth, such as a better education system. In the second or actual catch-up phase,

are still lagging behind the Western European countries. Some indicators of educational attainment, such as public spending on education and the share of the workforce with at least secondary education, suggest a favourable situation in Central Eastern Europe. However, other indicators related to innovation input (R&D expenditures relative to GDP)[14] and innovation output (the number of patent applications) put the CEE-4 behind the countries at the technology and science frontier. Study indicates that R&D activity in Central Eastern Europe is concentrated in high-tech sectors (pharmaceuticals, motor vehicles and ICT) and is conducted by a small number of firms. FDI played an important role in sector developments and business R&D growth in the CEE-4 countries. The share of foreign affiliates in total business R&D has expanded significantly in the region. In 2004, foreign affiliates accounted for over 60 per cent of business R&D in Hungary, about 50 per cent in Czech Republic and around 20 per cent in Slovakia, Poland (Veugelers and Mrak, (2009), p. 22). None of the CEE-4 countries have met yet the 3 per cent target of GDP to be invested in R&D, set out by the Lisbon Agenda in 2000 and later succeeded by the Europe 2020 strategy.[15] The gap in terms of investment in R&D remains largest between EU-28 and Slovakia followed by Poland. Within the CEE-4 group, the Czech Republic has the largest gross domestic expenditure on R&D.

With regard to innovation outputs, data on patents point to very low scores for the CEE-4 region which remain significantly below the Euro area average. The gap on patents granted by USPTO (United States Patent and Trademark Office) per million inhabitants is largest and most difficult to close. Among the CEE-4 economies, Hungary and the Czech Republic are the best performer but still are lagging far behind the western countries (Germany, Japan and the United States) (Ibidem, p. 24).

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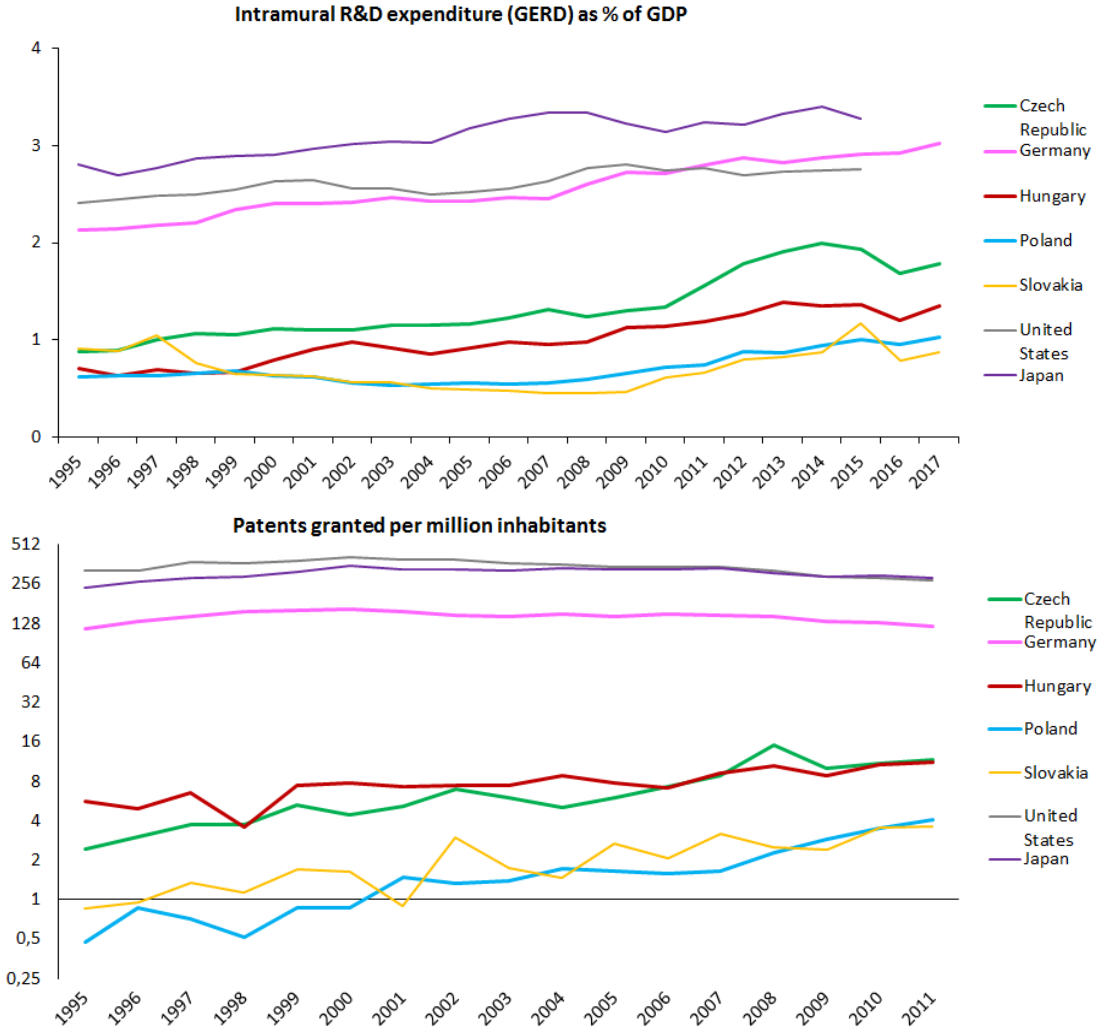
technology absorption gradually increases. Finally, there is a post-catch-up phase during which the country begins to develop the capability to conduct its own research and development. Veugelers (2010).

[14] R&D expenditures include both private expenditures by companies as well as expenditures by public institutes (research institutes and universities).

[15] The aim of the Lisbon strategy was to make the EU "the most competitive and dynamic knowledge-based economy in the world capable of sustainable economic growth with more and better jobs and greater social cohesion", by 2010. Since most of its goals were not achieved by 2010, the Lisbon Agenda has been succeeded by another 10-year strategy. The Europe 2020 strategy emphasises smart, sustainable and inclusive growth as a way to overcome the structural weaknesses in Europe's economy and to improve its competitiveness and productivity. See European Commission (2010).

Figure 2.2 Innovation input and output performance of CEE-4 countries



Source: Eurostat

According to a composite indicator - the Summary Innovation Index[16] - published by the European Commission's European Innovation Scoreboard (EIS) in 2018, all CEE-4 countries fall into a group of Moderate Innovators.[17] This group includes the EU Member States with an innovation performance between 50 per cent and 90 per cent of the EU average. Within the CEE-4 region, the Czech Republic emerged in 2017 relative to that of the EU average in 2010 as the most innovative country (86.8 per cent of the EU average), followed by Hungary

[16] It is obtained by taking an unweighted average of the 27 indicators in total. Four main types of indicators – Framework conditions, Investments, Innovation activities, and Impacts - encompass ten innovation dimensions. See European Commission (2018) for the measurement framework.

[17] The remaining three groups encompass: Innovation Leaders, Strong Innovators, Modest Innovators. Over recent years, the CEE-4 scores have been gradually increasing towards the EU average. In 2008, only the Czech Republic belonged to the group of Moderate Innovators while Hungary, Poland and Slovakia were still classified as Catching-up countries.

(69.3 per cent) and Slovakia (67.6 per cent) with Poland scoring the lowest (56.6 per cent). It should also be noted that between 2017 and 2010 the performance of the Czech Republic and Hungary has declined to that of the EU while for Slovakia and Poland it has improved (European Commission (2018)).

Due to its 'composite' character, the Summary Innovation Index masks interesting underlying trends in the individual innovation subcomponents, which may be of particular relevance for the catching-up process of the CEE-4 region towards the knowledge economy (Veugelers and Mrak, (2009), p. 18). As the CEE-4 countries are not yet sufficiently developed in the area of innovations and score low on these traditional indicators, the analysis has been focused - similar to Veugelers (2010) - on identifying their potential for future knowledge-based growth. Therefore, the CEE-4 countries have been assessed based on their performance in areas that have been identified in the literature as prerequisites for knowledge-based growth. In particular, it has been taken into account how these countries combined technology-acquisition ('technology-buy') and technology-creation ('technology-make') strategies in their progress towards the knowledge-based growth.[18] The evaluation is conducted using survey-based information from the World Economic Forum Global Competitiveness Index 2015-2016 (WEF-GCI)[19] published by the World Economic Forum (World Economic Forum (2015)).

Table 2.3 Technology-buy and/or technology-make: benchmarking of CEE-4 countries

	Germany	Japan	US	Czech Republic	Hungary	Poland	Slovak Republic
Buy-Make	5.6	5.3	5.9	4.8	3.1	3.9	3.8
Firm-level technology absorption	5.7	6.1	6.1	5.0	4.7	4.2	4.8
Company spending on R&D	5.5	5.7	5.6	3.9	2.9	3.1	3.3

Note: BuyMake: companies obtain technology from licensing or imitating foreign companies (=1); by conducting formal research and pioneering their own new products and processes (=7)
Firm technology absorption: companies do not absorb new technologies (=1); aggressively absorb new technologies (=7)
Company spending on R&D: companies do not spend on R&D (=1); spend heavily on R&D (=7)
Source: WEF-GCI 2015-2016

[18] Technology-acquisition (when countries acquire foreign technologies and modify them to make them suitable for domestic circumstances) is more important during the earlier part of this process, whereas technology-creation (which requires a large base of local or foreign customers willing to pay for innovative products, effective intellectual property rights (IPR) legal enforcement, skilled human capital and well-functioning capital markets) becomes more significant when the country has moved closer to the technology frontier. Veugelers (2010).
[19] The WEF indicators are a mixture of hard data and information from the WEF Executive Opinion Survey. While the latter information is subjective, it nevertheless allows the assessment of dimensions for which hard data is lacking. The Global Competitiveness Index rankings of the CEE-4 are presented in Table 2.8A in the Appendix.

The *Buy-Make* indicator measures the country's capacity for innovation, while the *Firm-level technology absorption* - the use of technology-buy strategies. *Company spending on R&D* reflects the allocation of company funds to R&D. R&D activities are an important part of the firm's technology-make strategy because they generate new knowledge, and they are also an important component of the firm's technology-buy strategy as they enhance the ability to understand and apply existing knowledge (Veugelers (2010), p. 6). The lower score on *Buy-Make* for the CEE-4 countries, compared to advanced economies, indicates that technology-buy is still more important component in innovation strategies for the firms in the CEE-4 region. This is also reflected in the higher score on *Firm-level technology absorption* relative to *Company spending on R&D.*

In the next stage of the analysis, the CEE-4 countries have been classified based on their innovation activity. The following criteria have been used: to be in the innovation-active group, countries had to score at least 4 (out of the maximum of 7) on *Firm technology absorption*. In addition, they needed at least a score of 3 on *Company spending on R&D* and a score of 1.5 on *Total R&D expenditure (as a percentage of GDP)*[20]. Within the innovation-active group, the classification into technology-buy and/or technology-make countries is done according to their *Buy-Make* score (Ibidem, p. 7-8).

Table 2.4 Classifying CEE-4 countries by innovation activities

				GDP per capita 2007	GDP per capita 2015
Innovation Weak	**Little BUY-No MAKE**	**I1**	:	:	:
	Some BUY-No MAKE	**I2**	:	:	:
Innovation Active	**Mostly BUY-Little MAKE**	**I3**	:	:	:
	BUY-MAKE	**I4**	Hungary, Poland, Slovakia	78.3	87.2
	BUY-MORE MAKE	**I5**	Czech Republic	100	100

Note: GDP per capita is expressed as a gap relative to maximum GDP per capita in the CEE-4 group. Values are subgroup unweighted averages
Source: Author's calculations based on WEF-GCI 2015-2016 and GGDC Total Economy Database, November 2017

[20] R&D expenditures include both private expenditures by companies as well as expenditures by public institutes (research institutes and universities). Scores for this indicator are presented in Appendix. It is rescaled on a 1-7 scale (1=series minimum; 7=series maximum) in order to align R&D to GDP data with the WEF Executive Opinion Survey results.

The results indicate that all four countries under discussion are innovation active. Nevertheless, they differ within the group with regard to '*Buy-Make*' strategies, with Hungary, Poland and Slovakia reporting less innovation activities compared to the Czech Republic, which emerges as the most active country in innovations and in technology-make strategies. Also, the innovation-activity profile of countries corresponds to the level of their economic development. This finding is in line with the Global Competitiveness Report 2017-2018 published by the World Economic Forum. According to the Report, within the CEE-4 group only the Czech Republic has achieved a status of the innovation-driven economy while Hungary, Poland and Slovakia are still in the transition stage between efficiency-driven and innovation-driven development (World Economic Forum (2017), p. 320).

As three out of four countries under examination are not yet strongly innovation active, their potential for knowledge-based growth has also been assessed taking into account each country's level of development. To examine the prerequisites for knowledge-based growth in the CEE-4, the following indicators proposed by Veugelers (2010) have been applied: (i) those that can be considered as broader framework conditions and (ii) those affecting innovation capacity. Broader framework conditions include the quality of institutions, macro-economic stability and the functioning of markets. The latter include the functioning of financial markets and labor markets, but most importantly the functioning of markets for goods and services. Innovation capacity, particularly important in assessing the potential for knowledge-based development, is divided into (a) factors affecting access to technology, (b) factors affecting capacity to absorb technologies and (c) factors affecting capacity to create technologies. To measure access to technology, the availability of new technologies will be considered, in particular the availability and use of information and communications technology (ICT), and transfer of know-how through FDI. Education and human-resource development is a major factor for determining absorptive capacity. This includes secondary and tertiary enrolment, availability of scientists and engineers, and it corrects for an assessment of the brain-drain problem. It also assesses the quality of education and the extent of on-the-job training (Aghion and Howitt (1998)). The creative capacity prerequisite further includes the quality of the public science infrastructure and the links between this infrastructure and the private sector, IPR protection and venture-capital availability. Table 2.5 presents the benchmark of the CEE-4 on the prerequisites for knowledge-based growth.

Table 2.5 International benchmarking of CEE-4 on composite prerequisites for knowledge-based growth

	Innovation Activity Category	Institutions	Macroeconomic environment	Markets	Technological readiness	Absorptive Capacity	Creative Capacity
Germany		5.22	5.98	4.84	6.01	4.92	4.89
Japan		5.51	3.67	4.85	5.72	4.61	4.85
US		4.82	4.35	4.89	5.85	5.26	5.29
Czech Republic	I5	4.09	5.97	4.87	5.43	4.15	4.04
Hungary	I4	3.52	4.94	4.22	4.60	3.66	3.70
Poland	I4	4.07	5.11	4.35	4.78	3.98	3.62
Slovak Republic	I4	3.43	5.21	4.55	4.64	3.53	3.79
CEE-4 average		3.78	5.31	4.50	4.86	3.83	3.79
CEE-4 st. deviation		0.35	0.46	0.29	0.39	0.29	0.18

Note: Definitions of the pillars are presented in Table 2.8B in the Appendix. Scores on a 1-to-7 scale. Countries are ordered according to their Innovation Activity Category and then by GDP per capita
Source: Author's calculations based on WEF-GCI 2015-2016 and GGDC Total Economy Database, November 2017

The indicators on broad framework conditions as well as on innovation capacity point out to a 'systemic' gap of the CEE-4 in the prerequisites for knowledge-based growth. Four Central Eastern European countries lag behind advanced western economies on almost all composite prerequisites. Particularly, quality of institutions and creative capacity are a common weakness in the CEE-4 region. Within the innovation capacity category, the four countries under study report higher scores for technology access except for the information and communication technologies (ICT) availability and use. ICT are essential for productivity gains and the CEE-4 countries still demonstrate a substantial gap relative to the advanced western economies. On the absorptive capacity prerequisite, the four countries under study face some challenges in the area of the education system quality, which indicates that human capital is not fully capitalised by the CEE-4 as a factor in innovation-driven growth. Also, brain drain - the loss of skilled and highly trained people emigrating to advanced western countries - is a serious problem in these four countries, limiting returns from human resource investment. Central Eastern European countries score lowest on creative capacity. Aside from the brain drain problem, their public research institutions are not well linked to the private sector. The private sector's technological activities are further constrained by ineffective intellectual property rights protection (Veugelers (2010), p. 13-14).

Based on the analysis carried out for the CEE-4 region, the countries have been classified as either having potential for knowledge-based growth in the near future or as falling short on the potential for knowledge-based growth in the near future. Mapping the development profile of countries, as measured by their GDP per capita, to the scores on prerequisites for knowledge-based growth shows that the scoring typically increases with the level of development. The Czech Republic is the only country from the group which has recorded the highest scores in terms of innovation input and output performance and which has been engaged in technology-make strategies. Therefore, it has the most developed innovation profile with potential for knowledge-based growth in the near future. The other three countries, due to some weak spots, fall short on the potential for knowledge-based growth in the near future. The least innovation-active country within the CEE-4 is Hungary which scores below the group on all prerequisites for knowledge-based growth.

2.4 Trade and financial linkages with the European Union

The speed of upgrading through innovation and technology transfer in the CEE-4 countries was reinforced by anchoring their economies to the EU pre-accession and accession arrangements. Therefore, the role of European integration has also been examined in supporting the catching-up process of the region. The CEE-4 countries have pursued a distinctive model of development since the collapse of centrally-planned economies, compared to other emerging countries. Their approach was based on integration with the EU, including deep trade and financial integration, institutional development and labor mobility (European Commission (2009)). This European 'integration model of growth' supported a sustained catch-up in productivity and income levels, although this has been interrupted by the crises in the 2000s. The four countries under discussion showed evidence of a significant qualitative upgrading of their industrial and export structures. In the CEE-4 group growth was accompanied by small and even improving trade balances. Following trade liberalization in the 1990s, openness to international markets increased competitive pressure on domestic firms in emerging market economies of Central Eastern Europe to innovate and to improve their competitive position and, thus, helped boost productivity growth. Therefore, increased trade openness - in large part owing to EU accession – has provided an important impetus to growth in the CEE-4. As the global crisis in 2008 has revealed, future growth in the CEE-4 is unlikely to be supported by the extent of current account deficits and the inflows of credit that were seen in these economies before the

crisis. The four countries under examination went through serious macroeconomic adjustments during the global crisis, which reflected sharp drops in GDP and sudden stops of international financial flows (International Monetary Fund (2010)). Therefore, supporting conditions for the successful development of the tradable sector, in order to invigorate exports and restore growth without incurring external imbalances is vital for the future sustainable convergence of the CEE-4 economies (Becker et al. (2010)). Exports are in fact an important channel for innovation due to firms' exposure to new technologies and foreign competition. Moreover, they expand market size and make it easier for firms to pay for the fixed costs of innovation, hence allowing for a more balanced long-term growth. Particularly important for the CEE-4 countries is in this regard their geographical proximity to Western Europe, in particular to its strongest economy - Germany. The importance of geographical proximity and accessibility of production factors is well illustrated in the cross-border linkages between Germany and Poland. Being closely integrated with Germany - linked by trade and factor movements - Poland experienced a positive boost in the post-transition period. By 1999, a re-unified Germany had become the major trading partner, accounting for 36.1 per cent of Poland's exports and providing 25.2 per cent of its imports.

The experience of the past two decades shows that trade ties between Western Europe and the CEE-4 have increased sharply since the mid-1990s, with the Euro area becoming the premier export market for Central Eastern European countries.

Table 2.6 CEE-4: Direction of Exports, 2007 (% of GDP)

	Euro area	Emerging Europe and CIS	Other	Total
Poland	18	9	6	33
Czech Republic	46	17	7	70
Slovak Republic	40	27	11	78
Hungary	40	20	9	69

Source: IMF Direction of Trade Statistics and IMF World Economic Outlook databases in Bakker and Klingen (2012)

Among the CEE-4, Poland has the closest trade connections with Western Europe, while Hungary is the most intertwined with Central Eastern Europe through trade.[21] While trade ties of Germany are understandably stronger with Western Europe than with Central Eastern Europe, they still remain one of the highest with the CEE region among countries of Western Europe.

[21] Trade interconnectedness between Western Europe and the CEE-4 has been measured by an index that takes into account trade flows relative to economic size, import and export market shares relative to what would be expected on the basis of relative economic sizes, and trade flows in absolute terms. For each country, it has been calculated by averaging that country's interconnectedness with all its partner countries. International Monetary Fund (2011).

Table 2.7 Trade Interconnectedness Index, 2010

	With Western Europe	With Central and Eastern Europe
GERMANY	0,570	0,354
CZECH REPUBLIC	0,192	0,261
HUNGARY	0,150	0,467
POLAND	0,239	0,353
SLOVAKIA	0,142	0,306

Note: **Western Europe**: Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Malta, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom
Central and Eastern Europe: Albania, Bosnia - Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia FYR, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia, Turkey, Ukraine
Source: International Monetary Fund (2011)

The importance of Germany as the main trading partner for the CEE-4 countries is apparent from their sizable bilateral trade with Germany relative to their GDP. For the Czech Republic, trade flows with Germany accounted for almost 41 per cent of its GDP in 2010. Also, bilateral trade flows between three other CEE countries (Hungary, Poland, Slovakia) and Germany remained high (double digits).

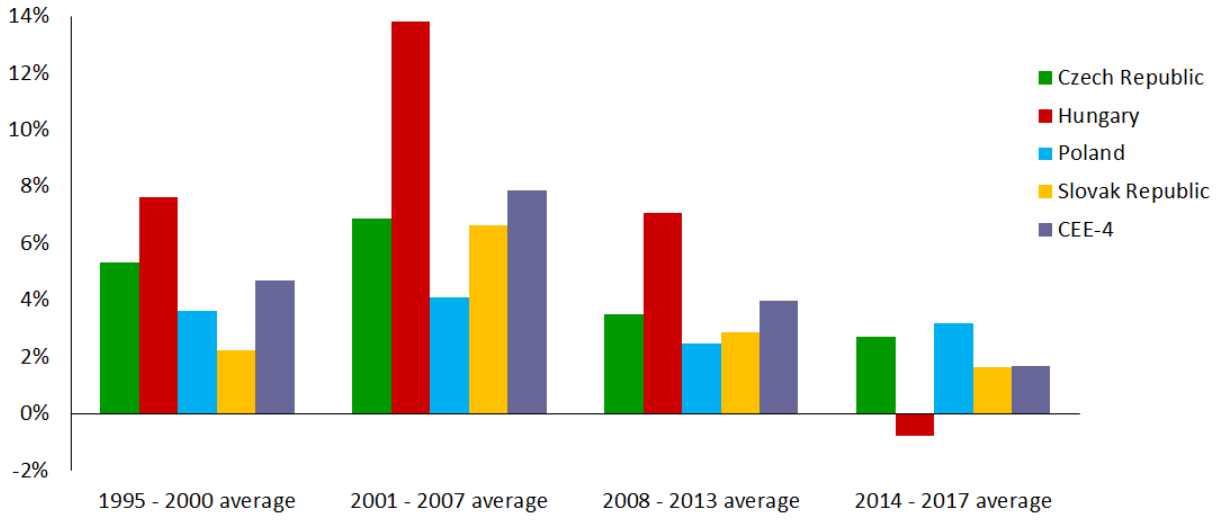
Germany and Central Europe hold a key position in cross-border production chains measured by the size of trade in intermediate goods, with Germany taking the upstream position within the production chain (providing core components rather than specializing in final assembly) and Central Europe occupying more downstream position. Cross-border production between Germany and Central Europe primarily involves transportation equipment and capital goods, which account for more than half of the trade between these countries.[22] The integration of production chains across east and west, often among different plants of the same group has helped many Western European companies to maintain their competitiveness on global markets despite mounting competition.

The EU entry of the CEE-4 in May 2004 has also contributed to further deepening of the region's financial integration with Western Europe which facilitated consumption smoothing through improved access to cross-border finance (Čihák and Fonteyne (2009), p. 5). The CEE-4 countries have been major recipients of capital flows, mainly bank loans followed by foreign direct investment (FDI) while portfolio inflows remained very small with the exception of

[22] For automobiles, which account for 14 per cent of German exports to Central Europe and 18 per cent of Central Europe's exports to Germany, two-thirds of German exports are parts and components, whereas the remaining third is final vehicles. For Central Europe, the composition is about 50 per cent each. Therefore, Germany supplies more intermediate inputs. This pattern of production chains broadly applies to electrical equipment and other machinery as well. International Monetary Fund (2011), p. 90.

Hungary.[23] Until 2003, capital inflows remained moderate and went largely to the tradable sector. From 2003 onward, however, they became important in fueling the credit and demand boom in Central Eastern Europe. These booms contributed to rapid GDP growth, but also led to a sharp increase in current account deficits and an overheating of the economies. Overheating was visible in inflation and wages as well as in rapidly rising housing prices.

Figure 2.3 Net FDI inflows in CEE-4 as a share of GDP (% of GDP)



Source: WDI World Bank

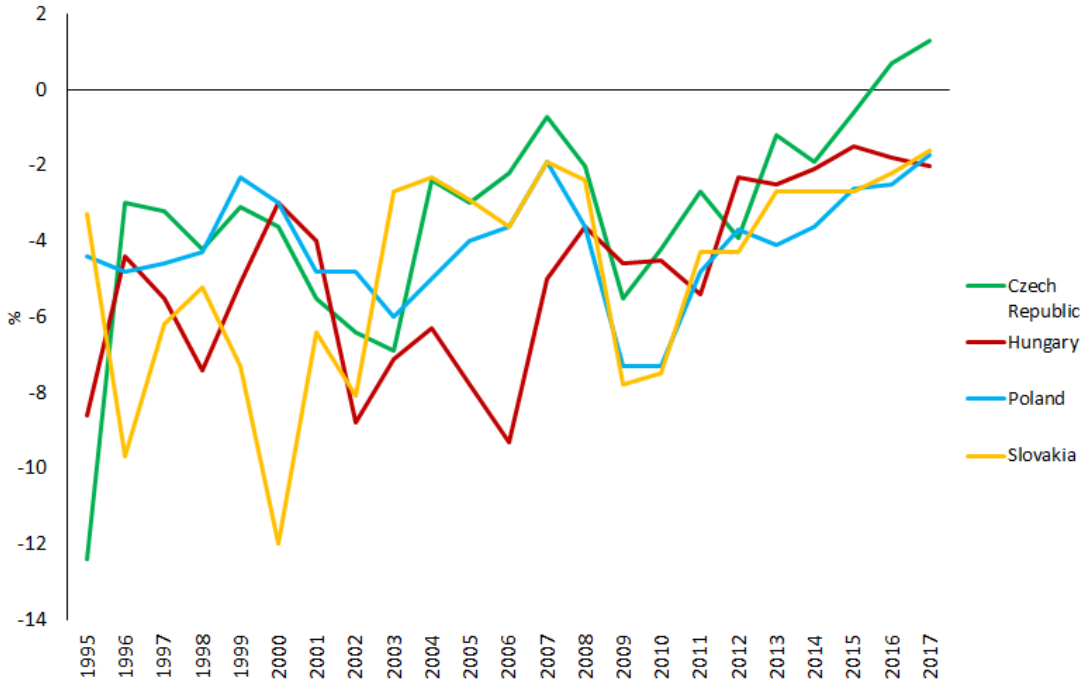
In Central Eastern Europe, Hungary, Poland, Slovakia and the Czech Republic managed, however, to avoid much of the overheating. The Czech Republic and Slovakia also saw a substantial reduction in their current account deficits. In Poland, Slovakia and the Czech Republic domestic demand growth was more moderate (at 4-6 per cent) compared to the Baltics or Bulgaria and Romania, while in Hungary - weak, partly due to the substantial fiscal consolidation that took place in the pre-crisis years. With their flexible exchange rates allowing for appreciation and small interest rate differentials to the Euro area, the economies of Poland, Slovakia and the Czech Republic managed to avoid excessive credit boom. The CEE-4 also did not experience a full-fledged banking crisis when the global financial and economic crisis began in 2007. While the macro prudential and supervisory measures did not manage to slow down

[23] Capital inflows were stimulated by post-transition reforms. With low wages and low capital labor ratios, returns on investment in emerging Europe were very high. Among push factors were also low interest rates in advanced economies and low global risk aversion in the pre-crisis years, as well as the dismantling of barriers to capital flows in the context of EU accession. Rosenberg and Tripák (2008).

credit growth significantly, they did help create large capital and liquidity reserves in the banking system which proved their value when the crisis broke (Bakker and Klingen (2012)).

During the pre-crisis years, public finances in most countries appeared to be improving due to strong revenue performance. Yet, in most countries of Central Eastern Europe, fiscal policy during the boom was procyclical and public expenditures grew rapidly. The notable exception was Hungary, which began a fiscal consolidation program in 2006 to tackle its twin deficit.[24] The fiscal deficit in Hungary felt from -9.4 per cent of GDP in 2006 to -5.1 per cent of GDP in 2007.

Figure 2.4 CEE-4: General Government Overall Balance (% of GDP)



Source: IMF, World Economic Outlook Database, April 2018

However, public debt in Hungary was still at the highest level in emerging Europe – in 2007 it amounted to 66 per cent of GDP. Since about one-third of that debt was held by foreign investors and the Hungarian debt market was very liquid, Hungary was very vulnerable to sudden changes in international risk aversions. There were also significant vulnerabilities in private sector balance sheets. With domestic interest rates well above the interest rates for euro- and Swiss franc-denominated loans, the share of foreign currency loans in private sector credit had

[24] Rosenberg and Sierhej (2007) find that EU-related transfers also contributed to procyclical fiscal policy in the new EU member states.

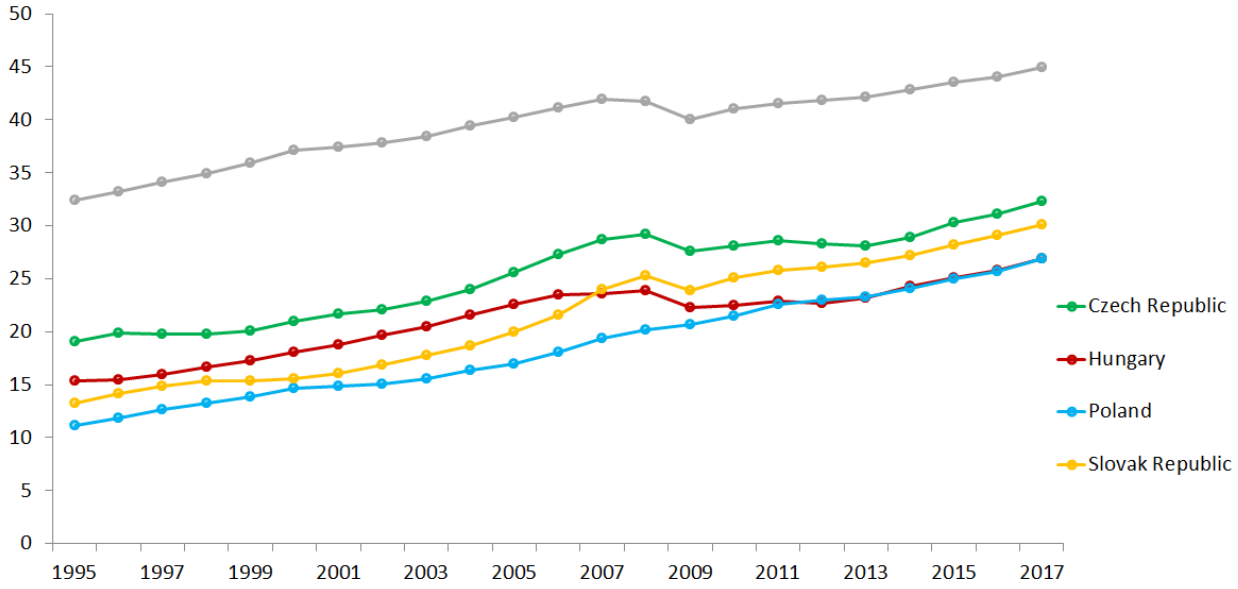
increased sharply. Therefore, Hungary together with the Baltics were the first countries which felt the impact of the global crisis and the turmoil on financial markets before the default of Lehman Brothers in September 2008 (Bakker and Klingen (2012), p. 36-37).

In mid-September 2008, the global crisis spilled over to emerging Europe with full force through financial and trade channels. Global financial markets froze and international trade collapsed, affecting the whole region severely. As the capital flows from Western European banks into the region dropped sharply, exchange rates came under pressure. In Hungary, Poland and the Czech Republic, exchange rates fell sharply even though central banks attempted to slow the pace of depreciation. Due to declining asset prices, the balance sheets of households, enterprises and financial institutions deteriorated, and undermined significantly growth. In 2009, all CEE-4 countries experienced a severe contraction in GDP. Hungary (-6.6 per cent), Slovakia (-5.4 per cent) and the Czech Republic (-4.8 per cent) recorded negative growth rates, with Poland (2.8 per cent) managing to avoid a recession. Hungary with highest vulnerabilities (public and external debt) within the CEE-4 group recorded the largest drop in GDP. Growth in the Euro area - Central Eastern Europe's most important trading partner - turned positive in the second half of 2009, boosted by the revival of the world trade and global manufacturing output. The economic recovery in Western Europe benefited the CEE-4 exports. Also, falling global interest rates provided direct relief for many borrowers in the region as large share of local mortgages in the CEE-4 were denominated in euros, Swiss francs and yen, and as local currency depreciation increased the debt service burden in local currency terms. Year-over-year GDP growth in emerging Europe returned to positive figures in 2010 (0.7 per cent in Hungary, 3.6 per cent in Poland, 5 per cent in Slovakia and 2.3 per cent in the Czech Republic). By 2011, the recovery expanded from exports to domestic demand, and nearly all the crisis-affected countries of Central Eastern Europe returned to positive growth (Ibidem, p. 39).

Undoubtedly, the CEE-4 countries have made significant progress since the 1990s, but the vulnerabilities and structural problems exposed by the global crisis in 2007 are still present in their economies indicating by no means the end of their 'transition'. Many challenges still lie ahead and the real convergence process, defined as the convergence of per capita income levels between the CEE-4 and the Euro area, is far from over (Ibidem, p. 64, 82). Although living standards have improved considerably since the beginning of the transition period and the Central Eastern European countries have been able to increase their relative level of per capita income

vis-à-vis the Euro area in recent years, the gaps still remain quite large. Before the crisis, per capita income levels in the CEE-4 region in 2005 constituted on average about 56 per cent of the Euro area level in purchasing power parity (PPP). There were also some differences among the CEE-4 countries, with the Czech Republic achieving the highest level of income per capita (67.3 per cent), followed by Hungary (59.2 per cent) and Slovakia (52.1 per cent), with Poland having the lowest income of 45.1 per cent.[25]

Figure 2.5 GDP (PPP) per capita, 1990-2017, CEE-4 countries and advanced economies



Source: IMF World Economic Outlook, April 2018

2.5 Conclusion

The Sollow growth accounting approach provides evidence that capital and TFP contributions were the most significant growth inputs in the CEE-4 region during the years 1995-2014. At the country level, capital contribution was most distinct in the case of Hungary, while TFP - in Poland. For the CEE-4 region the contributions of those two factor inputs - capital and TFP - were higher in the growth process compared to advanced western economies. Furthermore, the four emerging CEE economies experienced a strong decline in labor input in the examined time frame. This effect was most significant in the Czech Republic. Before the global crisis, all CEE-4 countries experienced significantly higher growth rates than Western European countries which can be explained with a convergence process known in the literature as

[25] Arratibel et al. (2007), p. 8. According to the International Monetary Fund's classification, Slovakia and the Czech Republic have already obtained the status of advanced economies.

'β-convergence'.[26] As lower-income and lower-productivity economies, the CEE-4 benefited from technology transfer which was the main driver behind the catching-up process.

The results obtained from the non-parametric approach, while more detailed, remain in line with the main findings of the Solow growth accounting. Based on the quadripartite decomposition, it appears that productivity growth has been driven in the CEE-4 countries primarily by technological change and physical capital accumulation. Contribution to productivity growth from efficiency change has been negative in Hungary and the Czech Republic, neutral in Poland and only slightly positive in Slovakia. Higher efficiency in the use of inputs can be achieved by investing in "knowledge," which can be defined as investment in R&D and higher education. With regard to the growth contributions from human capital accumulation, the CEE-4 countries recorded positive yet single-digit figures over the span of two decades.

Subsequently, potential for knowledge-based growth in the CEE-4 region has also been examined as the CEE-4 countries are not yet sufficiently developed in the area of innovations and score low on these traditional indicators. Mapping the development profile of countries, as measured by their GDP per capita, to the scores on prerequisites for knowledge-based growth shows that the scoring typically increases with the level of development. The Czech Republic is the only country from the group which has recorded the highest scores in terms of innovation input and output performance and which has been engaged in technology-make strategies. Therefore, it has the most developed innovation profile with potential for knowledge-based growth in the near future. The other three countries, due to some weak spots, fall short on the potential for knowledge-based growth in the near future. The least innovation-active country within the CEE-4 appears to be Hungary which scores below the group on all prerequisites for knowledge-based growth.

Finally, the role of European integration has also been examined in supporting the catching-up process of the region by examining trade and financial linkages of the CEE-4 with the European Union. The importance of Germany as the main trading partner for the CEE-4 countries is apparent from their sizable bilateral trade with Germany relative to their GDP. For the Czech Republic, trade flows with Germany accounted for almost 41 per cent of its GDP in 2010. Also, bilateral trade flows between three other CEE countries (Hungary, Poland, Slovakia)

[26] It stems from the convergence hypothesis of the neoclassical growth literature and it occurs when poorer economies grow faster than rich ones.

and Germany remained high (double digits). The EU entry of the CEE-4 in May 2004 has also contributed to further deepening of the region's financial integration with Western Europe which facilitated consumption smoothing through improved access to cross-border finance.

2.6 Appendix

Solow growth accounting

The Solow decomposition is built, as in Neuhaus (2006), on the standard neoclassical production function, where output of period t, Y_t, is produced by a combination of capital K_t and labor L_t while A_t ("Total Factor Productivity", TFP) represents the level of "technology" in the economy:

$$Y_t = A_t F(K_t, L_t) \tag{2.3}$$

The growth rate of output is derived by taking logarithms on both sides and then by differentiating the production function with respect to time (for simplicity the time indices were dropped)[27]:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \left(\frac{AF_K K}{Y}\right) \cdot \frac{\dot{K}}{K} + \left(\frac{AF_L L}{Y}\right) \cdot \frac{\dot{L}}{L} \tag{2.4}$$

F_K and F_L denote the partial derivatives of $F(\cdot)$ with respect to K and L. Hence the growth rate of output consists of the growth rate of TFP and the weighted average of the growth rates of the two input factors. Under the assumption of perfect competition on the factor markets both factors are paid their marginal product, $AF_K = r$ and $AF_L = w$, then $AF_K K/Y$ is the share of capital income and $AF_L L/Y$ is the share of labor income in total income. Since the Inada conditions hold, the production function exhibits constant returns to scale and the two income shares sum to 1.[28] Let $(1 - \alpha)$ be the capital income share and we can rewrite the equation (2.4) as:

$$\dot{Y}/Y = \dot{A}/A + (1 - \alpha) \cdot \dot{K}/K + \alpha \cdot \dot{L}/L \tag{2.5}$$

TFP and its change over time is computed as the residual of equation (3). For the empirical analysis, the equation needs to be reformulated in discrete time. As annual data and

[27] A dot on a variable indicates changes of the variable over time.

[28] In the neoclassical production function the Inada conditions hold: the production function (i) exhibits positive and diminishing marginal products with respect to each input, (ii) has constant returns to scale and (iii) the marginal product of each input goes to infinity if the input approaches 0 and goes to 0 if the input approaches infinity. Inada (1963).

most quantities are given as "end of period" figures, modifying Thörnqvist's approach, the growth figures in period t+1 are associated with the income shares in period t+1:

$$\frac{Y_{t+1} - Y_t}{Y_t} = \left(\frac{A_{t+1} - A_t}{A_t}\right) + (1 - \alpha_{t+1})\left(\frac{K_{t+1} - K_t}{K_t}\right) + \alpha_{t+1}\,\frac{L_{t+1} - L_t}{L_t} \qquad (2.6)$$

This is the standard model of Solow growth accounting, which allows for variations in the factor income shares α_{t+1} and $(1 - \alpha_{t+1})$, as it is built on the standard neoclassical production function.[29]

Non-parametric growth accounting

The production-frontier approach is a non-parametric estimation of the technology through enveloping the data by the smallest convex free disposable cone of the observed data on inputs and outputs, the upper boundary of which would be the observed "best-practice" world production frontier. Technology contains as in Henderson and Russell (2005) four macroeconomic variables: aggregate output and three aggregate inputs - labor, physical capital, and human capital. Let $\langle Y_{nt}, L_{nt}, K_{nt}, H_{nt}\rangle$, $t = 1, ..., T; n = 1, ..., N$ represent T observations on these four variables for each of the N countries. Following macroeconomic literature, it is assumed that human capital enters the technology as a multiplicative augmentation of physical labor input, so that our NT observations are $\langle Y_{nt}, \hat{L}_{nt}, K_{nt}\rangle$, $t = 1, ..., T; n = 1, ..., N$; where $\hat{L}_{nt} = H_{nt}L_{nt}$ is the amount of labor input measured in efficiency units in country n at time t.

The approach to constructing the frontier follows Kumar and Russell (2002) methodology, which does not preclude implosion of the frontier over time. The technology set is estimated under the assumption of constant returns to scale:

$$\begin{aligned} T_t = \{\langle Y_t, \hat{L}_t, K_t\rangle : & \textstyle\sum_{n=1}^{N} z_{nt}\, K_{nt} \le K_t, \\ & \textstyle\sum_{n=1}^{N} z_{nt}\, \hat{L}_{nt} \le \hat{L}_t, \\ & \textstyle\sum_{n=1}^{N} z_{nt}\, Y_{nt} \ge Y_t, \\ & z_{nt} \ge 0, \mathrm{n} = 1, ..., \mathrm{N}\} \end{aligned} \qquad (2.7)$$

where z_{nt}, $n=1, ..., N$ are *Intensity Variables*, one for every activity and for time period. These variables are non-negative real numbers and they indicate to what extent a particular activity is involved in turning inputs into outputs.

[29] This, however, would not be valid under the Cobb-Douglas production function, which is a special case of the standard neoclassical production function. The Cobb-Douglas production function assumes an exact relationship between output and inputs, i.e. $F(K_t, L_t) = K_t^{1-\alpha}L^{\alpha}$, and assumes constant factor income shares, α and (1 – α). Neuhaus (2006), p. 11.

The Farrel (output-based) efficiency index for a country n at time t is defined as in Henderson and Russell (2005) by:

$$\mathrm{E}\,(Y_{nt}, \hat{L}_{nt}, K_{nt}) = \min\{\lambda \mid \langle \tfrac{Y_{nt}}{\lambda}, \hat{L}_{nt}, K_{nt}\rangle \in T_t\} \tag{2.8}$$

This index is the inverse of the maximal proportional amount that output Y_{nt} can be expanded while remaining technologically feasible, given the technology T_t and the input quantities $\hat{L}_{nt}$ and K_{nt}. It is less than or equal to 1 and takes the value of 1 if and only if the *nt* observation is on the period-*t* production frontier.

In the quadripartite decomposition, the growth of output per efficiency unit of labor is broken down into the components: technological change, efficiency change, capital deepening (increases in the capital–labor ratio) and human capital accumulation. Letting b and c stand for the base period and the current period, respectively, by definition, potential (production-frontier) outputs per efficiency unit of labor in the two periods are given by $\bar{y}_b(\hat{k}_b) = \frac{\hat{y}_b}{e_b}$ and $\bar{y}_c\,(\hat{k}_c) = \frac{\hat{y}_c}{e_c}$, where e_b and e_c are the values of the efficiency indexes in the respective periods. Therefore:

$$\frac{\hat{y}_c}{\hat{y}_b} = \frac{e_c\,\bar{y}_c\,(\hat{k}_c)}{e_b \bar{y}_b\,(\hat{k}_b)} \tag{2.9}$$

Now it can be defined $\tilde{k}_c = \frac{K_c}{L_c\ H_b}$ (the ratio of capital to labor measured in efficiency units under the counterfactual assumption that human capital had not changed from its base period level) and $\tilde{k}_b = \frac{K_b}{L_b H_c}$ (the counterfactual capital/efficiency–labor ratio in the base period if human capital were equal to its current-period level). Let $\bar{y}_b\,(\tilde{k}_c)$ and $\bar{y}_c\,(\tilde{k}_b)$ denote potential output per efficiency unit of labor at $\tilde{k}_c$ and $\tilde{k}_b$ using the base-period and current period technologies, respectively.

The growth of productivity, $y_t = \frac{Y_t}{L_t}$, can be decomposed into the growth of output per efficiency unit of labor and the growth of human capital, as follows:

$$\frac{y_c}{y_b} = \frac{H_c}{H_b} \cdot \frac{\hat{y}_c}{\hat{y}_b} \tag{2.10}$$

As technological change is not Hicks neutral, the decomposition of productivity changes is path dependent and does not yield the same results. Following Caves et al. (1982) and Färe et al. (1994) and more recent research by Kumar and Russell (2002), Henderson and Russell (2005) adopt the "Fischer ideal" decomposition, based on geometric averages of the two measures of the

effects of technological change and physical and human capital accumulation, obtained by multiplying top and bottom of (2.9) by $[\bar{y}_b(\hat{k}_c)\ \bar{y}_b\ (\tilde{k}_c)]^{1/2}[\bar{y}_c(\hat{k}_b)\ \bar{y}_c(\tilde{k}_b)]^{1/2}$,

$$\frac{y_c}{y_b} = \text{EFF} \times (TECH^b \cdot TECH^c)^{1/2} \times (KACC^b \cdot KACC^c)^{-1/2} \times (HACC^b)^{-1} \times HACC^c =: \text{EFF} \times \text{TECH} \times \text{KACC} \times \text{HACC} \quad (2.11)$$

Knowledge-based growth

Table 2.8A Global Competitiveness Index 2015–2016 rankings

SUBINDEXES OVERALL INDEX BASIC REQUIREMENTS EFFICIENCY ENHANCERS INNOVATION AND SOPHISTICATION FACTORS

Country	Rank	Score	Rank	Score	Rank	Score	Rank	Score
Czech Republic	31	4.69	31	5.27	26	4.78	32	4.14
Hungary	63	4.25	59	4.67	49	4.31	69	3.57
Poland	41	4.49	44	4.91	34	4.64	57	3.70
Slovak Republic	67	4.22	56	4.73	47	4.34	59	3.68

Note: Ranks out of 140 economies and scores measured on a 1-to-7 scale
Source: WEF-GCI 2015-2016

Table 2.8B Key prerequisites for knowledge-based growth

Composite Factors	Individual Factors	
Institutions	**Institutions**	Public institutions (75%; property rights, ethics and corruption, undue influence, public-sector performance, security and Private institutions (25%; corporate ethics, accountability)
Macroeconomic environment	**Macroeconomic environment**	Government budget balance, national savings rate, inflation, government debt, country credit rating
Markets	**Goods market efficiency**	Competition (67%; domestic competition and foreign competition) and Quality of demand conditions (33%)
	Labor market efficiency	Flexibility (50%) and Efficient use of talent (50%)
	Financial market development	Efficiency (50%; financial market sophistication, financing through local equity market, ease of access to loans, venture capital availability, restriction on capital flows, strength of investor protection) and Trustworthiness and confidence (50%; soundness of banks, regulation of securities exchanges, legal rights index)
	Market size	Domestic market size (75%) and Foreign market size (25%)
	Intensity of local competition*	Competition in local market is 1=limited in most industries and price-cutting is rate, 7= intense and market leadership changes over time
	Proclivity to trade*	Imports and exports as % of GDP (hard data) rescaled to 1-7
	Prevalence of FDI*	Foreign ownership of companies in your country is (1 = rare, limited to minority stakes, and often prohibited in key sectors, 7 = prevalent and encouraged)
	Days to start Business*	Days required to start a business (Doing Business World Bank) rescaled to 1-7
Technological readiness	**Technological readiness**	Technological adoption (50%) and ICT use (50%)

Composite Factors	Individual Factors	
Absorptive capacity	**Secondary enrolment**	The ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education, hard data rescaled to 1-7
	Quality of the educational system	The educational system in your country (1 = does not meet the needs of a competitive economy, 7 = meets the needs of a competitive economy)
	Extent of staff training	The general approach to human resources in your country is to invest =1 little in training and development, 7=heavily to attract, train and retain staff
	Brain drain	Your country retain and attract talented people (1 = no, the best and brightest normally leave to pursue opportunities in other countries; 7 = yes, there are many opportunities for talented people within the country)
	Tertiary education enrollment	The ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education, hard data rescaled to 1-7
Creative capacity	**Brain drain**	Your country retain and attract talented people (1 = no, the best and brightest normally leave to pursue opportunities in other countries; 7 = yes, there are many opportunities for talented people within the country)
	Tertiary education enrollment	The ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education, hard data rescaled to 1-7
	Availability of scientists and engineers	Scientists and engineers in your country are (1 = nonexistent or rare, 7 = widely available)
	Quality of scientific research institutions	Scientific research institutions in your country (e.g. university laboratories, government laboratories) are (1 = nonexistent, 7 = the best in their fields internationally)
	University-industry collaboration in R&D	Companies' collaboration with local universities in R&D in your country is (1 = minimal or nonexistent, 7 = intensive and ongoing)
	Intellectual property protection	Intellectual property protection and anticounterfeiting measures in your country are (1 = weak and not enforced, 7 = strong and enforced)
	Venture capital availability	How easy is it in your country for entrepreneurs with innovative but risky projects to find venture capital? (1 = impossible, 7 = very easy)

Note: * These variables are also represented in the composite Goods market efficiency, but are nevertheless also introduced separately to increase their weight in the Markets pillar
Source: WEF-GCI 2015-2016, Veugelers (2010)

Chapter 3

Financial Interlinkages of the CEE-4 countries with Western Europe

3.1 Historical overview

The transition from a centrally planned to a market economy has profoundly transformed the financial sector of Central Eastern European (CEE) countries since the second half of the 1990s (De Haas and van Lelyveld (2004), p. 125). In the early years of transformation their financial systems remained underdeveloped, affected by the legacies of central planning and the structural and macroeconomic turbulences stemming from the reform programs (EBRD (1998), p. vii). Due to a key role financial institutions and markets play in the allocation of resources, it was thus essential to build a sound market-oriented financial system during the transition process from a command to a market economy. Financial markets provide a platform for intermediation between savers of funds and entrepreneurs seeking external finance for their investment projects. They also help to establish hard budget constraints on enterprises by evaluating projects for risk and return. Moreover, financial institutions, banks in particular, provide ways of making monetary payments that substantially lower the cost of market transactions (EBRD (1998), p. 92). Since the CEE-4 economies inherited underdeveloped financial institutions and markets from the era of central planning, the major challenge of the 1990s remained to build from scratch market-oriented financial systems. In a command economy, the role of financial system was little more than a bookkeeping mechanism for recording the governments' decisions about the allocation of resources between different enterprises and sectors. Securities and capital markets were absent, since the authorities created no marketable financial instruments (Ibidem).

The dominant role in the financial system of the CEE-4 region played the banking sector. Under central planning, banks played essentially a passive role. Credit institutions were not used for financial intermediation between savers and investors but carried out payment transactions and provided credits to state-owned enterprises (SOEs) for the execution of central production plans (Schmieding (1993); Bonin et al. (2013)). The socialist monobank system was a "one-tier" banking system generally consisting of three basic functional units: the state bank, foreign trade banks and state savings banks. The state bank itself (Státní banka Československá, Magyar

Nemzeti Bank, Narodowy Bank Polski) was in charge of overall control of the payment and credit system and was the sole provider of loans to SOEs. Loans could be granted for short-term periods to cover current expenditures and inventories and for long-term investments. Sometimes the latter function was carried out by a separate entity – a state investment or development bank (Barisitz (2008), p. 8). In a centrally planned economy, enterprises depended financially on the monetary authority and were obliged to transfer any 'profits'[30] to the state budget. The foreign trade bank specialised in foreign currency transactions, external debt management and the financing of foreign trade, which was a state monopoly. Money was not convertible and every exchange was strictly regulated by the state. As a rule, foreign currency savings by the population were prohibited or restricted, except in Poland. The last functional unit of a "one-tier" banking system was the state savings bank which functioned as a recipient for cash savings of the population.[31] In the command economy, there was no demand for banks to perform the tasks of financial intermediaries and no need for the prudential regulation and supervision of financial activities - beyond the direct control of accounting activities by the government (EBRD (1998), p. 92).

The functioning of state-owned enterprises was not based on the concept of market solvency or profitability, and financial discipline was replaced by the objective of central plan fulfillment (Barkovsky (1998), p. 73). As a result, the command economies of Central and Eastern Europe were characterized by systemic inefficiencies and soft budget constraints, as well as by corresponding absence of the institution of bankruptcy and liquidation (Montias (1994), p. 13). Therefore, building a market-oriented financial system based on the old institutions was a challenging task. State banks' portfolios were dominated by non-performing loans and their personnel did not have skills required in market economies. At the same time, the state inherited little capacity from a centrally planned economy to regulate effectively a decentralised banking system. Given the problems of restructuring the banking sector, it seemed reasonable to base financial systems in the transition economies on securities markets instead. However, in the case of the CEE-4 countries such an approach was unrealistic due to the aforementioned dominance of banking in their financial system (EBRD (1998), p. 92). Moreover, in almost all market

[30] Surpluses of planned revenues over planned costs.
[31] In some socialist countries, like GDR (East Germany) and Czechoslovakia, the state savings banks offered special savings plans or consumer credits for the purchase of durables, particularly cars and apartments. Barisitz (2008), p. 8, 13.

economies banks have played a dominant role among financial institutions in the early stages of their development. The legal and institutional preconditions for efficiently functioning securities markets are more demanding, and historically such markets developed relatively late. The formerly planned CEE-4 economies lacked the prerequisites for the development of active and efficient securities markets, such as prudential regulations and company and investor-protection laws. Also significant for the choice of state banks as the foundation of the nascent financial systems in the CEE countries was their proximity to Germany and the rest of Western Europe, where financial systems are based largely on banks. In western banking systems, banks not only grant commercial loans but also invest in equities and other securities. They hence provide a wide range of financial services to enterprises and dominate the financial sectors (Ibidem).

The accumulation of systemic inefficiencies in the centrally planned CEE-4 economies, combined with unstable macroeconomic environment of the first years of transition (recession with high inflation and unemployment, output falls), led to the first wave of banking reforms in the region. In contrast to the former Soviet Union's "bottom-up" (entry-friendly) approach to financial reform, Central and Eastern European countries reformed their financial systems "top down". State-owned commercial banks were emerging from the mono-bank system, which were then restructured and eventually prepared for privatisation (Ibidem, p. 97). The first banking reform phase of the early 1990s was based on the abolition of mono-bank system with its central credit and cash plans, accompanied by price liberalization and the creation of a two-tier banking system with the admission of private domestic banks and independent commercial-bank activities (so called "surface privatization") (Barisitz (2008), p. 16). The emergence of new, often undercapitalized, banks placed a burden on an underdeveloped regulatory structure. Non-performing loans were a serious problem in all transition economies, due partly to the inherited legacies but also to continuing lending practices (Bonin et al. (2013), p. 10). Macroeconomic instability of the mid 1990s with high inflationary pressure, combined with unsolved structural and institutional problems and accumulating bad loans led to repeated banking crises in Central Eastern Europe. In response to those crises, the second wave of reforms was implemented which included stricter banking regulation and tighter supervision. The reform efforts contributed to establishing hard budget constraints in the banking sector (Barisitz (2008), p. 80). Also, privatization and bank restructuring efforts had been intensified in the second half of the 1990s. Hungary, Poland, Slovakia and the Czech Republic turned out to be among the swiftest banking

reformers of the CEE region. In order to attract banking know-how, strengthen corporate governance and capital, Hungary and Poland opted for "in-depth privatization" by selling or re-selling credit institutions to foreign investors while Slovakia and the Czech Republic chose a more gradual approach. Within a few years, foreign-owned banks acquired some of the CEE-4 countries' largest credit institutions and took over a large share of the banking sector in the region.[32] These acquisitions, mostly by Western European investors, fundamentally changed banking in the CEE-4 region and structurally linked it with EU banks (Barisitz (2008), p. 80). Western European banks with saturated home markets were particularly attracted to the region due to its further financial deepening and high profit margins (de Haas (2014), p. 272). The newly founded private banks were either joint ventures, foreign bank branches or subsidiaries, and helped to modernize and create competition in the CEE-4 banking sector (Barisitz (2008), p. 20). Bank privatisation in transition economies brought not only the benefits to privatised banks but also to the depositors and borrowers through the improvement of banking services.[33] Most importantly, foreign bank entry in emerging markets was hoped to provide access to foreign savings, increase investments and speed up the economic convergence of the CEE-4 region with Western Europe (De Haas (2014), p. 273).

The chapter is composed of four sections. Section 2 presents the impact of the global financial crisis and European debt crisis on capital flows into the CEE-4 region. It also provides an in-depth empirical analysis of factors affecting credit growth in the Central Eastern and South-Eastern Europe (CESEE) by taking into account home-host country macroeconomic conditions and parent-subsidiary banks' characteristics and health. Section 3 concludes.

3.2 Capital flows into the CEE-4 countries

3.2.1. Introduction

The development of a well-functioning financial system, in particular banking sector, was essential to attract long-term foreign investors and capital to the CEE-4 region. Investment - one of the long-term growth factors determined by the neo-classical growth theory - has been a key

[32] In Hungary, foreign ownership of the country's credit institutions increased from 42 per cent of total assets in 1995 to 67 per cent in 2000; in Poland it increased swiftly from 4 per cent in 1995 to 70 per cent in 2000 while in the Czech Republic - to 72 per cent in 2000 compared to 16 per cent in 1995. In Slovakia, the share of foreign-owned banks in total banking assets rose only from 33 per cent in 1995 to 39 per cent in 1997 and felt to 28 per cent by 2000. Barisitz (2008), p. 24-37.

[33] Foreign investors turned out to be decisive in improving the quality of banking intermediation in the CEE economies. Rugraff (2000), p. 114.

component of the convergence process in the region during the transition process. As the gross saving rate in Central Eastern Europe has been the lowest among emerging-market regions, the CEE-4 economies had to rely on large-scale import of saving (capital inflows) to fill in the savings-investment gap (Dabrowski (2014)). Since the transformation, foreign investors increasingly appreciated the region's growth potential which had its reflection in the acceleration of capital flows into the CEE-4 economies (EBRD (1998), p. 88). In the transition economies domestic savings were low while financing cost high. At the same time the physical and human capital stock in the CEE-4 region was large by the standards of middle-income countries, yet it was inefficiently employed and partially obsolete. Therefore, the potential productivity and, thus, profitability of new capital in the CEE-4 countries was likely to be higher than in more advanced economies (Ibidem, p. 77). In accordance with the economic theory, capital flowed downhill - from richer Western European countries to the less developed CEE-4 region - driven by higher marginal returns to capital in emerging CEE-4 economies (Gill and Raiser (2012), p. 132).

The transition process significantly affected both the volume and composition of external capital flows. Until 1993, these flows were driven by Western governments' determination to make the transition process irreversible, coupled with a "wait-and-see" approach by private investors. Due to uncertain macroeconomic and political environment as well as sharp relative prices' adjustment, both countries' and commercial risks were perceived to be very high. Only when macroeconomic conditions improved, private capital (equity investment, commercial bank lending) began to enter the market, first tentatively, then with greater speed (EBRD (1998), p. 78). Since 1995 there has been a gradual easing of restrictions on capital movements by the Central and Eastern European countries, shaped to a large extent by the process of accession to the European Union where free movement of capital is a legal requirement (Hermann and Winkler (2009), p. 20). Within the CEE-4 group, capital flows were most liberalised in the Czech Republic followed by Hungary, Poland and Slovakia. A large portion of private flows constituted foreign direct investment (FDI) which increased gradually in line with the region's transformation progress. Other flows of finance, especially short-term, were catching up with the reform process and began to grow significantly since the second half of the 1990s. These included commercial loans, international bond issues by governments and corporates from the region, and portfolio investments into the regional equity and money markets (EBRD (1998), p. 77, 84).

Foreign capital benefited the CEE-4 countries by helping to fill the savings-investment gap, by lowering financing costs, increasing the competition and speeding up economic convergence with Western Europe (EBRD (1998), p. 77). FDI facilitated transfer of technology, know-how and skills, and helped local enterprises to obtain management expertise (Krkoska (2001)). Commercial bank lending complemented FDI in providing access to trade and project finance, introducing superior financial technologies and exposing private counterparties to financial discipline. In emerging markets, foreign banks also generated positive spillovers to domestic banks which copied the risk management methods and marketing know-how of their new foreign competitors (De Haas (2014), p. 273). International bond issues from the CEE-4 region became, in turn, a means of raising revenues for governments as a consequence of underdeveloped domestic securities markets, and often at more favourable terms. Also, international equity issues exposed corporates across the region to international disclosure and accounting standards and, thus, contributed to improving corporate governance (EBRD (1998), p. 85). Therefore, capital inflows were supporting the region's economic development and growth potential since the transition.

Evidence from currency or balance of payments crises in other emerging market economies (East Asian crisis of 1997, Russian crisis of 1998) suggests that financial contagion resulted from a combination of weak macroeconomic fundamentals and the accumulation of short-term domestic and/or foreign liabilities (Kaminski et al. (1997)). Capital inflows accompanied by incomplete structural reforms contain considerable risks and may magnify underlying macroeconomic weaknesses. Also, capital inflows may themselves be a cause of rising external imbalances as the global financial crisis of 2008 has showed. If they are used to cover excessive public borrowing or a rapid increase in consumption, rather than laying the basis for productivity improvements and future export earnings, they may exacerbate the underlying imbalances and eventually result in a loss of investor confidence (EBRD (1998), p. 86-87).

The risk of sudden exit of foreign investors has been more muted with regard to the CEE-4 countries which integrated themselves into the international capital markets yet managed to establish the foundations for macroeconomic and financial stability. Foreign investors appreciated the region's growth potential, a sound investment climate, including stable macroeconomic conditions, and reliable and non-distortionary government policies (EBRD (1998), p. 77, 86). Another important factor which distinguished emerging CEE-4 economies

from other regions such as East Asia and Latin America was their accession process to the European Union. The future EU membership and related to this a requirement of harmonisation with EU legislation contributed to deepening financial integration of the CEE-4 countries with Western Europe. A distinctive feature of this financial integration process was the dominance of Western European banks in the CEE-4 region. This interconnectedness has made capital flows more durable during financial turmoils and allowed to mitigate their effects on emerging European economies (Gill and Raiser (2012), p. 65, 132). However, as the global financial crisis of 2008 and sovereign debt crisis in the Euro area have shown, the risk capital flows reversal was still present in the CEE-4 region.

3.2.2. The impact of the global financial crisis and European debt crisis on capital flows into the CEE-4 region

3.2.2.1 Accumulation of vulnerabilities in the CEE-4 countries in the pre-crisis years

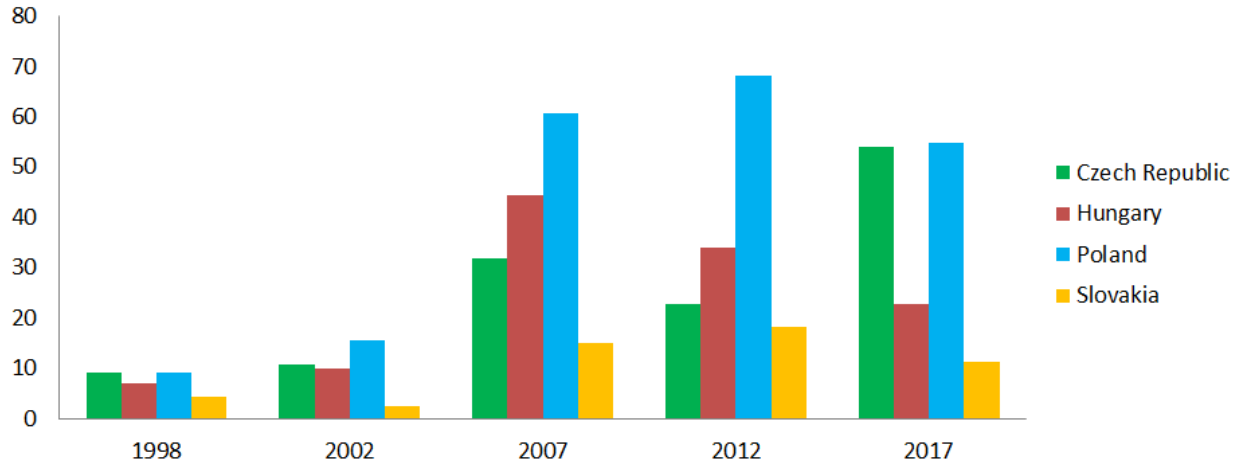
Financial integration – in the form of large capital inflows and an increasing presence of foreign banks – has been an integral part of the "development model" of transition CEE-4 countries with Western Europe in the years preceding the global crisis of 2008 (EBRD (2009), p. 60). It has shaped to a large extent the convergence process which allowed the CEE-4 economies to enter a growth path driven by domestic demand financed substantially by foreign savings (Hermann and Winkler (2009)). The CEE-4 countries reduced barriers to capital account transactions as part of the accession process to the EU, where free movement of capital is a legal requirement. While integration process was a powerful driver of growth, it also created potential channels for contagion by contributing to financial and macroeconomic vulnerabilities, particularly between 2005 and 2007. They coincided with a period of high global output growth, rising commodity prices and abundant liquidity which resulted in large-scale capital inflows to the CEE-4 economies. As a result, excessive reliance on short-term capital inflows increased external macroeconomic vulnerabilities of the region in the case of adverse shocks (EBRD (2009), Dabrowski (2014)).

In the years preceding the worst global financial crisis since the Great Depression of the 1930s, the Central Eastern Europe attracted an unprecedented amount of $515 billion in net private capital inflows, the second highest amount only to emerging Asia. Approximately 47 per cent of cumulative net inflows accounted for FDI, 7 per cent - for net portfolio

investments and about 46 per cent - for cross-border loans to banks and the non-bank sector.[34] Opportunities created by the accession to the European Union contributed to a large extent to large private capital flows into the CEE-4 region (Mihaljek (2008)). Between 2002 and 2007, total net FDI inflows accounted for a cumulative $128.1 billion with Poland ($54.9 billion) and the Czech Republic ($38.7 billion) receiving the largest amount of net FDI inflows.[35] Net portfolio investment reached in total $26.8 billion in the CEE-4 region over the same period. Portfolio inflows have been less stable compared to FDI inflows and subject to reversals. Since the CEE-4 financial sector is mainly bank-based and cross-border bank flows are considered a less stable form of foreign financing than FDI, the most important for macro-financial stability analysis is cross-border credit.

The CEE-4 region attracted also a significant amount of cross-border bank inflows. Between 2002 and 2007, external (cross-border) loans of BIS reporting banks to Hungary, Poland, Slovakia and the Czech Republic increased about four times, from $38.7 billion to $152 billion at the end of 2007.[36]

Figure 3.1 External loans of BIS reporting banks vis-a-vis all sectors in CEE-4 countries



Note: External loans of BIS reporting banks vis-à-vis Hungary, Poland, Slovakia and the Czech Republic; end of period
Source: BIS locational banking statistics

[34] 'Other investment' in the balance of payments statistics. (Mihaljek (2010), p. 6).
[35] See Table 3.2 in the Appendix.
[36] Data on external loans of BIS reporting banks vis-à-vis banks and the non-bank sector in the CEE-4 countries are presented in Table 3.3 in the Appendix.

Banks and the non-bank sector in the CEE-4 region received approximately equal proportions of these large inflows. This constituted a sharp contrast to other emerging regions. In Latin America gross cross-border bank inflows decreased between 2002 and 2007, by 4 per cent of the region's GDP, while in emerging Asia they increased by just 2 per cent of GDP (Mihaljek (2010), p. 7-8). In the CEE-4 countries cross-border inflows of bank lending acquired boom proportions during this period and exposed the region to the risk of a sudden reversal in lending flows. While a portion of these bank inflows went directly to end-borrowers, a substantial part was intermediated by local banks. Subsidiaries of Western European banking groups, aiming to expand their market shares across the emerging CEE-4 region, had access to ample funding from parent banks.[37] Foreign banks were attracted by the growth prospects in the CEE-4 economies as interest margins were generally higher in those countries than in their saturated home markets in Western Europe.[38] The share of foreign ownership in banking system assets (through both branches and subsidiaries) increased significantly since the transition. In Hungary, Slovakia and the Czech Republic above 80 per cent of the banking sector was foreign-owned in 2006 while in Poland this figure was lower at 74 per cent (EBRD (2006, 2009)). Foreign ownership was spread relatively evenly over a number of foreign banks in Hungary, Poland and Slovakia while in the Czech Republic a small number of large foreign banks owned high market shares.[39] The availability of foreign finance in the CEE-4 region allowed banks to rapidly expand their loan portfolios (EBRD (2009), p. 42).

In many cases, the credit boom in the CEE-4 countries allowed households and corporations to access credit markets for the first time. A large share of bank inflows was lent to local households for the purchase of housing and consumer durables. Foreign bank subsidiaries and branches contributed to the rapid deepening of local mortgage markets in the CEE-4 region, building on the mortgage lending experience in their home countries (De Haas, et al. (2010)). Many housing loans, almost all of them in Hungary and Poland in 2007–2008, were denominated in foreign currencies (mostly in euro or Swiss francs) or were linked to local currency exchange

[37] In contrast, domestically-owned banks relied on borrowing in the international bond and syndicated loan markets. EBRD (2009), p. 42.

[38] Due to low capital-labor ratios, the emerging CEE-4 economies had higher expected rates of return to capital, making investment more attractive. Gill and Raiser (2012), p. 135.

[39] Economic research shows that when the financial health of a parent bank deteriorates, it tends to have negative implications for the ability of its foreign subsidiaries to expand local lending. This, in turn, has important implications for macroeconomic stability of host countries where foreign banks from a single home country own substantial market shares. EBRD (2006), p. 29.

rates vis-a-vis major international currencies (such as Japanese yen). Also firms, which were often active in non-tradable sectors (real estate or wholesale and retail trade), borrowed in foreign currencies to take advantage of lower foreign exchange interest rates and local currency appreciation.[40] Since many of these borrowers were households or firms that did not generate foreign exchange income, they (and indirectly the banks that had extended the loans) became vulnerable to exchange rate depreciations. Within the CEE-4 group, the share of foreign exchange loans in the banking system increased most significantly in Hungary during the boom years of 2005-2007 (EBRD (2009), p. 44). Gross external debt rose to 45-55 per cent of GDP in Poland, Slovakia and the Czech Republic, and up to 97 per cent of GDP in Hungary. As exports of goods and services expanded much more slowly than foreign borrowing, significant currency mismatches developed at the aggregate level and on many private sector balance sheets in the CEE-4 region (Mihaljek (2010), p. 8). In summary, large capital flows into the CEE-4 economies which fueled domestic demand led to fast growth but also unsustainable investment, consumption and asset price inflation. Real estate booms and foreign exchange lending had exposed many banking systems to asset price declines and currency depreciations. The macroeconomic counterpart to large capital inflows was a sharp increase in current account deficits and a related private sector external indebtedness. Since high current account deficits and rising private external debt had created large external financing needs, the region thus became vulnerable to a sudden reversal in lending flows (EBRD (2009), p. 44, 46).

Among the CEE-4 countries, Hungary was the most vulnerable to a sudden reversal in capital inflows on the eve of the global crisis in 2007 (Table 3.1). It had the highest current account deficit of 7.1 per cent of GDP with its FDI coverage below 50 per cent, making Hungary more vulnerable to capital flight (EBRD (2006), p. 20). The country also faced a chronically high fiscal deficit of –5 per cent of GDP with cross-border loans accounting for 47 per cent of its domestic credit (Mihaljek (2010), p. 8). Hungary's persistent fiscal difficulties (the highest deficit in the region since 2002) have been reflected in declining investor interest and downgrades by the main rating agencies. Moreover, since many loans in Hungary, and virtually all housing loans, were denominated in foreign currencies, gross external debt rose to 96.8 per cent of GDP in 2007

[40] Real exchange rates have been appreciating in the CEE-4 region since 2001 as a result of strong capital inflows and the boost to productivity in the tradable sector relative to the non-tradable sector, i.e. the Balassa-Samuelson effect. Since wages are determined in the tradable goods sector in line with productivity, hence unit labor costs in the economy as a whole increase, causing a real appreciation. Gill and Raiser (2012), p. 141.

and was the highest in the region. During 2006, the Hungarian forint but also the Polish zloty and the Slovak koruna have come under pressure in foreign exchange markets. The currencies' deprecations reflected a generally more critical assessment by foreign investors of vulnerabilities in the CEE-4 region's economies (EBRD (2006), p. 20-21).

Table 3.1 External vulnerability indicators of CEE-4 countries, 2007

	Current account (% of GDP)	Gross external debt (% of GDP)	Fiscal deficit (% of GDP)	Cross-border loans[a] (% of Domestic credit)
Czech Republic	-4.7%	41.4%	-0.7%	40.7%
Hungary	-7.1%	96.8%	-5.0%	47.4%
Poland	-6.4%	54.8%	-1.9%	24.1%
Slovakia	-5.4%	52.7%	-1.9%	42.5%

Note: a. Consolidated cross-border claims of BIS reporting banks (ultimate risk basis) vis-à-vis Hungary, Poland, Slovakia and the Czech Republic; in all currencies; amounts outstanding
Source: BIS consolidated banking statistics, EBRD, Eurostat, WDI World Bank

Compared to the Asian crisis of 1996, the nature of pre-crisis vulnerabilities in the CEE-4 transition countries was different with macroeconomic imbalances more prominent than financial sector problems. Credit-fueled domestic demand booms led to large current account deficits in Central Eastern Europe, which by 2007 have culminated in stocks of gross external debt in excess of East Asian countries. Financial sector vulnerabilities were, however, less severe in the CEE-4 region, which entered the crisis with smaller and more foreign-owned banking systems than those of East Asia in the mid-1990s (EBRD (2009), p. 13). Furthermore, capital inflows were less prone to sudden reversal as they were largely intermediated in the CEE-4 economies through subsidiaries and branches of foreign banks with long-term interests in the region.[41] Foreign parent banks have set credit growth targets for their subsidiaries in the CEE-4 region and have provided substantial capital and liquidity support through internal funding (EBRD (2006), p. 59).

3.2.2.2 The impact of the crises on cross-border capital flows

In July and August of 2007, the crisis in the US mortgage sector spilled over to asset-backed securities, such as collateralised debt obligations. As investors' confidence in financial institutions holding such assets was badly damaged, many financial institutions in the United States and in Europe faced the liquidity problem. Risk premiums rose sharply, affecting interbank borrowing. At the outset of the crisis, the CEE-4 region was clearly in an exposed position due to

[41] EBRD (2009, p. 10). Empirical studies indicate a positive effect of the foreign banks' entry on the efficiency and stability of the banking systems in transition countries. See De Haas and Naaborg (2006), Bonin et al. (2005).

aforementioned accumulated macro-financial vulnerabilities. Therefore, a global shock at the center of international financial system was expected to quickly spill over to the CEE-4 economies. Yet, the first year of the global crisis (July 2007 - September 2008) left the region largely unaffected (EBRD (2009), p. 3, 8). When credit flows to other emerging markets begun to contract in the first half of 2008, the external loans of BIS reporting banks to the CEE-4 countries were still high and accounted for about 90 per cent of the total for 2007.[42] This ability of the region to weather the financial crisis for over a year was at least partly attributed to the high share of foreign bank ownership in the CEE-4 economies. Before the crisis, Western European banks have significantly expanded their operations in the CEE-4 region with their market shares in 2006 ranging from 97 per cent of total banking sector assets in Slovakia to 74 per cent in Poland (EBRD (2006, 2009)). Taking into account their long-term interests in the region, foreign banks provided some insulation from reversals in cross-border bank flows and the drop in domestic financing (Mihaljek (2010)).

The turmoil in the region began in the third quarter of 2008 when disruptions in international credit markets turned into a full-scale global financial crisis after the collapse of Lehman Brothers in September 2008. Due to sharp reductions in interbank liquidity, multinational banking groups operating in emerging Europe began to deleverage both at home and abroad. Major international banks reduce their loans to banks in the CEE-4 region by $4.6 billion. Countries initially affected most were those with more liquid banking systems[43] and included Poland and the Czech Republic. Cross-border loans to the Polish banks were reduced in the fourth quarter of 2008 by $4.5 billion[44] while in the Czech Republic by $2.2 billion. Moreover, the last quarter of 2008 saw a further reduction in cross-border loans to the non-bank sector in Hungary and Poland (by $3.2 billion totally) (Mihaljek (2010), p. 15). Foreign financing in the CEE-4 region deteriorated further in 2009. Cross-border loans to banks and the non-bank sector in CEE-4 countries fell by $11.5 billion between the first and third quarter of 2009, compared to an increase of $47.3 billion over the same period a year before. This decrease of external loans was much larger for banks compared to the non-bank sector. The largest contraction took place in the first quarter of 2009 and it was concentrated in two countries

[42] See Table 3.4A in the Appendix.
[43] Measured by the ratio of private sector loans to total deposits in the domestic banking system (short-and long-term). Mihaljek (2010), p. 15.
[44] As Poland was the only EU economy with positive growth in the first quarter of 2009, parent banks increased their positions vis-à-vis Polish banks in the second quarter of 2009. Ibidem.

with liquid banking systems: Slovakia and the Czech Republic. Cross-border loans to banks in Slovakia decreased by as much as $9.1 billion and in the Czech Republic by $2.5 billion. This provides an indication that some parent banks might have temporarily used these markets to maintain liquidity at home during the most severe phase of the crisis or to reallocate funds to their subsidiaries in other CEE countries which were harder affected by the crisis. In Central Eastern Europe, Poland, Slovakia and the Czech Republic were in fact those with the strongest fundamentals before the crisis. Lower inflows into these countries were caused not by the loss of confidence in their policies or banking systems, but by aforementioned decisions of the parent banks. Banks in Poland and Slovakia and the Czech Republic had sufficient liquid funds at their disposal - partly because of low loan-to-deposit ratios, partly because credit demand had fallen.[45] These 'reverse flows' from subsidiaries in the CEE-4 region to parent banks in Western Europe finds its confirmation in bilateral data of the Bank for International Settlements (BIS) locational banking statistics. The figures show that the largest reductions in cross-border loans to the Czech Republic and Slovakia took place from those Western European countries where banks faced major difficulties in maintaining liquidity in the fourth quarter of 2008 and the first quarter of 2009.[46]

In response to growing concerns about the withdrawal of international banks from emerging Europe, a formal coordination mechanism was put in place in January 2009 - the 'Vienna Initiative (VI)' (European Bank Coordination Initiative).[47] The creation and development of the "Vienna Initiative" have been driven by the European Investment Bank (EIB), the European Commission (EC), the European Bank for Reconstruction and Development (EBRD), the IMF and the World Bank. Soon the VI meetings were joined by the ministries of finance, central banks and bank regulators from multinational banks' home and host countries. The aim of the "Vienna Initiative" was to provide a forum for decision making and coordination in order to

[45] Some of the decrease in cross-border loans to banks in Slovakia reflected bank accounting and risk management changes associated with an introduction of the euro in January 2009. Ibidem, p. 17.

[46] Ibidem, p. 18-19. De Haas et al. (2014) using an international dataset find that foreign bank subsidiaries in emerging Europe reduced lending earlier and faster than domestic banks during the whole crisis period. Likewise, Popov and Udell (2012) show that western banks propagated the crisis to emerging Europe, and that the severity of shock transmission depended on the strength of parent banks' balance sheets. On the other hand, Navaretti et al. (2010) stress that multinational banks were a stabilizing force in emerging Europe as they displayed a relatively stable loan-to-deposit ratio. However, their analysis focuses on the years 2007-2008 while much of the reduction in lending took place in 2009 and after.

[47] The Austrian government and various multinational banks with high exposures to emerging Europe began informal discussions already in the fall of 2008. http://vienna-initiative.com.

prevent a systemic banking crisis in Central, Eastern and South-Eastern Europe (CESEE). Work focused on avoiding withdrawal from the region by cross-border banking groups. The EIB, the World Bank and the EBRD also acted to maintain a flow of credit into these economies. Within the context of the VI, the EBRD, the EIB and the World Bank Group launched in February 2009 a 'Joint IFI Action Plan' in support of banking systems and lending to the real economy in Central and Eastern Europe (CEE). The plan was integrated with the IMF and European Union macro-financial support programs to Bosnia and Herzegovina, Hungary, Latvia, Serbia, and Romania. In return for financial support under the Joint IFI Action Plan, a number of Western European banks signed country-specific commitment letters in which they pledged to continue to provide credit to firms and households in the CEE countries. Parent banks also confirmed they would keep subsidiaries sufficiently capitalized and provide them with necessary liquidity.[48] Since a large-scale, uncoordinated withdrawal of banks from the CEE region did not materialize, the Vienna Initiative is viewed as a successful coordination mechanism.[49]

In the second quarter of 2009 there was a small increase in cross-border financing ($890 million) which was viewed as a sign that later in the year cross-border loans would start growing. While there was a small reduction in cross-border loans by $515 million during the third quarter of 2009, the last quarter of 2009 saw finally an increase in loans to the CEE-4 countries by almost $2 billion. This might have been an indication that parent banks have started restructuring their operations in the region after the worst phase of the crisis was over by October 2009 (Mihaljek (2010), p. 17-18). Nevertheless, as the situation began to slowly stabilise in the region towards the end of 2009, negative repercussions of the global financial crisis became apparent in the Eurozone economies. In the course of 2010, a new crisis erupted in Europe - the sovereign debt crisis. Several peripheral Eurozone countries (Greece, Ireland, Portugal, Spain and Cyprus) experienced the collapse of financial institutions, high government debt and rapidly rising bond yield spreads in government securities. Due to their exposure to, and dependence on, the Eurozone economy through trade and financial linkages, the CEE-4 countries remained particularly vulnerable to prolonged economic slow-down and financial market turmoil in the

[48] De Haas et al. (2014), p. 326-327.
[49] De Haas et al. (2012, 2014) and Cetorelli and Goldberg (2011) provide empirical evidence on the stabilising impact of the Vienna Initiative.

Euro area.[50] Since Eurozone-based banks represented large shares of banking systems in emerging Europe, the risk of transmitting funding shocks to the CEE-4 region became acute (EBRD (2011), p. 27). The debt crisis intensified in the second half 2011 with the subsequent slowdown of economic growth across Europe - a key demand-side driver of funding from foreign banks. Cross-border bank financing for the CEE-4 countries turned already negative in the second quarter of 2011 when the external loans of BIS reporting banks to the region fell by $8.4 billion.[51] This reversal in flows was followed by a sharp decrease in the third and fourth quarter of 2011. Cross-border loans to banks and to the non-bank sector in the CEE-4 region fell between July and December 2011 by $19.4 billion. Major international banks reduced their external positions most substantially vis-à-vis Poland ($12.3 billion) and Hungary ($8.1billion). The combination of intensifying funding strains in the markets, regulatory and market pressures to improve capitalization, and weak credit demand prompted Western European banking groups to resume the withdrawal of funding from the region.[52] The ECB's long term refinancing operations (LTROs)[53] in December 2011 and February 2012 helped to ease somewhat liquidity strains for Western European banking groups at the beginning of 2012 ($1.5 billion) (Vienna Initiative (2012), p. 2). Moreover, to limit the negative consequences of uncoordinated national policy responses to the European sovereign debt crisis and to avoid a sudden deleveraging by cross-border bank groups in emerging Europe, the 'Vienna Initiative 2.0' was launched in January 2012. The aim of this coordination platform was to monitor and address the regional challenges of financial intermediation from multiple angles.[54] Specifically, the objectives of the Vienna Initiative 2.0 were to: avoid disorderly deleveraging, ensure that potential cross-border financial stability issues were resolved and that policy action (notably in the supervisory area) were taken in the collective interest.[55] While this new coordination effort focused again on the short-term task of preventing an uncoordinated and excessive decline in bank lending in the

[50] According to the EBRD's 'exposure index', Hungary and Slovakia were most vulnerable to shock in the Eurozone economy. The index is calculated as the sum of three components (expressed as a share of GDP): exports to the Eurozone, FDI from the Eurozone, and an approximation of the share of short-term external debt financing by the Eurozone. EBRD (2011), p. 27-28.
[51] See Table 3.4B in the Appendix.
[52] The BIS empirical study shows that the second wave of deleveraging that started in mid-2011 was predominately driven by home factors of Euro area banks. As these cross-border banking groups came under pressure they curtailed the supply of funding for their CEE-4 subsidiaries. Avdjiev et al. (2012).
[53] The aim of the LTRO was to provide liquidity for Eurozone banks holding illiquid assets, and thus prevent interbank lending from grinding to a halt.
[54] EIB (2013).
[55] http://vienna-initiative.com

region, it also aimed at moving the cross-border banking model of emerging Europe in the direction of a new more balanced banking model that relies to a greater extend on local sources of funding.[56]

Since the second quarter of 2012 funding withdrawals of western banks again took place, however at a more moderate pace than in the second half of 2011. While the acute phase of the Eurozone debt crisis was coming to an end in 2012, decreasing figures reflected an underlying process of rebalancing the funding of western banks' subsidiaries toward local sources via retail deposits.[57] Cumulative exposure reductions over the last three quarters of 2012 were most significant for Hungary ($8.4 billion), followed by Poland ($7 billion). Using a broader measure of capital flows - the financial account of the balance of payments, which includes FDI and portfolio investment (bonds and equities) - net capital flows were still positive in 2008 in the CEE region (EBRD (2009), p. 11). The CEE-4 countries recorded total net FDI inflows of $17.7 billion and portfolio outflows of $5 billion. However, as the crisis began to spread through financial markets leading to a significant tightening of external financing conditions, total net FDI inflows to the CEE-4 region in 2009 fell by almost half compared to the year before. Hungary had the lowest net FDI inflows with Slovakia recording almost $1 billion FDI outflows. The crisis triggered a sharp reduction in FDI and portfolio flows, which were expected to remain below pre-crisis levels in the medium term (EBRD (2013), p. 11). Economic recovery which began in 2010 led to foreign investors' regained interest in the region through mergers and privatisations, and the relocation of production facilities to the CEE-4 countries (Mihaljek (2010), p. 17). However, the sovereign debt crisis which intensified in 2011 and the CEE-4 region's exposure to the Eurozone (captured by the EBRD's 'exposure index') were the main factors behind depressed FDI and portfolio inflows in the following years. A prolonged weakness in Western European economies caused capital outflows in the CEE-4 countries. Particularly strong was the portfolio investment reversal between 2010 and 2011 - from net inflows of $38.4 billion to net outflows of $26.5 billion. In 2012, FDI decreased further in the region coinciding with a drop in outward investment from the Euro area.

[56] De Haas et al. (2012).

[57] Vienna Initiative (2013), p. 5. While this was expected to raise funding costs, it was also aimed at making subsidiaries operating in the CEE-4 countries less exposed to liquidity shocks in the future when cross-border funding markets did not function normally. Greater reliance on domestic funding was also hoped to encourage more prudent lending by subsidiaries. Mihaljek (2010), p. 24-25.

Economic developments in the CEE-4 region since the Eurozone sovereign debt crisis showed a strong dependence of the CEE-4 economies on the single currency area. Exports, capital flows and bank financing have all been affected by the Euro area turmoil, resulting in lower overall growth in the region (EBRD (2012), p. 38).

3.2.2.3 Empirical analysis of cross-border credit flows

The "Vienna Initiative 2.0" - via the Deleveraging and Credit Monitor - has been monitoring the international banks deleveraging process and related constraints to lending activity since the second quarter of 2012. In this context, the EIB has developed the CESEE Bank Lending Survey (BLS), administered on a semi-annual basis since October 2012. The results of the survey were discussed and approved by the Vienna Initiative Steering Committee and initially presented at an aggregate level in the Vienna Initiative Deleveraging and Credit Monitoring Report. The survey investigates the strategies of international banks active in the CESEE region as well as the market conditions and market expectations perceived by the local subsidiaries/local banks. It also aims at disentangling the effects of demand and supply factors on credit developments, in addition to the impact of national and international elements on demand and supply conditions. The EIB's survey complements domestic bank lending surveys by adding comparability across countries and by exploring the unique features of the parent/subsidiary nexus in the region.[58]

The main contribution of this chapter is an in-depth empirical study of factors affecting credit growth in the CESEE region in the years 2012-2016 following the global financial crisis. For this purpose, an extensive database has been built based on the answers from the EIB's Bank Lending Surveys.[59] This new database allows to account for cross-border effects, namely home-host country macroeconomic conditions and parent-subsidiary banks' characteristics and health, while controlling systematically for the answers from the BLS. It covers the period of 2012-2016 and obtains the questionnaire responses of the major international banks present in 16 CESEE countries[60] and their subsidiaries operating in the region. Therefore, it allows to analyse cross-border banking behavior, as well as the effects of the macroeconomic environment and parent

[58] EIB (2013).
[59] At the time of conducting the study, only data up to 2016 was available. Data have been utilised in the Economics Department of the EIB and no confidential and bank specific information was or will be disseminated outside the EIB's Economics Department.
[60] Albania, Bosnia-Herzegovina, Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Kosovo, Macedonia, Montenegro, Poland, Romania, Serbia, Slovakia, Slovenia and Ukraine.

banks' characteristics on their subsidiaries' capacity to extend credit to households and firms in the CESEE region.

The BLS database contains the answers of 16 international banks active in the CESEE region, interviewed at group level, and 85 local banks/local subsidiaries of these groups interviewed at single-entity level. It is highly representative of international groups active in CESEE and also of local market conditions, as it relates on average to 50 per cent of the local banking assets. The EIB's Questionnaire survey has been carried out on a semi-annual basis (September-October and March-April) since October 2012 and is divided into two parts: Part A addressed to the parent banks (international groups) and Part B addressed to the domestic/subsidiary banks. The questions have a backward- and a forward-looking component, covering the last six months as well as the expectations for the following six months.[61] For the purpose of the study, in order to examine the effects of past developments on the current loan growth, only the questions referring to the last six months were considered. In the first step of the analysis, the questions referring to the overall activities of the banks were taken into account. At a later stage, more detailed questions on a disaggregated level were also considered.

Since the subsidiary banks participating in the CESEE Bank Lending Survey respond to the questions anonymously, it was necessary, at an initial stage of the analysis, to determine the names of the subsidiaries. It was done on the basis of available information on the parent banks' names and the country of operation of a given subsidiary. In this way, the bank's name and the ultimate owner (parent) of each subsidiary bank were defined. In addition, for identification purposes, a unique bank number in the Stata database was assigned to each individual bank (parents and subsidiaries) based on retrieved bank BvD IDs.

Data on the balance sheet position of the banks was retrieved primarily from Bureau van Dijk's Orbis Bank Focus (former Bankscope)[62] and Orbis Company Information across the Globe. Additional missing financial indicators were complemented with information contained in annual financial statements published on banks' websites and in the S&P Capital IQ database. In order to obtain the longest uniform time series possible, data was retrieved at all available consolidation levels. Orbis databases derive data from financial statements and distinguish between the types of accounts. The two major categories are Consolidated and Unconsolidated

[61] The content of the questions is presented in the CESEE Bank Lending Surveys published by the EIB.
[62] As of January 1, 2017, the Bankscope database is no longer available and its closest alternative is Orbis Bank Focus.

statements. Within each of them there are three subcategories: two subcategories referring to whether or not the (un)consolidated accounts have other (un)consolidated companions of the controlled subsidiaries or branches (C2/C1 and U2/U1), and one referring to additional (un)consolidated statements (C*/U*). In order to compute the missing data points, preference was given to consolidated accounts. Instead of, however, simple replacements the growth rates were calculated and applied to the time series with breaks imputing forward and backward the missing values. When this procedure was still generating some missing values, the availability of a complete time series based on unconsolidated accounts was checked and data gaps were filled in with unconsolidated statements, with the growth rates of unconsolidated statements (U2/U1, possibly U*) being applied. This procedure allows one to remove the effect of accounting rules from the data series. If only replacements had been done this could have introduced in the data a level shift which can only be attributed to differences in accounting rules and not to actual changes in banks' balance sheets.

Due to the fact that the semi-annual surveys carried out in October-March cover in the CESEE BLS database the last quarter of the previous year and the first quarter of the following year, in order to aggregate data at annual level, it was necessary, first of all, to disaggregate it into quarterly data. For this purpose, the answer values for a given half of the year were duplicated and assigned to two quarters of the given year(s). In the BLS, a three-level symmetric Likert scale has been applied with the value "-1" assigned to a "decrease/tighten/negative effect", "0" assigned to "no change/remained unchanged/maintain the same level" and "1" assigned to "increase/ease/positive effect".[63] Since the answers in the Questionnaire take the values -1, 0 and 1, the summation method across the quarters does not allow for a sufficient differentiation between the answers provided by individual banks. Therefore, this method was discarded and the simple arithmetic averages of answer values were adopted as more appropriate. In the next step, the data was formatted for the purpose of calculating the arithmetic averages of answer values, using the pivot tables.[64] After the disaggregation procedure, it was possible to calculate the averages on an annual basis. In addition, for comparison purposes, four databases with more rounded values of the calculated arithmetic averages were created for the last and next six months with regard to the surveyed parent banks and their subsidiaries. For this purpose, the average

[63] The above answer values have been assigned irrespective of the intensity of a change, so for example for "marginally/somewhat or substantially decreased" the value mapped is still "-1".
[64] The list of constructed variables has been provided in Tables 3.5A and 3.5B in the Appendix.

values above 0.5 were rounded to 1, those below 0.5 - to 0.5, while the averages greater than -0.5 were approximated to -0.5 and those smaller than -0.5 - to -1. Various rounded values depending on the ranges adopted were assigned to the variable, ensuring at the same time that empty fields were omitted. Based on the calculated arithmetic averages, eight separate BLS databases were constructed: two databases containing the averages referring to the last six months for the surveyed parent banks and their subsidiaries, and two databases referring to the next six months for the parent banks and the subsidiaries. Moreover, the above-mentioned four databases with the rounded values of arithmetic averages were also created.

At the final stage, all eight BLS databases were merged in Stata with two Orbis databases containing the balance sheet indicators of the parent banks and their subsidiaries. Firstly, the databases (including the rounded averages) referring to the last and next six months for the surveyed subsidiaries were merged with the database specifying their balance sheet positions by the subsidiary bank number "banknr_sub" and "year". The same procedure was applied to the parent banks whose databases were merged by the parent bank number "banknr_par" and "year". Lastly, these two databases for the subsidiaries and the parent banks were combined into one final database in Stata by the parent bank number "banknr_par" and "year". In this way, the final database for the econometric analysis was created, which contains the BLS dataset as well as the data on the balance sheet position of the surveyed banks.

The aim of the study was to investigate the determinants of credit growth in the CESEE region accounting for cross-border effects while controlling systematically for the answers from the EIB's Bank Lending Survey. For this purpose, linear panel data models in a four-year perspective (from 2012 to 2015) were employed. With regard to the macroeconomic and financial factors of host and home countries, real GDP growth, the inflation rate and interest rates were employed. Real GDP growth controls for aggregate economic growth. It was expected to exert a positive impact on credit growth in the CESEE region. The inflation rate was measured as the year-to-year change of the consumer price index. A rise in prices was assumed to increase the demand for loans and also to inflate the value of banks' loan portfolios. The inflation rate, however, may also reflect instability thus forcing banks to ration credit (Boyd et al. (2001)). Therefore, the effect of this variable can run in both directions. Finally, interest rates were also controlled for. High interest rates can create an incentive for banks to lend more while reducing clients' demand for credit. Moreover, high interest rates may reflect high funding costs. The latter

may, in turn, signal higher costs of inter-bank arrangements and intra-group lending, thus limiting credit growth. As a result, the sign of this variable can also be positive or negative depending on the prevailing effect.

As already mentioned above, only the questions referring to the last six months have been considered. The first part of the survey investigates international banks' short- and long-term (beyond 12 months) strategies in the region, access to funding, the profitability of operations and deleveraging at the global and group level. The second part of the survey is addressed to domestic banks/subsidiaries operating in the CESEE region and investigates the main determinants of local banking conditions. On the supply side, attention has been given to credit standards and credit terms and conditions, as well as to the various factors affecting credit supply. The demand for loans or credit lines has also been investigated in terms of loan applications. Moreover, the survey includes specific questions on credit quality (measured by the non-performing loans ratio) and funding conditions. For the purpose of this analysis, three random-effects linear panel data models have been estimated using the xtreg parametric method, with the dependent variable - credit growth at a subsidiary level - defined as the growth rate of gross loans (%).[65] Due to the stability problem, no lags have been taken into account in the modeling. The panel dataset used for the purposes of the econometric analysis is unbalanced and any regressor could be correlated, to some extent, with the lagged dependent variable. Therefore, their coefficients could be seriously biased.

To investigate the parent-subsidiaries nexus, the most general model has been employed encompassing macroeconomic and financial factors of host and home countries: real GDP growth, interest rates and the inflation growth rate, controlling systematically for the BLS answers.[66] In the first step, only macroeconomic and financial factors at subsidiary level, together with the BLS answers at aggregate level have been considered as the explanatory variables (Model 1). The regression results pointed to a positive effect of the inflation growth rate in the host country on credit expansion in the CESEE region. This indicates that a more robust inflation triggered larger asset price increases in the region, ultimately stimulating more credit via amplified asset valuations. On the other hand, long-term interest rates had a negative effect on subsidiaries' lending. This suggests that borrowers were more reluctant to demand more debt

[65] Beforehand the Hausman test of random versus fixed effects has been conducted, and individual random effects have been applied in the analysis. The *t*-statistics have been based on panel-robust standard errors.
[66] The results of the models can be provided by the author at a request.

when interest rates were higher. Quite counterintuitively, economic growth at host country level did not seem to have an impact on credit extension by subsidiaries. It should be emphasised here, however, that the empirical analysis of the linkages between economic activity and credit growth entails difficulties, and findings are mixed[67]. With regard to the questions on credit supply conditions, an increase in the bank's (local subsidiary's) approval rate for loan applications across the client and loan spectrum exerted a positive effect on credit extensions. On the demand side, an increase in the demand for loan applications: demand for loans or credit lines to enterprises and households (to your local subsidiary/branch) was a significant factor in credit growth at subsidiary level in the region. This might suggest that subsidiaries' operating environment has become less volatile and uncertain in the post-crisis period. Also, a decrease in the total gross non-performing loans (NPL) ratio, both for the corporate and retail segments, in a local subsidiary/branch (excluding extraordinary operations) pointed to increased lending. This finding indicated that credit quality in the examined period 2012-2015 continued to improve. It was also in line with the EIB's releases of the survey pointing to a recovery in net balance terms of the aggregate regional NPL ratios. The speed of deterioration in NPL ratios has been slowing down since October 2012, with the September 2015 release of the survey indicating a turning point in the negative spiral of NPL flows. The resolution of NPLs in the CESEE region remains crucial for a resumption of the healthy flow of credit into the economy. In terms of funding, an improvement in access to total funding at subsidiary and group level also increased the propensity to expand credit. This confirmed continued easing in access to funding in the region detected in the EIB's Bank Landing Surveys. Moreover, in reference to a longer-term strategic approach (beyond 12 months) of the parent banks, the extension of their operations via subsidiaries in the CESEE had likewise a positive and significant effect on credit growth. Operations in the region remain a key component of the global strategy for the majority of the international groups operating in the CESEE.

As the real GDP growth of the host country turned out to be insignificant in the above general model, it was excluded as an explanatory variable in subsequent regressions. What was added, though, were survey questions at lower aggregation levels (sub-questions) (Model 2). Only the inflation growth rates and long interest rates of the host country were analysed together with all (total and sub-total) answers of the EIB's Bank Lending Questionnaire. As in the

[67] For a literature overview see Garcia-Escribano and Han (2015).

previous model's specification, the results indicated a positive impact of the inflation growth rate and a negative one of the long-term interest rates at subsidiary level. Concerning the factors affecting credit supply, an increase in the bank's (local subsidiary's) overall approval rate for loan applications was a relevant factor for credit growth. Also, local bank's outlook, local banks access to total funding comprising: domestic funding as well as international/intra-group funding, local bank capital constraints, competition, credit quality (NPLs), bank's liquidity position and risk on collateral demanded, as the domestic factors contributing to the easing of credit standards (supply conditions) had a positive and significant effect on credit extensions. As regards the international factors leading to the easing of credit standards: group company outlook, global market outlook, EU regulations, group capital constraints and credit quality (NPLs), they turned out to have a positive impact on credit growth. On the demand side, as in the previous model's specification an increase in the overall demand for loans or credit lines to enterprises and households (to local subsidiary/branch) exerted a significant and positive effect on lending. In addition, inventories and working capital, as factors contributing to a higher demand for loan applications in the enterprise segment, increased significantly the propensity to extend credit in the CESEE region. This might be an indication of an improving and stabilising macroeconomic and financial environment in the examined period, which seemed to be more conducive to investment. Overall optimism on the demand side was in alignment with an improvement detected in the EIB's releases of the survey. As in the previous model, a decrease in the gross non-performing loans ratio in a local subsidiary/branch (excluding extraordinary operations) translated into an increase in credit supply. Also an increase in the access to total funding of a local subsidiary/branch was relevant for lending. In reference to Part A of the Questionnaire, an increased access to funding at parent level: total, retail and corporate (deposits and bonds to clients) as well as long-term funding (any source) positively affected credit growth. This was an indication of improvements in funding conditions for cross-border banking groups. Last but not least, with regard to a longer-term strategic approach (beyond 12 months) of the parent banks, the extension of their operations via subsidiaries in the CESEE also had a significant and positive effect on credit growth.

In the final step of the analysis, the macroeconomic and financial factors of the home country were added to the model as the independent variables (Model 3). The results obtained were very similar to those generated in Model 2. Only the answers to questions regarding the

increase in the local subsidiary's overall approval rate for loan applications, local bank's liquidity position and increased access to funding at parent level: long-term funding (any source) proved statistically significant. As opposed to Model 2, however, an increased access to funding at parent level: loans or credit lines from the central bank became relevant, which indicates that a decrease in the Group's access to the central bank's funding had a negative impact on credit extensions in the region. This result was in line with the findings of the EIB's Bank Lending Questionnaire, which pointed to a trend of reducing cross-border banking groups' recourse to central bank financing in the years 2012-2015.

In order to assess the robustness of the obtained results, the additional three models have been estimated using the weights constructed as the share of each subsidiary's assets in the sum of total assets held by all examined subsidiaries operating in the CESEE region.[68] This allows to measure the size of each subsidiary and to assess its importance in extending credit to households and firms in the region. It is generally agreed that a larger bank can supply a broader range of services and has greater capacity to provide large-scale financing and to take on risks.

3.3 Conclusion

The purpose of this chapter is to examine financial linkages of the CEE-4 countries with Western Europe. It provides a valuable assessment of a distinctive "development model" pursued by the CEE-4 region since the transition, of which financial integration - in the form of large capital inflows and an increasing presence of foreign banks - has been an integral part. To a large extent, this model has shaped over two decades the convergence process of the region. It allowed the CEE-4 economies to enter a growth path driven by domestic demand financed substantially by foreign savings. Foreign investors appreciated the region's growth potential and higher marginal returns to capital. Another important factor which distinguished emerging CEE-4 economies from other regions such as East Asia and Latin America was their accession process to the European Union. The future EU membership and related to this a requirement of harmonisation with EU legislation contributed to deepening financial integration of the CEE-4 countries with Western Europe. A distinctive feature of this financial integration process was the dominance of Western European banks in the CEE-4 region.

[68] The results of the models can be provided by the author at a request.

While integration process was a powerful driver of growth, it also created potential channels for contagion in the region by contributing to financial and macroeconomic vulnerabilities, particularly between 2005 and 2007. The study provides an assessment of the impact of the global financial crisis and European debt crisis on capital flows into the CEE-4 region. Since the CEE-4 financial sector is mainly bank-based and cross-border bank flows are considered a less stable form of foreign financing than FDI, the analysis in this chapter has focused on cross-border credit. Between 2002 and 2007, external (cross-border) loans of BIS reporting banks to Hungary, Poland, Slovakia and the Czech Republic increased about four times, from $38.7 billion to $152 billion at the end of 2007. Banks and the non-bank sector in the CEE-4 region received approximately equal proportions of these large inflows. While a portion of these bank inflows went directly to end-borrowers, a substantial part was intermediated by local subsidiaries of Western European banking groups operating in the region. Foreign parent banks have set credit growth targets for their subsidiaries in the CEE-4 countries and have provided substantial capital and liquidity support through internal funding. Nevertheless, during the financial crises due to sharp reductions in interbank liquidity multinational banking groups operating in the region began to deleverage both at home and abroad. This had a significant impact on the availability of credit in the region.

The main contribution of this chapter has been an in-depth empirical study of factors affecting credit growth in Central Eastern and South-Eastern Europe in the years 2012-2016, following the global financial and European sovereign debt crises, based on the Bank Lending Survey of the European Investment Bank. It allows to account for cross-border effects, namely home-host country macroeconomic conditions and parent-subsidiary banks' characteristics and health, while controlling systematically for the answers from the BLS. The results point to a less volatile and uncertain environment for subsidiaries operating in the CESEE region in the post-crisis period. Moreover, credit quality in the examined period 2012-2015 has continued to improve as a decrease in the total gross non-performing loans (NPL) ratio pointed to increased lending. The resolution of NPLs in the CESEE region remains crucial for a resumption of the healthy flow of credit into the economy. The findings also indicate that operations in the region remain a key component of the global strategy for the majority of the international groups operating in the CESEE.

3.4 Appendix

Cross-border capital flows

Table 3.2 Net capital flows

Czech Republic	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Net FDI (current USD, bln)	-8.3	-1.8	-3.9	-11.6	-4.0	-8.9	-2.3	-1.9	-4.9	-2.6	-6.2	0.4
Net portfolio investment (current USD, bln)	1.6	1.2	-1.9	3.4	1.1	2.7	0.04	-8.6	-7.7	-0.4	-2.8	-4.7
Hungary												
Net FDI (current USD, bln)	-2.6	-0.4	-2.9	-5.4	-0.5	-2.5	-1.4	-0.8	-3.8	-1.9	-2.8	-0.2
Net portfolio investment (current USD, bln)	-1.8	-2.9	-6.8	-4.5	-6.3	2.3	3.0	5.1	0.1	-8.9	-1.9	-4.0
Poland												
Net FDI (current USD, bln)	-3.9	-4.3	-11.7	-6.9	-10.7	-17.4	-9.9	-8.1	-8.9	-13.7	-6.0	-4.2
Net portfolio investment (current USD, bln)	-1.9	-2.4	-9.2	-12.6	2.9	6.2	2.4	-14.8	-29.0	-17.4	-19.7	-0.2
Slovakia												
Net FDI (current USD, bln)	-4.1	-0.5	-4.0	-2.9	-5.2	-3.4	-4.1	0.9	-0.8	-2.7	-3.0	0.3
Net portfolio investment (current USD, bln)	-0.6	0.6	-0.2	4.2	-4.2	2.5	-0.4	2.4	-1.7	0.2	-10.6	-8.6

Source: World Development Indicators, World Bank

Table 3.3 External loans of BIS reporting banks vis-a-vis CEE countries

	Amount outstanding (USD millions)				
Czech Republic	**1998**	**2002**	**2007**	**2012**	**2017**
vis-à-vis all sectors	9,150	10,770	31,846	22,644	53,944
vis-à-vis banks	6,517	6,190	16,433	6,713	42,121
vis-à-vis the non-bank sectors	2,633	4,580	15,413	15,931	11,823
Hungary					
vis-à-vis all sectors	7,097	9,935	44,301	33,862	22,619
vis-à-vis banks	4,005	5,699	26,841	17,818	12,694
vis-à-vis the non-bank sectors	3,092	4,236	17,460	16,044	9,925
Poland					
vis-à-vis all sectors	9,170	15,487	60,758	68,121	54,770
vis-à-vis banks	4,121	7,494	34,716	37,852	29,453
vis-à-vis the non-bank sectors	5,049	7,993	26,042	30,269	25,317
Slovakia					
vis-à-vis all sectors	4,330	2,504	15,066	18,169	11,151
vis-à-vis banks	1,640	1,144	9,631	9,318	4,836
vis-à-vis the non-bank sectors	2,690	1,360	5,435	8,851	6,315

Note: External loans of BIS reporting banks vis-à-vis Hungary, Poland, Slovakia and the Czech Republic; end of period

Source: BIS locational banking statistics

Table 3.4A Cross-border financing of CEE-4 economies (USD millions) during the global financial crisis

Czech Republic	2007	1Q 2008	2Q 2008	3Q 2008	4Q 2008	1Q 2009	2Q 2009	3Q 2009	4Q 2009
Cross border loans:	7,513	4,311	1,534	-2,600	-1,576	-2,520	671	-1,002	-411
To banks	5,263	3,035	387	-1,672	-2,241	-2,506	80	-498	-43
To the non-bank sector	2,250	1,276	1,147	-928	665	-14	591	-504	-368
Hungary									
Cross border loans:	10,953	4,577	9,018	3,139	2,717	1,445	-1,176	-1,593	2,109
To banks	5,302	2,334	3,601	-37	3,931	1,142	-2,310	-3,005	1,752
To the non-bank sector	5,651	2,243	5,417	3,176	-1,214	303	1,134	1,412	357
Poland									
Cross border loans:	24,186	15,832	7,440	-483	-6,414	-972	1,674	199	1,307
To banks	19,733	13,168	5,356	-2,466	-4,460	-569	1,873	-188	-321
To the non-bank sector	4,456	2,664	2,084	1,983	-1,955	-403	-199	387	1,627
Slovakia									
Cross border loans:	6,832	714	2,801	1,052	880	-9,741	-279	1,821	-1,016
To banks	4,881	53	2,513	-421	974	-9,148	-513	1,962	-1,357
To the non-bank sector	1,952	660	289	1,472	-95	-593	233	-141	340

Note: Cross border loans: external loans of BIS reporting banks vis-a-vis individual countries; exchange rate adjusted changes in gross amounts outstanding
Source: BIS, locational banking statistics

Table 3.4B Cross-border financing of CEE-4 economies (USD millions) during the European sovereign debt crisis

Czech Republic	2010	1Q 2011	2Q 2011	3Q 2011	4Q 2011	1Q 2012	2Q 2012	3Q 2012	4Q 2012
Cross border loans:	2,127	349	-971	1,021	-523	-956	-1,220	-3,682	441
To banks	1,977	171	-1,335	1,090	-692	-1,175	-439	-3,265	228
To the non-bank sector	151	179	364	-69	170	219	-782	-416	213
Hungary									
Cross border loans:	-12,392	497	-672	-3,628	-4,448	-2,067	-1,029	-3,568	-3,806
To banks	-3,171	1,559	-170	-3,983	-3,373	-2,248	-1,427	-2,983	-2,681
To the non-bank sector	-9,238	-1,062	-502	355	-1,075	181	398	-587	-1,124
Poland									
Cross border loans:	3,629	12,080	-5,135	-9,752	-2,548	-426	-2,323	-2,190	-2,489
To banks	3,637	10,547	-5,604	-8,132	-2,837	-760	-2,239	-2,562	-1,712
To the non-bank sector	-8	1,533	469	-1,620	289	333	-84	372	-778
Slovakia									
Cross border loans:	2,843	997	-1,596	2,975	-2,521	1,958	1,972	1,269	603
To banks	1,872	939	-1,380	3,188	-2,724	1,667	1,407	962	688
To the non-bank sector	970	58	-216	-214	203	290	565	307	-85

Note: Cross border loans: external loans of BIS reporting banks vis-a-vis individual countries; exchange rate adjusted changes in gross amounts outstanding
Source: BIS, locational banking statistics

Table 3.5A Data descriptive statistics: Subsidiary & Host Country characteristics

Variable	Description	Obs.	Mean	Std. Dev.	Min	Max
Loan growth	Growth rate of gross loans, %	364	.1535563	14.08436	-50.86607	87.81166
Inflation growth rate	Growth rate of CPI, %	392	-.2985693	4.000044	-24.59522	9.742647
GDP growth	Growth rate of real GDP, %	392	1.564179	2.416183	-9.869784	9.400238
Long interest rate	%	392	4.731752	4.88209	.057319	27.07264
Economic capital ratio	Equity to total assets, %	366	13.80069	5.671425	-6.15	36.234
Liquidity ratio	Liquid assets to total assets, %	346	17.87129	9.190431	1.017	59.16213
Profitability	Return on average assets (ROAA), %	330	.1916589	3.057386	-21.59296	7.125469
Deposit rate	Customer deposits to total funding, %	311	82.20801	12.87286	46.339	99.989
Size	Natural logarithm of total assets	366	7.93658	1.465669	3.968611	10.60077
Loan impairments	Impaired loans to gross loans, %	297	18.81523	16.63719	.003	91.203

Source: Author's calculations based on Bureau van Dijk's Orbis Bank Focus, S&P Capital IQ databases, banks' websites

Table 3.5B Data descriptive statistics: Parents & Home Country characteristic

Variable	Description	Obs.	Mean	Std. Dev.	Min	Max
Home country: Inflation growth rate	Growth rate of CPI, %	392	.5322253	1.40897	-3.961162	3.093397
Home country: GDP growth	Growth rate of real GDP, %	392	-.0849437	2.194345	-7.323701	3.945458
Home country: Long interest rate	%	392	4.393793	4.941949	.1141667	22.4975
Parent: Economic capital ratio	Equity to total assets, %	387	7.447991	3.00229	-3.289	14.976
Parent: Liquidity ratio	Liquid assets to total assets, %	387	15.5926	8.044151	2.684	39.076
Parent: Profitability	Return on average assets (ROAA), %	375	-.0481599	1.260144	-3.70457	4.429267
Parent: Deposit rate	Customer deposits to total funding, %	387	64.35633	13.98867	41.145	92.303
Parent: Size	Natural logarithm of total assets	387	12.14239	1.40335	8.642552	14.13922
Parent: Loan impairments	Impaired loans to gross loans, %	380	16.40672	11.38254	3.387	53.288

Source: Author's calculations based on Bureau van Dijk's Orbis Bank Focus, S&P Capital IQ databases, banks' websites

Note: The study based on the EIB's Bank Landing Survey data has been conducted during the author's consultancy assignment at the ECON Department of the EIB and:

1. All data has been treated with absolute secrecy and the author will not make the data accessible to third parties (including other departments within the EIB, or the EIB's affiliated companies) in whole or in part.

2. The identity of the single banks has not been disclosed to the author, and in case the author has obtained such information she has treated it and will treat it with secrecy and will not be sharing it with anybody else except the relevant parties within the EIB's Economics Department.
3. The author will not disclose (whether orally, in writing, via fax, Email, on an electronic storage or any other medium, or in any other way) the data to anyone, except to those of its representatives in the EIB's Economics Department who in each case need to receive the data in connection with the Vienna Initiative - Bank Lending Survey.
4. The author is aware of the fact that not respecting the above requirements is subject to special restrictions as to its use and disclosure (including the criminal law provisions and other sanctions thereto).
5. The author acknowledges that she cannot use the Bank Lending Survey data other than for the purpose of the analysis that was defined in the consultancy contract with the EIB's Economics Department.

Chapter 4

Synchronization of Business Cycles of the CEE-4 countries with the Euro Area

4.1 Introduction

The purpose of this chapter is to determine the fluctuations of business cycles in Hungary, Poland, Slovakia and the Czech Republic, as well as the degree of synchronization of their business fluctuations with economic cycles of Germany and the Euro area-12.[69] The analysis of the interdependencies between the business cycles is important in monitoring the effectiveness of pursued economic policies in the CEE-4 region since the transition. It is also useful in formulating macroeconomic forecasts. Last but not least, studying the degree of synchronization of the CEE-4 business cycles is also vital in connection with the future introduction of the Euro in Hungary, Poland and the Czech Republic. The study examines the premise that fluctuations in economic activity in the CEE-4 countries have become over time, to a relatively large extent, synchronized with business cycles of Germany and the whole Euro area.

The synchronization of business cycle fluctuations should be understood not only as a match, in terms of the occurrence of turning points, between the economic activity of a given CEE-4 country and the corresponding business cycle fluctuations of Germany and the Euro area-12 as a whole, but also as a match in terms of the amplitude of these fluctuations. To this end, the time series analysis methods were used in this study, which focus on an analysis in the domain of both time (cross-correlation analysis) and frequency (cross-spectral analysis). This allows to obtain a more comprehensive picture of the dependencies between the business cycles of the CEE-4 countries and the economic cycle of Germany and the Euro zone.[70] The main contribution of the study has been an approach based on introducing the spectral methods, and a band-pass filter, to estimate components illustrating the GDP fluctuations.[71] The methods used in the study, namely the Christiano-Fitzgerald (CF) filter, is now commonly used for extracting business

[69] In the study, the Euro area comprises the following members states: Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain.
[70] See for comparison Skrzypczyński (2010), p. 7.
[71] A band-pass filter is a filter which passes through components of the time series with periodic fluctuations between six and thirty-two quarters while removing components at higher and lower frequencies. Baxter and King (1995) p. 3.

cycles from economic data.[72] For the purpose of robustness testing, the Hodrick-Prescott (HF) and Baxter-King (BK) filters have also been employed.

The chapter is structured as follows. Section 2 presents the literature review. Sections 3 and 4 describe the data and methodology used. The empirical results are presented in section 5 and section 6 provides the summary.

4.2 Literature overview

The synchronization of business cycles between the Euro area countries and the EU member states from Central Eastern Europe has been examined by many authors. The results of their studies differ depending on the methodologies and the data used. Bencik (2011) documents increased synchronization of Hungary, Poland, Slovakia and the Czech Republic and the Euro area business cycles after the CEE-4 entry to the EU, and even tighter co-movement during the financial crisis of 2008-2009. Also, Stanisic (2013) shows that while there is no common CEE business cycle, a synchronization trend is evident. Similarly, there is a strong trend of convergence of the CEE national business cycles toward that of the Euro area. On the other hand, Carmignani (2005) concludes that European emerging market economies are poorly synchronized with the Eurozone except for Hungary and Poland, for which synchronization is significant. Similarly, Eickmeier and Breitung (2005) and Frenkel and Nickel (2005) find considerable heterogeneity among the CEE countries concerning cycle and shock convergence with the Euro area. According to Frenkel and Nickel (2005), only more advanced Central Eastern European countries, such as Hungary, Estonia and the Czech Republic, have relatively strong economic links with major Euro area members and therefore may be better prepared for the euro. Also Eickmeier and Breitung (2005) point to Hungary, Estonia, Poland and Slovenia as "more suitable EMU candidates". Likewise, the main findings of Darvas and Szapáry (2008) show that only Hungary, Poland and Slovenia have achieved high degree of synchronization for GDP, industry and exports, but not for consumption and services. The other CEE countries have achieved less or no synchronization. More recent study by Kolasa (2013) indicate that business cycles of five CEE countries - Hungary, Poland, Slovakia, Slovenia and the Czech Republic - do differ from those observed in the Euro area, even though substantial convergence has been

[72] The term filter should generally be understood as a system with specific characteristics that generates an output signal based on an impulse received, which is an input signal. Thus, the output signal is the filter's response to an impulse received. Skrzypczyński (2010), p. 6.

achieved after the eastern EU enlargement. The Czech Republic stands out in the region as most similar to the Euro zone in terms of sources of output fluctuations. Finally, Fidrmuc and Korhonen (2006) in their meta-analysis of the business cycle correlation between the Euro area and the CEE countries offer a review of 35 studies related to this topic. They find that many new EU member states from Central Eastern Europe have achieved a relatively high degree of business cycle correlation with the Euro area. This seems to be especially true for Hungary, Poland and Slovenia. Moreover, Hungary is more highly correlated with the Euro area compared to countries such as Greece, Ireland, or Portugal. The study by Campos, Fidrmuc and Korhonen (2019) complements, updates and extends previous research by Fidrmuc and Korhonen (2006). The authors conclude that the available evidence suggests a significant increase in business cycle synchronization within Europe: larger in the Eurozone core countries than in non-euro countries.

4.3 Data

The analysis of the synchronization of the CEE-4 business cycles with the Euro area and Germany was performed on the basis of quarterly time series of the real GDP per capita of a given CEE-4 country expressed in euros (chain linked volumes for a reference year of 2010) and the analogous time series representing Germany's and the Euro zone's GDP per capita. The GDP per capita time series adopted for the analysis come from the Eurostat database and include, for a given country, all available observations beginning from the first quarter of 1995 to the second quarter of 2018 inclusively. The above time series were logarithmised in order to convert an exponential trend in the GDP data into a linear trend and, due to the occurrence of seasonality, their seasonal clearing was performed using the TRAMO/SEATS method.[73] Due to the specification of a band-pass filter presented by Christiano and Fitzgerald (1999) and used for a 'trend-cycle' decomposition of the above-mentioned GDP time series, it was necessary to check the stationarity of the data. In order to determine whether a time series analysed is stationary, i.e. integrated of order zero I(0), or non-stationary, i.e. integrated of a higher I(d) order (where d>0), a unit root test using the ADF test[74] and a stationarity test based on the KPSS test[75] were performed. This made it possible to determine the degree of integration of the variable examined.

[73] *Time Series Regression with ARIMA Noise, Missing Observations, and Outliers/Signal Extraction in ARIMA Time Series* is a widely used procedure for removing seasonality and decomposing economic time series. This method is used by, among others, the Eurostat. Skrzypczyński (2010), p. 46.
[74] Dickey and Fuller (1979).
[75] Kwiatkowski et al. (1992).

4.4 Methodology[76]

For the empirical analysis, in order to determine a band of business fluctuations for the band-pass filter by Christiano-Fitzgerald, the definition of the business cycle presented by Burns and Mitchel (1946) has been adopted. According to this definition, business cycles are fluctuations in economic activity, not strictly periodic in nature, lasting between 1.5 years and 8 years.[77] Therefore, in the following analysis it has been assumed that the business cycle component is oscillations with cycle lengths between 6 and 32 quarters. The separation of the time series components was made using the CF band-pass filter (Skrzypczyński (2006), p. 10). For this purpose, approximations of the CF filter for the trend-cycle decomposition have been presented below. Also the time series analysis methods were used in studying the business cycles synchronization, which focus on an analysis in the domain of both time (cross-correlation analysis) and frequency (cross-spectral analysis).

4.4.1. Christiano-Fitzgerald filter for 'trend-cycle' decomposition

This part presents Christiano-Fitzgerald filter[78] that is used to decompose a time series into a trend component and a cyclical component. Trend and cyclical fluctuations are, in addition to seasonal and irregular fluctuations, the most important factors responsible for changes occurring in a time series. Therefore, it is necessary to ensure the separation of desired cycle components according to: the frequency, duration or amplitude of fluctuations. The Christiano-Fitzgerald filter has features common for both the Baxter-King (BK) filter and the Hodrick-Prescott (HP) filter.[79] The CF filter, similarly to the HP filter, makes it possible to obtain an output time series consisting of the same number of observations as the input series. On the other hand, setting the lower and upper cutoff frequencies in the CF band-pass filter takes place in a manner that is analogous to the BK filter. The basic feature that, however, distinguishes the CF filter from the HP and BK filters is the requirement of determining the type of process that generates data before proceeding with the filtration. The CF filter requires the determination whether the decomposed time series is a stationary or non-stationary variable. In case of non-stationarity, it is also important to specify its type, i.e. to distinguish between first-order

[76] Skrzypczyński (2006, 2010).
[77] It is consistent with the Lucas (1977) approach which states that conjunctural fluctuations is a process of repeated but irregular oscillations of GDP around its long-term growth path.
[78] Christiano and Fitzgerald (1999).
[79] The Baxter-King filter and the Hodrick-Prescott filter have been presented in the Appendix.

increment-stationarity (unit root) and trend-stationarity. For variables integrated in the first degree - I(1), the CF filter requires a prior removal of the drift, as long as it is present. On the other hand, for the trend-stationary variables the CF filter requires a removal of the deterministic (usually linear) trend. In case of variables integrated of order one, the CF filter is referred to as the I(1) filter, while in case of stationary variables it is referred to as the I(0) filter. Similarly to the BK filter, the CF filter also requires that the input time series be cleared of seasonal fluctuations, due to the occurrence of the "leak" effect of the spectral power accumulated on seasonal frequencies.

The estimator of the cyclical component y_t^c resulting from the use of the CF filter (in the I(1) or I(0) variant) for the variable y_t is given as:[80]

$$\widehat{y}_t^c = \widehat{B}_t(L)\, y_t \text{ where } \widehat{B}_t(L) = \sum_{j=-(T-t)}^{t-1} \widehat{B}_{j,t}\, L^j \text{ for } t = 1,2,\ldots, T \tag{4.1}$$

Thus, a CF filter given by the formula (4.1) is a Wiener-Kolmogorov filter. The set of weights $\widehat{B}_{j,t}$ is a solution of the following minimization problem:

$$\min_{\widehat{B}_{j,t}, j=-(T-t)} \int_{-\pi}^{\pi} |B(e^{-i\omega}) - \widehat{B}_t(e^{-i\omega})|^2\, S_y(\omega)\, d\omega \text{ for } t = 1,2,\ldots, T \tag{4.2}$$

where $B(e^{-i\omega})$ means an amplification of the 'ideal' band-pass filter, $\widehat{B}_t(e^{-i\omega})$ an amplification of the approximated filter, while $S_y(\omega)$ corresponds to the power (pseudo-)spectrum of the process subjected to filtration (depending on the filter version it is the power pseudo-spectrum of the I(1) process, i.e. a random walk process or the power spectrum of the I(0) process, i.e. a white noise). In addition, in case of the I(1) filter, the limiting condition for the problem (4.2) is a requirement of the summability of the weights to zero, i.e. $\sum_{j=-(T-t)}^{t-1} \widehat{B}_{j,t} = 0$ for $t=1,2,\ldots,T$, which ensures the removal of stochastic trends by the filter. In case of the I(0) filter this condition is not taken into account, as stationary variables are not affected by stochastic trends. The function $B(e^{-i\omega})$ in case of the 'ideal' band-pass filter is defined as:

$$B(e^{-i\omega}) \equiv \begin{cases} 1 & \text{for} \quad \omega \in [-\overline{\omega}, -\underline{\omega}] \cup [\underline{\omega}, \overline{\omega}] \\ 0 & \text{for} \quad \omega \in [-\pi, -\overline{\omega}) \cup (-\underline{\omega}, \underline{\omega}) \cup (\overline{\omega}, \pi] \end{cases} \tag{4.3}$$

where $\omega = 2\pi/\tau$ is a frequency expressed in radians with the period equal to τ. The values of $\underline{\omega} = 2\pi/\tau_\upsilon$ and $\overline{\omega} = 2\pi/\tau_L$ are referred to as the lower and upper cut-off frequency and fulfill the condition $0 < \underline{\omega} < \overline{\omega} < \pi$. Thus, the 'ideal' band-pass filter removes from the input variable fluctuations with periods greater than τ_υ and fluctuations with periods smaller than τ_L, leaving

[80] The symbol *L* denotes a lag operator, which is defined as $L^k y_t \equiv y_{t-k}$ for each *k* belonging to the set of integers.

fluctuations with periods between τ_L and τ_υ. Properly selected periods τ_L and τ_υ determine a band of fluctuations of a business nature. According to the adopted definition of a business cycle of Burns and Mitchell (1946), this means that for quarterly data $\tau_L = 6$ and $\tau_\upsilon = 32$ were used.

4.4.2. Cross-correlation analysis[81]

In order to obtain a comprehensive picture of the dependencies between the business cycles of the CEE-4 countries and the corresponding business cycle fluctuations of Germany and the Euro area as a whole, time series analysis methods were used in this study, which focus on an analysis of both time and frequency. For the purpose of correlation analysis, the coefficient of cross-correlation between the time series $\{y_t\}_{t=1}^{T}$ and $\{x_t\}_{t=1}^{T}$ is calculated according to the following formula:

$$\widehat{\rho}_k^{yx} = \begin{cases} \dfrac{\sum_{t=1}^{T-k}(y_t - \overline{y})(x_{t+k} - \overline{x})}{\sqrt{\sum_{t=1}^{T}(y_t - \overline{y})^2}\sqrt{\sum_{t=1}^{T}(x_t - \overline{x})^2}} \; for\; k = 0,1,\dots,T-1 \\ \dfrac{\sum_{t=1-k}^{T}(y_t - \overline{y})(x_{t+k} - \overline{x})}{\sqrt{\sum_{t=1}^{T}(y_t - \overline{y})^2}\sqrt{\sum_{t=1}^{T}(x_t - \overline{x})^2}} \; for\; k = -1,-2,\dots,-(T-1) \end{cases} \tag{4.4}$$

where *k* is the shift of the variable x_t expressed in a time unit that is forward or backward in relation to the variable y_t. The variable y_t is a dependent variable, while the variable x_t is an independent variable. The negative and positive critical value for the cross-correlation coefficient with the significance level α equals $U_{\alpha/2}/\sqrt{T}$ and $U_{1-\alpha/2}/\sqrt{T}$ respectively, where $U_{\alpha/2}$ and $U_{1-\alpha/2}$ are the points of the standard normal distribution, *U~N(0,1)*, for the probability *α/2* and *1-α/2* accordingly. The cross-correlation coefficient for the *k* shift, which exceeds the critical value is statistically significant, i.e. there is a basis for rejecting the null hypothesis stating that this coefficient is equal to zero.

4.4.3. Cross-spectral analysis[82]

In analyzing the relationship of two variables in the frequency domain the cross-spectrum is applied, which is the distribution of the covariance of two stationary stochastic processes in the frequency domain. Let us assume that a stochastic process with the discrete time $\{x_t\}_{t=-\infty}^{+\infty}$, zero

[81] Skrzypczyński (2006), p. 43
[82] Skrzypczyński (2006), p. 46-48.

mean and a stationary covariance function is an independent variable (input variable), while a process with the analogous properties $\{y_t\}_{t=-\infty}^{+\infty}$ is a dependent variable (output variable). Then the cross-spectrum of these variables is defined as the Fourier transform of the cross-covariance sequence $\{\gamma_k^{xy}\}_{k=-\infty}^{+\infty}$ of these variables and is given by the formula:

$$S_{xy}(\omega) = \frac{1}{2\pi} \sum_{k=-\infty}^{+\infty} \gamma_k^{xy}\, e^{-i\omega k} \; for\; \omega \in \langle -\pi, \pi \rangle \tag{4.5}$$

Using the De Moivre theorem $e^{\pm i\omega} = \cos(\omega) \pm i\sin(\omega)$, we may write the cross-spectrum in the following form:

$$S_{xy}(\omega) = \frac{1}{2\pi}\sum_{k=-\infty}^{+\infty} \gamma_k^{xy} \cos(\omega k) - i\frac{1}{2\pi}\sum_{k=-\infty}^{+\infty} \gamma_k^{xy} \sin(\omega k) = c_{xy}(\omega) - iq_{xy}(\omega) \quad for\; \omega \in \langle -\pi, \pi \rangle \tag{4.6}$$

$c_{xy}(\omega)$ is referred to as the co-spectrum and constitutes the real part of the cross-spectrum, while $q_{xy}(\omega)$, referred to as the quadrature spectrum, constitutes the negative imaginary part of the cross-spectrum. On the basis of the cross-spectrum it is possible to define three measures referred to, respectively, as amplification of the variable x_t in relation to y_t, phase shift and coherence, which are given respectively by the following formulas:

$$G_{xy}(\omega) = \frac{(c_{xy}(\omega)^2 + q_{xy}(\omega)^2)^{\frac{1}{2}}}{S_x(\omega)} \; and\; G_{xy}(\omega) \geq 0 \; for\; \omega \in \langle -\pi, \pi \rangle \tag{4.7}$$

$$\phi_{xy}(\omega) = \tan^{-1}\left(\frac{-q_{xy}(\omega)}{c_{xy}(\omega)}\right) for\; \omega \in \langle -\pi, \pi \rangle \tag{4.8}$$

$$K_{xy}^2(\omega) = \frac{c_{xy}(\omega)^2 + q_{xy}(\omega)^2}{S_x(\omega)S_y(\omega)} \; and\; 0 \leq K_{xy}^2(\omega) \leq 1 \; for\; \omega \in \langle -\pi, \pi \rangle \tag{4.9}$$

In the case of cross-spectrum estimation for finite observation samples the procedure is the same as with regard to power spectrum estimation, i.e. the series of theoretical cross-covariances should be replaced with the empirical series, using for this purpose the estimator of cross-covariance between the time series $\{x_t\}_{t=1}^T$ and $\{y_t\}_{t=1}^T$:

$$\hat{\gamma}_k^{xy} = \begin{cases} \frac{1}{T}\sum_{t=1}^{T-k}(x_t - \overline{x})(y_{t+k} - \overline{y}) & \text{for} \quad k = 0,1,\dots,T-1 \\ \frac{1}{T}\sum_{t=1-k}^{T}(x_t - \overline{x})(y_{t+k} - \overline{y}) & \text{for} \quad k = -1,-2,\dots,-(T-1) \end{cases} \tag{4.10}$$

where $\overline{y} = T^{-1}\sum_{t=1}^T y_t$ and $\overline{x} = T^{-1}\sum_{t=1}^T x_t$.

The cross-periodogram between the finite time series $\{x_t\}_{t=1}^{T}$ and $\{y_t\}_{t=1}^{T}$ is given as:

$$I_{xy}(\omega) = \frac{1}{2\pi} \sum_{k=-(T-1)}^{T-1} \grave{\gamma}_k^{xy}\, e^{-i\omega k}$$

$$= \frac{1}{2\pi} \sum_{k=-(T-1)}^{T-1} \grave{\gamma}_k^{xy}\, cos(\omega k) - i\frac{1}{2\pi} \sum_{k=-(T-1)}^{T-1} \grave{\gamma}_k^{xy}\, sin(\omega k) \tag{4.11}$$

$$for \omega \in \langle -\pi, \pi \rangle$$

The cross-periodogram is usually computed for the discrete Fourier frequencies ω_j, where ω_j denotes the discrete Fourier frequency that is $\omega_j = \frac{2\pi j}{T}$ where j=0,1,..,$\frac{T}{2}$ for T being even $or\, j$=0,1, …,$\frac{T-1}{2}$ for T being odd. The cross-power spectrum is a continuous function with real values and symmetric about zero, so for the purposes of analysis it is possible to limit the frequency domain to the interval [0, π]. The cross-periodogram $I_{xy}(\omega)$ takes complex values. The real part and the negative imaginary part of the cross-periodogram, i.e. $C_{xy}(\omega) = \frac{1}{2\pi}\sum_{k=-(T-1)}^{T-1} \grave{\gamma}_k^{xy}\, cos(\omega k)$ and $Q_{xy}(\omega) = \frac{1}{2\pi}\sum_{k=-(T-1)}^{T-1} \grave{\gamma}_k^{xy}\, sin(\omega k)$,stand for the estimators of power co-spectrum and quadrature power spectrum from the observation sample.

The cross-periodogram is an asymptotically unbiased estimator of the cross-power spectrum, but it is not a consistent estimator, i.e. its variance does not decrease with an increasing number of observations. In order to reduce the variance of the cross-periodogram, it is smoothed by binning over (grouping) consecutive frequencies.[83] The smoothing of the cross-periodogram is conducted, however, at the cost of the asymptotical unbiasedness of the estimator.

The smoothed form of the cross-periodogram was estimated the time domain, or more specifically, in the lag domain. For this purpose, the so-called Daniell window (also known as the rectangular window) was introduced. In this approach the weights κ_h applied to the estimation of the real and imaginary parts of the cross-periodogram, are denoted as:

$$\kappa_h = \begin{cases} 1/(2H+1) & for \quad |h| \le H \\ 0 & for \quad |h| > H \end{cases} \tag{4.12}$$

The parameter *h* determines how many frequencies are used in the estimation and is called the width of the passband. According to the approach of smoothing the cross-periodogram in the lag domain, the estimator of the cross-power spectrum is given as:

[83] Epitropakis and Papadakis (2016), p. 3.

$$\hat{S}_{xy}(\omega) = \frac{1}{2\pi}\sum_{k=-K}^{K} w_k \hat{\gamma}_k^{xy} e^{-i\omega k} = \frac{1}{2\pi}\left[\hat{\gamma}_0^{xy} + 2\sum_{k=1}^{K} w_k \hat{\gamma}_k^{xy} cos(\omega k)\right] \quad (4.13)$$

$$for \omega \in \langle -\pi, \pi \rangle$$

where the weights w_k for $k = 0, \pm1, ..., \pm K$ are defined as a lag window, while the parameter K determining the number of autocovariances used in the estimation, and is called a truncation lag.

The estimation of amplification, phase shift and coherence requires the use of smoothed forms of co-spectrum, quadrature spectrum and power spectrum of the variables x_t and y_t. To this end, the Daniell window was used in the analysis. The critical value of coherence at the α significance level is:

$$\hat{K}_{xy}^2(\omega_j) = \frac{2F_{2,\upsilon-2}(1-\alpha)}{\upsilon - 2 + 2F_{2,\upsilon-2}(1-\alpha)} \quad (4.14)$$

where $F_{2,\upsilon-2}(1-\alpha)$ denotes the point of F-distribution with 2 and υ - 2 degrees of freedom for the probability 1 - α. The strips of the $100 \cdot (1-\alpha)\%$ confidence interval for amplification are given by the following formula:

$$\hat{G}_{xy}(\omega_j) \pm \hat{G}_{xy}(\omega_j)\sqrt{\frac{2}{\upsilon-2} \cdot F_{2,\upsilon-2}(1-\alpha) \cdot \frac{1-\hat{K}_{xy}^2(\omega_j)}{\hat{K}_{xy}^2(\omega_j)}} \quad (4.15)$$

where $\hat{G}_{xy}(\omega_j)$ is the amplification estimator, while $\hat{K}_{xy}^2(\omega_j)$ is the coherence estimator. On the other hand, the strips of the $100 \cdot (1-\alpha)\%$ confidence interval for the phase shift are given as:

$$\hat{\phi}_{xy}(\omega_j) \pm \sin^{-1}\sqrt{\frac{2}{\upsilon-2} \cdot F_{2,\upsilon-2}(1-\alpha) \cdot \frac{1-\hat{K}_{xy}^2(\omega_j)}{\hat{K}_{xy}^2(\omega_j)}} \quad (4.16)$$

where $\hat{\phi}_{xy}(\omega_j)$ is the phase shift estimator.

4.5 Analysis of business cycles synchronisation based on GDP time series

The results of the ADF unit root test (Table 4.1) and the KPSS stationarity test (Table 4.2) confirm the non-stationarity of the GDP time series due to the presence of a long-term stochastic trend.[84] The ADF and KPSS tests were carried out on the logarithmised data cleared of seasonality using the TRAMO/SEATS method. The null hypothesis of the ADF test assumes the presence of a unit root in the time series studied, while the alternative hypothesis - its trend-

[84] Nelson and Plosser (1982).

stationarity. On the other hand, the null hypothesis of the KPSS test assumes trend-stationarity and the alternative hypothesis - the presence of a unit root. The number of lags in the ADF test was determined on the basis of the minimization of the Schwarz information criterion, while the bandwidth in the KPSS test was selected based on the Newey-West method. In the KPSS test, the so-called Bartlett kernel was used to estimate the long-term variance.[85]

Table 4.1 Results of the ADF test for GDP

Country	Statistics	Critical value	Conclusion
Euro area-12	2.706	-1.95	I(1)
CEE-4	3.811	-1.95	I(1)
Germany	2.829	-1.95	I(1)
Czech Republic	3.46	-1.95	I(1)
Hungary	3.637	-1.95	I(1)
Poland	6.685	-1.95	I(1)
Slovakia	4.42	-1.95	I(1)

Source: Author's calculations

Table 4.2. Results of the KPSS test for GDP

Country	Statistics	Critical value	Conclusion
Euro area-12	0.314	0.146	I(1)
CEE-4	0.264	0.146	I(1)
Germany	0.054	0.146	TS*
Czech Republic	0.215	0.146	I(1)
Hungary	0.289	0.146	I(1)
Poland	0.235	0.146	I(1)
Slovakia	0.219	0.146	I(1)

Note: *Trend-Stationary process
Source: Author's calculations

The ADF test demonstrates that GDP time series in the CEE-4 countries and the Euro area should be treated as realizations of I(1) process, i.e. they are non-stationary variables. Similar conclusions may be drawn from the results of the KPSS test, which also points to the non-stationarity of GDP time series. Only with regard to Germany, the KPSS does not allow to reject the null hypothesis about the trend-stationarity of the GDP series.

In the next step of the analysis, the GDP time series were transformed using the band-pass filter proposed by Christiano and Fitzgerald (1999) under the assumption the variables were non-stationary and that the business cycle oscillations were fluctuations with periods between 6 and 32 quarters. The GDP time series cleared of the drift were then transformed using the CF filter. The obtained cyclical components of the GDP time series were then subjected to the ADF and

[85] Skrzypczyński (2006), p. 12.

KPSS tests. The null hypothesis of the ADF test assumes the presence of a unit root and the alternative hypothesis - stationarity. On the other hand, the null hypothesis of the KPSS test assumes stationarity and the alternative hypothesis - the presence of a unit root. As previously, in the ADF test the Schwarz information criterion was used whereas in the KPSS test the Newey-West method and Bartlett's kernel were applied. The results of the ADF and KPSS tests are presented in Tables 4.3 and 4.4 and they point to the stationarity of variables illustrating business cycle fluctuations. The results of the ADF and KPSS tests for cyclical components of GDP for the HP filter are presented in Tables 4.6 and 4.7 while for the BK filter – in Tables 4.8 and 4.9 respectively in the Appendix. The stationarity of the cyclical components stems directly from the properties of the band-pass filter, which removes the unit root from the input data. The stationarity of the filtered time series is a prerequisite for the application of the cross-correlation and cross-spectral analyses.[86]

Table 4.3 Results of the ADF test for cyclical components of GDP, CF filter

Country	Statistics	Critical value	Conclusion
Euro area-12	-6.586	-1.95	I(0)
CEE-4	-6.247	-1.95	I(0)
Germany	-6.546	-1.95	I(0)
Czech Republic	-5.269	-1.95	I(0)
Hungary	-4.064	-1.95	I(0)
Poland	-4.658	-1.95	I(0)
Slovakia	-5.605	-1.95	I(0)

Source: Author's calculations

Table 4.4 Results of the KPSS test for the cyclical components of GDP, CF filter

Country	Statistics	Critical value	Conclusion
Euro area-12	0.035	0.146	I(0)
CEE-4	0.029	0.146	I(0)
Germany	0.03	0.146	I(0)
Czech Republic	0.03	0.146	I(0)
Hungary	0.037	0.146	I(0)
Poland	0.03	0.146	I(0)
Slovakia	0.033	0.146	I(0)

Source: Author's calculations

4.5.1. Cross-correlation analysis

Based on the stationarity of the obtained business cycle components of GDP, it was possible to conduct an analysis of business cycles synchronization between the CEE-4 countries,

[86] Skrzypczyński (2006), p. 13.

Germany and the Euro area-12. To this aim, in the first phase an estimation was made of the coefficients of cross-correlation between the time series representing the business cycle component of the Euro area-12 as a whole and the business cycle components of the CEE-4 countries and Germany. Table 4.5A presents the results of the cross-correlation analysis taking into account the shift of the business cycle fluctuations of a given country by 6 quarters back and forward in relation to the business cycle of the Euro zone using the CF filter. The results for the HP and BK filters are presented respectively in Tables 4.10A and 4.11A in the Appendix. In the next step, an estimation was made of the coefficients of cross-correlation between components of the business cycles of the CEE-4 countries and Germany's business cycle components. The results of the cross-correlation analysis for those countries using the CF filter are presented in Table 4.5B. The results for the HP and BK filters are presented respectively in Tables 4.10B and 4.11B in the Appendix. The bold print indicates the largest, as to the module, value of the cross-correlation coefficient.

Table 4.5A Coefficients of cross-correlation between the time series representing the Euro area-12 business cycle and the time series representing the business cycles of the CEE-4 countries and Germany (analysis based on GDP data), CF filter

	t-6	t-5	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4	t+5	t+6
Germany	-0.281	-0.088	0.161	0.437	0.694	0.875	**0.934**	0.854	0.653	0.369	0.060	-0.224	-0.449
Czech Republic	-0.299	-0.098	0.131	0.358	0.554	0.687	**0.741**	0.701	0.572	0.374	0.140	-0.093	-0.291
Hungary	-0.448	-0.280	-0.055	0.203	0.455	0.653	**0.753**	0.743	0.641	0.486	0.314	0.150	0.006
Poland	-0.104	0.024	0.161	0.307	0.449	0.547	**0.548**	0.430	0.210	-0.031	-0.231	-0.347	-0.368
Slovakia	-0.017	0.093	0.232	0.387	0.514	**0.564**	0.497	0.313	0.062	-0.200	-0.412	-0.542	-0.588

Source: Author's calculations

Table 4.5B Coefficients of cross-correlation between the time series representing the business cycle of Germany and the time series representing the business cycles of the CEE-4 countries (analysis based on GDP data), CF filter

	t-6	t-5	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4	t+5	t+6
Czech Republic	-0.373	-0.216	0.001	0.250	0.483	0.656	**0.728**	0.694	0.564	0.373	0.155	-0.057	-0.237
Hungary	-0.476	-0.313	-0.095	0.167	0.431	0.644	**0.756**	0.745	0.628	0.454	0.275	0.127	0.020
Poland	-0.132	0.038	0.216	0.376	0.484	**0.515**	0.453	0.323	0.147	-0.037	-0.194	-0.296	-0.336
Slovakia	-0.059	0.070	0.222	0.389	0.538	**0.620**	0.595	0.441	0.190	-0.101	-0.362	-0.545	-0.631

Source: Author's calculations

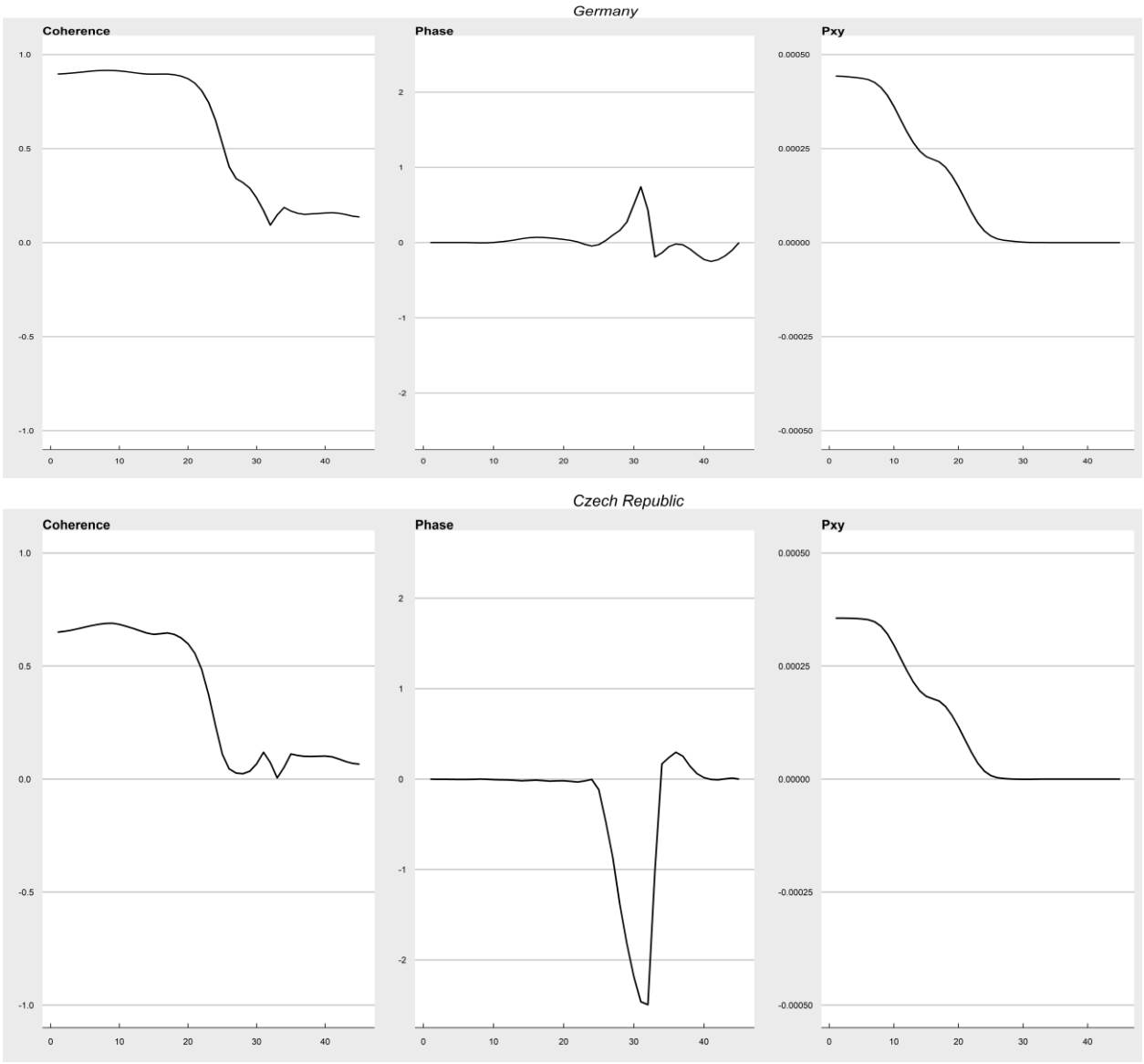
An analysis of cross-correlation between the Euro area-12 business cycle and the business cycles of the CEE-4 and Germany based on the CF filter indicates that the business cycles of Germany, the Czech Republic, Hungary and Poland are positively correlated with the business

cycle of the Euro area as a whole, and they do not show a tendency to overtake or lag behind the business cycle of the Euro zone. Predictably, Germany as the main economy of the Euro area displays the highest synchronization followed by Hungary and the Czech Republic within the CEE-4 group. Quite counterintuitively, Slovakia - as the only country of the CEE-4 group which has joined the Euro area on January 1, 2009 - demonstrates lower positive correlation of its business cycle with the Euro zone compared to the Czech Republic and Hungary, yet higher than Poland. Slovakia's business cycle overtakes the business cycle of the Euro area by one quarter. Overall, the cross-correlation analysis shows that the examined CEE-4 countries record the phases of growth and decline in economic activity at very approximate moments, which points to a high degree of their business cycles' synchronization with the Euro area cycle. With regard to Germany as the reference area, the business cycles of the CEE-4 countries show even stronger synchronization. The business cycles of Hungary and the Czech Republic show the highest synchronization with the business cycle of Germany, followed by Slovakia and Poland. Within the CEE-4 group, the business cycles of the Czech Republic and Slovakia show the highest synchronization with the business cycle of Germany, while the economic activity fluctuations in Hungary lag behind the business cycle of Germany by one quarter and Poland's business cycle outpaces it by one quarter.

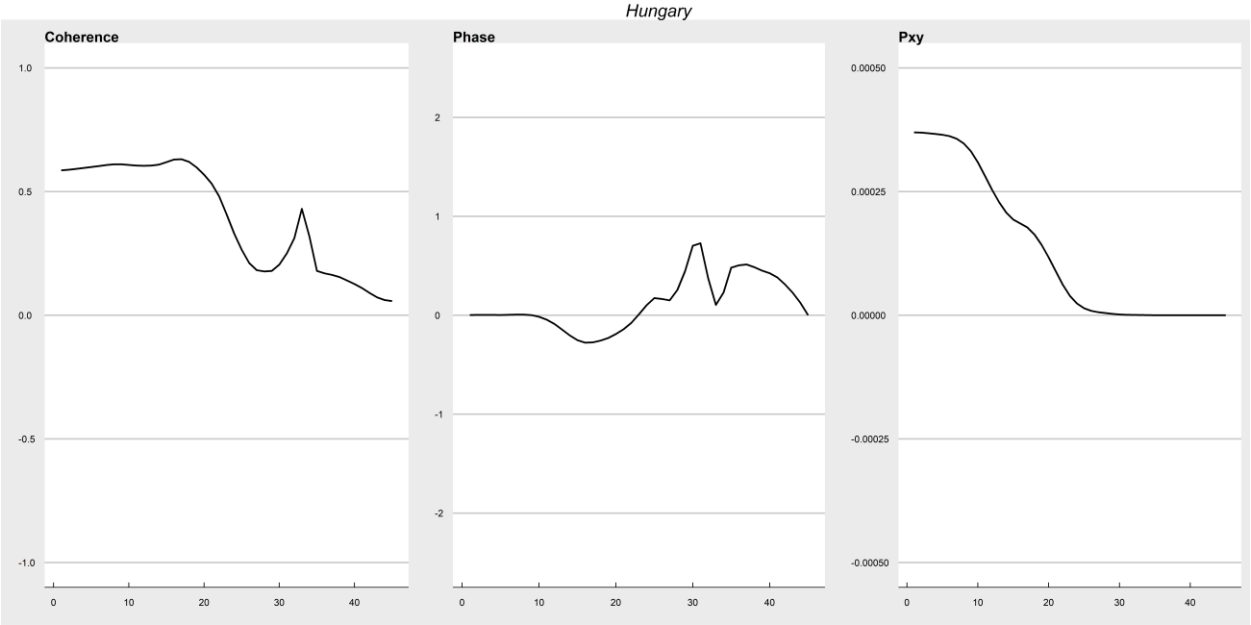
4.5.2. Cross-spectral analysis

At the final stage, the cross-spectral analysis of the GDP cyclical components obtained by applying the band-pass filter has been conducted. As in previous examinations, the component for the Euro area is treated as a dependent variable, while the component for Germany, Hungary, Poland, Slovakia and the Czech Republic - as an independent variable. The results of the cross-spectral estimation - coherence, phase shift and cross-periodogram (Pxy) - has been presented in Figure 4.1. It shows the measures of cross-spectral analysis between the cyclical component of the Euro area-12 and the cyclical components of individual CEE-4 countries and Germany obtained from the Christiano-Fitzgerald (CF) filter. The results for the HP and BK filters are presented respectively in Figures 4.2 and 4.3 in the Appendix.

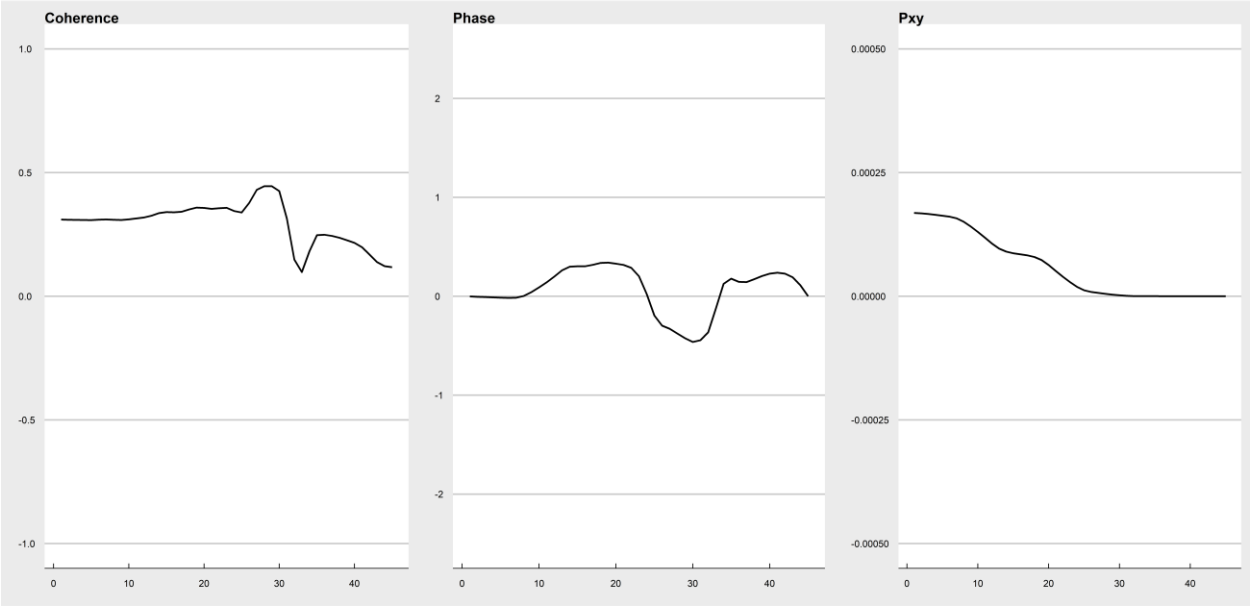
Figure 4.1 Measures of cross-spectral analysis between the cyclical component of the Euro area-12 and the cyclical components of individual CEE-4 countries and Germany (analysis based on GDP data), CF filter

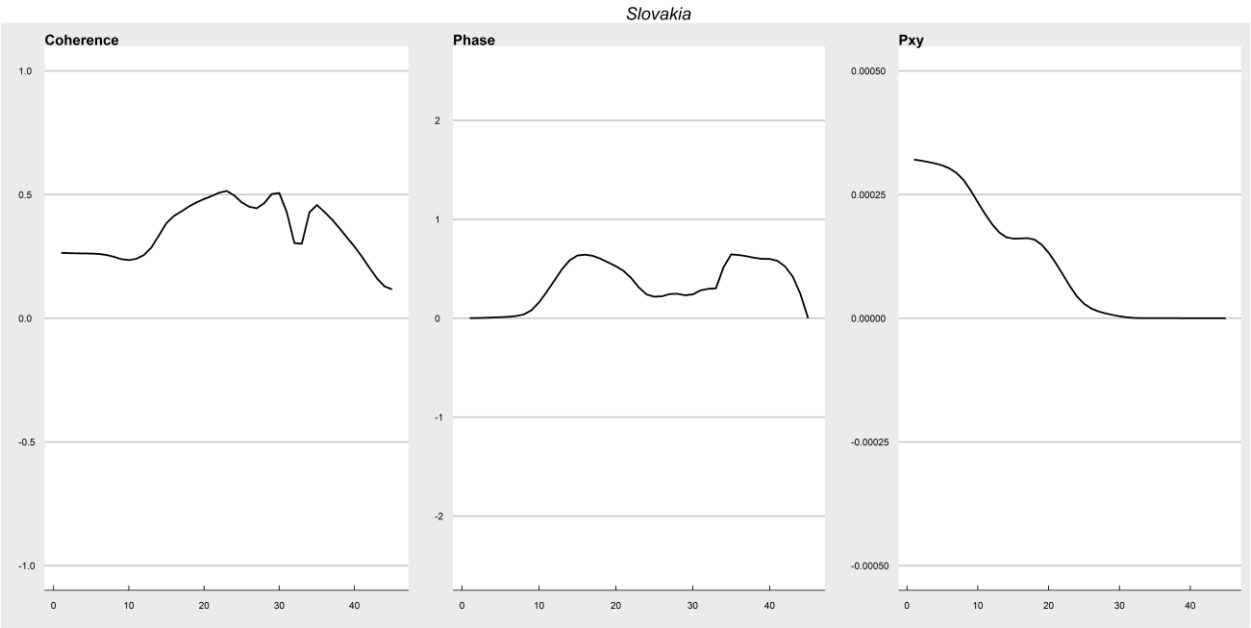


Hungary



Poland





Source: Author's calculations

The results obtained for Germany point to a high coherence in a lower range of the business cycle length (up to 5 years). The cyclical component of the German economy then depicts a decreasing coherence with the cyclical component of the Euro area as the cycle length increases. The phase shift is low, with its largest value for the cycle length of about 7 years, and points to a slightly delaying nature of the German cycle compared to the corresponding cycle of the Euro area. The phase shift lowers as the cycle length increases and turns somewhat negative, indicating a slight overtaking of German cycles with longer periods.

The figure of the cross-periodogram smoothed in the time domain using the modified Daniel window indicates that the signal cross-spectrum is highest for Germany at the lowest cross-spectral frequencies. This means that the influence of the Euro area's cyclical component on German economic fluctuations is greatest for the lowest cross-spectral frequencies. The magnitude of the signal cross-spectrum begins to decrease for Germany at cross-spectral frequencies corresponding approximately to 2 years and the signal cross-spectrum ceases after about 6 years (at spectral frequencies corresponding to approximately the 25 quarters). This provides an indication that, compared to the CEE-4 countries, the business cycle of Germany is most synchronized with the economic cycle of the Euro area-12.

The coherence of the Czech cyclical component with its counterpart for the Euro area reveals the similar trend to the German economy, yet it stays at a lower level for cycles with length up to 5 years. The relationship between the cyclical fluctuations of GDP between the

Czech and Germany weakens considerably and stays close to zero with the increase in the length of the cycle under consideration. The phase shift remains constant for the shorter length of the cycle and does not reveal any upward or downward trend for a cycle length of about 6 years. Then, the Czech cycle overtakes the corresponding Euro zone cycle for a cycle length of up to 8 years to stabilise afterwards.

Within the CEE-4 group, the cross-periodograms for the Czech Republic and Hungary display a similar pattern, with the signal cross-spectrum somewhat below the level of Germany in the case of the lowest cross-spectral frequencies. This indicates that the business cycles of those two countries in general show the closest synchronization with the economic cycle of the Euro area-12.

The cyclical component of the Hungarian economy is characterized by a low coherence with the Euro area component along the entire length of the cycle. Coherence reaches values of about 60-70 per cent, for a frequency that marks a cycle of approximately 4 years. Then, it fluctuates below 50 per cent as the cycle length increases. The phase shift becomes slightly negative for a lower cycle length of about 2,5 - 5,5 years indicating that the Hungarian cycle outpaces the corresponding Euro area cycle. It then slightly increases and becomes positive pointing to a lag of the Hungarian cycle compared to corresponding cycle in the Euro area.

The two remaining CEE-4 countries - Poland and Slovakia - display similar trends with regard to the three measures of cross-spectral analysis. Both in Poland and Slovakia, the coherence remains low and positive. It remains in Poland below a value of 50 per cent at the lower length of the business, it declines for a cycle length of about 6 years and stays at a slightly positive level afterwards. While Slovakia shows a somewhat more upward trend in a lower range of the cycle length, the direction of changes in coherence level remains the same. With reference to the phase shift, it first increases in Poland to some extent for a shorter length of the cycle (about 5 years), then decreases and becomes negative to become again slightly positive for a cycle length of over 8 years. Therefore, the Polish cycle first lags behind the Euro area cycle, then overtakes it and finally again remains behind the Euro area business fluctuations. The phase shift in Slovakia depicts a similar trend, yet it stays positive on the whole length of the cycle.

With regard to the cross-periodogram, Poland and Slovakia form the second group of CEE-4 countries, whose signal cross-spectrum for the lowest frequencies stays at a lower level compared to the Czech Republic and Hungary. This indicates that the cyclical fluctuations of

Slovakia and Poland fit more weakly the business fluctuations of the Euro area-12 and Germany. In the case of Slovakia and Poland, the signal cross-spectra decrease more slowly compared to the Czech Republic and Hungary as the spectral frequencies increase.

4.6 Conclusion

The chapter analysis the degree of synchronization of the CEE-4 countries' business fluctuations with economic cycles of Germany and the Euro area. This allows to assess the effectiveness of pursued economic policies in the CEE-4 region since the transition, and is also vital in connection with the future introduction of the Euro in Hungary, Poland and the Czech Republic. To this aim, the time series analysis methods have been employed in the study, which focus on an analysis in the domain of both time (cross-correlation analysis) and frequency (cross-spectral analysis). This allows to obtain a more comprehensive picture of the dependencies between the business cycles of the CEE-4 countries and the economic cycle of Germany and the Euro zone. The main contribution of the study has been an approach based on introducing the spectral methods and a band-pass filter, to estimate components illustrating the GDP fluctuations. This analysis shows that fluctuations in economic activity in the CEE-4 countries have become over time, to a relatively large extent, synchronized with the business cycles of Germany and the whole Euro area.

4.7 Appendix

Hodrick-Prescott filter[87]

Let a time series with the finite observation sample $\{y_t\}_{t=1}^{T}$ be a non-stationary variable, cleared of seasonal fluctuations. A HP filter makes it possible to conduct an additive decomposition of the variable y_t into the trend component g_t and the cyclical component c_t:

$$y_t = \mathrm{g}_t + c_t \;\; dla \;\; t = 1,2,\dots,T \tag{4.17}$$

The estimation of the trend component g_t as part of the HP filter narrows down to solving the following minimisation problem:

$$\min_{(\mathrm{g}_t)_{t=1}^{T}} [\sum_{t=1}^{T} (y_t - \mathrm{g}_t)^2 + \lambda \sum_{t=3}^{T} (\Delta^2 \mathrm{g}_t)^2] \tag{4.18}$$

where λ is a non-negative real parameter, referred to as a smoothing parameter, which specifies the degree of 'smoothness' of a trend. If $\lambda \to 0$, matching a trend to the time series being

[87] Hodrick and Prescott (1997); Skrzypczyński (2010), p. 78-83.

observed becomes ever stronger, and in the borderline case of $\lambda = 0$ one obtains $g_t = y_t$. Otherwise, i.e. if $\lambda \to +\infty$, the trend resulting from the use of an HP filter is the same as the deterministic line trend obtained using the least squares method. From the first order conditions of the optimisation problem (4.18) one obtains a system of T linear equations with a total of T unknowns (Cramer's rule). The solution for such a system is the variable $\hat{g}$ for t=1,2,...,T, being the estimator of the trend component g_t. The variable $\hat{c}_t$, being the estimator of the cyclical component c_t, is given as $\hat{c}_t = y_t - \hat{g}_t$ for t=1,2,...,T.

In order to describe the choice of the smoothening parameter λ for the HP filter, let us consider its application for the time series y_t with the infinite observation sample, i.e. the time series in the form of $\{y_t\}_{t=-\infty}^{+\infty}$ (infinite sample Hodrick-Prescott filter). In this case, the estimators of the trend and cycle component may be noted in the form of the symmetric infinite moving average of the variable y_t (a representation of the Wiener-Kolmogorov filter), i.e. $\hat{g}_t = G(L)y_t$ and $\hat{c}_t = C(L)y_t$, where the condition $G(L) + C(L) = 1$ is fulfilled. Polynomials describing the HP filter in case of a time series $\{y_t\}_{t=-\infty}^{+\infty}$ are given as $G(L) = (1 + \lambda(1-L)^2(1-L^{-1})^2)^{-1} = \sum_{j=-\infty}^{+\infty} G_j L^j$, where $\sum_{j=-\infty}^{+\infty} |G_j| < +\infty$ and $G_{-j} = G_j$, $C(L) = 1 - G(L) = \sum_{j=-\infty}^{+\infty} C_j L^j$, where $\sum_{j=-\infty}^{+\infty} |C_j| < +\infty$ and $C_{-j} = C_j$. The weights of the low-pass filter G(L) sum to one, while those of the high-pass filter C(L) – to zero, i.e. $\sum_{j=-\infty}^{+\infty} G_j = 1$ and $\sum_{j=-\infty}^{+\infty} C_j = 0$. In addition, the properties $C_0 = 1 - G_0$ and $C_j = -G_j$ for $j \neq 0$ are met. An amplification of the HP filter is defined as the Fourier transform (without the $1/2\pi$ factor) of the polynomial representing the filter in the domain of time. In case of the G(L) filter, the amplification is the even function $G(z)$ for $z = e^{-i\omega}$ which assumes real values from the range of [0, 1], i.e.:

$$G_G(\omega) \equiv G\left(e^{-i\omega}\right) = \frac{1}{1 + \lambda(1 - e^{-i\omega})^2(1 - e^{i\omega})^2} = \frac{1}{1 + 4\lambda(1 - \cos(\omega))^2} \quad (4.19)$$
$$for\ \omega \in [-\pi, \pi]$$

The amplification $G_G(\omega)$ may be written equivalently to (4.19) as $G_G(\omega) = \sum_{j=-\infty}^{+\infty} G_j\, e^{-i\omega j} = G_0 + 2\sum_{j=1}^{+\infty} G_j \cos(\omega j)$ for $\omega \in [-\pi, \pi]$. Given the amplification of the C(L) filter, the relation $G_C(\omega) = 1 - G_G(\omega)\ for\ \omega \in [-\pi, \pi]$ is fulfilled. As the amplification of the HP filter is an even function, the frequency domain may be limited to the [0, π] range. The weights of a low- and high-pass filter in the infinite observation sample variant may be computed on the basis of the inverse Fourier transform (with the $1/2\pi$ factor) of a given

amplification. For instance, for a low-pass filter the relevant formula will then take the following form: $G_j = 2\pi^{-1}\int_{-\pi}^{\pi} G_G(\omega)e^{i\omega j}d\omega \; for \; j = 0, \pm 1, \pm 2, \ldots$. The parameter λ determines the degree of 'smoothness' of the trend. Hodrick and Prescott (1997) proposed the value $\lambda = 1600$ in the case of the filter applied to quarterly data.

Baxter-King filter[88]

Let a time series with finite observation sample $\{y_t\}_{t=1}^{T}$ be a (non)stationary variable cleared of seasonal fluctuations. The purpose is the estimation of a cyclical component of the variable y_t, thus the estimation of a component y_t^c, which has power solely in frequency band $\{[-\overline{\omega}, -\underline{\omega}] \cup [\underline{\omega}, \overline{\omega}]\} \in [-\pi, \pi]$, where $0 < \underline{\omega} < \overline{\omega} < \pi$. Value τ_U means the period corresponding to the lower truncation frequency, i.e. $\underline{\omega} = 2\pi/\tau_U$, while τ_L means the period corresponding to the upper truncation frequency, i.e. $\overline{\omega} = 2\pi/\tau_L$, which implies that $2 < \tau_L < \tau_U < +\infty$. The estimator of component y_t^c resulting from the use of the BK filter is given as:

$$\widehat{y}_t^c = \widehat{B}_J(L)y_t, \; where \; \widehat{B}_J(L) = \sum_{j=-J}^{J} \widehat{B}_j L^j, \; for \; t = 1 + J, 2 + J, \ldots, T - J \qquad (4.20)$$

where weights $\widehat{B}_j$ fulfill the symmetry condition, i.e. $\widehat{B}_{-j} = \widehat{B}_j$. The corresponding estimator of the non-cyclical component is given as the difference $y_t - \widehat{y}_t^c$ for $t = 1 + J, 2 + J, \ldots, T - J$. Parameter *J*, similarly as in the case of power spectrum estimation is referred to as a truncation lag.[89] Due to the structure of the BK filter (symmetrical moving average), the obtained cyclical component estimator is a time series which consists of $T - 2J$ observations. A set of weights $\widehat{B}_j$ of the parameter *J* is a solution to the minimisation problem:

$$\min_{\widehat{B}_j, j=-J,\ldots,J} \frac{1}{2\pi}\int_{-\pi}^{\pi} |B(e^{-i\omega}) - \widehat{B}_J(e^{-i\omega})|^2 d\omega \qquad (4.21)$$

where $B\left(e^{-i\omega}\right)$ means the amplification of the 'ideal' band-pass filter, while $\widehat{B}_J\left(e^{-i\omega}\right)$ means the amplification of the approximated band-pass BK filter. The filter amplification (4.20) is given, according to the definition, as the Fourier transform of polynomial $\widehat{B}_J(L)$, thus it is a function

[88] Baxter and King (1995); Skrzypczyński (2010), p. 98-103.
[89] Skrzypczyński (2010), p. 98-99.

$\widehat{B}_J(z)$ for $z = e^{-i\omega}$. In addition, due to the fact that the weights of the BK filter are symmetrical, this function assumes real values and is given as[90]:

$$G_{\widehat{B}_J}(\omega) \equiv \widehat{B}_J\left(e^{-i\omega}\right) = \sum_{j=-J}^{J} \widehat{B}_j\, e^{-i\omega j} = \widehat{B}_0 + 2\sum_{j=1}^{J} \widehat{B}_j \cos(\omega j) \qquad (4.22)$$
$$for\ \omega \in [-\pi, \pi]$$

The limiting condition for the problem (4.21) is the requirement of the summability of weights to zero, i.e. $\sum_{j=-J}^{J} \widehat{B}_j = 0$, which ensures that the condition $\widehat{B}_J(e^{-i0}) = 0$ is met and, thus, the BK filter removes from the input data the stochastic trend caused by the presence of a unit root, which is connected with the zero frequency. The weights $\widehat{B}_j$ for $j = 0 \pm 1, \dots, \pm J$, being the solution of (4.21), are given as:

$$\widehat{B}_j = B_j + \theta \qquad (4.23)$$

where the weights B_j correspond to the weights of the 'ideal' band-pass filter while the parameter θ, which ensures the summability of the weights $\widehat{B}_j$ to zero, takes the following form:

$$\theta = \frac{-\sum_{j=-J}^{J} B_j}{2J+1} \qquad (4.24)$$

In a manner that is analogous to the structure of a band-pass filter one can obtain a low- and high-pass filter. With regard to the high-pass filter the solution narrows down to the replacement of the weights of the 'ideal' band-pass filter with the weights of the 'ideal' high-pass filter. Thus, for the BK-type high-pass filter the weights take the form of $\widehat{\widetilde{B}}_j = \widetilde{B}_j + \theta$ for $j = 0, \pm 1, \dots, \pm J$, where $\widetilde{B}_j$ are the weights of the 'ideal' high-pass filter and, similarly as in the case of a band-pass filter, the parameter $\theta = (-\sum_{j=-J}^{J} \widetilde{B}_j)/(2J+1)$ ensures the fulfillment of the condition $\sum_{j=-J}^{J} \widehat{\widetilde{B}}_j = 0$. This type of operation is equivalent to setting the upper cut-off frequency of the band-pass filter at the level of π. In case of a low-pass filter, the weights of the 'ideal' band-pass filter are replaced with the weights of the 'ideal' law-pass filter. Also, a limiting condition is imposed which forces the summability of weights to one, due to the fact that the purpose of a low-pass filter is to estimate the trend component. Therefore, for a low-pass filter of

[90] Due to its structure, the BK filter does not introduce a phase shift between the input and the output variable. The symmetrical nature of the filter for each observation in the sample results in the fact that the imaginary part of the amplification of this filter is always equal to zero. Ibidem, p. 99.

the BK-type the weights take the form of $\widehat{\underline{B}}_j = \underline{B}_j + \theta$ for $j = 0, \pm 1, \ldots, \pm J$, where $\underline{B}_j$ are the weights of the 'ideal' low-pass filter while the parameter $\theta = (1 - \sum_{j=-J}^{J} \underline{B}_j)/(2J + 1)$ ensures the fulfillment of a condition $\sum_{j=-J}^{J} \widehat{\underline{B}}_j = 1$, which at the same time guarantees that the amplification of this filter assumes the value of one for the zero frequency, i.e. $\widehat{\underline{B}}_J\ (e^{-i0}) = 1$. Baxter and King (1995) suggested the use of filters for which $J = 12$ in the case of quarterly data.

Robustness test

Table 4.6 Results of the ADF test for cyclical components of GDP, HP filter

Country	Statistics	Critical value	Conclusion
Euro area-12	-3.907	-1.95	I(0)
CEE-4	-3.534	-1.95	I(0)
Germany	-3.707	-1.95	I(0)
Czech Republic	-3.221	-1.95	I(0)
Hungary	-3.001	-1.95	I(0)
Poland	-4.236	-1.95	I(0)
Slovakia	-4.486	-1.95	I(0)

Source: Author's calculations

Table 4.7 Results of the KPSS test for the cyclical components of GDP, HP filter

Country	Statistics	Critical value	Conclusion
Euro area-12	0.037	0.146	I(0)
CEE-4	0.06	0.146	I(0)
Germany	0.028	0.146	I(0)
Czech Republic	0.063	0.146	I(0)
Hungary	0.059	0.146	I(0)
Poland	0.054	0.146	I(0)
Slovakia	0.049	0.146	I(0)

Source: Author's calculations

Table 4.8 Results of the ADF test for cyclical components of GDP, BK filter

Country	Statistics	Critical value	Conclusion
Euro area-12	-6.586	-1.95	I(0)
CEE-4	-6.247	-1.95	I(0)
Germany	-6.546	-1.95	I(0)
Czech Republic	-5.269	-1.95	I(0)
Hungary	-4.064	-1.95	I(0)
Poland	-4.658	-1.95	I(0)
Slovakia	-5.605	-1.95	I(0)

Source: Author's calculations

Table 4.9 Results of the KPSS test for the cyclical components of GDP, BK filter

Country	**Statistics**	**Critical value**	**Conclusion**
Euro area-12	0.035	0.146	I(0)
CEE-4	0.029	0.146	I(0)
Germany	0.03	0.146	I(0)
Czech Republic	0.03	0.146	I(0)
Hungary	0.037	0.146	I(0)
Poland	0.03	0.146	I(0)
Slovakia	0.033	0.146	I(0)

Source: Author's calculations

Table 4.10A Coefficients of cross-correlation between the time series representing the Euro area-12 business cycle and the time series representing the business cycles of the CEE-4 countries and Germany (analysis based on GDP data), HP filter

	t-6	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**
Germany	-0.200	-0.039	0.149	0.321	0.550	0.754	**0.839**	0.743	0.543	0.292	0.068	-0.142	-0.325
Czech Republic	-0.139	0.001	0.138	0.285	0.447	0.574	**0.602**	0.542	0.487	0.344	0.252	0.114	-0.062
Hungary	-0.402	-0.260	-0.114	0.089	0.322	0.512	**0.601**	0.596	0.514	0.398	0.333	0.217	0.155
Poland	-0.009	0.074	0.107	0.283	0.371	0.390	**0.429**	0.290	0.212	0.092	0.016	-0.065	-0.157
Slovakia	-0.030	0.018	0.094	0.214	0.353	**0.439**	0.402	0.279	0.132	0.022	-0.081	-0.178	-0.228

Source: Author's calculations

Table 4.10B Coefficients of cross-correlation between the time series representing the business cycle of Germany and the time series representing the business cycles of the CEE-4 countries (analysis based on GDP data), HP filter

	t-6	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**
Czech Republic	-0.223	-0.152	-0.020	0.173	0.334	0.460	**0.515**	0.448	0.382	0.277	0.170	-0.014	-0.104
Hungary	-0.403	-0.304	-0.125	0.070	0.243	0.451	**0.593**	0.502	0.395	0.289	0.198	0.096	0.063
Poland	-0.071	0.018	0.102	0.277	0.352	**0.328**	0.284	0.279	0.099	0.017	0.080	-0.117	-0.123
Slovakia	-0.092	-0.051	0.095	0.199	0.309	0.441	**0.446**	0.329	0.167	0.039	-0.114	-0.299	-0.340

Source: Author's calculations

Table 4.11A Coefficients of cross-correlation between the time series representing the Euro area-12 business cycle and the time series representing the business cycles of the CEE-4 countries and Germany (analysis based on GDP data), BK filter

	t-6	**t-5**	**t-4**	**t-3**	**t-2**	**t-1**	**t**	**t+1**	**t+2**	**t+3**	**t+4**	**t+5**	**t+6**
Germany	-0.217	-0.025	0.217	0.479	0.716	0.876	**0.917**	0.826	0.618	0.336	0.031	-0.249	-0.473
Czech Republic	-0.229	-0.013	0.219	0.438	0.614	0.723	**0.750**	0.687	0.540	0.329	0.087	-0.149	-0.345
Hungary	-0.457	-0.263	-0.017	0.255	0.513	0.709	**0.805**	0.792	0.689	0.533	0.355	0.177	0.012
Poland	-0.072	0.079	0.223	0.363	0.488	**0.567**	0.562	0.455	0.266	0.053	-0.126	-0.232	-0.260
Slovakia	0.012	0.122	0.256	0.399	0.512	**0.545**	0.469	0.288	0.044	-0.200	-0.392	-0.504	-0.536

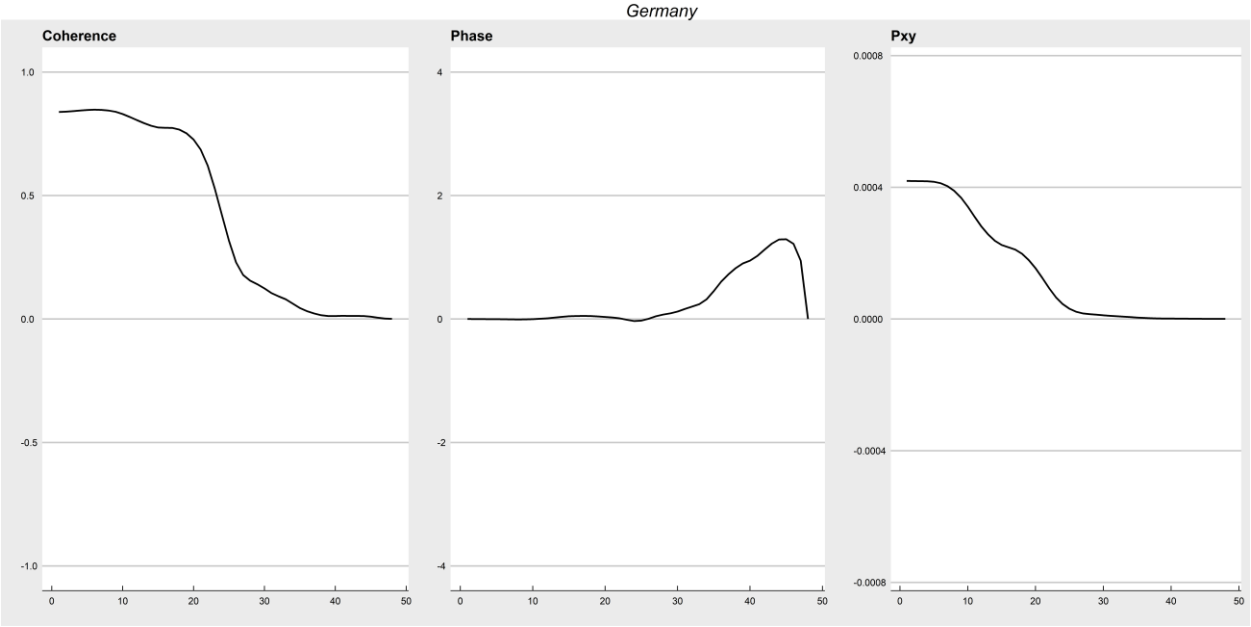
Source: Author's calculations

Table 4.11B Coefficients of cross-correlation between the time series representing the business cycle of Germany and the time series representing the business cycles of the CEE-4 countries (analysis based on GDP data), BK filter

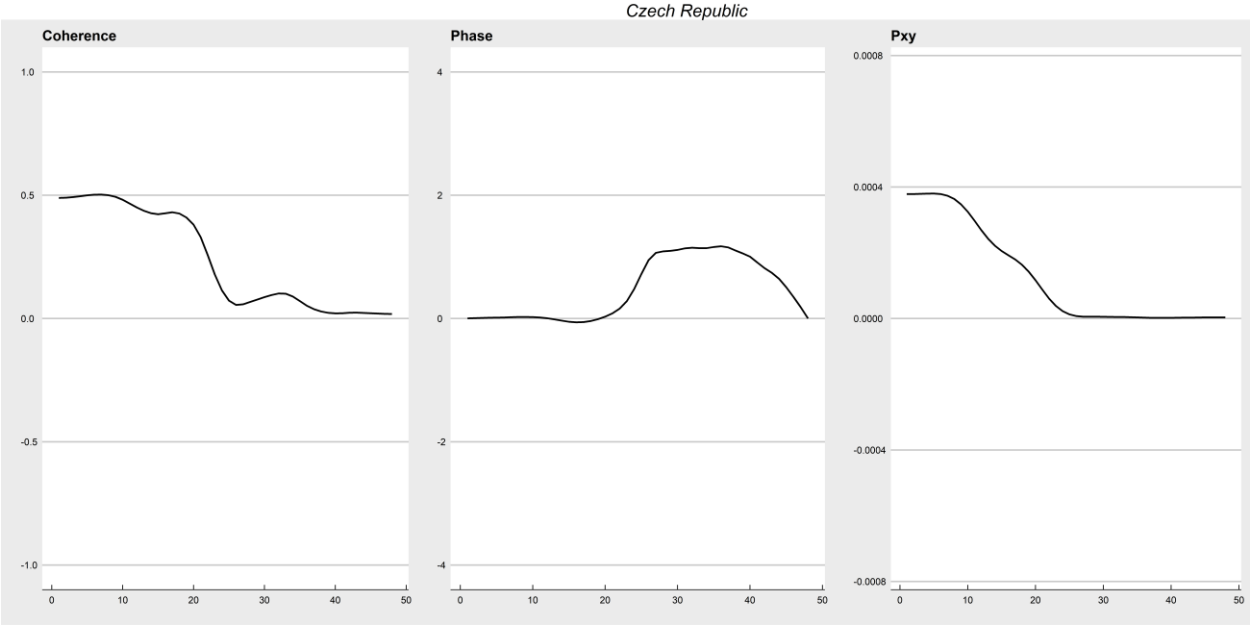
	t-6	t-5	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4	t+5	t+6
Czech Republic	-0.347	-0.171	0.053	0.298	0.523	0.681	**0.739**	0.690	0.551	0.352	0.131	-0.080	-0.255
Hungary	-0.542	-0.369	-0.134	0.143	0.422	0.646	**0.763**	0.758	0.647	0.478	0.300	0.148	0.035
Poland	-0.120	0.065	0.241	0.388	0.484	**0.509**	0.455	0.337	0.179	0.014	-0.128	-0.222	-0.262
Slovakia	-0.044	0.090	0.244	0.407	0.549	**0.624**	0.593	0.441	0.195	-0.089	-0.345	-0.523	-0.604

Source: Author's calculations

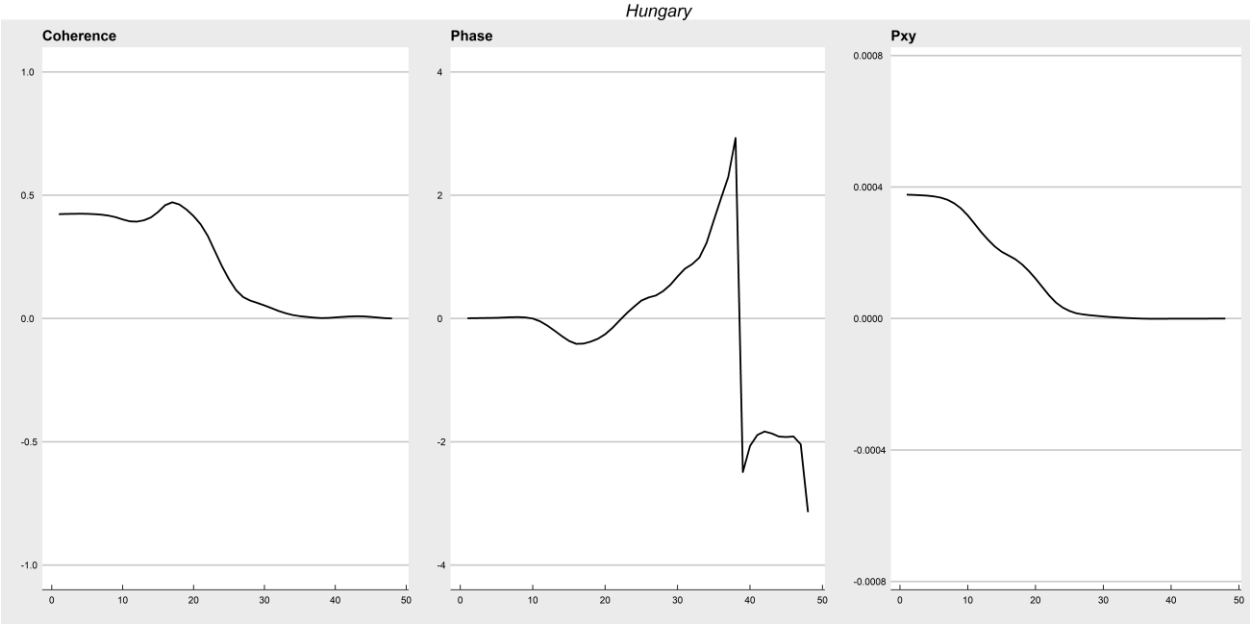
Figure 4.2 Measures of cross-spectral analysis between the cyclical component of the Euro area-12 and the cyclical components of individual CEE-4 countries and Germany (analysis based on GDP data), HP filter

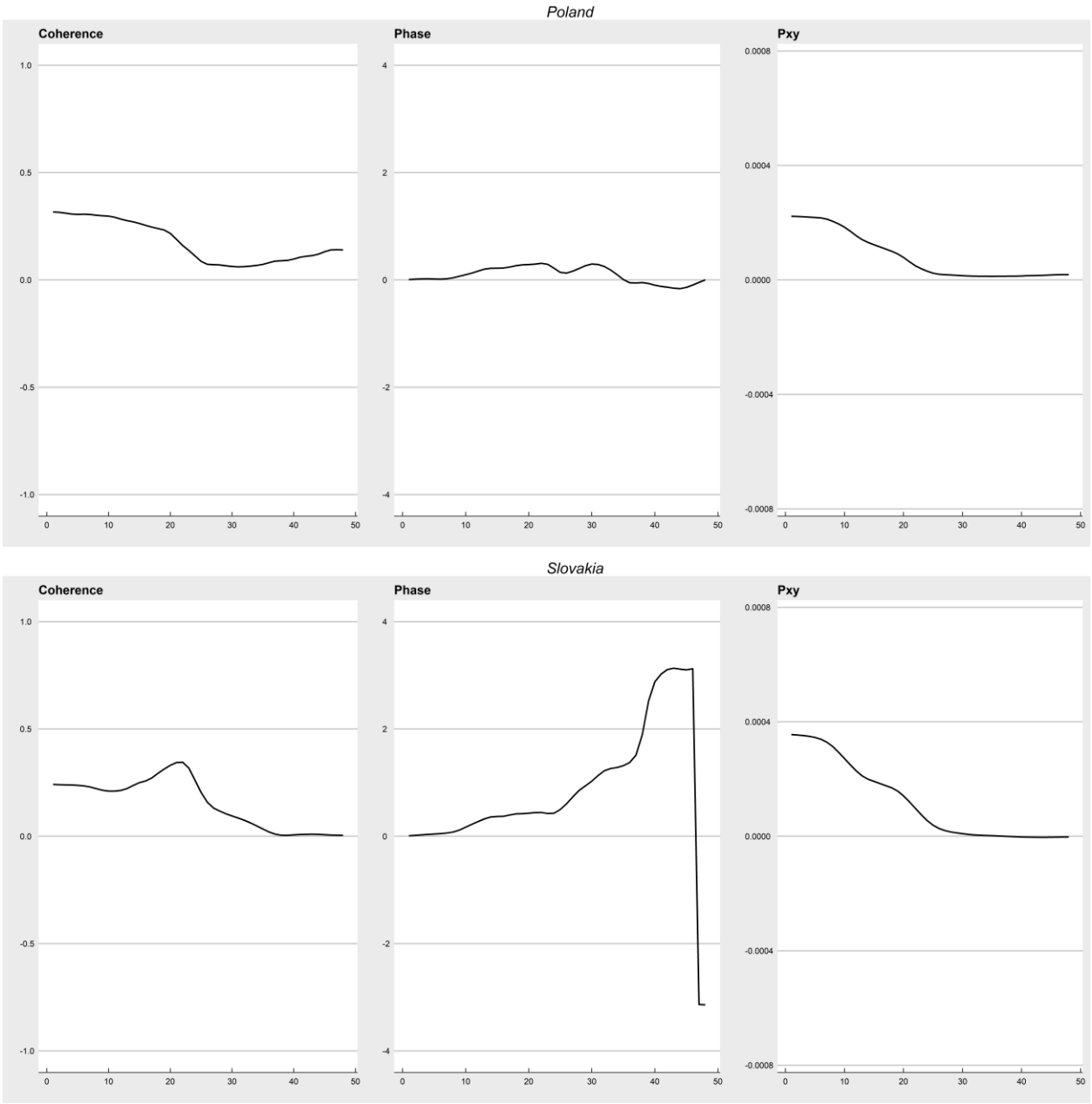


Czech Republic



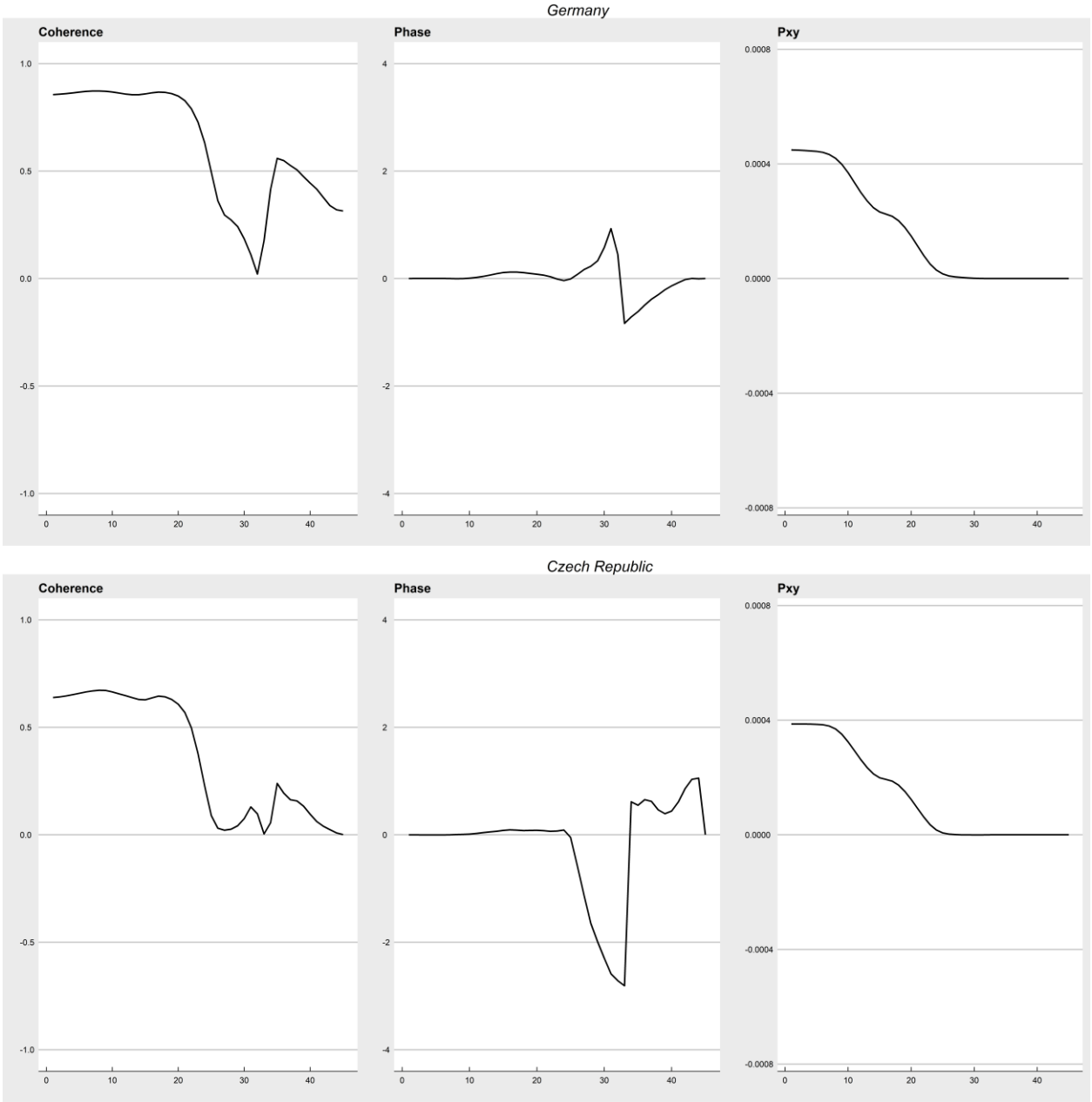
Hungary



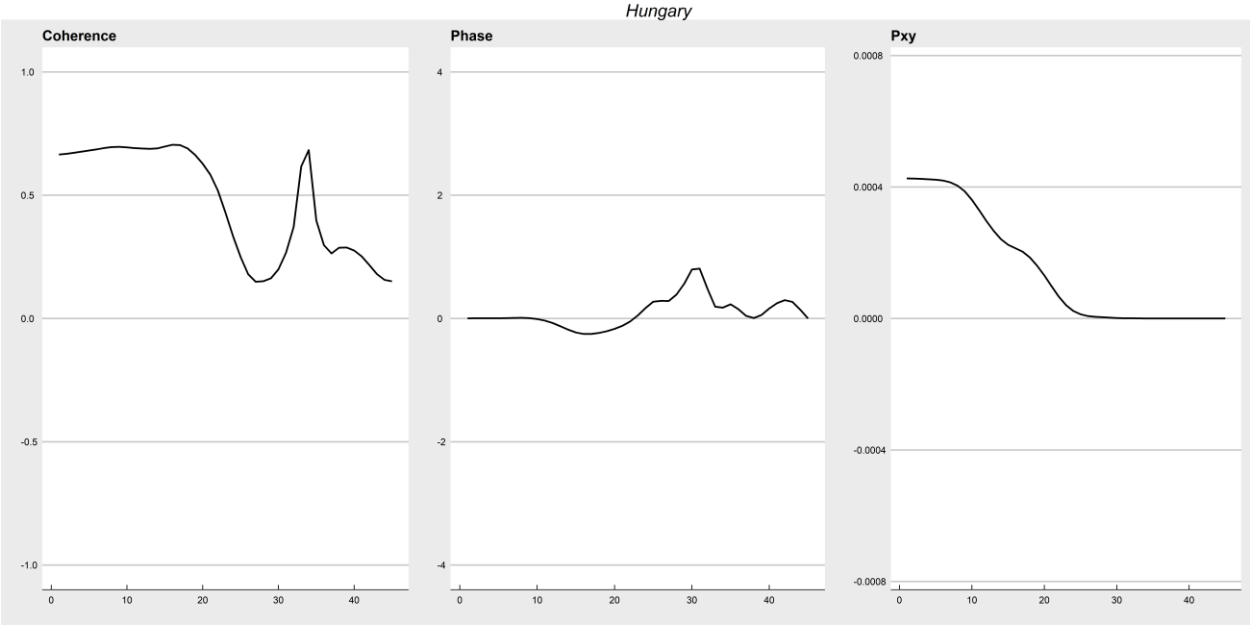


Source: Author's calculations

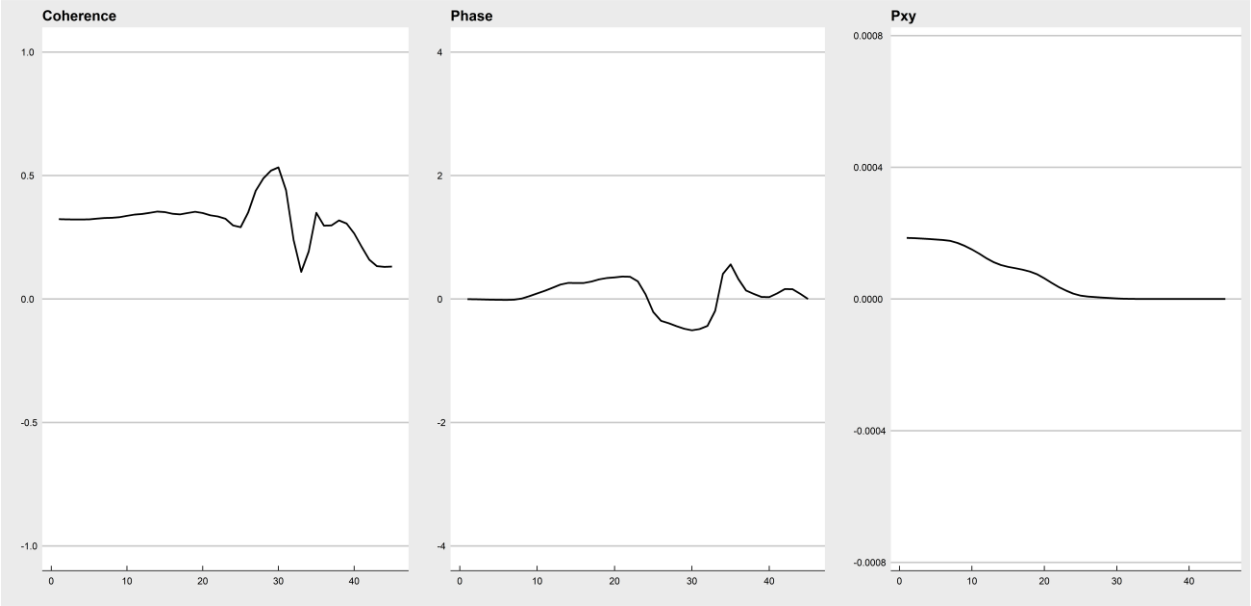
Figure 4.3 Measures of cross-spectral analysis between the cyclical component of the Euro area-12 and the cyclical components of individual CEE-4 countries and Germany (analysis based on GDP data), BK filter

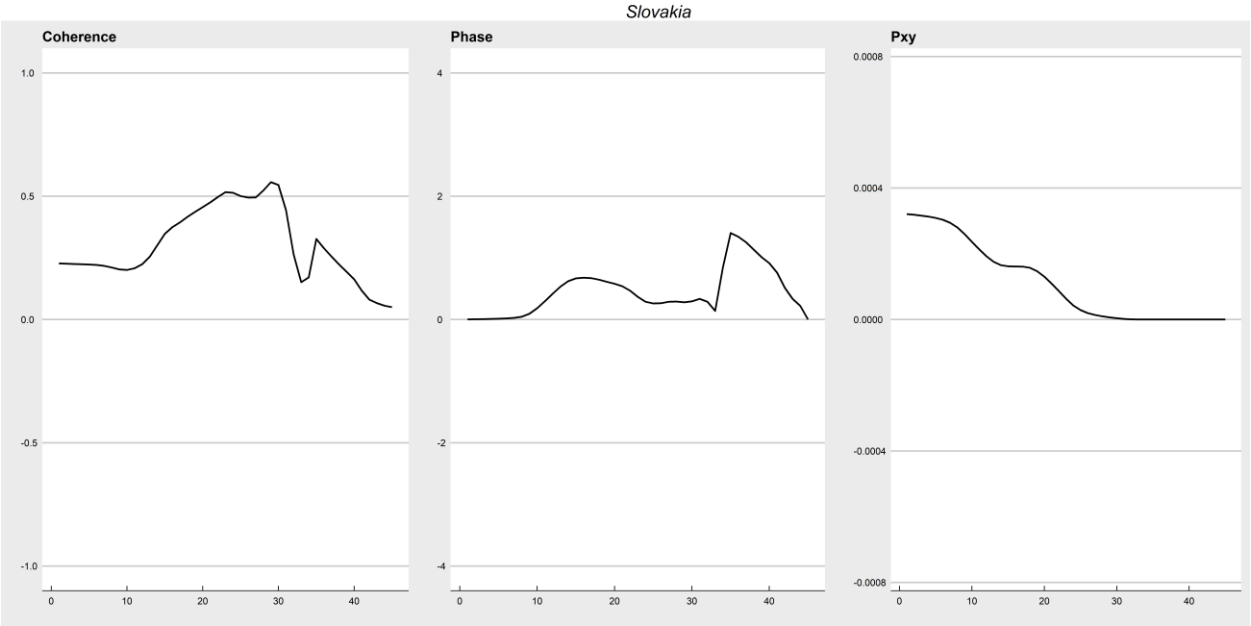


Hungary



Poland





Source: Author's calculations

Chapter 5

The impact of macroeconomic and institutional factors on economic growth in the CEE-4 countries

5.1 Introduction

The aim of the study is to examine the main factors driving economic growth in the CEE-4 countries since the transition with the main focus on macroeconomic policies and institutions. The building of a market economy in the region required deep macroeconomic reforms and the creation of a wide range of institutions and business practices needed to support those reforms. Since the collapse of communist regimes, the CEE-4 countries have adopted in the early 1990s a set of policy principles termed as the so-called Washington Consensus. They focused on fiscal discipline, interest rate liberalisation, trade and financial liberalisation, privatisation, deregulation and openness to direct foreign investment. These policies were perceived to be the key elements of "free markets and sound money" (Rodrik (2007), p. 16). The growth literature always stressed the stabilizing role of monetary and fiscal policies for long-term economic growth. They affect both aggregate demand and supply conditions as they influence: the money supply in an economy, which in turn impacts interest rates and inflation rate, investment spending on business capital goods, government spending on public goods and services, taxation, exports and imports. Macroeconomic stability by itself, however, does not ensure high rates of GDP growth. In most cases, sustained high rates of growth also depend upon key structural measures, such as regulatory reform, civil service reform, improved governance, and banking sector reform (Ames et al. (2001)). Institutions of central planning in the CEE-4 region were one of the key barriers to growth prior to the transition. Therefore, there was a growing recognition that market-oriented policies in the CEE-4 countries might not be fully sufficient without more serious institutional transformation. Toward the end of the 1990s, the Washington Consensus' list was thus augmented with a series of so-called second-generation reforms that were more institutional in nature and targeted at problems of "good governance" (Rodrik (2007), p. 17). According to Douglass North, institutions are made up of formal constraints (e.g., rules, laws, constitutions), informal constraints (e.g., norms of behavior, conventions, self-imposed codes of conduct), and their enforcement characteristics. Together they

define the incentive structure of societies and specifically economies (North (1994), p.360). In essence, institutions set the "rules of the game" that determine the incentives for production, investment, and consumption (Schadler et al. (2006), p. 19). Generally shared view among economists studying economic growth is that institutional quality is crucial for achieving prosperity. Rich countries are those where investors feel secure about their property rights, the rule of law is upheld, monetary and fiscal policies are anchored in solid macroeconomic institutions and citizens have civil liberties and political representation.[91] As the development of institutions has been necessary to support the well-functioning market economies in the CEE-4 region, the study also examines deep factors of production - institutions - in addition to the demand-side and the supply-side factors affecting output. It is in line with earlier research which provides evidence that policy and institutions affect the level of economic efficiency with which resources are allocated in the economy.[92]

Since the transition from centrally planned systems to market economies, the CEE-4 countries have pursued a distinctive model of development based on economic and political integration and institutional anchoring to the EU. The prospect of membership in the EU and the adoption of its acquis communautaire significantly differentiated the CEE-4 countries from other emerging market economies (Becker et al. (2010), p. 5). Economic policies and institutions of central planning were the key constraints on growth in the CEE-4 region before the transition. To examine significant changes which have occurred in the last two decades in the region, a wide range of macroeconomic and demographic variables as well as key institutional indicators have been analysed within the Bayesian Model Averaging (BMA) framework to avoid model uncertainty problem. Another contribution of this comprehensive study has been an empirical analysis of growth determinants in the CEE-4 region in comparison to the Euro area-12 group as well as within the EU-28 block.

The rest of the chapter consists of five sections. Section 2 provides the literature overview while sections 3 and 4 describe the data and methodology. The main findings of the study are presented in section 5 and section 5 then concludes.

[91] It should be noted, however, that causality can run in both directions as strong institutions can be as much a result of economic prosperity as they are its cause. See Rodrik (2007), p. 184.
[92] See i.a. Bassanini and Scarpetta (2001), IMF (2003), Acemoglu et al. (2004), Schadler et al. (2006) and Rodrik (2007).

5.2 Literature overview

The early studies of economic growth determinants focused on the impact of macroeconomic policies such as low inflation, reduced budget deficits and exchange rate stability.[93] Only later, the literature on growth factors de-emphasized macroeconomic policies in favor of the role of institutions as drivers of economic performance (Fatás and Mihov (2005), p. 1). The main advocates of the view that economic and political institutions were the major source of economic growth included, among others, North (1981, 1990), Jones (1981), Bardhan (1984), Hall and Jones (1999), Rodrik (1999), Acemoglu and Robinson (2000, 2002), Acemoglu at al. (2001, 2002). Those studies focused on the effect of institutions on economic growth, investment or the level of development (Acemoglu et al. (2003), p. 56). The simultaneous impact of policy settings and institutions on economic growth was also examined empirically, for example, by Bassanini and Scarpetta (2001), Acemoglu et al. (2003), Rodrik (2003), Easterly (2004) and Fatás and Mihov (2005). Acemoglu et al. (2003) and Easterly (2004) provided evidence that macroeconomic policies (monetary, fiscal, trade) have an explanatory power for the cross-country variation in growth rates and income per capita only because they serve as proxies for institutions. Both poor macroeconomic performance and distortionary macroeconomic policies are more likely to be symptoms of underlying institutional problems rather than the main causes of economic instability. Under various specifications, policy variables turn insignificant once institutions are included in the regressions, which implies that bad policies are simply a reflection of bad institutions.[94] The results presented by Fatás and Mihov (2005) indicated, however, that policy volatility had a significant negative effect on economic growth and that this was a direct effect, not simply a spurious correlation due to the fact that both variables were caused by bad institutions. In their analysis, institutions had an effect on growth but only through the effects they had on macroeconomic policies. Therefore, institutions mattered to a large extent because they affected policy and, in particular, policy volatility.

Due to model uncertainty which prevents researchers to reach consensus on the key determinants of economic growth, a number of studies adopted more recently Bayesian-inspired frameworks to examine the impact of economic policies and institutions. Fernandez et al. (2001)

[93] For the literature overview see Temple (1999), Ahn and Hemmings (2000).
[94] This does not mean, however, that macroeconomic policies do not matter for macroeconomic outcomes. Certainly, overvalued exchange rates or high inflation would discourage certain investments, and unsustainable policies will necessarily lead to some sort of crisis (Acemoglu et al. (2003), p. 54).

applied the Bayesian Model Averaging approach to determine which of 41 regressors should be included in cross-country growth regressions. Their results for 140 countries over the period 1960-1992 differed somewhat from the findings obtained by Sala-i-Martin (1997). The authors did not advocate selecting a subset of the regressors, but they used BMA, where all inference was averaged over models, using the corresponding posterior model probabilities as weights. Among the most important regressors for explaining cross-country growth patterns identified by Fernandez et al. (2001) were GDP level in 1960, life expectancy, investment in equipment, rule of law, number of years an economy was 'open', degree of capitalism as well as geographical and religious variables. Sala-i-Martin et al. (2004) examined the robustness of explanatory variables in cross-country economic growth regressions employing a novel approach, Bayesian Averaging of Classical Estimates (BACE), which constructs estimates by averaging OLS coefficients across models. The weights given to individual regressions have a Bayesian justification similar to the Schwarz model selection criterion. Of 67 explanatory variables collected for 88 countries over the years 1960-1996, the authors found 18 to be significantly and robustly correlated with long-term growth, and another three variables to be marginally related. Those variables included, among others, primary schooling, investment price, initial level of GDP per capita, geographical and religious variables, life expectancy in 1960, number of years an economy was 'open' and government consumption share in GDP. Moral-Benito (2007) extended the Bayesian Model Averaging approach to panel data models with country-specific fixed effects. The dataset covered 34 explanatory variables for 73 countries over the period 1960-2000. The empirical results pointed to economic, institutional, geographic and demographic factors affecting growth. The most robust growth determinants were investment price, air distance to big cities and political rights. Among other variables which could be considered as robust were demographic factors (population growth, urban population and population), geographical dummies (such as the dummy for landlocked countries), measures of openness and civil liberties, as well as macroeconomic indicators such as investment share and government share.

Two studies by Bergh and Karlsson (2010), Próchniak and Witkowski (2014) examined the relationship between economic freedom and growth. Bergh and Karlsson (2010) focused on one out of five dimension of the economic freedom (EF) index developed by the Fraser Institute,

namely on government size.[95] They analysed the impact of government size on economic growth while controlling for economic freedom and globalization, and using Bayesian Averaging over Classical Estimates in a panel of 29 rich countries. The study included the set of 21 control variables and covered the 1970-1995 and 1970-2005 periods. The results pointed to the negative effect of government size on economic growth. The authors also found some evidence that countries with big government could use economic openness and sound economic policies to mitigate negative effects of big government. Próchniak and Witkowski (2014) also examined the impact of regulations - measured by the Fraser Institute index of economic freedom – on economic growth. Their study covered 111 countries of the world as well as the EU-27 and 14 post-socialist countries from Central and Eastern Europe over the years 1970-2010. The authors used Bayesian Model Averaging method applied to Blundell and Bond's generalized method of moments (GMM) system estimator. The method of the analysis was based on growth regressions where economic freedom was included in the set of explanatory variables, along with other 12 macroeconomic and demographic control factors. Their results showed that the level of and the change in economic freedom both had a positive and nonlinear relationship with economic growth.

5.3 Data

For the purpose of an empirical analysis, 21 macroeconomic and institutional variables[96] have been examined as growth factors for the Euro area-12, Euro area-19, and EU-28 member states.[97] Annual data cover the period of 23 years: from 1995 till 2018. For the purpose of the analysis, three BMS models were estimated, which differ in terms of the sample of countries: for the CEE-4 group, Euro area-12 and EU-28. The dependent variable - economic growth – is measured by GDP per capita at purchasing power parity (PPP) in constant prices. Among the explanatory variables collected for a study of the regulatory framework were: economic freedom,

[95] The authors constructed a measure of economic freedom based on the remaining four dimensions of the EF: legal structure and security of property rights, access to sound money, freedom to exchange with foreigners, and regulation of credit, labor and business.

[96] The list of variables and their sources is presented in Table 5.4 in the Appendix.

[97] The Euro area-12 group consists of Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain. The Euro area-19 comprises Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovak Republic, Slovenia, Spain. The EU-28 encompass Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom.

democracy index and financial development. The economic freedom index published by the Heritage Foundation is based on 12 quantitative and qualitative factors, grouped into four broad pillars: rule of law (property rights, government integrity, judicial effectiveness), government size (government spending, tax burden, fiscal health), regulatory efficiency (business freedom, labor freedom, monetary freedom) and open markets (trade freedom, investment freedom, financial freedom). Each of those 12 components of economic freedom is graded on a scale from 0 to 100, with higher outcome representing greater scope of economic freedom.[98] Since the regulatory environment in which an economy operates is very important, more economic freedom is viewed as detrimental to economic growth. Another qualitative index referring to deep growth determinants considered in the study is democracy index. It is published by the Freedom House and calculated as an average of political rights (PR) and civil liberties (CL). The political rights questions are grouped into three subcategories: electoral process, political pluralism and participation, and functioning of government. The civil liberties questions refer to: freedom of expression and belief, associational and organizational rights, rule of law, personal autonomy and individual rights. The original scale of rating is from 1 to 7, with 1 representing the greatest degree of freedom and 7 the smallest degree of freedom.[99] While there is no clear evidence on the strong relationship between political participation and levels of long-run growth[100], some empirical results imply that stable and persistent democracy has a stronger effect on development rather than democracy per se (Persson and Tabellini (2006)). Other studies argues that the effect of the political system is indirect, with political systems influencing the quality of institutions and only from there to growth. Moreover, democracy makes governments more accountable and thus improves their commitment to chosen policies (Borner et al. (2004)). Also, a new broad-based index of financial development introduced by the IMF in 2016 has been considered in the study.[101] A well-developed financial systems contribute to economic growth by providing funding for capital accumulation and by helping the diffusion of new technologies. They mobilise savings by channeling small savings of individuals into profitable large-scale investments, while

[98] They are equally weighted and averaged to produce an overall economic freedom score for each economy. More information on the grading and methodology can be found in Miller et al. (2019), p. 457-469.
[99] For the purpose of the study, the original scale has been rescaled by first calculating the average of PR and CL and then by using the following transformation: 1 - (average - 1)/6. Hence, the original value of 7 takes the value of 0 (the smallest degree of freedom) and the original value of 1 remains 1 (the greatest degree of freedom).
[100] See Barro (1997), Brunetti (1997), Durham (1999).
[101] The index database provides data for over 180 countries with annual frequency from 1980 onwards. Svirydzenka (2016).

offering savers a high degree of liquidity (Bassanini and Scarpetta (2001), p. 20). The IMF's index of financial development is created based on nine indices that summarise how developed financial institutions and financial markets are in a given country in terms of their depth (size and liquidity), access (ability of individuals and companies to access financial services), and efficiency (ability of institutions to provide financial services at low cost and with sustainable revenues and the level of activity of capital markets). These indices are then aggregated into an overall index of financial development which ranges between 0 and 1 (with 1 being the best outcome).

In the empirical investigation of the sources of economic growth also macroeconomic variables have been considered. Economic growth has been measured by GDP per capita at purchasing power parity (PPP) in constant prices. The variables associated with monetary and fiscal policies refer to: inflation, interest rates, government consumption and government balance. Economic theory points to a negative relationship between inflation and growth while empirical evidence is somehow mixed and point to a nonlinear association. At some (low) rate of inflation, the relationship could be positive or nonexistent, but at higher rates it becomes negative.[102] Nevertheless, higher inflation is associated with lower growth because lower real balances reduce the efficiency of factors of production. Inflation also disturbs efficient resource allocation by obscuring the signaling role of relative price changes – the most important guide to efficient economic decision making.[103] With regard to interest rates, an increase in interest rates moderates economic growth. Higher interest rates increase the cost of borrowing, reduce disposable income and, therefore, limit the growth in consumer spending and investment.[104] Fiscal policy conduct can also affect output and growth. It is acknowledged that a high level of fiscal deficit may lead in the longer run to a crowding-out of the private sector, higher interest rates, and distortions through future tax increases which affect the efficient allocation of resources. Therefore, one can expect a negative impact of the government deficit on economic growth in the long run.[105]

[102] See Bruno and Easterly (1998).

[103] While inflation distorts price and wage fluctuations (sand), at the same time it facilitates adjustment to shocks when wages are rigid downwards (grease). When inflation is low, the net impact of grease and sand effects may be positive. However, at higher inflation rates, sand effects are expected to dominate as grease effect is bounded by the size of real shocks. See Khan and Senhadij (2000).

[104] It should be noted, however, that high nominal and real interest rates may not decrease economic growth if there are mechanisms such as low inflation expectations, economy's attractiveness to foreign investors, the technological transfer effect and the accumulation of domestic savings. See Drobyshevsky et al. (2017).

[105] Temporarily, however, an increase in the fiscal deficit caused by higher government spending may have an expansionary effect on the growth rate as long as it is not used for the service of higher interest rate liabilities. In

Government consumption as a percentage of GDP is used in empirical studies as a proxy for the size of government. Its negative impact on the growth rate stems from the underlying rationale that public spending is supposedly less productive than private. Moreover, tax distortions to finance government consumption may be harmful to economic growth.[106] Furthermore, variables related to components of aggregate demand have also been examined: the level of investment as well as trade. Trade facilitates more efficient production of goods and services by shifting production to countries that have comparative advantage in producing them. Aside from the benefits stemming from comparative advantages, additional gains from trade arise through economies of scale, exposure to competition and the diffusion of knowledge.[107] As a consequence, this can result both in higher overall efficiency and possibly a higher level of investment (since the adoption of foreign technologies requires investment in new types of capital) (Bassanini and Scarpetta (2001), p. 20). More investment provides, in turn, more production capacity and contributes to capital formation. A rise in capital spending has important effects on both the demand and supply side of the economy - including a positive multiplier effect on national income. Since foreign direct investment has been an important source of financing for transition economies, it has also been considered in the study.[108] FDI helps to cover the current account deficit, fiscal deficit (in case of privatisation-related FDI), and supplements inadequate domestic resources to finance both ownership change and capital formation. Also, compared with other financing options FDI facilitates transfer of technology, know-how and skills, and helps local enterprises to obtain management expertise.[109] The accumulation of physical and human capital have also been analysed as the basic determinants of economic growth, proxied by gross fixed capital formation and mean years of schooling.[110] Expenditure on research and development (R&D) measured by two indices - GERD (Gross domestic expenditure on R&D as % of GDP) and BERD (Business enterprise expenditure on R&D as % of GDP) - has also been considered as an investment in knowledge. It translates into new technologies as well as more efficient ways of using existing resources of physical and human capital (Ibidem, p. 15).

empirical research, the relationship between government deficit and economic growth has been found to be weak. See Levine and Renelt (1992).

[106] Barro and Lee (1994)

[107] See Frankel and Romer (1999), Alcalá and Ciccone (2004).

[108] A significant and positive impact of foreign direct investments on transition economies has been acknowledged by many studies. See for example Neuhaus (2006) and Krkoska (2001).

[109] Krkoska (2001).

[110] Average number of years of education received by people ages 25 and older, converted from educational attainment levels using official durations of each level. Barro and Lee (2013).

In addition, the value added in services has been included as services are generally perceived as the most productive sector which highly influences the economic growth. It is also viewed that the expansion of the service sector in the CEE-4 countries was one of the key factors which significantly stimulated the economic growth in the region since the transition. Finally, the remaining variables related with demography and health situation such as life expectancy, fertility rate, population level and growth have also been considered.

5.4 Methodology[111]

Due to a model uncertainty in applied econometrics to explain variation of the response variable - economic growth - Bayesian Model Averaging (BMA) has become a popular alternative to the selection problem of explanatory variables. In the search for a satisfactory statistical model of growth, the main area of effort has been the selection of appropriate variables to include in growth regressions (Moral-Benito (2007), p. 2). Since the choice of exogenous variables is highly subjective and reflects views of the researcher on what the true model is, different preselected sets of independent variables can lead to different conclusions including a risk of omitted variables bias (Próchniak and Witkowski (2013), p. 325).[112] BMA addresses model uncertainty in a canonical regression problem and has gained popularity in empirical studies over the last two decades. For the purpose of the study, the Bayesian Model Sampling (BMS) package for R presented by Zeugner and Feldkircher (2015) has been employed. It implements Bayesian Model Averaging for linear regression models. The BMS package allows to sample data according to different g-priors and model priors, and leaves the choice of different samplers.

Given a linear model structure, with y being the dependent variable, α_γ a constant, β_γ the coefficients, and ε a normal IID error term with variance σ^2:

$$y = \alpha_\gamma + X_\gamma \beta_\gamma + \varepsilon \; \varepsilon \sim N(0, \sigma^2 I) \tag{5.1}$$

a selection problem occurs when there are many potential explanatory variables in a matrix X. The inference based on a single linear model including all variables $X_\gamma \, \epsilon \, \{X\}$ is inefficient and

[111] Zeugner and Feldkircher (2015).

[112] Sala-i-Martin et al. (2004) tried to solve this problem using a novel approach, Bayesian Averaging of Classical Estimates (BACE) to determine which explanatory variables should be included in linear cross-country growth regressions. BACE constructed estimates as a weighted average of OLS estimates for every possible combination of included variables. The weights applied to individual regressions were justified on Bayesian grounds in a way similar to the well-known Schwarz criterion.

even infeasible with a limited number of observations. BMA offers a solution to the problem by estimating models for all possible combinations of $\{X\}$ and constructing a weighted average over all of them. With *X* containing *K* potential variables, this means estimating 2^K models. The model weights for this averaging stem from posterior model probabilities that arise from Bayes' theorem:

$$p(M_\gamma|y, X) = \frac{p(y|M_\gamma,X)\, p(M_\gamma)}{p(y|X)} = \frac{p(y|M_\gamma,X)\, p(M_\gamma)}{\sum_{s=1}^{2^K} p(y|M_s,X)\, p(M_s)} \tag{5.2}$$

where $p(y|X)$ is the integrated likelihood which is constant over all models. Hence, the posterior model probability (PMP) $p(M_\gamma|y,X)$ is proportional to the marginal likelihood of the model $p\left(y\middle|M_\gamma,X\right)$ (the probability of the data given the model M_γ) multiplied by a prior model probability $p(M_\gamma)$, which indicates how probable the researcher thinks model M_γ is before looking at the data.[113] After re-normalization, the PMPs can be inferred and, thus, the model weighted posterior distribution for any statistic θ (e.g. the coefficients β):

$$p\,(\theta|y, X) = \sum_{\gamma=1}^{2^K} p\,(\theta|M_\gamma\,, y, X)\; p\,(M_\gamma|X, y) \tag{5.3}$$

The model prior $p(M_\gamma)$ is provided by the researcher and should reflect prior beliefs. Very often, a uniform prior probability is chosen for each model $p(M_\gamma) \propto 1$ to represent the lack of prior knowledge.

With regard to the estimation framework, the literature standard is to use a 'Bayesian regression' linear model with a specific prior structure called ‘Zellner's g prior’. For each individual model M_γ, a normal error structure as in (5.1) is assumed. In order to obtain posterior distributions, the priors on the model parameters need to be specified. Placing ‘improper’ priors on the constant and error variance means they are evenly distributed over their domain: $p(\alpha_\gamma) \propto 1$, i.e. there is complete prior uncertainty where the constant is located. Similarly $p(\sigma) \propto \sigma^{-1}$. As far as the crucial prior on regression coefficients β_γ is concerned, the researcher formulates prior beliefs on coefficients into a normal distribution with a specified mean and variance before looking into the data (y, X). Often a conservative prior mean of zero for the coefficients is assumed to reflect that not much is known about them. Their variance structure is defined according to Zellner's g: $\sigma^2(\frac{1}{g}X'_\gamma X_\gamma)^{-1}$ as follows:

[113] Proportionality is expressed with the sign ∝: $p(M_\gamma|y,X) \propto p\,(y|M_\gamma, X)\; p\,(M_\gamma)$.

$$\beta_\gamma | g \sim N\,(0, \sigma^2(\frac{1}{g} X'_\gamma X_\gamma)^{-1}) \tag{5.4}$$

The hyperparameter g expresses how certain the researcher is that coefficients are indeed zero. A small g means few prior coefficient variance and thus implies the researcher is quite certain that the coefficients are indeed zero. Conversely, a large g means that the researcher is very uncertain that coefficients are zero.

The posterior distribution of coefficients reflects prior uncertainty: given g, it follows a t-distribution with expected value $E(\beta_\gamma | y, X, g, M_\gamma) = \frac{g}{1+g}\widehat{\beta_\gamma}$, where $\widehat{\beta_\gamma}$ is the standard OLS estimator for model γ. The expected value of coefficients is thus a convex combination of OLS estimator and prior mean (zero). The more conservative (smaller) g is, the more important is the prior, and the more the expected value of coefficients approaches the prior mean zero. As $g \to \infty$, the coefficient estimator approaches the OLS estimator. Also, the posterior variance of β_γ is affected by the choice of g:[114]

$$Cov\,(\beta_\gamma | y, X, g, M_\gamma) = \frac{(y-\bar{y})'(y-\bar{y})}{N-3} \frac{g}{1+g}\,(1 - \frac{g}{1+g} R^2_\gamma)\,(X'_\gamma X_\gamma)^{-1} \tag{5.5}$$

so the posterior covariance is similar to that of the OLS estimator, times a factor that includes g and R^2, the OLS R-squared for model γ.

For BMA, this prior framework results into a simple marginal likelihood $p(y|M_\gamma, X, g)$ that is related to the R-squared and includes a size penalty factor adjusting for model size k_γ:

$$p(y|M_\gamma, X, g) \propto (y-\bar{y})'(y-\bar{y})^{\frac{-N-1}{2}}\,(1+g)^{\frac{-k_\gamma}{2}}\,(1 - \frac{g}{1+g})^{\frac{-N-1}{2}} \tag{5.6}$$

The choice of the form of the hyperparameter g is crucial. A popular 'default' approach is the 'unit information prior' (UIP), which sets g = N commonly for all models and thus attributes about the same information to the prior as is contained in one observation.

5.5 Results

The results of the analysis for 2^{21} (2097152) model combinations are presented in Tables 5.1 - 5.3 with the corresponding statistics. For each model specification, Tables 5.1 - 5.3 contain estimated coefficients obtained with the use of BMS approach for the CEE-4 group, the Euro area-12 and the EU-28 member states. The column PIP represents posterior inclusion probabilities, i.e. the sum of posterior model probabilities (PMPs) for all models where a variable

[114] N denotes here sample size, and $\bar{y}$ the sample mean of the response variable.

was contained. The next column Post Mean displays the coefficients averaged over all models, including the models in which the variable was not included (implying that the coefficient was zero in that case). The column Post SD reflects the coefficients' posterior standard deviations while the column Cond. Pos. Sign represents the 'posterior probability of a positive coefficient expected value conditional on inclusion', respectively 'sign certainty'. The last column Idx denotes the index of the variables' appearance in the original data set, while the results in the study are sorted by PIP.[115]

Analysing the CEE-4 countries, the most significant and positive effect on GDP growth has the economic freedom as it occurs in all models, with the highest PIP of 100 per cent, and the value of its coefficient inferred from the Post SD and Cond. Pos. Sign being certainly positive (Table 5.1). This finding is in line with numerous studies which confirm a positive impact of economic freedom on economic growth.[116] During the transformation, the CEE-4 countries moved from centrally managed to market-oriented economies. This meant the need to significantly expand the scope of economic freedom by the introduction of liberalization and market reforms. Since the regulatory environment in which an economy operates is very important, policy-makers in the region should continue necessary reforms aiming at increasing the scope of economic freedom. The second variable which exerts a significant impact on economic growth with the posterior model probability of 99.86 per cent is long-term interest rate. Almost all of posterior model mass rests on models that include this covariate. In all encountered models containing this variable, its (expected value of) coefficient has a negative sign. This result is confirmed by all major economic schools of thought which claim that higher interest rates hinder economic growth. High inflation along with the lack of proven record of monetary and fiscal credibility during the transition led to adaptive-inflation expectations in the CEE-4 region. Therefore, long-term interest rates as an average of expected future short-term interest rates were very high in the 1990s. The remaining variables which exert a significant impact on economic growth - life expectancy and democracy index - appear in above 94 per cent of models. The coefficient signs for these two variables is certainly positive in all models which include them. While empirical evidence is mixed about the causal impact of life expectancy on economic performance, recent studies show that living longer may have initially a negative effect on

[115] Zeugner and Feldkircher (2015), p. 5.
[116] Heckelman (2000), Dawson (2003), Weede (2006), Piątek et al. (2013), Próchniak and Witkowski (2014).

growth, but once fertility declines the effect becomes significantly positive.[117] Increased life expectance in the CEE-4 countries, thanks to improved health conditions observed in the post-transition years, might have contributed to a drop in mortality and, thus, in fertility rates and consequently to a reduction in population growth. Acceleration in human capital formation might have led, in turn, to increased income per capita in the region. Also obtained evidence that democracy has a significant positive effect on GDP per capita in the CEE-4 countries finds its explanation in empirical literature.[118] Political transformation and democratization process which began in the early 1990s made the governments in the region more accountable and improved their commitment to chosen policies. This, as a result, provided a more stable environment for investment and economic reforms. The remaining variables - fertility rate, service value added, trade, stock market capitalization, financial development and population - occur in above 57 per cent of models and its effect on GDP is almost certainly positive.

Table 5.1 CEE-4 countries

Estimator	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
economic freedom	1	294,6697	52,8096	1	4
interest rate	0,9986	-408,967	106,9823	0	12
life expectancy	0,975	788,8843	266,6119	1	14
democracy index	0,9432	8907,835	3654,261	1	2
fertility rate	0,762	4074,524	2838,294	1	6
service value added	0,7554	278,8441	199,9739	1	18
trade	0,7532	27,06935	19,1767	0,999203	21
stock market capitalisation	0,6504	54,01734	46,22908	1	19
financial development	0,5886	6473,914	6354,366	0,998641	7
population	0,568	-66,5649	69,72243	0,000352	15
gross fixed capital formation	0,4358	-39,5849	193,0274	0,546581	10
total investment	0,4222	116,2782	183,8212	0,991	20
gov consumption	0,2638	3,504161	196,8994	0,545868	9
population growth	0,1864	140,9713	562,151	0,904506	17
berd	0,1692	206,3737	829,8443	0,833333	3
education	0,1642	124,1031	391,5314	0,945189	1
gerd	0,141	0,0000	0,0000	0,937589	8
population 15 64	0,133	-17,8102	78,12956	0,075188	16
lend borrowing	0,1134	4,429824	32,28648	0,751323	13
inflation	0,1062	0,01071	1,212435	0,491525	11
FDI net inflows	0,0918	0,66585	5,4265	0,978214	5

Source: Author's calculations

[117] See among others Acemoglu and Johnson (2006), Lorentzen et al. (2008), Kunze (2014).
[118] See Papaioannou and Siourounis (2008), Persson and Tabellini (2008), Bates et al. (2012), Acemoglu et al. (2014)

As far as the advanced economies of the Euro area-12 are concerned[119], the importance of the variables in explaining the data given in the PIP column representing posterior inclusion probabilities (PMPs) differs to a large extent (Table 5.2). The sum of PMPs was highest for all models where BERD, government consumption, service value added and trade were included. With 100 per cent, all of posterior model mass rests on models that contain the above four variables. With regard to their coefficient signs, it appears that in all encountered models containing these variables, the values of coefficients for BERD, service value added and trade are certainly positive, while for government consumption – negative. The Euro area-12 countries have already the status of the innovation-driven economies while within the CEE-4 group only the Czech Republic has recently emerged as the most active country in innovations and in technology-make strategies. The significant and positive impact of business sector R&D expenditure on economic growth in the Euro area-12 reflects those countries' high development status with growth being knowledge-driven.[120] In contrast, BERD does not seem to matter much in the CEE-4 region. Consequently, its coefficient is low as the results quite often include models where this coefficient is zero. Recent studies have indicated a systemic disadvantage of Central Eastern European countries relative to the Euro area and their limited potential for knowledge-based growth.[121] In the 1990s the CEE-4 lacked the capability to develop frontier technologies and technological progress in these countries took place mainly through the adoption and imitation of technologies developed by advanced economies. The importance of services in stimulating the Euro area's economic growth can be explained with the rising contribution of the service sector to GDP in high-income countries in the past two decades.[122] Services are generally perceived as the most productive sector which highly influences the economic growth. The expansion of the service sector has also been observed in the CEE-4 countries since the transition, yet the increase in services' share of GDP in the region has been less pronounced. Trade intensification and its significant and positive impact on economic growth in the Euro area-12 is considered as one of the successes of the single currency introduction. Scholars such as Bun

[119] The results for the Euro area-19 countries have been presented in Table 5.5 in the Appendix.
[120] R&D activity in the business sector accounts for the majority of overall R&D expenditure in most OECD countries and has greater impact on output growth than publicly financed R&D. Public-sector R&D expenditure is often directed at making improvements in areas not directly related to growth, such as defense and medical research, and its effect on growth could be diffused and slow to emerge. See Bassanini and Scarpetta (2001).
[121] See Chapter 2.
[122] In 2015, services' value added accounted for 74 per cent of GDP in high-income countries, up from 69 per cent in 1997. Buckley and Majumdar (2018), p. 2.

and Klaassen (2002), De Nardis and Vicarelli (2003), Berger and Nitsch (2005) estimated the effect of increased bilateral commercial transactions within the Euro area on trade at around 10-15 per cent level.[123] The insightful analysis by Berger and Nitsch (2005) provides a new perspective on the explanation of increased trade within the Euro area as a continuation of a long-term trend in European economic integration fostered by policy changes.[124] The last variable which enters all models (PIP of 100 per cent) is government consumption. It exerts a negative effect on growth in the Euro area-12 as its coefficient is certainly negative. Studies conducted for the EMU countries by, among others, Turrini (2008), Schuknecht (2009) and Hauptmeier et al. (2010, 2015) show an overall expansionary expenditure stance in the period of 1999-2009 which was mainly driven by increasing public consumption. As a result, fiscal positions were already unsound in the Euro area when the global financial crisis began. Further attempts to smoothen the crisis via expansionary fiscal policies led to over-indebtedness and resource misallocation and, consequently, to the sovereign debt crisis of 2010-2011. Ultimately, output levels and growth trend dropped in the post-crisis years (Schuknecht (2009)). The negative impact of excessive government spending on economic growth stems from the underlying rationale that public spending is less productive and tends to crowd out the private sector. Moreover, excessive budget deficits lead to higher interest rates which are harmful to investment. Also, tax increases to finance government consumption may be harmful to economic growth.[125]

The remaining variables – population growth, fertility rate, stock market capitalization, population and economic freedom – also significantly affect GDP growth with the posterior model probabilities above 75 per cent. Among those covariates, only fertility rate enters the models with a negative sign. This can be explained with the aging process observed in most Euro area countries since the mid-1960s. In accordance with standard economic theory, low rates of fertility are associated in the long run with diminished economic growth. Due to the aging effect, the labor force declines and unless it is compensated by an increase in total factor productivity and/or an increase in the capital stock, it leads to the output decline. Research by Bloom et al.

[123] In the estimations conducted by Rose (2004), based on a meta-analysis, monetary unions can be associated with an effect on trade between 30-90 per cent. See Cîndea and Cîndea (2012).

[124] Also Baldwin et al. (2008) argue that the euro induced firms to export a wider range of their products to the Eurozone. Therefore, not only trade in existing products was stimulated; the pro-trade effect also came from newly trade goods.

[125] According to the OECD study, taxes and government expenditures affect growth both directly and indirectly through investment. An increase of about one percentage point in the tax pressure could be associated with a direct reduction of about 0.3 per cent in output per capita. Once the investment effect is taken into account, the overall reduction would be about 0.6 - 0.7 per cent. Bassanini and Scarpetta (2001), p. 35. See also Barro and Lee (1994)

(2009) provides confirmation that in the long run the economic burdens of old-age dependency dominates the youth dependency decline, and continued low fertility will lead to small working-age shares in the absence of large migration inflows.

Table 5.2 Euro area-12 countries

Estimator	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
berd	1	6935,840253	788,9942828	1	3
gov consumption	1	-904,506625	204,533283	0	9
service value added	1	794,6131353	151,1635667	1	18
trade	1	121,4053991	14,51212356	1	21
population growth	0,9896	3314,841764	836,4694391	1	17
fertility rate	0,9314	-5646,825507	2254,959213	0	6
stock market capitalisation	0,8978	30,0871836	13,58920384	1	19
population	0,8762	42,53305776	21,3138288	1	15
economic freedom	0,7516	190,5031574	133,5211895	1	4
lend borrowing	0,3142	73,51318051	129,0704003	1	13
financial development	0,1898	1374,758789	3358,097844	1	7
interest rate	0,1384	-26,28085199	82,84011063	0	12
gross fixed capital formation	0,1254	35,28444508	147,2074104	1	10
total investment	0,1158	2,401060677	107,1230435	0,84801382	20
democracy index	0,1096	875,997103	3769,428126	0,99270073	2
education	0,1044	-35,24795726	161,2836083	0,08429119	1
gerd	0,1042	0,0000	0,0000	0,99040307	8
FDI net inflows	0,0814	1,381611185	6,415049487	1	5
population 15 64	0,0626	-1,359048972	96,64348185	0,27476038	16
life expectancy	0,0576	15,47877796	83,83714046	0,98611111	14
inflation	0,0434	-0,197856121	1,600865311	0	11

Source: Author's calculations

For the 28 member states of the European Union, the most important factors of growth in the examined years 1995-2018 appear to be government consumption, service value added and trade as all of posterior model mass rests on models that include those variables (Table 5.3). Coefficient signs inferred from the Post SD and Cond. Pos. Sign point to a strong and negative effect of government consumption on economic growth, while two other covariates - service value added and trade - exert a positive impact on GDP. The remaining variables which positively affect growth, and for which the posterior inclusion probabilities are above 63 per cent, include BERD and population growth. The other covariates do not seem to matter much. Consequently their (unconditional) coefficients are quite low as the results quite often include models where these coefficients are zero. The EU-28 encompass the Euro area-12, the CEE-4 as

well as 6 new Euro area members[126] and the remaining 6 EU countries. Therefore, it contains a more heterogenous group of countries in terms of their economic development. This can explain why the ordering of the variables has changed compared to the modeling results for the Euro area-12 countries.

Table 5.3 European Union-28 countries

Estimator	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
gov consumption	1	-1362,94	268,144	0	9
service value added	1	901,1249	171,7788	1	18
trade	1	120,4328	19,33704	1	21
berd	0,9976	7437,441	1333,246	1	3
population growth	0,6304	1810,075	1604,164	1	17
stock market capitalisation	0,431	15,11027	19,67542	1	19
population	0,335	15,83512	25,9057	1	15
economic freedom	0,2764	73,02597	135,0099	1	4
interest rate	0,2704	-104,178	200,5111	0	12
lend borrowing	0,2518	82,11885	167,1212	1	13
gross fixed capital formation	0,2324	122,9058	291,6189	1	10
financial development	0,1848	1785,115	4398,716	0,994589	7
life expectancy	0,181	70,57892	208,2639	0,98453	14
total investment	0,1584	21,9713	196,7255	0,82702	20
fertility rate	0,1512	-650,759	1854,877	0	6
gerd	0,1138	0,0000	0,0000	1	8
inflation	0,0576	-0,44351	2,964069	0	11
population 15 64	0,0532	18,57197	141,135	0,890977	16
FDI net inflows	0,0518	0,368538	8,854284	0,72973	5
education	0,0416	12,21415	106,4495	0,966346	1
democracy index	0,0354	346,1998	2983,702	0,99435	2

Source: Author's calculations

5.6 Conclusion

The purpose of this study has been the examination of the main factors driving economic growth in the CEE-4 countries since the transition with the main focus on macroeconomic policies and institutions. To detect significant changes which have occurred in the last two decades in the region, a wide range of macroeconomic, demographic variables as well as key institutional indicators have been analysed. To avoid a model uncertainty in explaining variation of the response variable - economic growth - a new approach has been employed based on the Bayesian Model Sampling, which implements Bayesian Model Averaging for linear regression models. The BMS allows to sample data according to different g-priors and model priors, and

[126] Slovakia has joined the Euro area on January 1, 2009, yet in this analysis is considered as a member of the CEE-4 group.

leaves the choice of different samplers. Another contribution of this comprehensive study has been an empirical analysis of growth determinants in the CEE-4 region in comparison to the Euro area-12 group as well as within the EU-28 block.

5.7 Appendix

Table 5.4 The set of explanatory variables

Name Description	Source
GDP per capita GDP per capita, PPP (constant 2011 international $)	IMF WEO 2018
Gov consumption Government consumption expenditure (% of GDP)	World Bank WDI
Lend borrowing General government net lending/borrowing (% of GDP)	IMF WEO 2018
Gross fixed capital formation Gross fixed capital formation (% of GDP)	World Bank WDI
Trade Trade (% of GDP)	World Bank WDI
Total investment Total investment (% of GDP)	IMF WEO 2018
Inflation Inflation, consumer prices (annual %)	World Bank WDI
Life expectancy Life expectancy at birth (years)	World Bank WDI
Fertility rate Fertility rate (births per woman)	World Bank WDI
Population 15_64 Population ages 15–64 (% of total)	World Bank WDI
Population Population total	World Bank WDI
Population growth Population growth (annual %)	World Bank WDI
Interest rate Long-term interest rate (%)	Eurostat
FDI net inflows FDI, net inflows (% of GDP)	World Bank WDI
Service value added Services, value added (% of GDP)	World Bank WDI
Stock market capitalisation Stock market capitalization to GDP (%)	World Bank WDI
Gerd Gross domestic expenditures on R&D (% of GDP)	World Bank WDI
Berd Business enterprise expenditure on R&D (% of GDP)	World Bank WDI
Education Mean years of schooling	UNESCO UIS
Economic freedom Index of economic freedom (0–100 scale; 100 = the best outcome)	Heritage Foundation
Democracy index Democracy index: average of civil liberties and political rights (0–1 scale; 1 = the best outcome)	Freedom House
Financial development Index of financial development (0-1 scale; 1 = the best outcome)	IMF

Table 5.5 Euro area-19 countries

Estimator	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
berd	1	7520,26	1319,452	1	3
gov consumption	1	-1365,76	264,1405	0	9
service value added	1	914,4767	170,8375	1	18
trade	1	119,2978	19,17395	1	21
population growth	0,6212	1818,452	1638,516	1	17
stock market capitalisation	0,4346	15,13815	19,63292	1	19
economic freedom	0,297	80,3901	142,8254	1	4
population	0,2678	12,9276	24,36364	1	15
gross fixed capital formation	0,264	128,8922	279,3571	1	10
lend borrowing	0,2412	78,6057	165,977	1	13
financial development	0,235	2257,535	4900,474	0,964255	7
interest rate	0,204	-77,534	177,024	0	12

Estimator	PIP	Post Mean	Post SD	Cond.Pos.Sign	Idx
ferielity rate	0,1676	-760,457	2009,84	0	6
total investment	0,1302	19,16382	177,5002	0,847926	20
gerd	0,1172	0,0000	0,0000	1	8
life expectancy	0,1076	43,92921	169,6925	0,97026	14
education	0,0804	20,85812	164,4874	0,79602	1
population 15 64	0,0722	20,15974	141,7016	0,891967	16
FDI net inflows	0,054	0,425581	9,162172	0,837037	5
inflation	0,0476	-0,32661	2,567355	0	11
democracy index	0,0316	357,4656	2957,543	0,987342	2

Source: Author's calculations

Chapter 6
Conclusion

Since the beginning of its transition in the early 1990s, the countries under study - Hungary, Poland, Slovakia and the Czech Republic - have seen impressive progress. In a span of less than two decades, the region went from centrally-planned economies to fully-fledged market economies (Åslund (2007)). Having followed their economic transformation - marked by the accession to the European Union (EU) in 2004 - the CEE countries recorded, however, heterogeneous growth paths. The purpose of this study has been the examination of the main factors driving economic growth in the CEE-4 countries since the transition.

The CEE-4 countries have pursued a distinctive model of development since the collapse of centrally-planned economies, compared to other emerging countries. Their approach was based on integration with the EU, including deep trade and financial integration, institutional development and labor mobility (European Commission (2009)). This European 'integration model of growth' supported a sustained catch-up in productivity and income levels, although this has been interrupted by the global financial crisis and European debt crisis in the second half of the 2000s. Undoubtedly, the CEE-4 countries have made significant progress since the 1990s, but the vulnerabilities and structural problems exposed by the crises are still present in their economies indicating by no means the end of their 'transition'. Many challenges still lie ahead and the real convergence process, defined as the convergence of per capita income levels between the CEE-4 and the Euro area, is far from over (Bakker and Klingen (2012). Although living standards have improved considerably since the beginning of the transition period and the Central Eastern European countries have been able to increase their relative level of per capita income vis-à-vis the Euro area in recent years, the gaps still remain quite large.

It appears that productivity growth has been driven primarily by technological change and physical capital accumulation in the CEE-4 countries since the transition. This provides an indication that the CEE-4 economies still have not passed the phase common for developing countries, in which productivity growth is attributed mainly to these two factors. Contribution to productivity growth from efficiency change, obtained by applying non-parametric methods in growth accounting, has been negative in Hungary and the Czech Republic, neutral in Poland and only slightly positive in Slovakia in the examined period 1995-2014. Higher efficiency in the use

of inputs can be achieved by investing in "knowledge," which can be defined as investment in R&D and higher education (Arratibel et al. (2007)). With regard to the growth contributions from human capital accumulation, the CEE-4 countries recorded positive yet single-digit figures over the span of two decades. Conducted in this dissertation analysis indicates that the CEE-4 economies have a limited potential for knowledge-based TFP growth and a systemic disadvantage relative to the advanced countries (United States, Euro area and Japan).

This study show shows that the reliance on the so far development model based on domestic demand growth driven by foreign credit with large net capital inflows (and corresponding current-account deficits), rapid domestic credit expansion and significant real exchange-rate appreciation is neither possible nor desirable.[127] Capital inflows accompanied by incomplete structural reforms contain considerable risks and may magnify underlying macroeconomic weaknesses. Therefore, a new post-crisis growth model for the CEE-4 countries should favor investment-led growth over consumption and increase the region's ability to finance its future growth and attract foreign investment (McKinsey Global Institute (2013)). It should hence focus on strong links with western production systems and further structural changes including regulatory and institutional reforms.

[127] See also Becker et al. (2010).

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