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CROSS-BORDER PRODUCTION CHAINS AND BUSINESS CYCLE CO-MOVEMENT BETWEEN CENTRAL AND EASTERN EUROPEAN COUNTRIES AND EURO AREA MEMBER STATES

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In 2014 all ECB publications feature a motif taken from the €20 banknote.

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CONTENTS

TABLES

FIGURES

ABSTRACT

In this paper, we highlight the role of global value chains in the synchronization of economic activity between countries in Central and Eastern Europe (CEE) and the euro area. We start off by demonstrating that the degree of synchronization of the business cycles of CEE countries and their main trade partners from the euro area has increased in recent years. We next show that the cyclical fluctuations of GDP in CEE countries are strongly influenced by pro-cyclical movements of changes in inventories. We then present evidence of the importance of cross-border production chains for the economies of CEE countries. We build on these findings to show that the propagation of changes in demand for imports along global supply chains—linked to technological requirements and inventory stock adjustments—contributes to the synchronization of economic activity across Europe. We also show evidence that CEE exporters have started to set up their own value chains in the CEE region.

JEL Codes

E32, F44, F62, O52

Keywords

global value chains, cross-border production chains, business cycle, inventories, Central and Eastern European countries, CEE

NON-TECHNICAL SUMMARY

Economic activity in the euro area and Central and Eastern Europe (CEE) tends to move in sync. The positive correlation between the CEE and euro area business cycles has occurred in an environment of high degree of openness of the CEE region and close financial and trade integration with the euro area. The euro area is both the main trade partner and the largest provider of foreign direct investment in the CEE region.

The existing literature has documented the important role of international trade and its mode of organisation in the observed synchronization of business cycles around the world (Frankel and Rose, 1998; Caselli, Koren, Lisicky and Tenreyro, 2011). A number of recent studies have highlighted the need to go beyond gross flows, when considering the role of external trade in national business cycles and their interconnectedness. Hummels, Ishii, and Yi (2001) and Escaith, Lindenberg, and Miroudot (2010) demonstrate the growing importance of vertical specialization in international trade since the 1970s, as *"[c]ountries increasingly specialize in particular stages of a good's production sequence, as opposed to producing the entire good*" (Kose and Yi, 2001, p. 371). Vertical specialization occurs within global supply chains, which can be described as "*…a system of value-added sources and destinations within a globally integrated production network. Within a supply chain, each producer purchases inputs and then adds value, which is included in the cost of the next stage of production."* (Koopman, Powers, Wang, and Wei, 2010, p. 2).

From a theoretical standpoint, greater trade integration can have a different impact on the interrelation between trade partners' business cycles, depending on the nature of trade specialization and shocks. "*Reduced trade barriers can result in increased industrial specialisation by country and therefore more asynchronous business cycles resulting from industry-specific shocks. On the other hand, increased integration may result in more highly correlated business cycles because of common demand shocks or intra-industry trade*" (Frankel and Rose, 1998, p. 1023). Empirically, international trade and its mode of organisation have been shown to be important conduits of the synchronization of business cycles across Europe (Frankel and Rose, 1998; Bems, Johnson, and Yi, 2010).

In this paper, we highlight the role of global supply chains in the synchronization of economic activity between CEE countries and euro area member states. We first show that the business cycles of CEE countries are highly synchronized with the cyclical output fluctuations in their main trade partners from the euro area. Given the high degree of trade integration between the two regions, this can be a manifestation of common demand shocks and/or supply-side shocks that transmit along global value chains, and the associated global propagation of inventory adjustments. We proceed to show that the CEE business cycles are strongly influenced by pro-cyclical inventory adjustments and that cross-border production chains, and in particular those affiliated with euro area companies, play an important role in CEE economies. We then demonstrate that changes in demand for imports along global supply chains—linked to technological requirements and inventory stock adjustments—can account for a sizeable proportion of the cyclical fluctuations of imports across Europe. We argue that this reinforces the synchronization of economic activity across Europe. This is the case because, for example, a negative shock to exports of one country would translate in lower external demand for its trade partners positioned before it in the cross-border production chains, as a result of the lower technological requirement for imports (i.e., foreign value-added embodied in the country exports) and due to a possible scaling down of inventory stocks.

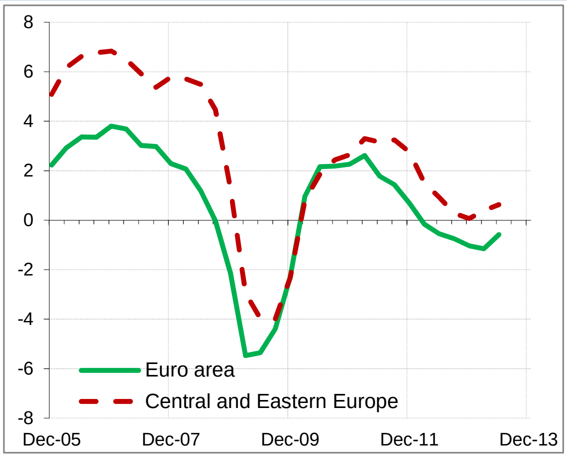
Overall, our analysis shows that a large share of exports from the CEE region passes through euro area-affiliated cross-border production chains, in which CEE exporters are, in general, located further downstream than their euro area partners. This production model, which is both pan-European and globally-integrated in nature, has several important implications. In the short run, it constitutes an important channel for transmitting output fluctuations between euro area and CEE countries, via the propagation of industry-specific shocks and of inventory adjustments along the supply chain. In the longer run, however, the economic prospects of CEE countries would depend less on euro area than on world demand and the ability of euro area and CEE exporters to remain competitive on the global stage. In this context, the high degree of synchronization of CEE and euro area business cycles since the onset of the global financial crisis can be seen as a manifestation of common demand shocks and/or supply-side shocks that transmit along global value chains. The associated propagation of inventory adjustments along global supply chains further reinforces the synchronization of economic activity across Europe. Finally, there will likely be increasing “halo effects” from the participation of CEE countries in global value chains, as suggested by the on-going efforts of CEE exporters to set up own value chains within their region.

1 INTRODUCTION

Economic activity in the euro area and Central and Eastern Europe (CEE) tend to move in sync. Periods of economic expansion and contraction in the two regions tend to overlap (Figure 1). At the same time, the experience from the global financial crisis and the most recent recession in the euro area (EA) shows that CEE[1] as a whole follows the euro area with a lag in an economic downturn. Among the main channels of transmission of output fluctuation between the two regions—documented in the context of the run-up to and the aftermath of the global financial crisis, for example by Gardó and Martin (2010) and IMF (2012)—the focus of this paper is on external trade links and their mode of organisation.

Figure 1 Real GDP, 2006-2013

(Year-on-year growth, percentage points; quarterly data)



Source: Eurostat and ECB staff estimates.

Notes: CEE data are weighted averages of country observations, using country shares in the 2011 GDP for the region, expressed in euros at actual exchange rates. Historical data for the euro area are based on the present-day country membership in the zone.

The positive correlation between the CEE and euro area business cycles has occurred in an environment of high degree of openness of the CEE region and close financial and trade integration with the euro area. In 2012, exports of goods and services, on average, amounted to 59% of GDP across CEE countries, while the respective share of imports was 58%. The main trade partner of CEE countries is the euro area, as it accounts for around 53% of both exports and imports of goods of CEE countries (Appendix Figure 1). The situation is similar for exports and imports of services, for which the share of intra-EU trade was close to 70% in 2010 (Eurostat, 2012). Euro area companies are also the largest providers of foreign direct investment in the CEE region, collectively controlling 78% of the FDI inward stocks at end-2005 (Eurostat, 2013b).

A number of studies have highlighted the need to go beyond gross flows, when considering the role of external trade in national business cycles and their interconnectedness. Hummels, Ishii, and Yi (2001) and Escaith, Lindenberg, and Miroudot (2010) demonstrate the growing importance of vertical specialization in international trade since the 1970s, as "*[c]ountries increasingly specialize in particular stages of a good's production sequence, as opposed to producing the entire good*" (Kose and Yi, 2001, p. 371). Vertical specialization occurs within global supply chains,[2] which can be described as "*…a system of value-added sources and destinations within a globally integrated production network. Within a supply chain, each producer purchases inputs and then adds value, which is*

[1] In this paper, Central and Eastern European (CEE) countries are defined as the following non-euro area EU member states: Bulgaria, Czech Republic, Hungary, Lithuania, Poland, and Romania.

[2] In this paper, we use the terms "cross-border production chains", "global value chains", and "global supply chains" interchangeably.

included in the cost of the next stage of production.” (Koopman, Powers, Wang, and Wei, 2010, p. 2). Intermediate products and services’ crisscrossing of international borders results in a high import content of exports. This makes the gross value of exports a poor proxy for the contribution of the external sector to domestic economic activity. For example, in an influential study Johnson and Noguera (2012) show that the imbalance in U.S. – China trade is 30 to 40% smaller in value-added terms than in gross flows.

From a theoretical standpoint, greater trade integration can have a different impact on the interrelation between trade partners’ business cycles, depending on the nature of trade specialization and shocks. “*Reduced trade barriers can result in increased industrial specialisation by country and therefore more asynchronous business cycles resulting from industry-specific shocks. On the other hand, increased integration may result in more highly correlated business cycles because of common demand shocks or intra-industry trade*” (Frankel and Rose, 1998, p. 1023). Caselli, Koren, Lisicky and Tenreyro (2011) introduce country-specific supply shocks affecting all productive sectors in a Ricardian model of international trade—developed by Eaton and Kortum (2002) and Alvarez and Lucas (2006)—that explicitly accounts for intra-industry trade in intermediates. In the special case of uncorrelated aggregate productivity shocks with equal variances across countries, the business cycles of countries participating in cross-border production chains are shown to be more correlated and less volatile than in the closed economy alternative.

Empirically, international trade and its mode of organisation have been shown to be important conduits of the synchronization of business cycles across Europe. For industrialized countries, Frankel and Rose (1998) present econometric evidence that increased trade links result in tighter synchronization of their business cycles. Bems, Johnson, and Yi (2010) use a global input-output table—that explicitly takes into account external trade of intermediate products and services—to simulate the response of Emerging Europe real GDP to the observed decline in EU15[3] final demand over the period 2008:Q1–2009:Q1, while holding non-EU15 final demand constant. Results show that economic activity in Emerging Europe would have declined by 1.4 per cent over the period, purely as a result of the global spillover of the EU15 demand shock through the international trade transmission mechanism.

We complement the literature by focusing on the link between international vertical specialization and import fluctuations over the business cycle. A number of recent studies have pointed to the role of inventory-adjustments in the steep decline of international trade during the 2008-09 Great Recession (Escaith et. al., 2010; Alessandria et. al., 2011; De Rougemont, 2011; Altomonte et al., 2011 and 2012). Alessandria et al. (2011) augment a standard demand function for imports—derived from a general equilibrium

[3] Emerging Europe: CEE countries plus Slovak Republic, Slovenia, Turkey, and Ukraine. EU 15: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, UK.

model of international trade—with an inventory-adjustment term. Using U.S. data, the authors show that, given the pro-cyclicality of inventories (including imported ones), their fluctuations can partially explain the more volatile pro-cyclical behaviour of imports over the business cycle. We put the Alessandria et al. (2011) insight in the context of global value chains and argue that the propagation of changes in demand for imports along global supply chains—linked to technological requirements (i.e., foreign value-added embodied in the country exports) and inventory stock adjustments—further reinforces the synchronization of economic activity across Europe. This is the case because, for example, a negative shock to exports of one country would translate in lower external demand for its trade partners positioned before it in the cross-border production chains, as a result of the lower technological requirement for imports and due to a possible scaling down of inventory stocks.

The rest of the paper is organized as follows. In Section II, we contribute to the existing studies on the degree and direction of co-movement of the business cycles of CEE and their main trade partners from the euro area.[4] We find that the degree of synchronisation of the business cycles of CEE countries and their main trade partners from the euro area has increased in the aftermath of the global financial crisis and the most recent recession in the euro area. In Section III, we carry what to our knowledge is the first CEE-wide analysis of the inventory-adjustment aspect of the business cycle. We show that the cyclical fluctuations of GDP in CEE countries are strongly influenced by pro-cyclical movements of changes in inventories. In Section IV, we highlight the role played by cross-border production chains in CEE external trade and examine the modalities of CEE exporters' participation in them. We present country-level details of the Koopman et al. (2010) finding that a large share of exports from the CEE region passes through cross-border production chains, in which CEE exporters are, in general, located more downstream than their EA partners. We also find evidence that CEE exporters have started to set up their own value chains in the CEE region. In Section V, we show that the propagation of changes in demand for imports along global supply chains—linked to technological requirements and inventory stock adjustments—can account for a significant proportion of the excess volatility of imports that cannot be attributed to the influence of standard demand factors. We argue that these forces contribute to the pan-European synchronization of economic activity. Section VI provides a summary of our main findings.

[4] See Fidrmuc and Korhonen (2006) for a review of the literature on the topic.

2 BUSINESS CYCLE CO-MOVEMENTS ACROSS CEE AND EA COUNTRIES

Our dataset comprises quarterly national accounts data over the period 1992-2012. The data in volume terms are based on chain-linking successive quarterly growth rates, estimated at the average prices of the previous year, starting from the nominal level in the reference period, in this case 2005 (Eurostat, 2013a). Our sample includes all CEE countries and their main trade partners in cross-border production chains from the euro area—Germany, France, Italy, and Austria (see Section IV)—as well as the euro area as a whole. The time span of the sample is 1992-2012, with missing data at the start of the sample interpolated from annual data (EC, 2013),[5] using the Stram and Wei (1986) approach. The techniques for assessing co-movement closely follow the Stock and Watson (1999) analysis of business cycle fluctuations in U.S. macroeconomic time series.

We extract the business-cycle of economic output in our sample countries using the Baxter-King bandpass filter. That filter decomposes, in the frequency domain, the analysed series into trend, cyclical, and irregular components, which are additive. In the case of data for the log of real GDP, the cyclical component provides one measure of the output gap, as its units correspond to percentage deviations (divided by 100) from the long-run trend (Appendix 2). In the application, and consistently for all countries, the Baxter-King filter is based on an 11-quarter centred moving average and the widely adopted definition of the business cycle—movements in economic series that occur with periodicity of between 6 quarters and eight years (32 quarters).[6] Compared to the more commonly used Hodrick–Prescott filter, the Baxter-King filter also suppresses the high frequency, irregular component of the series that includes measurement errors, which is important when working with CEE data as measurement errors are non-negligible. In order to obtain estimates of business-cycle fluctuations through end-2012, we augment the dataset with forecasts of quarterly GDP over the period 2013Q1-2015Q4, interpolated from the annual European Commission forecasts (spring 2013; EC, 2013) using the Stram and Wei (1986) approach.[7]

Results show that, over the full sample, the business cycles of CEE countries are highly synchronised with the cyclical output fluctuations in their main trade partners from the euro area. Figure 2 plots the estimated output gap series, using Germany as a reference country.[8] Visual inspection of the charts shows that the output gaps of CEE countries co-move with the output gap of Germany, with a lag in some countries that is more visible in the post-2007 dynamics. The output gaps of the euro area as a whole, as well as those of Austria, France,

5 Quarterly national accounts data for CEE countries is generally available from 1996 onwards.

6 Baxter and King (1999) adopt the above definition of business cycles, which is derived from the chronology of business cycles in the US done by the National Bureau of Economic Research (see Stock and Watson, 1999 for further details). Baxter and King (1999) suggest using a 12-quarter centered moving average for US data. They show that the choice of this parameter is an empirical question, involving a trade-off between the associated loss of observations at the beginning and the end of the sample and the closeness of the approximation to an ideal filter.

7 The use of an 11-quarter centred moving average to derive the output gaps results in the loss of 11 quarters at the start, as well as at the end of the augmented sample.

8 In Section IV, we show that German exporters are the most interconnected with producers from the CEE region.

and Italy move closely with the cyclical fluctuations of output in Germany.[9] Analysis of the cross-correlations of CEE countries output gaps with different leads and lags of the output gap of Germany confirm the existence of strong positive correlation in all cases (Table 1). For Bulgaria, Lithuania, and Romania, the maximum cross-correlation is observed at lags of between one and two quarters, indicating that the business cycles in these countries tend to follow developments in the business cycle of Germany. In the case of the Czech Republic, Hungary, and Poland, the co-movement with Germany's business cycle is more contemporaneous.[10] Furthermore, the cross-correlation patterns provide evidence of the high degree of contemporaneous synchronisation of the business cycles of Austria, France, Italy, and the euro area as a whole with the cyclical fluctuations of economic activity in Germany. The cross-correlations between the business-cycles of EA member states are notably higher than the correlations between cyclical output fluctuations in Germany and in CEE countries.

The positive interrelation between the business cycles of CEE countries and euro area member states is confirmed by existing regression studies. IMF (2011) estimate a global VAR of quarterly real GDP growth rates and show that—controlling for developments in the rest of the world—an exogenous shock on growth in Western Europe spills-over into a growth shock of the same sign and similar magnitude in Central, Eastern, and South-Eastern Europe.

The global financial crisis and the most recent recession in the euro area have increased the degree of synchronisation of the business cycles of CEE with EA countries and decreased cross-country differences in CEE. The existing literature (e.g., Fidrmuc and Korhonen, 2006) singles out Hungary, Poland, and Slovenia as exhibiting notably higher positive correlation with the EA business cycle, followed by the Czech Republic. Our analysis of the pre-2008 period shows a similar dispersion of correlation coefficients across CEE countries (Appendix Table 1).[11] Inclusion of the turbulent post-2007 period in the sample increases the strength of association between CEE business cycles and that of Germany across all CEE countries and decreases cross-country differences (Table 1 and Appendix Table 1). In contrast, results for euro area countries remain broadly unchanged between the full and truncated samples.

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[9] Similar patterns can be also observed in the raw data on quarter-on-last-year-quarter growth rates of real GDP (Appendix Figure 2).

[10] In all three cases the maximum correlation is the contemporaneous one (i.e., at k=0), with some asymmetry in cross-correlations at the first lag and lead: $Cor(x_t,y_{t-1}) > Cor(x_t,y_{t+1}) = Cor(x_{t-1},y_t)$.

[11] In the truncated sample, the evidence of a lag between developments in the business cycle of Germany and CEE countries is preserved only in the case of Bulgaria and Romania.

Table 1 CEE and Selected EA Countries: Business Cycles Co-Movements, 1994Q4 - 2012Q4

	Cross correlations at lag *k*: Cor (x_t,y_{t+k})													
k =	-3		-2		-1		0		1		2		3	
	Output gap of Germany (y_{t+k})													
Output gap of individual countries (x_t)														
Euro area	0.37	*	0.67	*	0.89	*	**0.97**	*	0.90	*	0.70	*	0.40	*
Austria	0.38	*	0.65	*	0.85	*	**0.92**	*	0.85	*	0.66	*	0.40	
France	0.31		0.58	*	0.80	*	**0.90**	*	0.86	*	0.71	*	0.47	*
Germany	0.39	*	0.69	*	0.92	*	**1.00**	*	0.92	*	0.69	*	0.38	*
Italy	0.25		0.57	*	0.81	*	**0.93**	*	0.89	*	0.71	*	0.44	*
Central and Eastern Europe [1]														
Bulgaria	0.45	*	**0.51**	*	0.49	*	0.39	*	0.22		0.02		-0.15	
Czech Republic	0.33		0.52	*	0.64	*	**0.66**	*	0.58	*	0.42	*	0.22	
Hungary	0.19		0.45	*	0.64	*	**0.70**	*	0.62	*	0.44	*	0.21	
Lithuania	0.50	*	0.62	*	**0.65**	*	0.55	*	0.39	*	0.18		-0.05	
Poland	0.28		0.44	*	0.56	*	**0.58**	*	0.51	*	0.34		0.13	
Romania	0.50	*	**0.51**	*	0.46	*	0.33		0.14		-0.09		-0.29	

Source: ECB staff estimates.

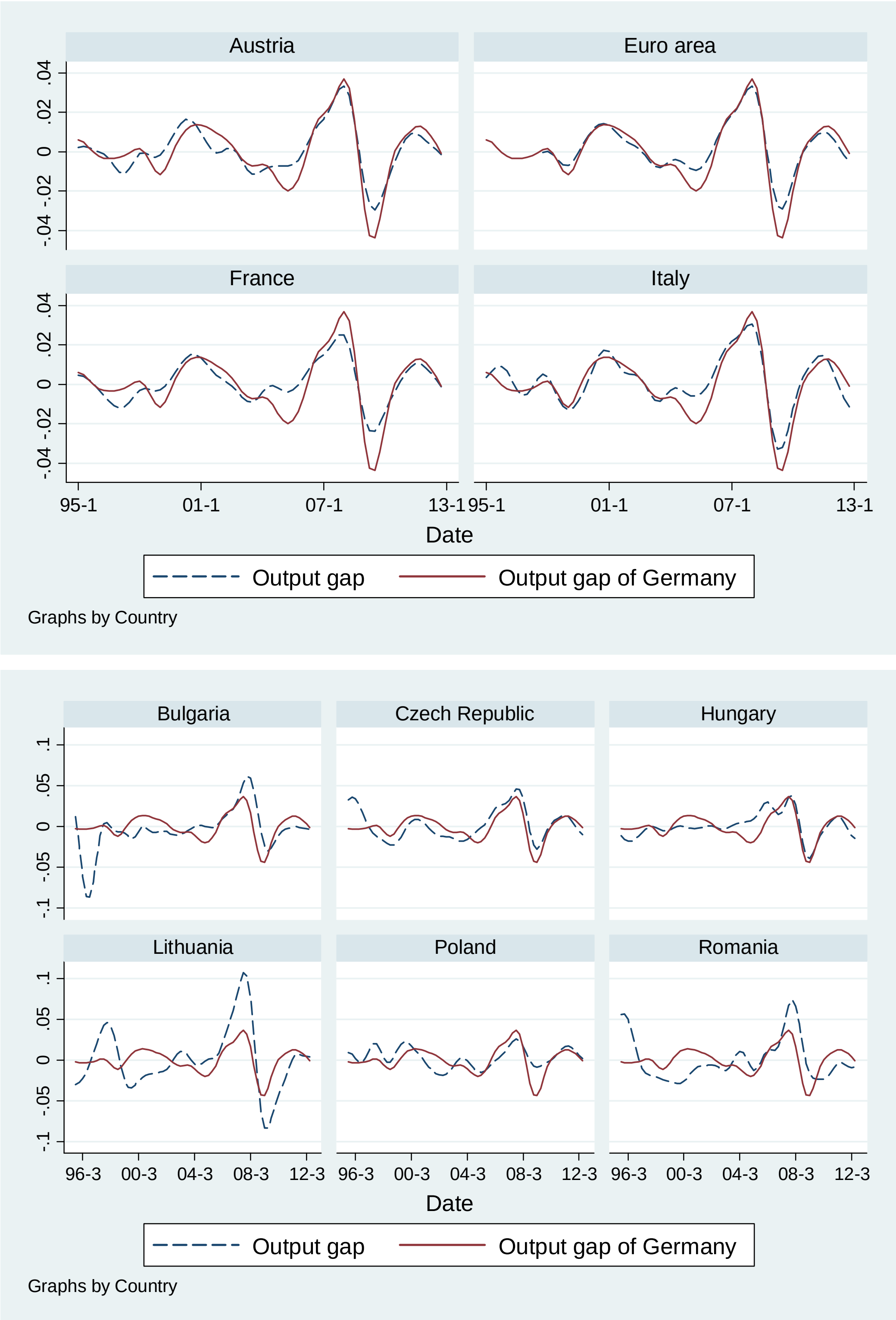
* Significant at 10% level of confidence.

Note: A large positive correlation at $k=0$ indicates that the two series co-move in the same direction; a large negative correlation at $k=0$ shows that the two series move in opposite directions; a maximum correlation at negative k (e.g., $k=-1$) indicates that the business cycle of the country follows developments in the business cycle of Germany with a lag of k quarters (Stock and Watson, 1999).

[1] Quarterly national accounts data for CEE countries is generally available from 1996 onwards.

Figure 2 CEE and Selected EA Countries: Output Gaps, 1995 – 2012

(Percentage points divided by 100)



Notes: ECB staff estimates based on Eurostat data.

Quarterly national accounts data for CEE countries is generally available from 1996 onwards.

3 INVENTORY ADJUSTMENT OVER THE BUSINESS CYCLE

The prominent role of inventory adjustment in cyclical output movements in advanced economies suggests that it might also be a key driver of CEE business cycles. Blinder and Maccini (1991) show that "*the drop in inventory investment has accounted for 87 percent of the drop in GNP during the average postwar recession in the United States*" (Blinder and Maccini, 1991, pp. 73-4). De Rougemont (2011) points out that the drop in inventory stocks had a sizeable contribution to the output losses in France and OECD countries (as a group) at the height of the global financial crisis (see also ECB, 2013a). Over the whole business cycle, changes in inventories are pro-cyclical in almost all developed countries analysed by Wen (2005) and account for approximately one fourth of the cyclical fluctuations of U.S. GDP (Stock and Watson, 1999). At the same time, Alessandria, Kaboski, and Midrigan (2012) find that firms involved in international trade hold approximately double the amount of inventories relative to sales than firms dealing solely with the domestic market. Based on these considerations, and taking into account the high degree of openness of CEE economies, we expect to find sizeable contribution of inventory adjustments to the cyclical fluctuations of economic activity in CEE countries.

We construct chain-linked volume series of changes in inventories from data on their contributions to quarterly real GDP growth.[12] Estimating chain-linked volume series of changes in inventories as the difference between published national accounts aggregates and their components is not appropriate, as chain-linked volumes are not additive (Lequiller and Blades, 2006). Instead, we start from the nominal level of changes in inventories in a base period (2005Q1)[13] and set the preceding and following values in such a manner, that the resulting contributions to quarterly real GDP growth of the derived chain-linked volume series are the same, as the published contributions of changes in inventories to quarterly real GDP growth, estimated at the average prices of the previous year. Lequiller and Blades (2006) show that this is equivalent to substituting the chain-linked price index of changes in inventories with the chain-linked price index of overall GDP in the correct, but non-implementable formula for calculating chain-linked volume series for changes in inventories. The same general procedure is also used by De Rougemont (2011).

Following Stock and Watson (1999), we express the chain-linked volume series of changes in inventories as a ratio to trend GDP prior to application of the Baxter-King bandpass filter. In this way, the units of the obtained cyclical components correspond to percentage points difference (divided by 100) from the trend of the transformed series

[12] Eurostat (2013a) does not publish chain-linked volume series for changes in inventories, but only their contributions to quarterly real GDP growth, estimated at the average prices of the previous year.

[13] We use as a starting value the average value of nominal changes of inventories by quarter in 2005.

and are comparable across countries. The transformation has the additional advantage that the ratio of the standard deviation of the cyclical component of the ratio of change in inventories to trend GDP to the standard deviation of the output gap can be interpreted as the average contribution of changes of inventories to the cyclical movements of GDP over the business cycle (Stock and Watson, 1999; see equation A2.1 in Appendix 2). The calibration of the Baxter-King bandpass filter is the same as the one used in the estimation of the output gaps. Trend GDP is obtained as the low-frequency component of real GDP (i.e., movements in economic series that occur with periodicity of more than eight years), derived from the Baxter-King bandpass filter.[14]

Results show that changes in inventories are pro-cyclical in all but one of the CEE countries and account for a large share of the cyclical fluctuations of GDP (Figure 3). Analysis of the cross-correlations of countries output gaps with different leads and lags of the cyclical component of the ratio of change in inventories to trend GDP confirm the existence of strong positive contemporaneous correlation in all analysed EA and most CEE countries, with the exception of Romania (Table 2). Consistent with our priors, the cyclical fluctuations in inventories can account for a much larger share of the cyclical fluctuations of GDP in CEE countries than in EA countries (Table 3).[15] Among CEE countries, the highest contribution of inventory adjustment to the business cycle is in the case of Poland and Hungary—where the cyclical fluctuations in inventories can account for over 80% of the cyclical fluctuations of GDP—followed by Bulgaria and Romania (around 60%), and the Baltic countries and the Czech Republic (around 40%). Among EA countries, the cyclical fluctuations in inventories account for only 17% of the cyclical fluctuations of GDP in Germany and 35% in France, with the other analysed countries falling inside this range. The findings related to the pro-cyclicality and degree of association between cyclical inventory adjustments and the broader business cycle broadly hold for most countries when the turbulent post-2007 period is excluded from the sample (Appendix Table 1), with the notable exception of Romania.[16]

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14 The sequential use of an 11-quarter centered moving average to derive trend GDP and extract the cyclical component of the ratio of change in inventories to trend GDP results in the loss of 22 quarters at the start, as well as 11 quarters at the end of the actual data sample (2012Q4) (or 22 quarters counting from the augmented sample through 2015Q4).

15 Following Stock and Watson (1999), we use the ratio of the standard deviations of the two series as a proxy for the contribution of inventory adjustment to the business cycle.

16 The switch in the sign of the contemporaneous correlation between the cyclical component of the ratio of change in inventories to trend GDP and the output gap in Romania between the full and truncated samples signals potential structural break or data quality issues.

Table 2 CEE and Selected EA Countries: Co-movement of the Output Gap and the Cyclical Component of Change in Inventories Relative to Trend GDP, 1997Q3 - 2010Q1

	Cross correlations at lag *k* : Cor (x_t,y_{t+k})						
k =	-3	-2	-1	0	1	2	3
				Cyclical component of the ratio of change in inventories to trend GDP in individual countries (y_{t+k})			
Output gap of individual countries (x_t)							
Euro area	0.37	0.61 *	0.80 *	**0.89** *	0.83 *	0.63 *	0.31
Austria	0.75 *	**0.78** *	0.73 *	0.62 *	0.48 *	0.30	0.09
France	0.37	0.58 *	0.75 *	**0.84** *	0.81 *	0.65 *	0.39 *
Germany	0.14	0.38	0.56 *	**0.65** *	0.61 *	0.48 *	0.27
Italy	0.14	0.41 *	0.63 *	**0.72** *	0.66 *	0.48 *	0.23
Central and Eastern Europe							
Bulgaria [1]	0.68 *	**0.74** *	0.71 *	0.59 *	0.38	0.13	-0.10
Czech Republic	0.30	0.49 *	0.66 *	**0.74** *	0.70 *	0.53 *	0.27
Hungary	0.25	0.46 *	0.65 *	**0.71** *	0.60 *	0.34	0.01
Lithuania	-0.03	0.17	0.31	**0.35**	0.28	0.16	0.03
Poland	0.52 *	0.66 *	**0.70** *	0.62 *	0.44 *	0.17	-0.12
Romania [1]	0.54 *	0.40	0.18	-0.12	-0.42	-0.64 *	**-0.71** *

Source: ECB staff estimates.

* significant at 10% level of confidence.

Note: A large positive correlation at $k=0$ indicates that the two series co-move in the same direction; a large negative correlation at $k=0$ shows that the two series move in opposite directions; a maximum correlation at negative k (e.g., $k=-1$) indicates that x follows developments in y with a lag of k quarters (Stock and Watson, 1999).

[1] Quarterly data on contribution to GDP growth of change in inventories available from 1998Q2 for Bulgaria and 2001Q2 for Romania.

Table 3. CEE and Selected EA Countries: Contribution of Change in Inventories to Output Gap, 1996 - 2012

Reference country / Indicator	Standard deviation: Output gap (1)	Standard deviation: Cyclical component of ratio of change in inventories to trend GDP (2)	Ratio of standard deviations (percent) (2) / (1)
Euro area	0.013	0.003	20.4
Austria	0.012	0.005	37.6
France	0.010	0.004	35.4
Germany	0.015	0.002	16.5
Italy	0.013	0.003	23.8
Central and Eastern Europe			
Bulgaria	0.028	0.018	63.2
Czech Republic	0.019	0.008	45.8
Hungary	0.015	0.013	87.3
Lithuania	0.041	0.013	31.4
Poland	0.012	0.010	83.5
Romania	0.026	0.016	62.5

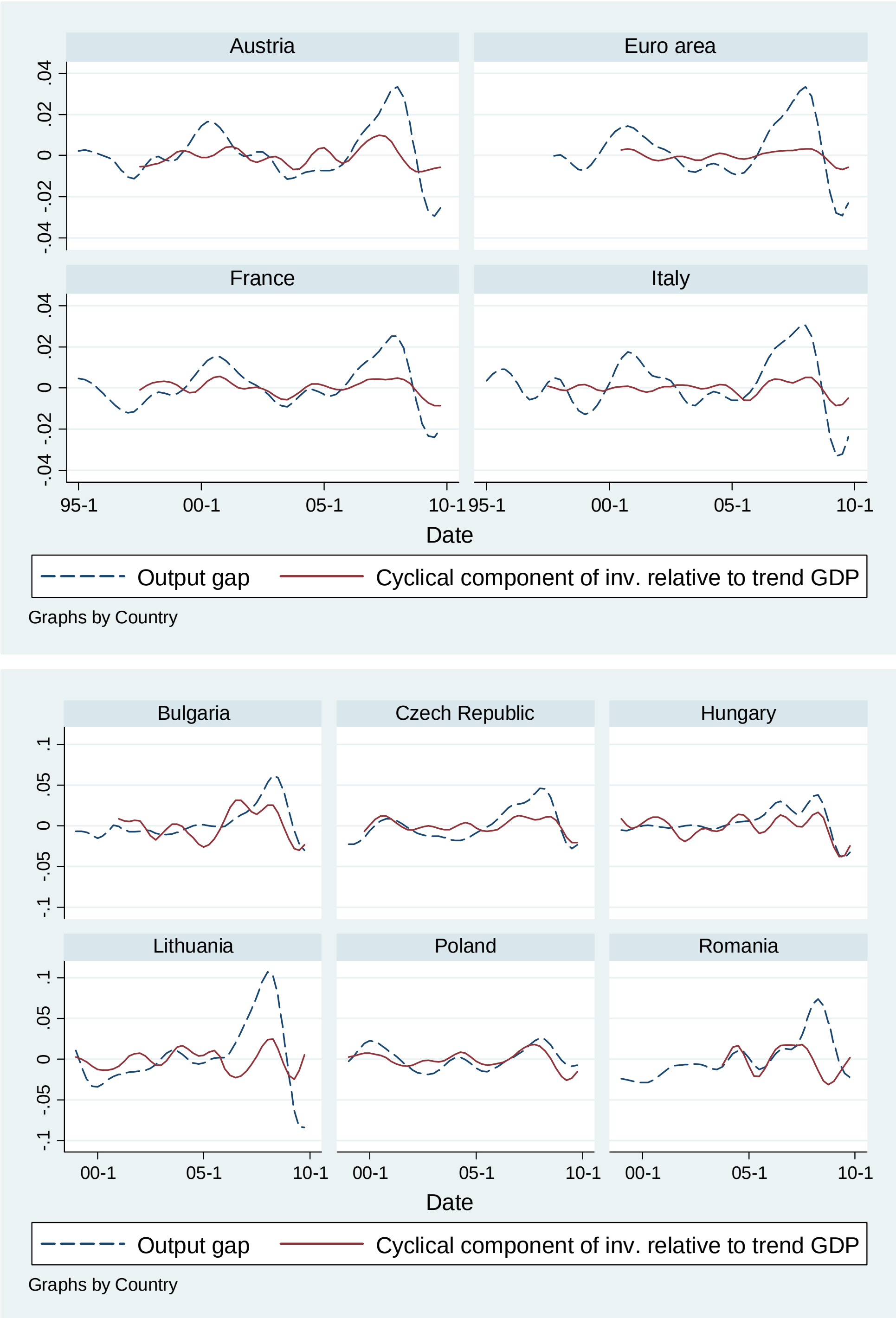
Source: Eurostat and ECB staff estimates.

In the management literature, the behavior of inventories is analyzed in the context of the main characteristics of supply chains (see for example Lee, Padmanabhan and Whang, 2004). In response to a shock to final demand, firms cut their orders of inputs not only by the amount that would have otherwise been embodied in the products for which there is no longer demand, but by an additional amount that allows them to adjust inventories to the new market conditions, based on the forecasted persistence of the shock. Research on the topic has identified a 'bullwhip'-shaped transmission of the original demand shock in supply chains, as the variance of orders of inputs is higher than that of sales to customers (Lee, et. al., 2004). As a result, firms located further away from the final customer (i.e., more upstream) in a production chain experience ever increasing variability of the demand for their products in response to a shock on final demand. Among other reasons, the farther a firm is from the final customer, the more difficult it is to identify what part of the drop in the apparent demand for its products is due to the "true" decline in final demand and what part is caused by downstream firms desire to rundown their inventories of inputs.

The propagation of inventory adjustments along global supply chains would tend to reinforce the synchronization of economic activity between CEE countries and euro area Member States. In light of the empirical evidence that firms involved in international trade maintain significantly higher inventory stocks (Alessandria et al., 2012) and given the high degree of openness of CEE economies, a sizeable proportion of inventory adjustments occur in their export sectors. A scaling down of inventory stocks, including imported intermediates, in one country would translate in lower external demand for its trade partners. The magnitude and pattern of propagation of inventory adjustments along global supply chains would depend on the importance of cross-border production chains in the economies of trade partners and their relative positions in the production process. We examine these issues in the following section.

Figure 3 CEE and Selected EA Countries: Cyclical Components of Real GDP and Inventories Relative to Trend GDP, 1996 – 2010Q1

(Percentage points divided by 100)



Note: ECB staff estimates based on Eurostat data.

Quarterly national accounts data for CEE countries is generally available from 1996 onwards, resulting in a shorter sample for the cyclical components series.

4 TRADE INTERLINKAGES BETWEEN CEE AND THE EURO AREA

Two recent databases allow the tracing of the sources and uses of value-added embedded in external trade around the globe. As noted above, the gross value of exports is a poor proxy for the contribution of the external sector to domestic economic activity, when a sizable share of international trade passes through cross-border production chains. To better capture the economic nature of external trade flows, the *Trade in Value Added (TiVA)* dataset compiles a global input-output table, by linking 57 individual countries' input-output tables—which show how goods and services flow between sectors of the domestic economy, domestic final consumers, and external trade partners—using bilateral external trade data (OECD-WTO, 2012a and 2013). The *World Input-Output Database (WIOD)* is a related, but separate data initiative funded by the European Commission, based on individual countries' supply-and-use tables (Timmer, 2012).[17]

Koopman, Powers, Wang, and Wei (2010) propose a comprehensive taxonomy of value-added components by source and use.18 In Koopman et al. (2010), total exports comprise the following four components: (1) CEE country domestic value-added embodied in exports of final goods and services absorbed by the direct importer; (2) CEE country domestic value-added embodied in exports of intermediate inputs used by the direct importer to produce final goods and services for its internal market; (3) CEE country domestic value-added embodied in intermediate exports used by the direct importer to produce goods and services for export to third countries (including back to the CEE country, which Koopman et. al. (2010) identify separately) *[IV]*; (4) value-added from trade partners embodied in the CEE country total exports *[FV]*.

We analyse the CEE exporters' participation in global value chains, with the view of better understanding the nature of the interlinkages between CEE and EA economies. Within the Koopman et al. (2010) conceptual framework, the importance of global production chains in country exports is captured by the sum of the last two value-added components *[IV+FV]* expressed as a ratio to total exports. The relative position of country exporters in global value chains is proxied by the ratio of the last two value-added components *[IV/FV]*. The *IV* value-added component of total exports can be interpreted as a measure of the CEE country "upstream" activities vis-à-vis its trade partners, whereas the *FV* component captures the CEE country "downstream" activities in global value chains. The higher (lower) the value of the index, the more upstream (downstream) the country exporters are situated in global value chains. *"At the global level, IV and FV equal each other, therefore, the average IV/FV ratio is equal to 1."* (Koopman et. al., 2010, p. 49). We use the latest available data for 2009 from the *TiVA* database to calculate the Koopman et al. (2010) measures of the importance of global

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[17] Using the *WIOD* database, Rahman and Zhao (2013) publish detailed country-level information on value-added components only for manufacturing and services exports in 2008. See also ECB (2013b).

[18] See OECD-WTO (2012) for an overview of the main concepts and literature on the topic.

value chains in CEE countries exports and of the relative position of CEE exporters in these value chains.[19]

The construction of a global input-output table involves simplifying assumptions to overcome important data issues, making derived results best estimates and not data points. OECD-WTO (2012a) details the limitations of the source data for identifying the flows of value-added between domestic sectors of the economy and in external trade. On the one hand, there are significant inconsistencies in aggregate bilateral trade data, as reported by each of the two countries involved. On the other hand, the global input-output table is based on the assumptions that: (1) all firms in a given industry use the same combination of inputs to produce the same outputs, regardless of whether the latter are destined for the domestic or export markets ("production assumption"); and (2) that "…the proportion of intermediates that an industry purchases from abroad is equal to the ratio of imports to total domestic demand in that product" (OECD-WTO, 2012b) ("proportionality" assumption). As export-oriented firms in emerging and developing countries typically use a more imports-heavy mix of inputs than their peers that cater to the domestic market, these assumptions would tend to underestimate the degree of participation of CEE countries in global value chains.

Country-level data from the *TiVA* datasets confirm Koopman et al. (2010) finding that a large share of exports from the CEE region passes through cross-border production chains. Approximately 50% of exports of CEE countries can be attributed to the countries' participation in intermediate stages of global value chains, with a further indeterminate share constituting domestic value-added contributed at the end-stage of the value chain (Table 4). Among CEE countries, exporters' participation in intermediate stages of global value chains matters the most for the Hungarian economy, as such exports account for 44% of GDP.[20] The Czech Republic follows suit, with a corresponding ratio of 37%. At the opposite end of the spectrum are Poland and Romania, in which the ratio to GDP of exports channelled through global value chains is below 20%.

[19] The measure of CEE country upstream activities is obtained from data on the *TiVA* variable EXGR_FVA for its trade partners ("Foreign value added content of gross exports" from the CEE country). The measure of CEE country downstream activities is, respectively, obtained from data on EXGR_FVA for the CEE country. The upstream activity measure does not cover value added from the CEE country embodied in its trade partners exports that end up being re-imported by the CEE country. This is because the share of this value-added component in CEE countries total exports is negligible (below one percent).

[20] In gross terms, i.e. not netting out imported value-added embedded in these exports.

Table 4 CEE and Selected EA Countries: Degree of Participation and Relative Position in Cross-Border Production Chains, 2009

Reference country / Indicator	Value added from trade partners embodied in country total exports (in % of country total exports) [100 * FV / EXP]	Value-added from country embodied in trade partners total exports (in % of country total exports) [100 * IV / EXP]	Degree of participation in global value chains (in % of country total exports) [100 * (FV+IV) / EXP]	Importance of participation in global value chains for the national economy (in % of country GDP) [100 * (FV+IV) / GDP]	Relative position in global value chain [1] (ratio) IV / FV
Central and Eastern Europe					
Bulgaria	32.1	15.7	47.8	22.7	0.58
Czech Republic	39.4	23.0	62.4	36.8	0.58
Hungary	39.9	16.7	56.6	43.9	0.42
Lithuania	36.1	14.1	50.2	27.2	0.53
Poland	27.9	20.5	48.3	19.1	0.73
Romania	24.2	21.9	46.1	14.1	1.01
Euro area					
Austria	31.6	24.2	55.8	28.0	0.77
Germany	26.6	22.8	49.5	21.0	0.86
France	24.8	21.1	45.9	10.7	0.85
Italy	20.1	21.7	41.8	9.9	1.08
Slovak Republic	44.4	17.9	62.2	43.9	0.40
Other countries					
China	32.6	13.4	46.1	12.3	0.41
Japan	14.8	33.0	47.7	6.1	2.23
United States	11.3	28.5	39.8	4.5	2.53

Source: OECD-WTO Trade in Value Added (TIVA) dataset and ECB staff estimates.

Notes: FV denotes foreign value-added, IV stands for intermediate domestic value-added, and EXP denotes total exports.

[1] The higher the value of the index, the more upstream the country exporters are situated in global value chains.

Significant share of the cross-border production chains, in which CEE exporters participate, are affiliated with euro area companies. Table 5 shows that euro area countries account for the bulk of CEE external trade associated with intermediate stages of global value chains. One third or more of CEE countries' top-15 trade partners in global value chains are from the euro area. Among the euro area countries, Germany is the most important trade partner of CEE countries in global value chains, followed by Italy, France and Austria. At the same time, EA companies held 78% of the stock of foreign direct investment (FDI) in the CEE region at end-2005 (Eurostat, 2013b), with Germany, Austria, France, and Italy accounting for a significant share of the total (Table 7). The large share of EA countries in CEE external trade passing through global value chains, coupled with their large share in FDI in the region, point to the central role of euro area, and in particular German, multinational companies in setting up pan-European cross-border production chains.[21] CEE exporters participating in such chains are often owned outright or operated as joint ventures of euro area companies (IMF, 2011, p. 90).

Our country-level estimates also support Koopman et al. (2010) finding that CEE exporters are, in general, located more downstream than their EA partners in global value

[21] The sizable share of the Russian Federation is largely on account of energy exports.

chains.[22] The euro area countries that actively participate in pan-European value chains (especially Germany, Italy and France, see Table 5) are generally located further upstream (i.e., away from the final customer) than CEE exporters, with a notable exception of Germany in its trade with Poland and Romania (Table 6). This is consistent with CEE exporters typically importing industrial equipment and higher value-added components from the EA, which they then use to assemble intermediate goods and final products, shipped along the value chain *en route* to final consumers around the globe. Relative to other CEE countries, Hungarian exporters are located the farthest downstream in global value chains, with Bulgaria close behind (Table 6). The upstream position of Romania and Poland relative to the other CEE countries and some EA countries could stem from specialization in industrial equipment and intermediate goods or from significant share of natural resources in exports. One way to distinguish between the relative importance of these two factors is to juxtapose trade and FDI linkages, as when examining the links between the euro area and CEE in global value chains. To this end, Table 7 presents data on the stock of FDI of selected euro area and CEE countries in the CEE region.

[22] Whereas, Western European countries overall occupy an upstream position in cross-border production chains, "[t]*he three largest advanced economies (the US, Western EU and Japan) have a relatively high share of domestic value-added embodied in their direct final goods exports in addition to their high share of indirect value-added exports through third counties including that which returns home, (…) indicating these economies are located in both upstream and downstream activities in the global production chain, consistent with the so called "smiling curve" phenomena found in the business economics literature*." (Koopman et al. 2010, pp. 45-6).

Table 5. Top 15 Trade Partners of Germany and CEE Countries in Cross-Border Production Chains, 2009

(Sum of value added from trade partner embodied in reference country total exports and domestic value added from reference country exported and then embodied in trade partner exports in per cent of reference country total exports)

Trade partners in GVC / Reference country	Germany
1 France	3.8
2 United States	3.5
3 Italy	2.9
4 United Kingdom	2.8
5 China	2.7
6 Netherlands	2.7
7 Switzerland	2.5
8 Austria	2.4
9 Belgium	1.8
10 Spain	1.6
11 Russian Federation	1.6
12 Poland	1.5
13 Czech Republic	1.5
14 Sweden	1.2
15 Japan	1.1

Trade partners in GVC / Reference country	Bulgaria
1 Russian Federation	6.0
2 Germany	4.6
3 Italy	3.1
4 United States	2.2
5 Turkey	2.1
6 China	1.9
7 Greece	1.9
8 France	1.9
9 Romania	1.4
10 Belgium	1.3
11 Japan	1.2
12 Spain	1.0
13 United Kingdom	0.9
14 Netherlands	0.9
15 Singapore	0.9

Trade partners in GVC / Reference country	Czech Republic
1 Germany	15.6
2 China	3.4
3 Russian Federation	3.3
4 Poland	3.1
5 Slovak Republic	3.0
6 France	2.8
7 Italy	2.7
8 United States	2.5
9 Austria	2.3
10 Japan	2.1
11 United Kingdom	1.9
12 Netherlands	1.7
13 Belgium	1.4
14 Spain	1.3
15 Switzerland	1.2

Trade partners in GVC / Reference country	Hungary
1 Germany	12.3
2 China	3.5
3 United States	3.4
4 Russian Federation	3.0
5 France	2.6
6 Austria	2.5
7 Italy	2.5
8 Japan	2.0
9 Netherlands	1.8
10 United Kingdom	1.8
11 Korea	1.5
12 Czech Republic	1.5
13 Slovak Republic	1.4
14 Poland	1.4
15 Romania	1.4

Trade partners in GVC / Reference country	Lithuania
1 Russian Federation	18.5
2 Germany	3.2
3 United States	2.1
4 Poland	2.1
5 Latvia	1.9
6 France	1.7
7 Sweden	1.4
8 China	1.4
9 Denmark	1.2
10 Estonia	1.1
11 Italy	1.0
12 Netherlands	1.0
13 Japan	0.9
14 United Kingdom	0.9
15 Hong Kong	0.8

Trade partners in GVC / Reference country	Poland
1 Germany	11.0
2 Russian Federation	3.4
3 Italy	3.0
4 France	2.4
5 China	2.3
6 Czech Republic	2.2
7 United States	2.0
8 United Kingdom	1.6
9 Netherlands	1.4
10 Sweden	1.4
11 Austria	1.1
12 Belgium	1.0
13 Japan	1.0
14 Spain	1.0
15 Korea	1.0

Trade partners in GVC / Reference country	Romania
1 Germany	7.3
2 Italy	4.6
3 France	3.1
4 Hungary	2.6
5 Russian Federation	2.2
6 China	1.8
7 United States	1.7
8 Turkey	1.6
9 United Kingdom	1.4
10 Austria	1.3
11 Spain	1.1
12 Netherlands	1.1
13 Poland	1.0
14 Belgium	1.0
15 Czech Republic	0.9

Source: OECD-WTO Trade in Value Added (TIVA) dataset and ECB staff estimates.

Note: The top 15 trade partners of CEE countries in cross-border production chains account for more than 75 per cent of CEE countries total external trade associated with intermediate stages of global value chains.

Table 6. Relative Positions of Main Trade Partners in Cross-Border Production Chains vis-à-vis Exporters of Germany and CEE Countries, 2009

(Value added from trade partner embodied in reference country total exports (USD mln) as a ratio to domestic value added from reference country exported and then embodied in trade partner exports (USD mln), unitless ratio)

	Trade partners in GVC / Reference country	**Germany**
Upstream ↓	Russian Federation	5.3
	United States	3.7
	Japan	2.9
	United Kingdom	1.7
	Spain	1.6
	Italy	1.4
	Romania	1.2
	Poland	1.1
	Germany	.
Downstream ↓	France	1.0
	Netherlands	0.9
	Austria	0.9
	Belgium	0.9
	Czech Republic	0.8
	Switzerland	0.8
	Bulgaria	0.8
	Sweden	0.7
	China	0.6
	Korea	0.5
	Hungary	0.5
	Lithuania	0.3

Trade partners in GVC / Reference country	**Bulgaria**
Russian Federation	19.9
Japan	6.9
United States	4.4
Switzerland	2.9
Austria	2.0
France	1.9
Romania	1.9
China	1.8
Lithuania	1.6
Poland	1.5
Korea	1.4
Italy	1.4
Germany	1.3
United Kingdom	1.3
Czech Republic	1.3
Bulgaria	.
Netherlands	1.0
Spain	1.0
Hungary	0.8
Sweden	0.7
Belgium	0.4

Trade partners in GVC / Reference country	**Czech Republic**
Japan	12.9
Russian Federation	8.7
United States	6.5
Korea	2.6
China	2.6
Italy	2.2
United Kingdom	2.1
Poland	1.9
Spain	1.8
Romania	1.6
Netherlands	1.6
France	1.5
Germany	1.2
Switzerland	1.0
Belgium	1.0
Czech Republic	.
Hungary	0.9
Sweden	0.9
Austria	0.8
Bulgaria	0.8
Lithuania	0.7

Trade partners in GVC / Reference country	**Hungary**
Russian Federation	11.4
Japan	8.6
United States	8.2
Korea	4.4
France	2.9
Netherlands	2.7
United Kingdom	2.3
Italy	2.2
Germany	2.1
China	2.0
Switzerland	1.7
Austria	1.7
Sweden	1.6
Romania	1.6
Poland	1.5
Lithuania	1.5
Spain	1.4
Belgium	1.4
Bulgaria	1.2
Czech Republic	1.1
Hungary	.

	Trade partners in GVC / Reference country	**Lithuania**
Upstream ↓	Russian Federation	39.3
	Japan	5.0
	United States	4.0
	Germany	3.2
	Italy	2.2
	China	1.8
	Romania	1.6
	Poland	1.6
	Czech Republic	1.5
	France	1.4
	Switzerland	1.3
	Austria	1.3
	Korea	1.0
	Lithuania	.
Downstream ↓	Netherlands	0.9
	Belgium	0.8
	United Kingdom	0.7
	Hungary	0.7
	Sweden	0.6
	Spain	0.6
	Bulgaria	0.6

Trade partners in GVC / Reference country	**Poland**
Russian Federation	11.5
Japan	6.0
United States	5.5
Korea	3.1
Italy	2.0
Spain	1.4
United Kingdom	1.4
China	1.3
France	1.3
Netherlands	1.3
Switzerland	1.2
Belgium	1.1
Poland	.
Austria	1.0
Romania	0.9
Germany	0.9
Bulgaria	0.7
Hungary	0.6
Lithuania	0.6
Sweden	0.6
Czech Republic	0.5

Trade partners in GVC / Reference country	**Romania**
Russian Federation	6.7
Japan	3.1
United States	2.7
Italy	1.4
Switzerland	1.3
Austria	1.3
United Kingdom	1.3
Poland	1.1
France	1.0
Romania	.
Netherlands	1.0
Germany	0.8
China	0.8
Korea	0.8
Sweden	0.7
Spain	0.7
Lithuania	0.6
Hungary	0.6
Czech Republic	0.6
Belgium	0.6
Bulgaria	0.5

Source: OECD-WTO Trade in Value Added (TIVA) dataset and ECB staff estimates.

Notes: The uniform set of trade partners comprises of all CEE countries and other countries that are among the top 15 trade partners of at least three CEE countries in cross-border production chains (see Table 5). A value of 1 indicates that the trade partner plays similar role to that of the reference country in global value chains. The higher the value of the index above 1, the more upstream the trade partner is situated in the cross-border production chain relative to the reference country exporters. The smaller the value of the index below 1, the more downstream the trade partner is situated in the cross-border production chain relative to the reference country exporters.

The relative positions of trade partners vis-à-vis one another do not capture their relative positions in the shown global value chains.

A novel finding of our analysis is that the larger CEE countries that became EU members early-on in 2004 appear to have started setting up their own value chains in the CEE region. CEE countries are among the top-15 trade partners of other CEE countries in global value chains and are also among the large providers of FDI in the region (Tables 5 and 7). For example, Poland stands out, as it occupies an upstream position in global value chains relative to all the other CEE countries (see Table 6). At the same time, Polish companies had made around USD 6 billion of FDI in the CEE region at the end of 2011 (see Table 7). The Czech Republic is similarly both located upstream from Bulgaria and provides it with sizeable FDI flows. All in all, this points to the ability of Polish and Czech exporters, including subsidiaries of euro area multinational companies, to set up regional value chains.

Table 7. Selected EA and CEE Countries: Foreign Direct Investment Position vis-à-vis Countries in Central and Eastern Europe, 2011

(US dollars, millions)

FDI recipients / FDI providers	Austria	France	Germany	Italy	Czech Republic	Hungary	Poland
CEE countries	47,127	43,596	74,449	21,155	1,971	2,340	6,141
Bulgaria	5,903	751	2,849	614	597	1,076	48
Czech Republic	14,100	10,842	18,165	1,298	-	323	2,453
Hungary	11,131	4,408	19,592	1,827	74	-	493
Lithuania	67	561	1,126	31	..	5	2,463
Poland	4,777	21,281	25,954	12,542	590	340	-
Romania	10,944	5,654	6,225	4,807	711	596	653

Source: OECD (2013).

Note: Data for Germany is for end-2010; .. indicates that data are not published; - indicates not applicable..

5 CROSS-BORDER PRODUCTION CHAINS AS CONDUITS OF OUTPUT FLUCTUATIONS

In this section, we examine the role of the propagation of changes in demand for imports along global supply chains—linked to technological requirements and inventory stock adjustments—in the pan-European synchronization of economic activity. In Section II, we showed that the business cycles of CEE countries are highly synchronized with the cyclical output fluctuations in their main trade partners from the euro area. Given the high degree of trade integration between the two regions, this can be a manifestation of common demand shocks and/or supply-side shocks that transmit along global value chains, and the associated global propagation of inventory adjustments. In Section III, we demonstrated that the CEE business cycles are strongly influenced by pro-cyclical inventory adjustments. In Section IV, we showed that cross-border production chains, and in particular those affiliated with euro area companies, are very important for the economies of CEE countries. In light of the empirical evidence that firms involved in international trade maintain significantly higher inventory stocks and given the large size of CEE export sectors and the important role played by global value chains in them, a sizeable proportion of inventory adjustments in CEE economies occur in domestic links of global value chains. A negative shock to exports of one country would, therefore, translate in lower external demand for its trade partners positioned before it in the cross-border production chains, as a result of the lower technological requirement for imports (i.e., foreign value-added embodied in the country exports) and due to a possible scaling down of inventory stocks.

We adapt Alessandria et al. (2011) analytical framework to global value chains and use it to test whether their modalities of operation can help explain imports' excess volatility. Alessandria et al. (2011) set out to explain the large fluctuations in US external trade in 2008-10. The starting point of their analysis is a suitably calibrated, stylized aggregate demand function for imports, derived from a general equilibrium model of international trade. The authors show that movements of the relative price of imported goods and real aggregate absorption alone cannot account for a significant proportion of the observed cyclical dynamics of imports. They call the unexplained difference an 'import wedge', which is given by the following formula derived in Appendix 2:

$$\widehat{\omega}_t = m_t - (-\gamma p_t + c_t)\text{ , where} \qquad \text{(A2.2)}$$

lower-case variables denote log-deviations from trend;
$\widehat{\omega}_t$ – standard import wedge;
M_t – imports of goods (real);
P_t – relative price of imports;
C_t – aggregate expenditure (real);
γ – Armington elasticity.

Alessandria et al. (2011) proceed to demonstrate that adding an inventory-adjustment term significantly improves the fit of the model, pointing to the important impact of inventory management on international trade flows.

We augment the Alessandria et al. (2011) formula for the import wedge with inventory-adjustment to further account for the import content of exports. The adjustment is necessitated by the high importance of exporters' participation in global value chains for CEE economies (Section IV). This makes the volume of imports less sensitive to the relative price of imports and domestic absorption, and more driven by the technological requirements of the production process (i.e., foreign value-added embodied in the country exports). The formula of the augmented import wedge is similar to the one used by Alessandria et al. (2011), except for the additional term $\left(\beta^m \frac{\bar{X}}{\bar{M}} x_t\right)$. The latter captures the industry demand for imported intermediates, which for simplicity is introduced as an exogenously given technological requirement (i.e., independent of the relative price of imports; see Appendix 2 for details):

$$\omega_t = \widehat{\omega}_t - \alpha^m \frac{\bar{Y}}{\bar{M}}\left(\frac{\Delta Inv_t}{\bar{Y}_t} - \frac{\overline{\Delta Inv_t}}{\bar{Y}_t}\right) - \beta^m \frac{\bar{X}}{\bar{M}} x_t \text{ , where} \qquad \text{(A2.3)}$$

lower-case variables denote log-deviations from trend;
variables with bars denote long-term trend of the respective variable;
ω_t – import wedge with inventory adjustment and accounting for the import component of exports determined by technological requirements;
ΔInv_t – change in aggregate inventories (real);
Y_t – GDP (real);
α^m – share of imported goods in total inventory stock (unitless ratio);
M_t – imports of goods (real);
X_t – exports of goods (real);
β^m – import component of goods exports (unitless ratio).

The inventory-adjustment term in equation A2.3 differs from the one used in Alessandria et al. (2011), as in the case of the United States the authors are able to use data on the stock of manufacturing and trade inventories (i.e., in levels). For CEE and EA countries, consistent data on inventory stocks are not available, which is why we derive the expression in terms of the cyclical component of the ratio of change in inventories to trend GDP derived from National Accounts data.

We estimate the import wedges in equations A2.2 and A2.3 using suitably calibrated structural coefficients and the cyclical components of series. The calibration of the Baxter-King bandpass filter is the same as the one used in the estimation of the output gaps. The trends of real GDP, and real imports and exports of goods are obtained as the low-frequency components of the respective series, derived from the Baxter-King bandpass filter.[23] The import component of goods exports (β^m) is set equal to the average foreign value-added embodied in

[23] The use of an 11-quarter centered moving average to derive the output gaps results in the loss of 11 quarters at the start and the end of the sample. Poland and Hungary are dropped out of the sample due to the lack of data on real exports and imports of goods.

exports obtained from the *TIVA* dataset (data column 2 in Table 8). The share of imported goods in total inventory stock is proxied by the unweighted average of foreign value-added embodied in domestic final demand and in exports (data column 3 in Table 8). We calibrate the constant elasticity demand for imported goods, using the mid-value of the Armington elasticity ($\gamma = 1$) presented in Alessandria et al. (2011). Our measure of aggregate expenditure (C_t) is the real domestic final demand, estimated as the difference between the Eurostat (2013a) data on real domestic demand and our estimate of changes in inventories, described in Section III. Finally, we proxy the relative price of goods imports by the ratio of the unit value index of merchandise imports from European Union (27 countries) (2005=100; Eurostat, 2013c), which is available only from 2000 onward, and the domestic demand deflator (2005=100; Eurostat, 2013a).[24]

Table 8. CEE and Selected EA Countries: Foreign Value-Added Content in Domestic and External Demand

(Percentage points)

Reference country / Indicator	Foreign value added embodied in domestic final demand (in percent of domestic demand)	Foreign value added embodied in exports (in percent of total exports)	Foreign value added content in domestic and external demand (unweighted average of columns 2 and 3, percent)
Central and Eastern Europe			
Bulgaria	36	32	34
Czech Republic	33	40	36
Hungary	35	44	40
Lithuania	36	37	37
Poland	26	29	28
Romania	28	26	27
Euro area [1]	15	23	19
Austria	27	32	29
France	18	25	22
Germany	21	26	23
Italy	19	24	21
Slovak Republic	40	46	43

Source: OECD-WTO Trade in Value Added (TIVA) dataset and ECB staff estimates.

Note: Reported values are averages for 2005 and 2009.

[1] Estimates of the import content of final domestic demand and exports from ECB (2010).

The import wedge narrows significantly, once the propagation of changes in demand for imports along global supply chains—linked to technological requirements and inventory stock adjustments—is taken into account. Figure 4 shows the standard import wedge (A2.2) and its counterpart that accounts for both inventory adjustments and import content of exports (A2.3). The values of the standard import wedge are sizeable in all sample countries, ranging between +10 and -15 per cent of trend imports in EA countries, and +15 and -20 per cent in CEE countries. The range of this baseline import

[24] Alessandria, et. al. (2011) use an import price deflator that excludes energy prices, due to their volatility and the relative inelasticity of energy demand. In the absence of consistent set of series of non-petroleum imports across CEE and EA countries, we use as proxy the unit value index of imports from European Union, in which the share of energy imports should be much smaller than in imports from the rest of the world.

wedge for euro area countries is very similar to what Alessandria et al. (2011) finds in the case of the United States. Accounting for the import content of exports and inventory adjustments along global supply chains significantly narrows the import wedge. The cyclical inventory adjustments can account for between 4 and 16 per cent of the import wedge across EA countries and between 6 and 18 per cent—in CEE countries (Table 9). The impact of changes in demand for imports linked to the import content of exports is several times larger, typically being able to account for between 40 and 60 per cent of the import wedge across both EA and CEE countries.

Table 9. Selected CEE and EA Countries: Contribution of Inventory Adjustment and Foreign Value-Added Embodied in Exports to Import Wedge, 2002Q4 - 2010Q1

(Percentage points)

Reference country / Indicator	Contribution of change in inventories to import wedge (percent)	Contribution of foreign value-added embodied in exports to import wedge (percent)
Euro area		
Austria	11.0	58.3
France	15.9	39.9
Germany	4.1	57.0
Italy	10.0	46.5
Central and Eastern Europe		
Bulgaria	18.1	60.6
Czech Republic	10.7	56.1
Lithuania	8.4	43.7
Romania	6.4	19.2

Source: Eurostat and ECB staff estimates.
Notes: Using Baxter-King filtered data from 1996Q4 to 2010Q1.
Assuming Armington elasticity (γ=1).
Following Alessandria et al. (2011), we calculate the contributions as

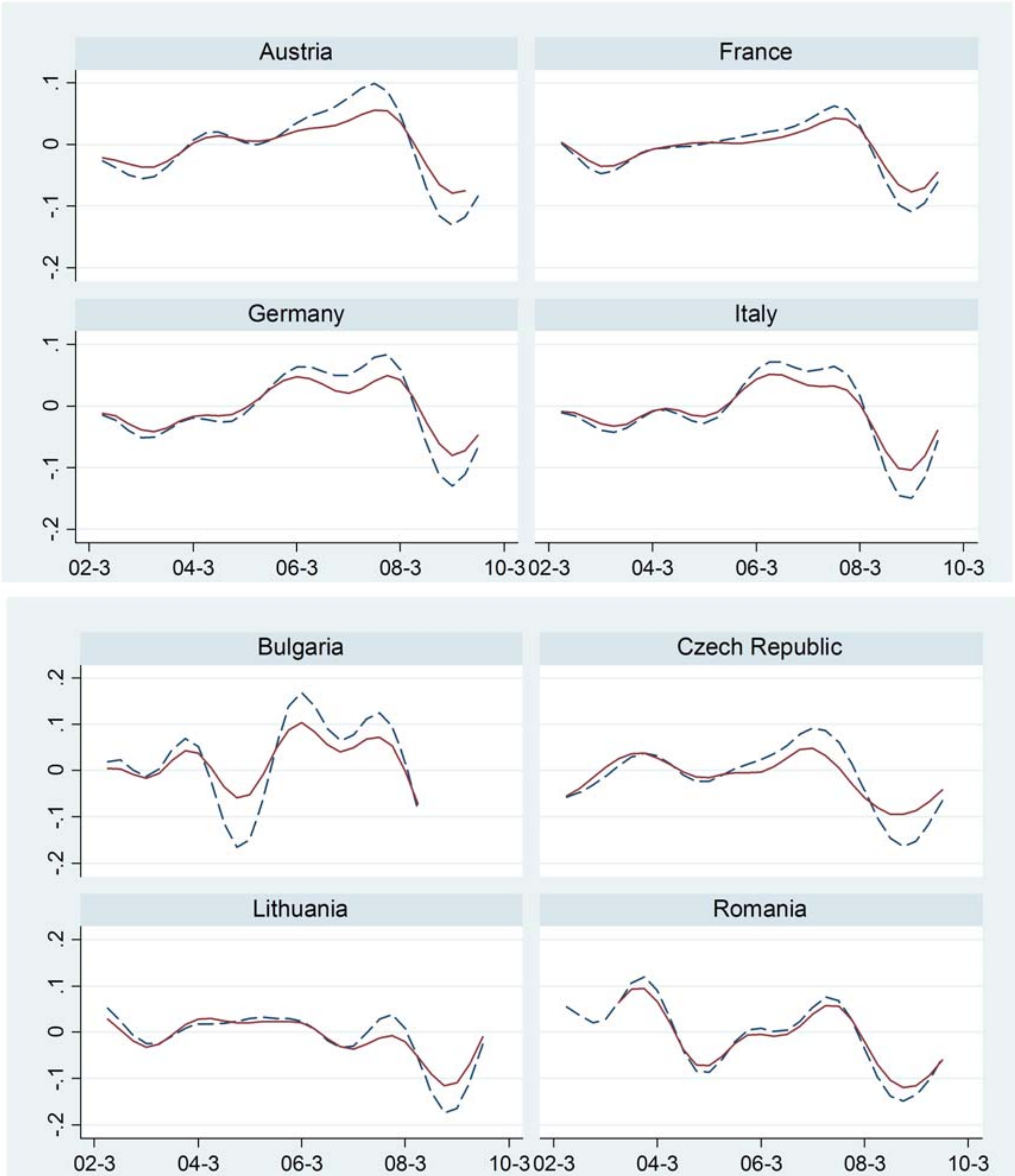
1 – variance $\left(\widehat{\omega}_t - \alpha^m \frac{\bar{Y}}{\bar{M}}\left(\frac{\Delta Inv_t}{Y_t} - \frac{\overline{\Delta Inv_t}}{\bar{Y}_t}\right)\right)$ / variance $(\widehat{\omega}_t)$ and

1 – variance $\left(\widehat{\omega}_t - \beta^m \frac{\bar{X}}{\bar{M}} x_t\right)$ / variance $(\widehat{\omega}_t)$, respectively.

The sizeable contributions of inventory adjustments and the import content of exports to the cyclical fluctuations of imports across Europe reflect the role of global supply chains in the pan-European synchronization of economic activity. This is the case because, for example, a negative shock to exports of one country would translate in lower external demand for its trade partners positioned before it in the cross-border production chains, as a result of the lower technological requirement for imports (i.e., foreign value-added embodied in the country exports) and due to a possible scaling down of inventory stocks.

Figure 4. Selected CEE and EA Countries: Cyclical Components of the Import Wedge with and without Accounting for Import Content of Exports and Inventory Adjustments

(Percentage points divided by 100)



Cyclical component of the standard import wedge

Cyclical component of the import wedge with inventory adjustment and accounting for the import component of exports determined by technological requirements

Note: ECB staff estimates based on Eurostat data.

6 CONCLUSION

In this paper we document the important role played by global value chains in transmitting output fluctuations between the euro area and CEE. We show that a large share of exports from the CEE region passes through euro area-affiliated cross-border production chains, in which CEE exporters are, in general, located further downstream than their euro area partners. This production model, which is both pan-European and globally-integrated in nature, has several important implications. In the short run, it constitutes an important channel for transmitting output fluctuations between the euro area and CEE countries, via the propagation of industry-specific shocks and of inventory adjustments along the supply chain. In the longer run, however, the economic prospects of CEE countries would depend less on euro area than on world demand and the ability of euro area and CEE exporters to remain competitive on the global stage. In this context, the high degree of synchronization of CEE and euro area business cycles since the onset of the global financial crisis can be seen as a manifestation of common demand shocks and/or supply-side shocks that transmit along global value chains. The associated propagation of inventory adjustments along global supply chains further reinforces the synchronization of economic activity across Europe. At the same time, the high degree of openness of the CEE region, achieved through its integration in global value chains, may have reduced the exposure of each country to domestic shocks. Finally, there will likely be increasing "halo effects" from the participation of CEE countries in global value chains, as suggested by the on-going efforts of CEE exporters to set up own value chains within their region.

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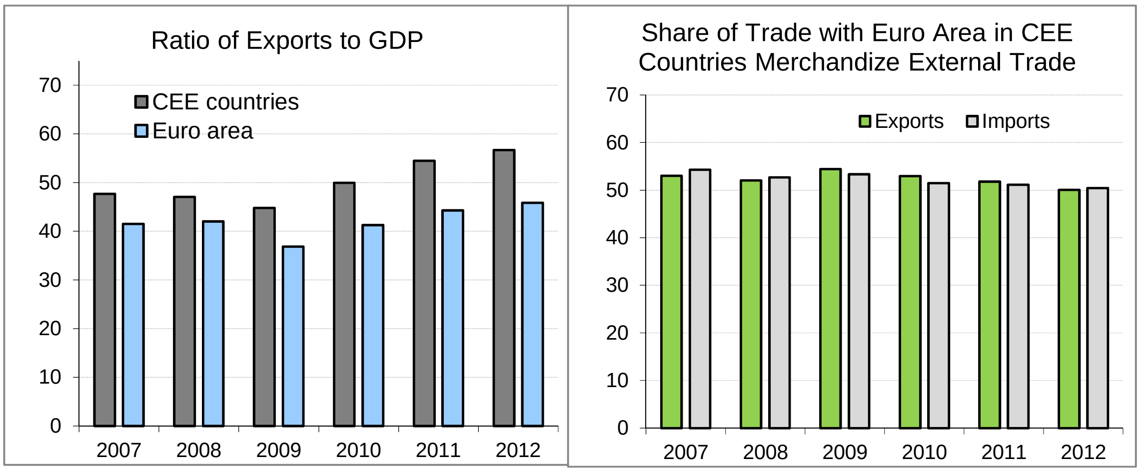
7 APPENDIX

7.1 ADDITIONAL CHARTS AND DESCRIPTIVE STATISTICS

Appendix Figure 1. CEE Countries External Trade Patterns, 2007-2012

(Percentage points divided by 100)

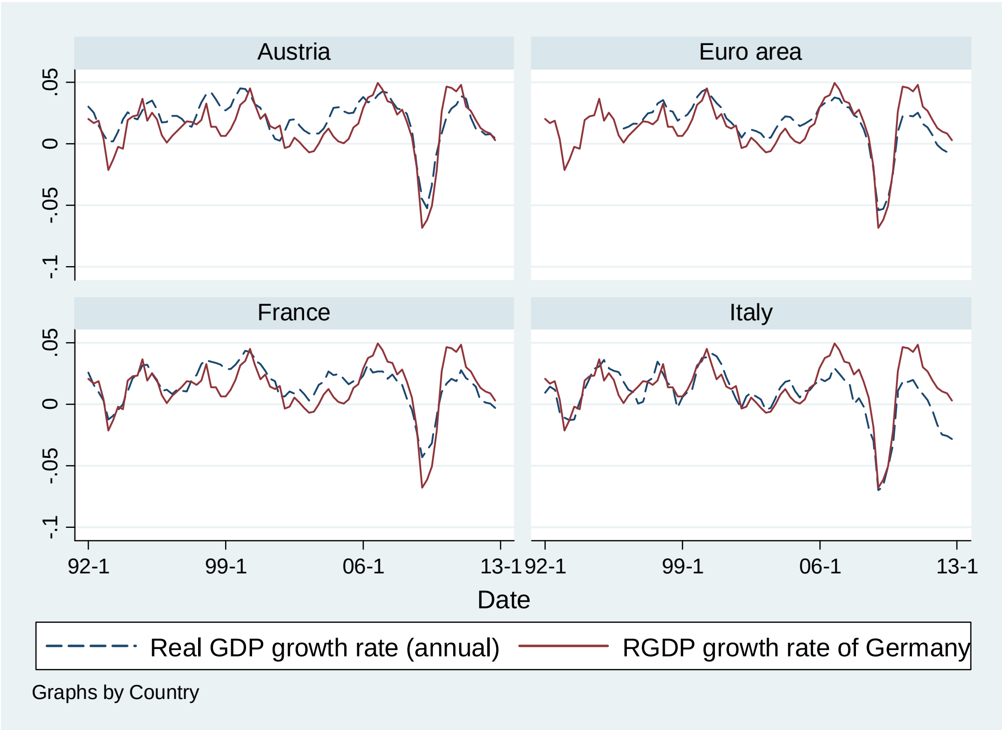


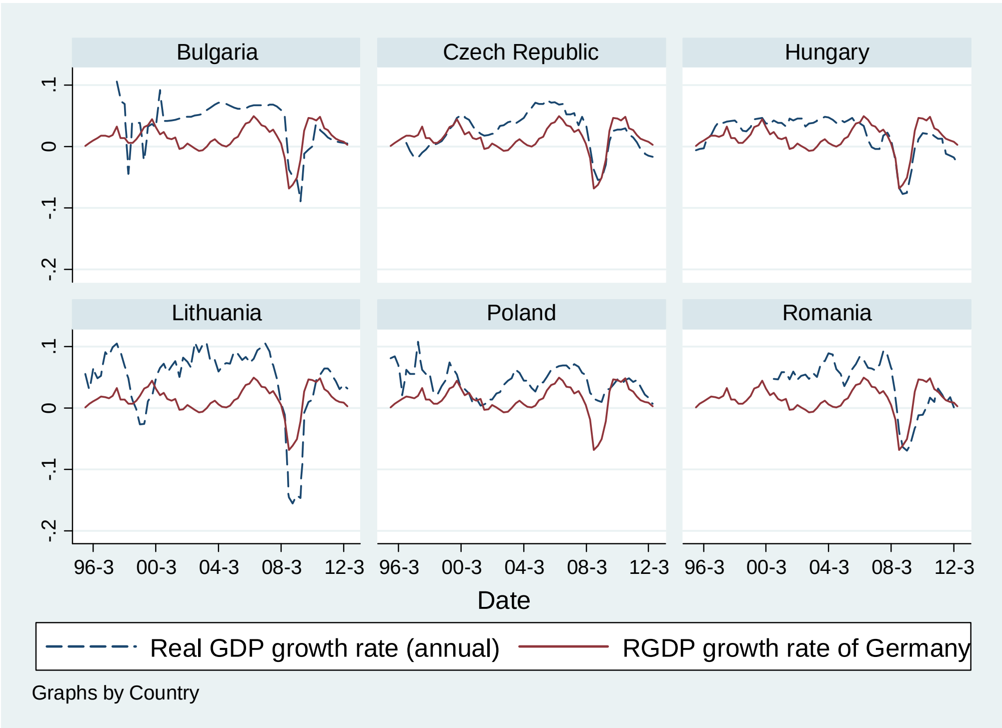
Source: Eurostat and ECB staff estimates.

Note: The CEE countries data are weighted averages, using countries' shares in regional GDP in 2010 at actual exchange rates. Historical data for the euro area are based on the present country membership in the zone.

Appendix Figure 2. CEE and Selected EA Countries: Real GDP Growth Rates, 1992 – 2012

(Percentage points divided by 100)





Source: Eurostat.

Quarterly national accounts data for CEE countries is generally available from 1996 onwards.

Appendix Table 1. CEE and Selected EA Countries: Co-movement of Cyclical Components of Series, 1994Q4 - 2007Q4

	Cross correlations at lag *k* : Cor (x_t,y_{t+k})						
k =	1	-2	-1	0	1	2	3
				Output gap of Germany (y_{t+k})			
Output gap of individual countries (x_t)							
Euro area	0.49 *	0.72 *	0.88 *	0.96 *	**0.97** *	0.91 *	0.78 *
Austria	0.35	0.57 *	0.74 *	0.85 *	**0.88** *	0.87 *	0.79 *
France	0.31	0.54 *	0.71 *	0.81 *	**0.84** *	0.82 *	0.74 *
Germany	0.60 *	0.81 *	0.95 *	**1.00** *	0.96 *	0.86 *	0.68 *
Italy	0.47 *	0.69 *	0.84 *	**0.89** *	0.87 *	0.79 *	0.66 *
Central and Eastern Europe							
Bulgaria	0.20	0.28	**0.31**	0.30	0.27	0.22	0.17
Czech Republic	0.23	0.37	0.47 *	0.54 *	0.57 *	**0.58** *	0.55 *
Hungary	-0.21	-0.01	0.19	0.35	0.45 *	0.51 *	**0.52** *
Lithuania	0.14	0.20	0.22	0.23	0.27	**0.29**	0.26
Poland	0.09	0.27	0.41 *	0.49 *	**0.50** *	0.46 *	0.35
Romania	0.21	**0.22**	0.20	0.18	0.15	0.10	0.03
				Cyclical component of the ratio of change in inventories to trend GDP in individual countries (y_{t+k})			
Output gap of individual countries (x_t)							
Euro area	0.52	0.62 *	0.71 *	**0.76** *	0.74 *	0.64 *	0.47
Austria	0.55 *	0.60 *	0.66 *	**0.70** *	0.67 *	0.54 *	0.32
France	0.35	0.50 *	0.63 *	**0.71** *	0.70 *	0.60 *	0.42
Germany	0.07	0.15	0.25	0.34	0.39	**0.40**	0.34
Italy	0.03	0.19	0.32	0.43	0.50 *	**0.52** *	0.47 *
Central and Eastern Europe							
Bulgaria [1]	**0.64** *	0.62 *	0.56 *	0.53 *	0.53 *	0.53 *	0.49
Czech Republic	0.35	0.52 *	0.62 *	**0.66** *	0.64 *	0.60 *	0.54 *
Hungary	0.05	0.05	0.13	0.26	0.36	**0.37**	0.28
Lithuania	-0.46	-0.37	-0.15	0.15	0.41 *	**0.53** *	0.50 *
Poland	0.54 *	0.70 *	**0.77** *	0.75 *	0.64 *	0.44	0.16
Romania [1]	0.36	0.61	**0.79** *	0.72 *	0.36	-0.15	-0.54

Source: ECB staff estimates.

* significant at 10% level of confidence.

Note: A large positive correlation at $k=0$ indicates that the two series co-move in the same direction; a large negative correlation at $k=0$ shows that the two series move in opposite directions; a maximum correlation at negative k (e.g., $k=-1$) indicates that x follows developments in y with a lag of k quarters (Stock and Watson, 1999).

[1] Quarterly data on contribution to GDP growth of change in inventories available from 1998Q2 for Bulgaria and 2001Q2 for Romania.

7.2 DERIVATION OF MATHEMATICAL EXPRESSIONS

- **Contribution of cyclical fluctuations of changes in inventories to the output gap**

$$Y_t = C_t + (I_t + \Delta Inv_t) + NX_t, \text{ where}$$

Y_t – GDP (real);
C_t – final consumption expenditure (total economy) (real);
I_t – gross fixed capital formation (total economy) (real);
ΔInv_t – changes in inventories (real);
NX_t – net exports of goods and services (real).

$\frac{Y_t-\bar{Y}_t}{\bar{Y}_t}=\frac{C_t-\bar{C}_t}{\bar{Y}_t}+\frac{I_t-\bar{I}_t}{\bar{Y}_t}+\frac{\Delta Inv_t-\overline{\Delta Inv}_t}{\bar{Y}_t}+\frac{NX_t-\overline{NX}_t}{\bar{Y}_t}$, where

variables with bars denote long-term trend of the respective variable.

$$\frac{Y_t-\bar{Y}_t}{\bar{Y}_t}=\frac{\bar{C}_t}{\bar{Y}_t}\frac{C_t-\bar{C}_t}{\bar{C}_t}+\frac{\bar{I}_t}{\bar{Y}_t}\frac{I_t-\bar{I}_t}{\bar{I}_t}+\left(\frac{\Delta Inv_t}{\bar{Y}_t}-\frac{\overline{\Delta Inv}_t}{\bar{Y}_t}\right)+\left(\frac{NX_t}{\bar{Y}_t}-\frac{\overline{NX}_t}{\bar{Y}_t}\right)$$

$y_t \approx \frac{\bar{C}_t}{\bar{Y}_t}c_t+\frac{\bar{I}_t}{\bar{Y}_t}i_t+\left(\frac{\Delta Inv_t}{\bar{Y}_t}-\frac{\overline{\Delta Inv}_t}{\bar{Y}_t}\right)+\left(\frac{NX_t}{\bar{Y}_t}-\frac{\overline{NX}_t}{\bar{Y}_t}\right)$, where (A2.1)

lower-case variables denote log-deviations from trend;
y_t – output gap.

- **Import wedge**

$M_t=S_t+\Delta Inv_t^m+\beta^m X_t$ – accounting identity, in which:

M_t – imports of goods (real);
X_t – exports of goods (real);
β^m – exogenously given import component of goods exports (unitless ratio);
S_t – sales of imported goods on the domestic market (real);
ΔInv_t^m – changes in inventories of imported goods (real);

$S_t=P_t^{-\gamma}C_t$ – constant elasticity demand function for imported goods, in which:

P_t – relative price of imports;
C_t – aggregate expenditure (real);
γ – Armington elasticity.

$\frac{M_t-\bar{M}}{\bar{M}}=\frac{S_t-\bar{S}}{\bar{M}}+\frac{\Delta Inv_t^m-\overline{\Delta Inv_t^m}}{\bar{M}}+\beta^m\frac{X_t-\bar{X}_t}{\bar{M}}$, where

variables with bars denote long-term trend of the respective variable;
$\bar{M}\equiv\bar{S}$ – following Alessandria, Kaboski, and Midrigan (2011 and 2012), we assume that in the long-run sales of foreign goods equal imports.

$\frac{M_t-\bar{M}}{\bar{M}}=\frac{S_t-\bar{S}}{\bar{S}}+\frac{\bar{Y}}{\bar{M}}\frac{\Delta Inv_t^m-\overline{\Delta Inv_t^m}}{\bar{Y}}+\beta^m\frac{\bar{X}}{\bar{M}}x_t$, where

lower-case variables denote log-deviations from trend;
Y_t – GDP (real);
$\frac{Inv_t^m}{Inv_t}\equiv\frac{Inv_{t-1}^m}{Inv_{t-1}}\equiv\frac{\Delta Inv_t^m}{\Delta Inv_t}\equiv\alpha^m$ – share of imported goods in total inventory stock (unitless ratio). Similar to Alessandria, Kaboski, and

Midrigan (2011 and 2012), we assume that the changes in imported inventories are perfectly correlated with those of aggregate inventories: $\Delta Inv_t^m = \alpha^m \Delta Inv_t$ and $\overline{\Delta Inv_t^m} = \alpha^m \overline{\Delta Inv_t}$.

$$\frac{M_t - \overline{M}}{\overline{M}} = \frac{S_t - \overline{S}_t}{\overline{S}} + \alpha^m \frac{\overline{Y}}{\overline{M}} \left(\frac{\Delta Inv_t}{\overline{Y}_t} - \frac{\overline{\Delta Inv_t}}{\overline{Y}_t} \right) + \beta^m \frac{\overline{X}}{\overline{M}} x_t$$

$m_t \approx s_t + \alpha^m \frac{\overline{Y}}{\overline{M}} \left(\frac{\Delta Inv_t}{\overline{Y}_t} - \frac{\overline{\Delta Inv_t}}{\overline{Y}_t} \right) + \beta^m \frac{\overline{X}}{\overline{M}} x_t$, where

lower-case variables denote log-deviations from trend;

$s_t = -\gamma p_t + c_t$ – log transformation of the demand function for imported goods.

$$m_t \approx -\gamma p_t + c_t + \alpha^m \frac{\overline{Y}}{\overline{M}} \left(\frac{\Delta Inv_t}{\overline{Y}_t} - \frac{\overline{\Delta Inv_t}}{\overline{Y}_t} \right) + \beta^m \frac{\overline{X}}{\overline{M}} x_t$$

$$\widehat{\omega}_t \equiv m_t - (-\gamma p_t + c_t) \quad \text{(A2.2)}$$

$\widehat{\omega}_t$ – standard import wedge.

$$\omega_t \equiv \widehat{\omega}_t - \alpha^m \frac{\overline{Y}}{\overline{M}} \left(\frac{\Delta Inv_t}{\overline{Y}_t} - \frac{\overline{\Delta Inv_t}}{\overline{Y}_t} \right) - \beta^m \frac{\overline{X}}{\overline{M}} x_t \quad \text{(A2.3)}$$

ω_t – import wedge with inventory adjustment and accounting for the import component of exports determined by technological requirements.