Office Memorandum

To: Members of the Executive Board July 3, 2013

From: The Acting Secretary

Subject: **German-Central European Supply Chain—Cluster Report—First Background Note—Trade Linkages**

Attached is the first background note to the cluster report on the German-Central European Supply Chain—trade linkages (FO/DIS/13/100, 7/3/13), which is being circulated as background for the **informal session to brief** Executive Directors that is tentatively scheduled for **Thursday, July 11, 2013.**

Unless an objection from the authorities of the Czech Republic, Germany, Hungary, the Republic of Poland, or the Slovak Republic is received prior to the conclusion of the informal session, the document will be published. Any requests for modifications for publication are expected to be received two days before the conclusion of the informal session.

Questions may be referred to Mr. Lall (ext. 36113), Mr. Aiyar (ext. 35973), and Mr. Elekdag (ext. 34835) in EUR.

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INTERNATIONAL MONETARY FUND

July 1, 2013

GERMAN-CENTRAL EUROPEAN SUPPLY CHAIN—CLUSTER REPORT—FIRST BACKGROUND NOTE—TRADE LINKAGES

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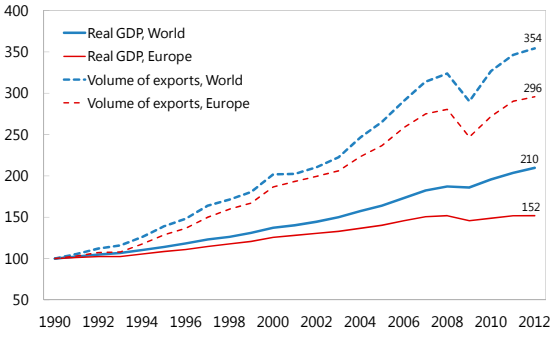
INTRODUCTION

1. Recent years have witnessed a rapid expansion in global and regional trade. Since 1990, the world's export volumes have registered more than a threefold increase, considerably surpassing global GDP growth. In Europe, while export volumes expanded more moderately, their growth was nearly double that of real output (Figure 1). The rapid expansion of trade was driven by trade liberalization, reflected in significant reduction in tariff rates and removal of non-tariff trade barriers,[1] and increased fragmentation of production (also known as "vertical-specialization"), which resulted in much higher trade volumes of intermediate inputs.[2]

Figure 1. Trade Volumes and Output
(1990=100)



Source: World Economic Outlook

2. The increase in vertical specialization has emerged in response to challenges from increased competition and new opportunities from stronger globalization. Firms have chosen to outsource or shift part of the production process to different locations to exploit efficiency gains, including from differences in wages, productivity, business laws, and taxation.[3] Vertical specialization has been driven by several factors, some related to the reduction of trade costs, including transportation and tariffs (Feenstra, 1997, Miroudot and Ragoussis, 2009), and improvements in communication technology (e.g. the internet), which significantly reduced the costs of information exchange and made it easier for firms to coordinate and monitor production in diverse locations (Hummels et al., 2001).[4] As documented in background paper #2, increased financial liberalization, which encouraged Foreign Direct Investment (FDI), and therefore allowed firms to shift production offshore more easily, also played an important role. Some studies, including Hummels et al. (1998), also suggest that the development of supply chains was in fact needed because goods production today requires more steps than in the past, therefore requiring multiple areas of specialization.

3. Vertical specialization has led to new trade patterns, in which advanced and emerging markets normally play different roles (Riad et al. 2012). Advanced economies tend to be upstream in the supply chain using relatively limited foreign content in their exports, while emerging

[1] In Europe, for instance, the accession to the EU's single market was accompanied by elimination of impediments for internal movement of goods and services.

[2] Today, more than half of world manufactured imports are intermediates goods and more than 70 percent of world services imports are intermediates services (OECD, 2012).

[3] Numerous empirical studies, using different definitions, data sources and methodologies, find robust evidence of the growing importance of vertical integration. See Koopman et al. (2011) for an extensive literature survey.

[4] Miroudot and Ragoussis (2009), for instance, found that a reduction of 10 percent in distance-related trade costs is associated with an increase of 9 percent in vertical trade.

markets are normally located in the downstream segment of the production chain.[5] In Asia, for instance, Japanese companies have located a large part of the "downstream" production process in the automobile and electronic industries in South East Asian economies, including China, (Koopman et al., 2008), [6] while, in North America, US companies use plants in Mexico for manufactured goods assembly ("Maquiladoras", Hummels et al. 1998).

4. In Europe, the emergence of vertical specialization has been particularly evident among German firms (Sinn, 2003, 2006). Proximity to Germany, cultural similarities, and relatively high labor costs differentials[7] have led many German firms to shift large parts of their production to central and eastern European (CEE) countries, most notably in the Czech Republic, Hungary, Poland and Slovakia (CE4, hereafter) either by directly investing there or by purchasing intermediate inputs from local firms.[8] This pattern is particularly evident in the automobile industry where increased competition in both domestic and foreign markets triggered a rapid process of international outsourcing of manufacturing activities (Box).

5. Against this background, the primary objective of this chapter is to look at the CE4's integration into the supply chain with the aim of assessing the magnitude and effects of this process. In particular, the chapter focuses on the following main questions:

- To what extent have the CE4's bilateral trade links with Germany changed over time, and do they differ from the trends observed in other European countries?
- What is the CE4's role in the German-Central European Supply Chain (GCESC) and which are the main sectors that participate in the GCESC?
- How has integration into the GCESC affected the CE4 countries both individually and as a group?

6. Evaluating recent trends in the CE4's trade linkages with Germany would shed light on the benefits and challenges of the integration process. While closer integration into the GCESC should lead to positive spillovers in terms of productivity gains (including from technology transfer) and external competitiveness, thereby engendering faster economic development and income

[5] Countries upstream normally produce the raw materials or intangibles involved at the beginning of the production process (e.g., research, design), while countries downstream do the assembly of processed products or specialize in customer services (OECD, 2012).

[6] Koopman et al. (2008) show that, on average, foreign companies contribute 80 percent or more of the VA embodied in Chinese exports of computers, and office telecom equipment.

[7] Sinn (2006) points to the excessive wages growth in Germany as one of the main factors for the fragmentation of production.

[8] According to a survey by Cologne Institute for Business Research (IW, 2002), by 2002, close to 60 percent of the SMEs with 1000-5000 employees had already established plants outside the old EU.

growth, it could in principle pose some challenges going forward. Higher concentration of trade could also imply that the CE4's dependency on the German economy has increased with ramifications for business cycle co-movement and vulnerabilities to shocks. Moreover, sustaining a country's role in the supply chain and continuing to derive the associated benefits could involve policy effort. Policies taken by the CE4 members should ultimately aim to safeguard the benefits of the GCESC while mitigating any risks related to greater exposure to the German economy.

7. This chapter is structured as follows: The next section provides some stylized facts on recent trends in Germany's bilateral trade links with the CE4, and, in light of challenges related to the interpretation of trade statistics in the context of supply chains, it looks at a decomposition of exports into domestic and foreign value added (VA) and assesses how they have changed over time. This section also evaluates Germany's and the CE4's exposure to other countries based on their final consumption and compares it to the exposure under the commonly used gross bilateral trade statistics published in the IMF Direction of Trade Statistics (DOTS). The following section examines the effects of the GCESC on the CE4 countries, with a particular focus on technology transfer, business cycles synchronization, and income convergence. The final section provides concluding remarks.

THE GERMAN-CENTRAL EUROPEAN SUPPLY CHAIN

A. Trends in CE4 Trade Linkages with Germany

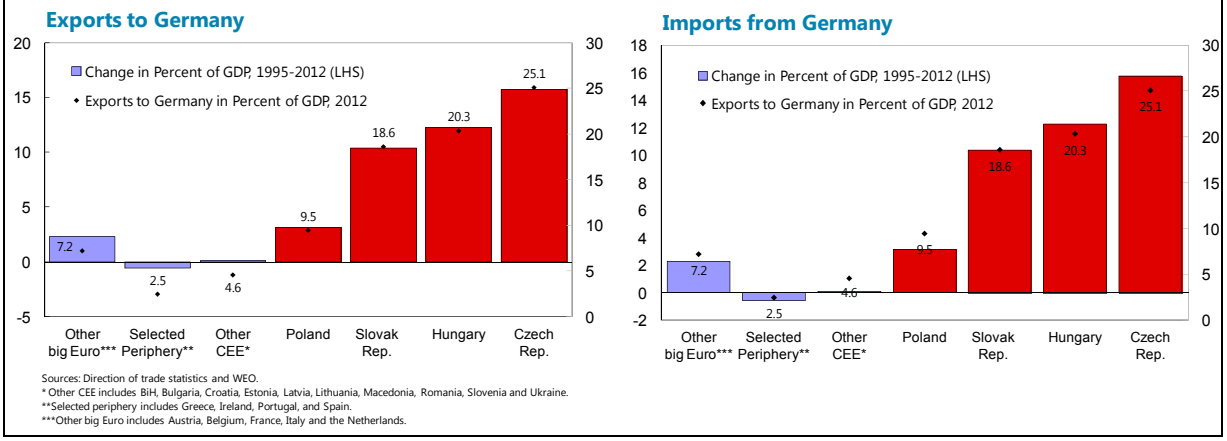
8. The CE4's trade links with Germany have strengthened considerably since the mid-1990s, largely reflecting their increased integration into the GCESC (Figure 2). Between 1995 and 2011, the CE4's imports from Germany grew by 8½ percent of GDP on average (cumulative basis), with Czech Republic leading the way (10½ percent of GDP), while exports to Germany increased sharply by nearly 10 percent of GDP on average. Consequently, Germany has become the main trading partner (with the largest export and imports as a share of GDP) of all the CE4 countries.

9. Compared with other countries, including CEE economies, the CE4 exhibits the strongest trade linkages with Germany. The CE4's average imports from Germany stood in 2012 at 16 percent of GDP, which, apart from Austria–which traditionally has a high German import content–is well above other European countries. Similarly, the average of the CE4's exports to Germany in 2012 stood at 18 percent of GDP, behind only the Netherlands (22 percent of GDP). A closer look at the sectoral level suggests that knowledge-intensive sectors, particularly transport and electrical equipment, account for the CE4's largest bilateral trade with Germany. As documented in the next section, the increased links in these sectors have led to the transfer of technology, which in turn has translated to sizeable gains in terms of comparative advantage.

10. While trends are similar, the CE4 is not a homogenous group (Figure 2). Poland's trade linkages with Germany (as a share of GDP) are significantly less than those in other CE4 countries, largely due to Poland's large GDP (Poland's GDP is about 54 percent of the CE4's GDP) and higher share of domestic demand, which mechanically dampens the magnitude of the trade intensity with

Germany as compared to other CE4 economies. In this regard, although Poland's openness has increased in recent years, it remains a relatively closed economy with the sum of overall imports and exports at 74 percent of GDP (compared to an average of 157 percent of GDP in rest of the CE4 countries).

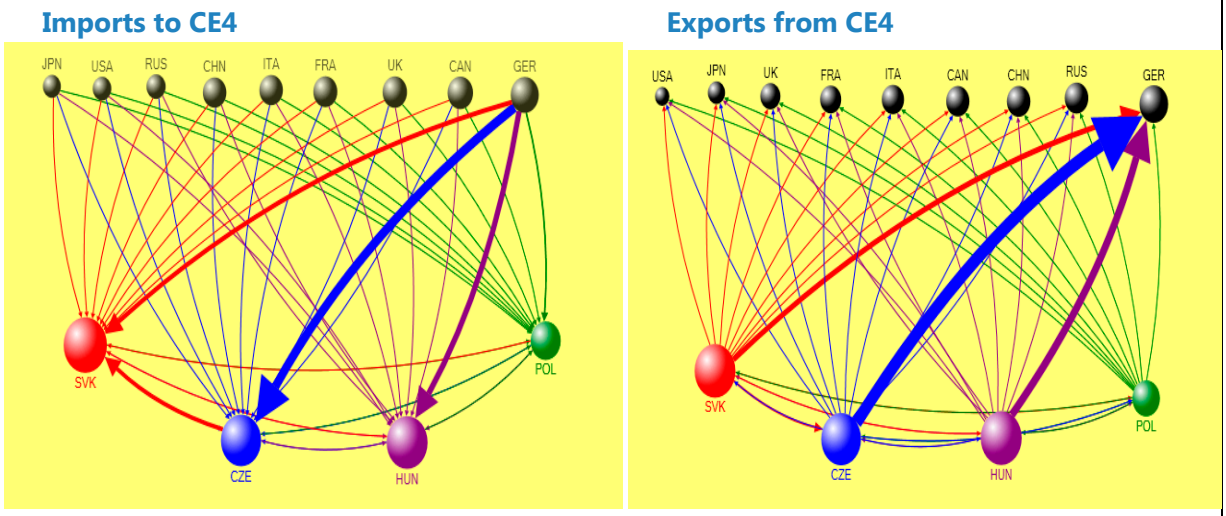
Figure 2. Bilateral Trade with Germany



Sources: Direction of trade statistics and WEO.
* Other CEE includes BiH, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Macedonia, Romania, Slovenia and Ukraine.
**Selected periphery includes Greece, Ireland, Portugal, and Spain.
***Other big Euro includes Austria, Belgium, France, Italy and the Netherlands.

11. The importance of Germany as a major trading hub for the CE4 is illustrated in Figure 3. The thickness of the arrows represents the share of imports (exports) relative to recipient (exporter) GDP and the bubble size indicates the country's total imports (exports) to GDP. The charts clearly show that, among the major global players, Germany is the largest trading partner for the CE4. For Czech Rep, Hungary, and Slovakia, imports from Germany are between 15 to 21 percent of the countries' GDP while exports to Germany amount to 16 to 24 percent of GDP. For Poland, Germany's exports and imports shares are somewhat lower, due to Poland's higher GDP level and less dependence on external trade, yet with exports and imports at 10-11 percent of GDP, Germany remains Poland's major trading partner.

Figure 3. CE4's Bilateral Trade with Major Global Players



* Source: Direction of Trade statistics and WEO.
* The arrows point to the receiving country.
* Line thickness indicates imports (exports) values relative to recipient's (exporter) GDP.
* The bubble size is proportional to the country's total imports (exports) to GDP.

12. The CE4's high degree of integration into the supply chain reflects a host of factors. Beyond the geographic proximity to Germany, cultural similarities, and high unit labor cost differentials,[9] the countries share a similar sectoral structure, which suggests that they have adequate labor skills to support the GCESC.[10] In this context, Rahman and Zhao (2013) computed the industrial similarity index relative to Germany. They showed that the CE4 countries had strong similarities with Germany even before they integrated into the supply chain.

B. Shortcomings of Traditional Trade Statistics

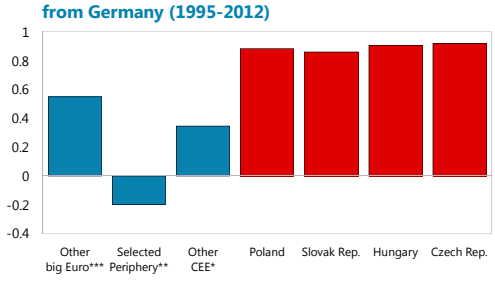
13. Vertical specialization networks have created challenges for interpreting official trade statistics. Trade statistics are usually measured in gross terms, which include both intermediate and final goods. In supply chain-related activities, particularly when imported intermediates are re-exported after some processing, export figures tend to be inflated and do not adequately reflect the countries' domestic VA, which matters most for domestic employment and economic growth.

[9] The average exchange rate-adjusted unit labor cost differential between the German manufacturing sector and that in the CE4 during 1995-2009 ranged between 35 percent (Poland) and 58 percent (Hungary).

[10] Among others, these variables were found to have a significant contribution to the share foreign VA in countries' exports. See Rahman and Zhao (2013).

14. The shortcomings of trade statistics in supply chain-integrated countries are illustrated in the high and positive correlation of the CE4 countries' import from and exports to Germany (Figure 4). This is in contrast to much lower correlations for other countries vis-à-vis Germany. This may owe partly to high business cycles synchronization, but also suggests that a large part of the CE4's exports to Germany contains German intermediates, which were imported and then processed in the CE4 as part of the fragmented production process. The high correlation may also suggest that the share of the CE4's foreign VA in these products is relatively high.

Figure 4. Correlation between Exports and Imports from Germany (1995-2012)



Sources: Direction of trade statistics and WEO.
* Other CEE include BiH, Bulgaria, Croatia, Estonia, Latvia, Lithuania, Macedonia, Romania, Slovenia and Ukraine.
**Selected periphery include Greece, Ireland, Portugal, and Spain.
***Other big Euro include Austria, Belgium, France, Italy and the Netherlands.

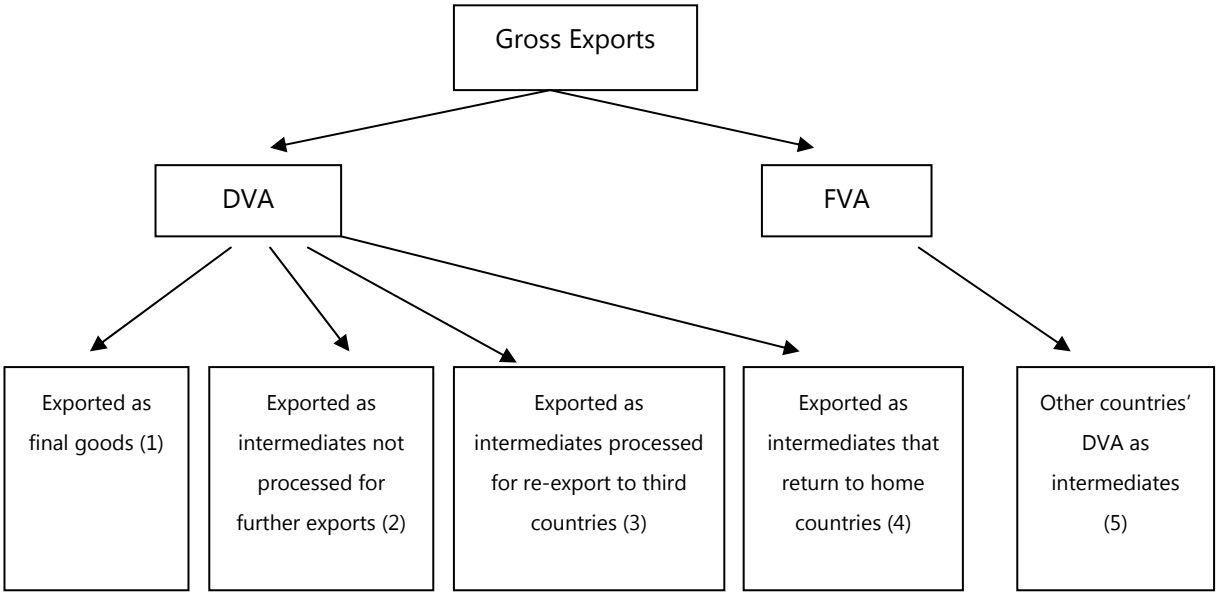
C. Decomposition of Gross Exports into Domestic and Foreign Value Added

15. To evaluate the CE4's role in the GCESC, we decompose gross exports into VA exports using the newly released World Input-Output Table (WIOT). We follow the Hummels et al. (2001) measure of vertical specialization by looking at the import content of production for exports. This measure was used in several studies, including Chen et al (2005), Johnson and Noguera (2012), Koopman et al. (2011), and more recently, in Rahman and Zhao (2013), and is different from the definition used in earlier studies such as Feenstra and Hanson (1996), which mainly focused on documenting trends in outsourcing, usually defined as the imported input shares of gross output or of material inputs.[11]

16. The analysis builds on the conceptual framework developed by Koopman et al. (2011). It decomposes gross exports into five main categories depending on the location of VA and stage of production (Figure 5). These include: (1) domestic VA (DVA) in final goods, (2) DVA in intermediate goods not processed for further exports, (3) DVA in intermediate goods processed for exports to third countries, (4) DVA exported to another country but returns back to the original country for exports to a third country, and (5) foreign VA (FVA) used as input into exports.

[11] The WIOT provides an annual time series for 1995-2009 for 35 sectors and covers forty countries, including all EU 27 countries and 13 other major advanced and emerging economies (see details in Annex 1).

Figure 5. Decomposition of Gross Exports into Value Added Exports



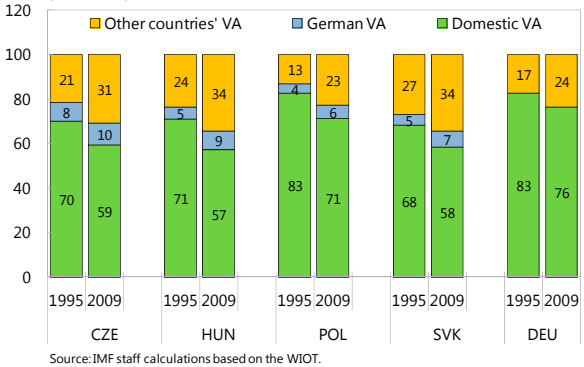
Source: Koopman et al. (2011), and Rahman and Zhao (2013).

17. The decomposition of the five-category VA is computed for manufacturing and services exports respectively (Annex 2). Components (1)-(4) measure the value of exports that are created domestically. Components (1)-(2) reflect the countries' stand-alone exports, i.e. outside the supply chain, while components (3)-(5) indicate supply chain-related exports. These have two components: upstream (components (3)-(4)), which include DVA that is processed for further exports, and downstream (component (5)). A large share of FVA in total exports would generally indicate that a country is a downstream participant in the supply chain, usually specializing in processing and assembly functions.

D. The Evolution of Domestic and Foreign Value Added Exports

18. Over the last 15 years, the share of FVA in the exports of CE4 countries and Germany has increased considerably (Figure 6). Among the CE4 countries, Hungary registered the sharpest increase (14 percentage points) bringing the share of FVA in exports to the highest level (43 percent), while Poland, which continues to maintain a relatively high share of domestic value exports, registered the smallest increase in FVA. The share of German VA in the CE4's exports increased by about 2 percentage points, with the exception of

Figure 6. Composition of Total Exports
(Percent)



Source: IMF staff calculations based on the WIOT.

Hungary (4 percentage points). Beyond higher German VA that is embodied in the CE4's exports, the increased integration into the GCESC has also led to:

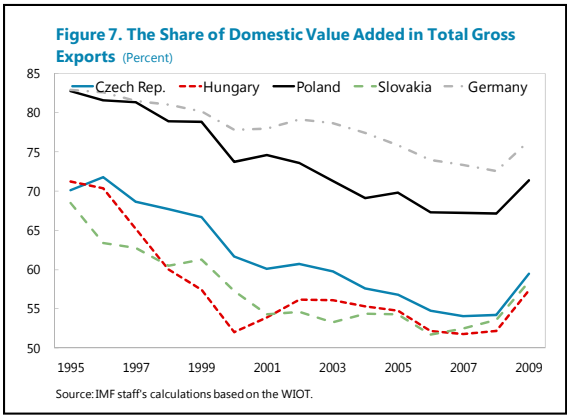
- Higher intermediates from other countries (captured by "other countries' VA") to support the GCESC's related activities, and;
- Increased intermediates that are exported by the CE4 to Germany for further processing (Table 1).

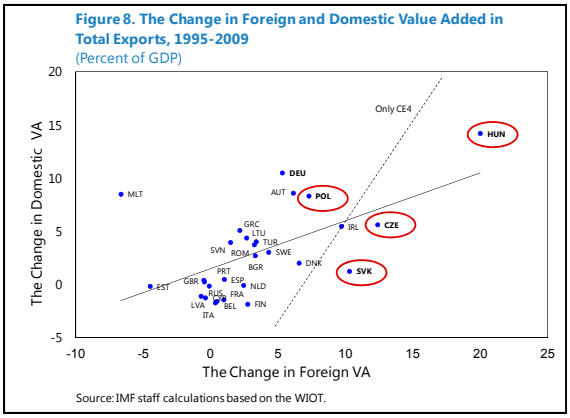
Table 1. Supply Chain-Related Activities

	Intermediates from DEU embodied in the CE4's exports (Percent of total CE4's exports)*		Intermediates from CE4 embodied in DEU's exports (Percent of total CE4's exports)*	
	1995	2009	1995	2009
CZE	8.45	9.75	5.53	5.82
HUN	5.31	8.52	3.09	3.77
POL	4.08	6.07	5.77	5.59
SVK	4.63	7.20	3.68	4.20

*The calculation of intermediates includes only the countries' domestic value added.

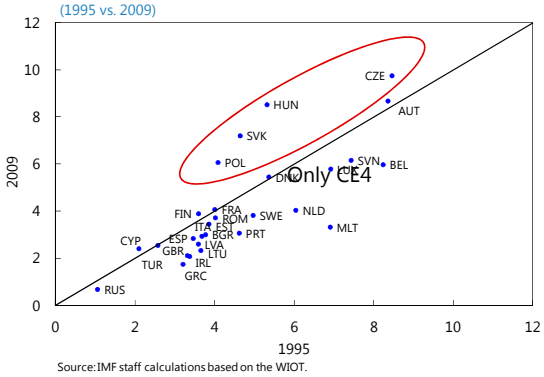
19. The counterpart to the increasing share of FVA in exports is a substantial secular decline in the share of DVA (Figure 7). A closer look at the evolution of the shares over time suggests that the lion's share of the decline in DVA occurred during the 1995-2002 period, while, during the "boom years" (2003-2008), it contracted only moderately until it reached a trough in 2008. In 2009, however, the share of DVA increased by about 4-5 percentage points on average, suggesting perhaps that supply chain-related activities were adversely affected by the global financial crisis, in part due to high exchange rate volatility, thus leading companies to consolidate their operations and perhaps switch back to domestic suppliers. This is consistent with the OECD's findings regarding the decline in the length of the value chains during 2008-09 (OECD, 2012).





20. While the shares of DVA in gross exports have broadly declined, they have increased significantly in nominal terms and as a percentage of GDP (Figure 8). Between 1995-2009, Hungary, Germany, Poland, and Czech Rep., registered an increase of 14, 10½, 8 and 5½ percentage points of GDP, respectively, while Slovakia recorded the smallest increase (1 percentage point of GDP). The increase in domestic VA was positively correlated with the increase in FVA. In this regard, Rahman and Zhao (2013), who examine the relationship between foreign and domestic VA growth across 40 countries during 1995-2008, found a positive and significant link. Moreover, they find econometric evidence that causality runs from growth in FVA to DVA. In other words FVA is not a substitute to domestic VA but tends to complement the production process and spur overall employment and growth.

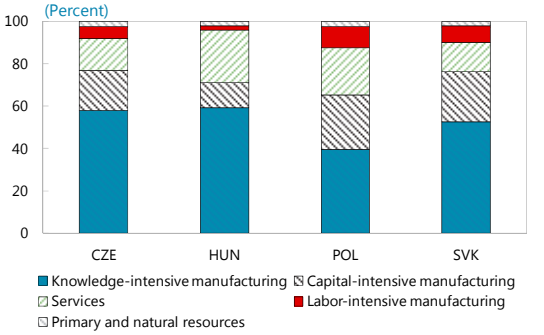
Figure 9. The Share of German Value Added in Total Exports
(1995 vs. 2009)



Source: IMF staff calculations based on the WIOT.

21. The increase in FVA in the CE4 is related to the German VA increase in both nominal and relative terms. In this regard, the CE4 group stands out when comparing the share of the German VA to that in other European countries; they are the only countries that recorded a significant increase in German VA as a share of total exports (Figure 9).

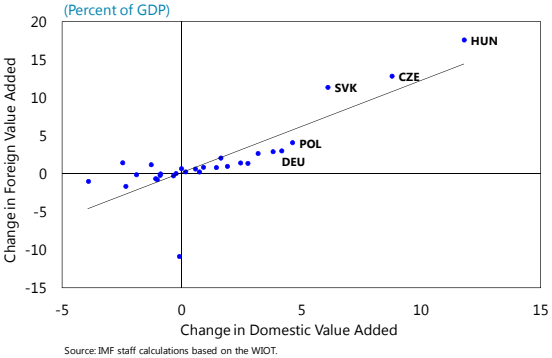
Figure 10. Sectoral Contribution to Exports Growth, 1995-2009
(Percent)



Source: IMF staff calculations based on the WIOT.

22. The sectoral decomposition shows that the knowledge-intensive sectors (transport and electrical equipment, machinery and chemicals) made the largest contribution to export growth in the period 1995-2009 (Figure 10).[12] In Czech Rep., Hungary and Slovakia, these sectors contributed about 50-60 percent of total exports growth, while, in Poland, their contribution was somewhat lower (40 percent) but still the highest compared to other sectors. At about 30-40 percent, the knowledge-intensive sectors also have the highest share in countries' domestic VA exports.

Figure 11. Knowledge-Intensive Sectors: The Change in the Domestic and Foreign Value Added, 1995-2009
(Percent of GDP)



Source: IMF staff calculations based on the WIOT.

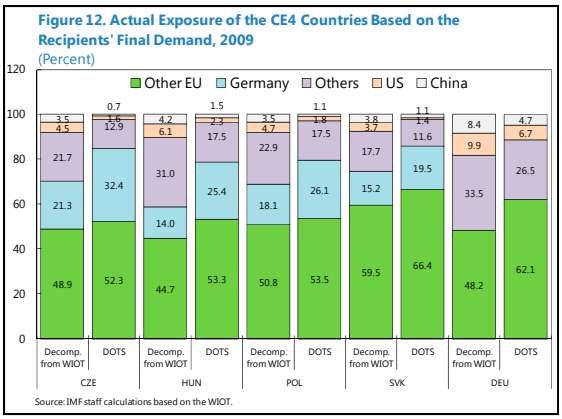
[12] The various sectors are grouped into five main categories: primary and natural resources, services, labor-intensive manufacturing, capital-intensive manufacturing and knowledge-intensive manufacturing (see annex 3 for detailed classification).

23. Knowledge-intensive sectors in the CE4 stand out in terms of the cumulative increase in both DVA and FVA (since 1995). The increase, which is well beyond that in other European countries, is a clear indication of their strong integration into the GCESC (Figure 11). More importantly, the changes in domestic and foreign VA in knowledge-intensive sectors exhibit a strong positive correlation. In these sectors, Hungary recorded the sharpest increase in both domestic and foreign VA, with the latter largely reflecting German VA. While Czech Rep. and Slovakia also registered a considerable increase in both domestic and foreign VA, the increase in Poland and Germany was more moderate, in part reflecting their large GDP.

E. Countries' Export Exposure Based on Final Demand

24. The VA decomposition also allows revisiting countries' export exposure to other trading partners based on final demand rather than proximate demand. This pattern would generally differ from exposures computed using the Direction of Trade statistics (DOTS) on bilateral gross trade flows as, in the context of global supply chains, a significant part of the countries' exports can be in the form of intermediates that are processed and re-exported by a third economy.

25. The countries' export exposure based on final demand underscore the strong presence of the GCESC (Figure 12). In particular, the comparison between the exposure under the WIOT and under the DOTS indicates that Germany's exposure to the EU under the WIOT (48 percent) is significantly below the implied exposure under the DOTS (62 percent) while its exposure to the rest of the world is much higher (33 percent vs. 26 percent). This is exactly what one would expect from vertical specialization activities under which Germany exports intermediates that are further processed in downstream facilities in the EU, including the CE4, and then re-exported directly or indirectly outside the EU to the rest of the world.

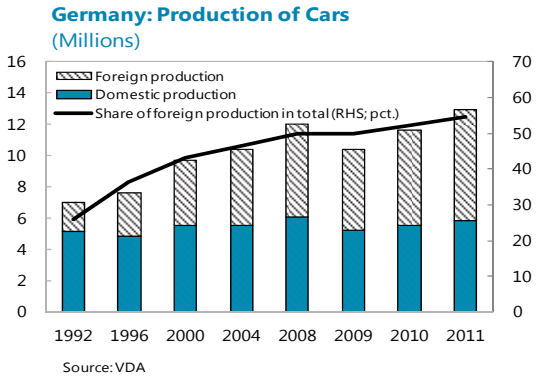


26. Similarly, the comparison indicates that the CE4's exposure to Germany is significantly lower than the implied exposure by the DOTS. This again suggests that part of the CE4's exports is passing through Germany before it is exported further outside the EU. And indeed, the comparison also shows that, under the WIOT, the exposure to the rest of the world is significantly higher than the exposure under the DOTS.

27. The comparison underlines the challenges in assessing trade exposures. As illustrated, the DOTS figures can be misleading in capturing the countries' exposure to trading partners' final demand, particularly in the context of supply chains where a large part of the flows are in the form of intermediate goods that are used for the production of exports. This may have ramifications for the calibration of economic models that aim at evaluating countries' vulnerabilities to shocks in external demand.

Box 1.The Automobile Industry

The German automobile industry is one of the most prominent examples of supply chains in Europe. Germany has been a leading producer and exporter of passenger cars with a global market share of around 20 percent as of 2012. Offshore production, particularly in Czech Republic, Hungary, Poland and Slovakia (CE4), has become significant in recent years, with 2009 marking the first year when foreign production overtook domestic production. In this regard, while domestic production has remained relatively constant at around 5.5 million vehicles per year between 1992 and 2011, foreign production registered more than a threefold increase in the same period, reaching 7.1 million.



The shift in German automotive production towards the CE4 started in the mid-1990s and was a natural outcome of demand and supply forces. On the demand side, German automobile manufactures needed to respond to a more competitive environment in an increasingly globalized world, while on the supply side, the CE4 countries offered an attractive mix of characteristics whose appeal only strengthened after their accession to the EU in 2004. Geographic proximity, relatively low unit labor costs, the favorable tax environment, and a highly qualified workforce with a history of expertise in the automobile industry played an important role.[1] [2]

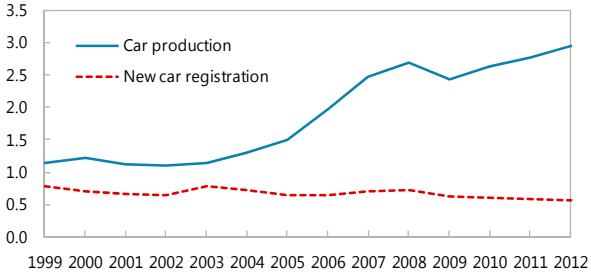
With greater integration into the supply chain, the CE4's automotive sector has become an important part of their economic activity. Although moderating somewhat after the global financial crisis, the inflow of foreign direct investment (FDI) into this sector increased markedly from the mid-1990s, while the production of vehicles reached a peak of nearly 3 million in 2012. The latter has had an enormous impact on the CE4's export growth (Table), accounting for over half of the cumulative increase in exports since 1995 in all CE4 countries except Hungary (where the contribution was still very substantial). Employment in the automobile sector has increased somewhat, but given that the sector is highly capital- and knowledge-intensive, its overall impact on direct employment has been more limited.

[1] The corporate income tax rate in the CE4 is significantly lower than in Germany. In 2011, for instance, it was 19 percent in all CE-4 countries compared with 29 percent in Germany.

[2] Czechoslovakia was one of the main car producers in the Soviet bloc.

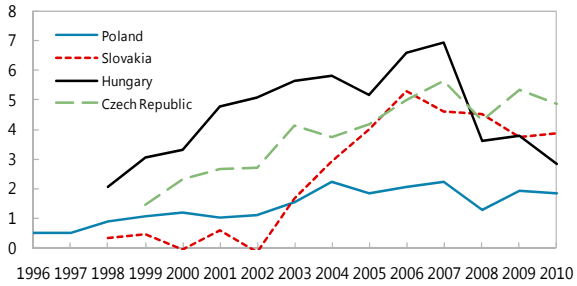
Box 1.The Automobile Industry (Concluded)

CE4: Passenger Car Production and Registration
(Millions)



Sources: OICA; ACEA

FDI Inflow into Automotive Sector
(Percent of GDP)



Source: OECD

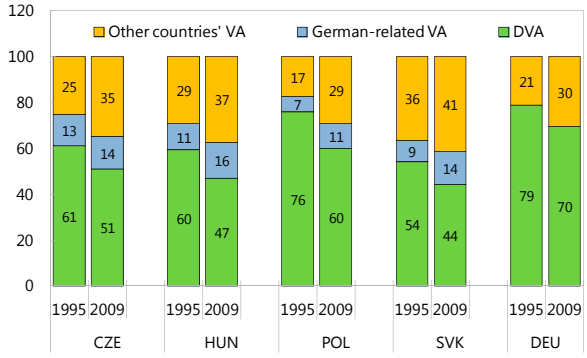
Automotive Sector: Some Stylized Facts

	2012 Passenger Car Production in multiple of 1999 level	Employment (ratio to manufacturing employment, 2010)	Share in Total Exports (2011)	Contribution to Exports Growth Since 1995* (percent)
Czech Rep.	3.4	11.7	17.1	50.7
Hungary	1.7	9.9	8.7	32.2
Poland	1.2	6.9	12.7	53.7
Slovakia	7.1	11.3	21.5	53.4
Germany	1.1	11.8	17.4	10.1

* Change in automobile exports between 1995-2011 relative to the 1995 total export level.

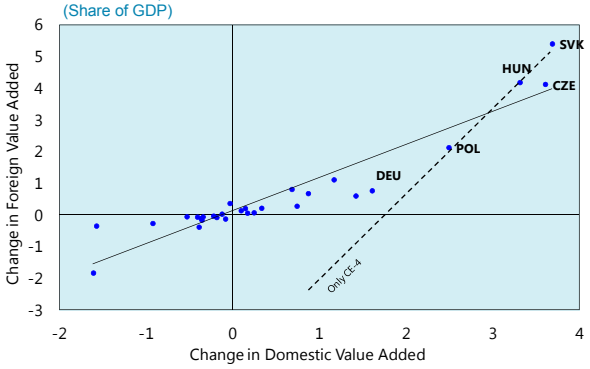
A decomposition of the automotive sector's gross exports based on the origins of the VA illustrates the increased integration of the CE4 countries with Germany. The share of German VA in total exports has increased in all the CE4 countries while the share of domestic VA declined by about 12 percentage points (on average) between 1995 and 2009. Despite the declining share of domestic value added in total exports, the automobile industry registered a significant increase in domestic value added in percent of GDP, exhibiting a positive and strong correlation with the increase in foreign VA in this sector.

Automotive Sector: Composition of Exports
(Percent)



Source: IMF staff's calculations based on the WIOT.

Automobile sector: The Change in the Domestic and Foreign Value Added, 1995-2009
(Share of GDP)



Source: IMF staff calculations based on the WIOT.

THE EFFECTS OF THE GERMAN-CENTRAL EUROPEAN SUPPLY CHAIN

The previous sections documented the evolution of the CE4's trade linkages with Germany and showed that their integration into the supply chain has increased dramatically since the mid-1990s. The literature suggests that increased trade linkages may affect economies across various dimensions. This section examines the possible effects in the context of technology transfer, business cycle synchronization, and income convergence.

A. Technology Transfer

28. The CE4's increased integration into the supply chain, particularly in knowledge-intensive sectors, allowed them to enhance the technology content of their exports in general, and the sophistication of domestic VA embodied in overall exports in particular. Therefore, it is likely that these economies have gained greater technological capacity in recent years, in part because German firms have provided them with technology and know-how to ensure that the produced components are of high quality (Jabbour and Mucchielli, 2007, Pack and Saggi, 2001).

29. A standard tool to evaluate whether the CE4 countries have increased their competitiveness, including through technology transfer, is by looking at the evolution of Revealed Comparative Advantage (RCA) over time.[13] Traditionally, RCA is defined as the proportion of a sector's exports in a country's total gross exports relative to the average share of the same sector's exports in the world's total exports. A value higher than one indicates that the country has a comparative advantage in that particular sector. Koopman et al. (2011) and Timmer et al. (2013) showed that such a computation can be misleading as, in the context of international production fragmentation, large part of the sectors' exports may contain imported intermediates. Therefore, as an alternative, the RCA in this subsection is calculated on the basis of domestic VA as in Rahman and Zhao (2013).

30. Table 2 provides the RCA calculation for the CE4 countries, Germany and some comparable countries for the manufacturing sectors. As in the previous section, the manufacturing sectors are grouped to labor-intensive, capital-intensive, and knowledge-intensive (see annex 3 for details). The RCA calculations confirm that the CE4 countries have benefitted from increased integration into the supply chain. With the exception of Poland, all other CE4 countries have largely "caught up" with Germany's comparative advantage in the knowledge-intensive manufacturing sectors, which are a significant part of the GCESC. This may point to a technology

[13] The concept of RCA was first proposed by Balassa (1965) and since then was used as a useful technique in research in international trade.

transfer.[14] While there has been a concomitant loss of comparative advantage in the labor and capital-intensive sectors, even in these sectors the RCA index remains greater than one (except in Hungary). These trends differs from those in selected periphery (SP) euro-zone countries, which have lost their comparative advantage in the knowledge-intensive sectors (Ireland and Spain) or retain their comparative disadvantage (Greece and Portugal).

Table 2. Revealed Comparative Advantage (RCA) in Manufacturing

	Manufacturing 1995			Manufacturing 2009		
	Labor-intensive	Capital-intensive	Knowledge-intensive	Labor-intensive	Capital-intensive	Knowledge-intensive
Czech	1.29	1.30	0.56	1.01	1.16	1.18
Hungary	0.68	1.06	0.50	0.37	0.77	1.18
Poland	1.95	1.39	0.59	1.52	1.39	0.93
Slovakia	1.05	1.61	0.60	1.16	1.41	1.11
Germany	0.64	1.07	1.48	0.64	1.20	1.49
Portugal	3.42	0.94	0.57	2.08	1.43	0.60
Spain	0.93	1.21	1.04	0.97	1.29	0.98
Ireland	0.34	1.79	1.01	0.11	0.72	0.89
Greece	1.56	1.26	0.03	0.33	0.72	0.20
China	3.55	1.03	0.64	2.52	0.66	1.27

31. A high degree of integration into the supply chain has positioned CE4 countries as leaders in knowledge-intensive sectors. However, this new status poses challenges going forward. With the progression of income convergence and narrowing of unit labor cost differentials with Germany, the CE4 may face challenges in sustaining their current role in the GCESC and further benefiting from vertical specialization, particularly given that other CEE economies have made substantial progress in removing impediments to trade and business environment that increases their attractiveness as new potential links in the GCESC. As the region grows and develops, the CE4 should therefore continue investing in human capital and maintain high skilled labor to cement their comparative advantage in the region, and perhaps develop new supply chains in the CEE region where they can become "upstream" countries, following the Chinese example.[15]

[14] The concept of "knowledge-intensive" sectors is very broad and captures a wide range of activities. Due to lack of more disaggregated data, the analysis cannot determine where each of the CE4 countries is located in the supply chain and, by extension, whether the domestic value added is generated from high skilled activities.

[15] In recent years China has moved up the production chain from being a giant assembly hub in the value chains of Japan and Korea to one of the main exporters of intermediates to advanced economies' high technology exports (Riad et al. 2012, IMF, 2011).

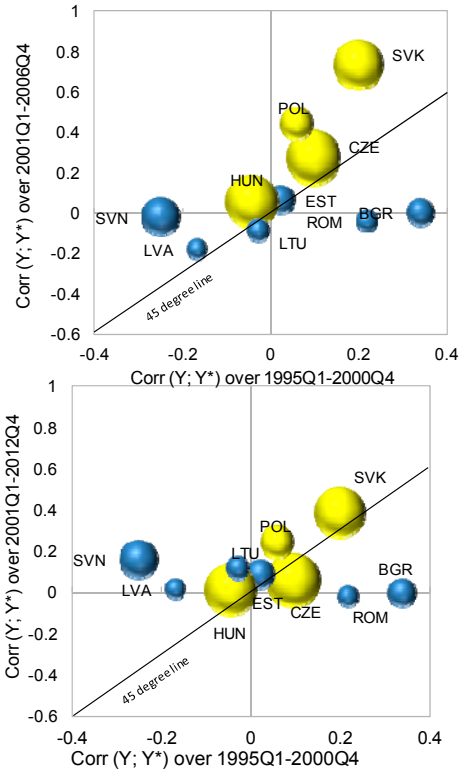
B. Business Cycles Synchronization

32. The link between trade integration and business cycles synchronization has been extensively analyzed in the literature. While a-priori the link between the two can be ambiguous, depending on the nature of trade and types of shocks affecting the economies,[16] empirical findings have generally found that higher trade integration contributes to increased cross country output correlations, especially among advanced economies (Frankel and Rose 1997, 1998; Clark and van Wincoop 2001; Imbs 2004; Calderon et al. 2007; and Inklaar et al. 2008, and Garcia-Herrero and Ruiz, 2008).

33. The conditional correlations of output gaps in Germany and other CEE countries highlight the specificity of CE4 countries.[17] The correlations of the CE4's output gaps with Germany's output gap seems to have increased and this appears to be correlated with the size of the German VA embodied in the countries' exports, particularly when comparing the period 2001Q1-2006Q4 with 1995Q1-2000Q4. For other CEE countries, output synchronization seems to have diminished over time. The inclusion of the crisis period also shows an increase in the bilateral correlations of the CE4's output gaps with Germany's output gap, though the relationship has somewhat weakened.

34. The impact of the CE4's increased integration into the supply chain on bilateral business cycle synchronization is also assessed through an empirical model.[18] The analysis broadly follows the standard literature on the determinants of international business cycle synchronization while complementing it in several ways.[19] First, the synchronization of business cycles is

Figure 13. Conditional Correlation of Output Gap*



Source: IMF Staff estimates. Output gaps are derived using the HP(1600) filter.
*Bubbles represent the size of German's Value-Added embodied in countries' i gross exports in 2009.

[16] Kose and Yi (2001), for instance, suggested that countries may become more synchronized if there is an increase in intra-industry trade and industry specific shocks are the main drivers of the business cycles. However, if inter-industry trade and industry shocks dominating, then the co-movement of output would decline.

[17] The correlation of output gaps has been computed using output gaps (for each country and Germany) after purging the effects of global economic conditions. The resulting output gap figures therefore represent idiosyncratic shocks observed in each country.

[18] See the model's specification in Annex 4.

[19] Our approach is similar to di Giovanni and Levchenko (2010) who examined the effects of vertical trade linkages on business cycle synchronization using industry-level data, and found that sector pairs that use each other as intermediates exhibit significantly higher elasticity of sectoral output growth co-movement with respect to trade.

measured in a time-varying way, which helps take advantage of the resulting panel data structure. Second, the analysis utilizes the exports' decomposition into domestic and foreign VA. Third, the econometric models control for other bilateral correlates of the synchronization of business cycles between Germany and each country. In this vein, financial linkages are accounted for through bilateral FDI flows and bank flows from Germany into each recipient economy.

35. The analysis uses various measures of business cycle synchronization. First, for each country the synchronization is measured as the rolling correlation coefficient of the country's specific real output growth rate with Germany's growth rate over an overlapping 7- year window. The second method is similar, but differs by making use of output gaps instead of real GDP growth rates. Finally, the paper follows the recent contribution of Aghion and Marinescu (2008) to compute time-varying co-movements between countries' growth rates by using Local Gaussian Weighted Ordinary Least Squares (LGWOLS) estimates.[20]

36. Our estimates broadly confirm that a higher level of vertical trade integration with Germany contributes to closer business cycle co-movement (Table 1A in Annex 4).[21] This result, which is consistent with recent evidence by di Giovanni and Levchenko (2010), holds regardless of the measure of output synchronization, and remains robust after accounting for potential endogeneity problems.[22] Moreover, the marginal effect of the vertical supply chain links with Germany is stronger in the case of CE4 countries compared to euro-zone countries and other sample countries, underscoring perhaps the exceptional magnitude and uniqueness of the CE4's trade linkages with Germany. Interestingly, while the impact of bilateral FDI flows is not significant, financial linkages in the form of bank flows are negatively associated with the co-movement of business cycles. This result is consistent with Garcia-Herrero and Ruiz (2008), who argued that financial integration allows easier transfer of resources between two economies, amplifying differences in business cycles.

[20] This method helps deal with the shortcomings of the rolling correlation method which can provide noisy estimates of the correlation coefficients, and suffers from data losses. In the LWOLS, all observations are used for each year, but those observations closest to the reference year are given greater weight.

[21] The paper also tried to separate the effects of downstream links from those of upstream links by controlling for the two variables in the model. It turned that only the downstream link (proxied by the share of foreign value-added embodied in countries' exports) was statistically significant.

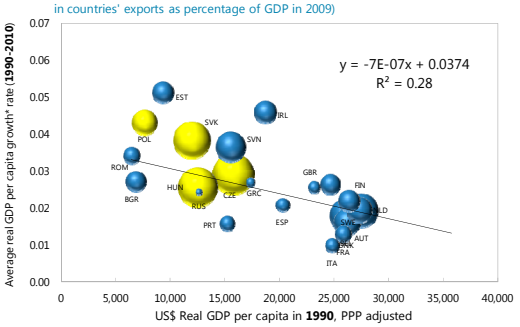
[22] Identification tests associated with the first-stage equation (instrumentation equations) do not reject the hypothesis that the selected instrumental variable is strongly correlated with the endogenous foreign value-added variables in all the models.

C. Income Convergence

37. There are several arguments for why trade, and supply chains in particular, may contribute to higher long term growth and income convergence. Higher trade can stimulate productivity gains as it comes with investment that embodies technological transfers with spillovers to other sectors in the economy. It could also foster financial deepening and could contribute to economic diversification. Moreover, trade can contribute to specialization in highly productive sectors, which could generate efficiency gains for the economy as a whole. Saito et al. (2013), for instance, examined the relationship between output growth and VA exports (relative to GDP) and found that a country's output growth is associated with greater exporting and importing of VA, which suggests that trade contributes to growth possibly through productivity gains from both export and import competition. They also found that higher levels of VA exports relative to GDP are associated with higher growth.

38. Income convergence in Europe is evident. While improved functioning of markets, greater market access, and better institutions have allowed developing countries, mostly from the CEE region, to catch up in the past two decades, the data suggests that countries' degree of integration with the supply chain may also have contributed to income convergence. Indeed, apart from Hungary, the CE4 countries are broadly above the regression line, implying that, even controlling for their initial income, they grew faster than the average growth of other economies, perhaps reflecting the rapid increase of the value added in knowledge-intensive activities.[23]

Figure 14. Income Convergence and the Role of Supply Chains
(Bubble size is proportional to the share of German foreign value added embodied in countries' exports as percentage of GDP in 2009)



Sources: Penn World Table 7.1; WIOT; IMF Staff estimates. (*) Instantaneous growth rate.

39. To evaluate more formally whether the CE4's increased trade linkages has also led to faster income growth we estimate an empirical model. The methodology applied follows the recent empirical literature, which has examined the factors shaping conditional beta-convergence of per capita income across countries by allowing the standard beta-convergence coefficient to vary according to the variable of interest.[24] The model, which is estimated through a standard cross-sectional growth equation, controls for standard determinants of long term growth, including the investment ratio, human capital, and macroeconomic policies and instability proxied by the inflation rate (See Annex 5 for details).

[23] This is also consistent with the theoretical framework of Hausman and Klinger (2007), who argue that economic development depends on a graduation from production of low-value goods to high-value goods (structural transformation).

[24] See for instance, Slaughter (2001) and Abiad et al. (2009).

40. The estimation results are presented in Table 2A in the Annex. Although the number of observations is relatively low, the results suggest statistically significant income convergence in the sample (the coefficient on initial real per capita income is negative and significantly different from zero) and a quicker convergence speed for countries with strong vertical trade linkages (the coefficient on the interaction term between initial income and the foreign value-added in countries' exports is also negative and significant). Interestingly, the share of foreign VA in countries' exports (as a share of GDP) was found to have a positive and significant effect on the countries' average GDP growth. This, together with the significance of its interaction with initial real per capita income, also suggests that the positive contribution of FVA to growth in recipient countries decreases with the level of economic development (proxied by initial per capita income). These results hold when potential endogeneity of the foreign VA is accounted for in IV estimations.[25]

[25] The results of the test of joint significance of the coefficients associated with initial income and its interaction with foreign value-added do not reject the hypothesis that the non-linearity is statistically significant. Identification tests associated with the first-stage equation (instrumentation equations) do not reject the hypothesis that the selected instrumental variable is strongly correlated with the endogenous foreign value-added variables in the models.

CONCLUDING REMARKS

41. Trade linkages between Germany and the CE4 have strengthened significantly since the mid-1990s, well beyond those with other countries, including in the CEE region. This pattern largely reflects the increased integration of the CE4 into the supply chain: with German firms having relocated parts of the production process to these countries, taking advantage of their proximity to Germany, cultural similarities, and a low cost but highly skilled labor force. While trade links with Germany have increased in many sectors, they have increased prominently in knowledge-intensive sectors, particularly in the automotive industry, which has been a major contributor to the CE4's export growth in recent years.

42. A decomposition of exports into domestic and foreign value added indeed suggests that foreign VA's share in total exports has increased significantly in recent years, reflecting the CE4's integration into the GCESC. Domestic VA registered a dramatic increase in both nominal terms and in percent of GDP, exhibiting a strong and positive link with the change in foreign VA. This indicates that the two are not substitutes but complement each other in the production process. A recent study by Rahman and Zhao (2013), which found that higher foreign VA contributes to higher domestic VA, also suggests that the increased integration of the CE4 in the GCESC has been a major contributor to economic activity in recent years.

43. The GCESC plays an increasing role in intra-EU trade. The countries' export exposure based on final demand underscores the strong presence of the GCESC in the EU's trade: It shows that Germany's exposure to the EU is significantly below the implied exposure under the more conventional direction of trade statistics while its exposure to the rest of the world is much higher. This suggests that a large part of Germany's trade with the EU is in the form of intermediates that are being processed in downstream economies and then re-exported outside the EU.

44. The GCESC has brought new opportunities and challenges for the CE4. The analysis indicates that the CE4 have rapidly gained comparative advantage in knowledge-intensive manufacturing sectors, suggesting a considerable technology transfer. While this has so far contributed to rapid export and GDP growth, it suggests that the CE4 may face challenges in maintaining their position in the GCESC, particularly given narrowing unit labor cost differentials and the fact that other CEE countries have made substantial progress in removing impediments to trade and becoming more attractive as potential members of the supply chain. In addition, the CE4's integration into the GCESC has fostered higher business cycle co-movement with Germany over time. The GCESC has also increased the exposure of member countries to the rest of the world. While this implies that the efficacy of domestic policies aimed at stabilizing economic activity may have weakened, the GCESC is anchored by Germany—a country with strong balance sheets and safe haven status—which could act as a source of stability in the face of external shocks (some evidence for this is provided by background paper #3).

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Annex 1. The World Input-Output Table

The World Input-Output Table used in our study is based on a newly released world Input-Output Table (WIOT) by Timmer et al. (2012). The database covers 27 EU countries and 13 other major countries in the world for the period 1995 to2009.[1] The 40 countries included in our world input-output table cover more than 85 percent of world GDP.

Differing from previous databases, the construction of WIOT relies on the national supply and use tables (SUTs) rather than input-output tables as its basic building blocks. Timmer and others (2012) argues that SUTs are a more natural starting point as they provide information on both products and (using and producing) industries.[2] Moreover, the input-output table is often constructed on the basis of an underlying SUT, requiring additional assumptions. Besides national SUTs, the construction of the WIOT also uses National Accounts time series data for industry output and final use, and bilateral international trade data in goods and services.

In the first step of the construction process, time-consistent output and final consumption series in the national accounts are used to benchmark national SUTs to ensure meaningful analysis over time.[3] In the second step, the national SUTs are combined with information from international trade statistics to construct so-called international SUTs. Basically, a split is made between use of products that were domestically produced and those that were imported. Finally, the international SUTs for each country are combined into a world input-output table.

For services trade, no standardized database on bilateral flows exists. These have been collected from various sources (including OECD, Eurostat, IMF and WTO), checked for consistency and integrated into a bilateral service trade database. As services trade is taken from the balance of payments statistics it is originally reported at Balance of Payments codes.

[1] Nevertheless to complete the WIOT and make it suitable for various modeling purposes, Timmer et al (2012) also added a region called the Rest of the World (RoW) that proxies for all other countries in the world. The RoW needs to be modeled due to a lack of detailed data on input-output structures. Production and consumption in the RoW is modeled based on totals for industry output and final use categories from the UN National Accounts, assuming an input-output structure equal to that of an average developing country. Imports from RoW are given as share of imports from RoW from trade data applied to the imports in the supply table. Hence, exports from the RoW are simply the imports by our set of countries not originating from the set of WIOT countries. Exports to RoW for each product and country from the set of WIOT countries are defined residually to ensure that exports summed over all destination countries is equal to total exports as given in the national supply and use tables (SUTs). This sometimes resulted in negative exports to the RoW. In those cases they added additional constraints to prevent negativity.

[2] A supply table provides information on products produced by each domestic industry and a use table indicates the use of each product by an industry or final user. In contrast, an input-output table is exclusively of the product or industry type.

[3] Typically, SUTs are only available for a limited set of years and once released by the national statistical institute revisions are rare. This compromises the consistency and comparability of these tables over time. By benchmarking the SUTs on consistent time series from the National Accounting System (NAS), tables can be linked over time in a meaningful way. In their database, for some countries full time-series of SUTs are available, but for other countries only some years are available.

Annex 2. Decomposition Methodology

Decomposing Gross Trade Statistics

We adopt the conceptual framework developed in Koopman and others (2011) to decompose the sources of VA in global production of tradables. The decomposition methods are summarized below.

Assume an *m*-country world, in which each country produces goods in *n* differentiated tradable sectors. The *m*-country production and trade system can be written as an Inter-County Input-Output model in the form of block partitioned matrix

$$(1)\quad \begin{bmatrix} X_1 \\ \vdots \\ X_m \end{bmatrix} = \begin{bmatrix} A_{11} & \cdots & A_{1m} \\ \vdots & \ddots & \vdots \\ A_{m1} & \cdots & A_{mm} \end{bmatrix} \begin{bmatrix} X_1 \\ \vdots \\ X_m \end{bmatrix} + \begin{bmatrix} Y_{11} + \ldots Y_{1m} \\ \vdots \\ Y_{m1} + \ldots Y_{mm} \end{bmatrix}$$

where X_m is the $n\times1$ gross output vector of country *m*, Y_{ij} is the $n\times1$ final demand vector that shows demand in country *j* for final goods produced in country *i*, and $A_{ij}$is the $n\times n$ IO coefficient matrix, giving intermediate use in country *j* of goods produced in country *i*.

Deriving the Leontief inverse matrix from equation (1) and pre-multiplying it with the final demand matrix, we get:

$$(2)\quad \begin{bmatrix} I - A_{11} & \cdots & -A_{1m} \\ \vdots & \ddots & \vdots \\ -A_{m1} & \cdots & I - A_{mm} \end{bmatrix}^{-1} \begin{bmatrix} Y_{11} & \cdots & Y_{1m} \\ \vdots & \ddots & \vdots \\ Y_{m1} & \cdots & Y_{mm} \end{bmatrix}$$

$$= \begin{bmatrix} B_{11} & \cdots & B_{1m} \\ \vdots & \ddots & \vdots \\ B_{m1} & \cdots & B_{mm} \end{bmatrix} \begin{bmatrix} Y_{11} & \cdots & Y_{1m} \\ \vdots & \ddots & \vdots \\ Y_{m1} & \cdots & Y_{mm} \end{bmatrix} = \begin{bmatrix} X_{11} & \cdots & X_{1m} \\ \vdots & \ddots & \vdots \\ X_{m1} & \cdots & X_{mm} \end{bmatrix}$$

where B_{ij}denotes the $n\times n$ block Leontief inverse matrix, which is the total requirement matrix giving the amount of gross output produced in country *i* required for a one-unit increase in final demand in country *j*. It follows that, X_{ji} is the output of country *j* used to produce goods eventually consumed in country *i*.

Regarding exports, let E_{ij} be the $n\times1$ vector of gross exports from *i* to *j*. Gross exports from *i* to *j* is divided into final good $Y_{ij}$and intermediates $A_{ij}X_j$. The intermediates are further divided into goods that are processed and consumed by country *j* ($A_{ij}X_{jj}$), goods that are processed and re-exported by *j* to third countries ($\sum_{k\neq i,j} A_{ij}X_{jk}$), and intermediate goods exported from *i* to *j* then processed and exported back to *j* $\left(A_{ij}X_{ji}\right)$:

(3) $E_{ij} = Y_{ij} + A_{ij}X_j = Y_{ij} + A_{ij}X_{jj} + \sum_{k\neq i,j} A_{ij}X_{jk} + A_{ij}X_{ji}$

Equation (3) traces the *downstream* use of exports from country *i* to country *j*, however, it does not provide information on the *upstream* contribution from other countries to the exports of country *i*. Thus, we still need to compute the upstream VA of country *i*'s exports in order to derive a complete picture of supply links and disaggregation of VA.

Formally, we define V_i to be the *1×n* direct VA coefficient vector. Each element of V_i gives the share of direct domestic VA in total output. This is equal to one minus the intermediate input share from all countries (including domestically produced intermediates):

(4) $V_i = u\left(I - \sum_j A_{ji}\right)$

Where, *u* is a 1×n unity vector.

Combining the VA coefficient vector with the partitioned Leontief inverse matrix provides information regarding the VA share. For example, each element in the 1×n vector V_iB_{ii} gives the domestic VA share of a particular sector in country *i*. Similarly, the corresponding element in vector $V_jB_{ji}$is the share of country *j*'s VA in the same sector produced in country *i*.

Let E_{i*} be the total export from *i*, i.e. $E_{i*} = \sum_{j\neq i} E_{ij} = \sum_{j\neq i}(A_{ij}X_j + Y_{ij})$

The gross exports from country *i* can be divided into domestic VA export (DV_i) and foreign VA export $(FV)_i$.

(5) $E_{i*} = DV_i + FV_i$

Using the derived information on VA share, Koopman and others (2011) shows that:

(6) $FV_i = \sum_{j\neq i} V_j B_{ji} E_{i*}$

(7) $DV_i = V_iB_{ii}E_{i*}$

Combining the downstream use of export in equation (3) with the VA decomposition in equation (5), we can decompose gross exports into five VA categories (Figure 3):

(8) $E_{i*} = DV_i + FV_i$

$$= V_iB_{ii}\sum_{j\neq i} Y_{ij} + V_iB_{ii}\sum_{j\neq i} A_{ij}Y_{jj} + V_iB_{ii}\sum_{j\neq i}\sum_{k\neq i,j} A_{ij}X_{jk} + V_iB_{ii}\sum_{j\neq i} A_{ij}X_{ji} + FV_i$$

For country *i*, the terms in equation (8) correspond to the following, respectively:

(A: $V_i B_{ii} \sum_{j \neq i} Y_{ij}$): DV in the form of final goods and services consumed by the direct importer;

(B: $V_i B_{ii} \sum_{j \neq i} A_{ij} Y_{jj}$): DV in the form of intermediate inputs used by the direct importer to produce its domestically consumed products;

(C: $V_i B_{ii} \sum_{j \neq i} \sum_{k \neq i,j} A_{ij} X_{jk}$): DV in the form of intermediate exports used by the direct importer to produce goods for third countries

(D: $V_i B_{ii} \sum_{j \neq i} A_{ij} X_{ji}$): DV in the form of intermediate exports used by the direct importer to produce goods shipped back to source country;

(E: FV_i): VA by foreign countries embodied in country i's gross exports.

Measuring Vertical Integration

In previous literature, measures of vertical integration have been developed. Most of these proposed measures are easily taken to the data, specifically with the use of the input-output tables.

Earlier literature such as Feenstra and Hanson (1996 and 1999), Feenstra (1998), Campa and Goldberg (1997), use the share of imported intermediate input (in total input or in gross output) to measure the level of outsourcing. However, these measures fail to fully capture the supply links as countries are grouped either as producers in intermediate stages or as exporters of final goods while in reality the links are more complex.

Hummels and others (2001) suggest a measure of vertical specialization, focusing on those imported goods that are used as inputs to produce a country's exports. (Hummels and others, 2001) Their measure emphasizes the twin ideas that the production sequence of a good involves at least two countries, and that, during this sequencing, the good-in-process crosses at least two international borders. The same approach is followed in Chen and others (2005), European Central Bank (ECB, 2005a), Breda and others (2008), and Koopman and others (2010).

Following the more recent group of literature originated from Hummels and others (2001), we define vertical integration or supply links as occurring when two or more countries provide VA in a good's production sequence; at least one country must use imported inputs in its production process, and the resulting output must be exported.

Note that the notion of vertical integration is only sensible in at least a bilateral context. Thus, it has both an upstream side and a downstream side. The upstream supplier exports intermediate goods to a downstream producer who uses these intermediates to add value for further export. As an upstream supplier, a country's participation in the global production chain depends on its VA to

other countries' exports. As a downstream assembler, a country's participation in the global production chain depends on the foreign VA in its exports.

To evaluate this bilateral relation in supply links, we need to measure, for all country-pairs, the embedded foreign VA from one country in another country's export. Koopman and others (2011) has shown that the matrix of VA by source in gross exports (VAS_E) can be specified as:

$$VAS\_E = \begin{bmatrix} V_1 B_{11} E_{1*} & \cdots & V_1 B_{1m} E_{m*} \\ \vdots & \ddots & \vdots \\ V_m B_{m1} E_{1*} & \cdots & V_m B_{mm} E_{m*} \end{bmatrix}$$

The elements of this matrix provide VA by source in gross exports between each country pair. For example, the element $VAS\_E_{ij} = V_i B_{ij} E_{j*}$ gives country i's VA embodied in country j's export. Therefore, diagonal elements of VAS_E matrix correspond to the domestic VA in each country's exports. Off-diagonal elements give the foreign VA embodied in each country's exports.

To link this bilateral VA relation with the country-level decomposition of export, note that the sum of off-diagonal elements along a column is the measure of VA from foreign sources embodied in a particular country's gross exports, which is just equal to FV defined in equation (8). Here, we call it Downstream Participation (DP) and use it to measure a country's participation in global VA chain as a downstream producer:

$$DP_i = FV_i = \sum\nolimits_{j \neq i} V_j B_{ji} E_{i*}$$

Similarly, the sum of off-diagonal elements along a row provides information on a country's VA embodied as intermediate inputs in all other countries' gross exports. It can be used to measure the country's participation in global VA chains as an upstream supplier. We call it Upstream Participation (UP):

$$UP_i = \sum\nolimits_{j \neq i} V_i B_{ij} E_{j*}$$

Annex 3. Classification of Merchandise and Services Exports

Categories	Sector number	Sector name
Primary and Natural resources	1,2	Agriculture, Hunting, Forestry and Fishing Mining and Quarrying
labor-intensive manufacuring	4,5,6,16	Textiles and Textile Products Leather, Leather and Footwear Wood and Products of Wood and Cork Manufacturing, Nec; Recycling
capital-intensive manufacuring	3,7,8,10,11,12	Food, Beverages and Tobacco Pulp, Paper, Paper , Printing and Publishing Coke, Refined Petroleum and Nuclear Fuel Rubber and Plastics Other Non-Metallic Mineral Basic Metals and Fabricated Metal
knowledge-intensive manufacuring	9,13,14,15	Chemicals and Chemical Products Machinery, Nec Electrical and Optical Equipment Transport Equipment
labor-intensive service	18,19,20,21,22,26,35	Construction Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods Hotels and Restaurants Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies Private Households with Employed Persons
capital-intensive service	17,23,24,25,27,29	Electricity, Gas and Water Supply Inland Transport Water Transport Air Transport Post and Telecommunications Real Estate Activities
knowledge-intensive service	28,30	Financial Intermediation Renting of M&Eq and Other Business Activities
health/education/public service	31,32,33,34	Public Admin and Defence; Compulsory Social Security Education Health and Social Work Other Community, Social and Personal Services

Annex 4. Business Cycle Synchronization

The model

More formally, the specification is the following:

$$\rho_{i,t} = \theta_1 fva_{i,t} + \mathbf{X}'_{i,t}\beta + u_i + \eta_t + \varepsilon_{i,t}, \quad [1]$$

where *fva* measures the ratio of the Germany's foreign VA embodied in each country's *i* exports normalized by country's *i* nominal GDP. Since the largest recipients of Germany's VA are the CE4 countries, the *fva* variable is already performing as a proxy for the CE4 group. The matrix **X** contains the other determinants of business cycle synchronization – mainly the variables capturing several dimensions of financial integration – such as bilateral FDI and Bank flows from Germany into each country *i*. Country and time fixed effects are controlled for to account for the effects of country specific and time-invariant factors and global common shocks.

To account for the specificity of CE4 countries and Eurozone countries, the model can re-written as:

$$\rho_{i,t} = \left(\theta_2 + \theta_3 CE_{4,i.} + \theta_4 EZ_{i,t}\right) fva_{i,t} + \gamma EZ_{i,t} + \mathbf{X}'_{i,t}\beta + u_i + \eta_t + \varepsilon_{i,t}, \quad [2]$$

where CE4 and EZ denote the dummy variable for CE4 and Eurozone countries, respectively. θ_2 measures the marginal impact of the GCESC when the given country is neither a CE4 or member of the Eurozone. $\theta_2 + \theta_3$ is the effect of the GCESC on CE4 whereas $\theta_2 + \theta_4$ gives the impact on Eurozone countries.[1]

Sample

The sample consists of 29 countries (advanced and emerging markets) observed over the period 1995-2009. The Germany's value-added embodied in countries' exports are computed using the methodology proposed by Koopman et al. (2011) based on the World Input Output Table (WIOT) and nominal dollar values are normalized by each country's GDP. Data on the export decomposition based on the WIOT are available from 1995 to 2009 at an annual frequency. Bilateral FDI and bank flows are drawn from the OECD Stat and the Bank for International Settlements (BIS) databases, respectively. Each financial flow is also normalized by nominal GDP. In the case of specifications using the rolling correlation coefficients over overlapping 7-year sub-periods, the control variables are measured as country-specific rolling averages of the variables whereas in the case of the model using the time-varying synchronization coefficient based on the Aghion and Marinescu (2008) methodology, variables are taken as they are (i.e. at an annual frequency) since the methodology does not require computing sub-periods.

[1] The CE4 dummy is not introduced additively because it is time-invariant and thus fully absorbed by the country fixed effects.

Annex Table 1. Business Cycles Synchronization and Its Determinants

	OLS	IV [a]	OLS	OLS	IV [a]	OLS	OLS	IV [a]	OLS
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Dependent variable: Correlation of:	Real growth rates			Output gaps			Real growth rates (Aghion and Marinescu, 2008)		
Germany VA in country i exports (as percentage of GDP)	5.816**	68.05***	-11.22	9.628***	51.13***	-11.03*	19.13***	33.40***	-4.742
	(2.485)	(3.781)	(-1.624)	(4.699)	(3.569)	(-1.872)	(11.27)	(8.703)	(-1.011)
Germany VA * CE4 dummy			16.16**			20.12***			24.77***
			(2.292)			(3.344)			(5.181)
Germany VA * Eurozone dummy			7.580**			4.969*			3.745
			(2.532)			(1.946)			(1.290)
Eurozone dummy			-0.399***			-0.452***			-0.315***
			(-4.123)			(-5.474)			(-4.055)
Germany's bilateral FDI flows (as percentage of GDP)	0.0189	0.0536	0.0158	-0.00509	0.0152	-0.0205	0.00528	0.0163	0.000284
	(0.431)	(0.877)	(0.357)	(-0.133)	(0.313)	(-0.545)	(0.368)	(1.146)	(0.0210)
Germany's bank bilateral flows (as percentage of GDP)	-0.00578**	-0.00998	-0.00335	-0.0102***	0.00318	-0.00626***	-0.00287	-0.00272	6.18e-05
	(-2.131)	(-1.463)	(-1.203)	(-4.317)	(0.585)	(-2.633)	(-1.632)	(-1.387)	(0.0339)
Global Financial crisis dummy	0.372***	0.0512	0.443***	0.732***	0.0249	0.824***	0.793***	0.339***	0.793***
	(4.048)	(0.712)	(4.807)	(9.094)	(0.435)	(10.48)	(11.68)	(4.611)	(11.84)
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-stat of the first-stage instrumentation equation of foreign value-added		36.07			36.07			126.52	
Observations	493	261	493	493	261	493	435	377	435
R-squared	0.379	0.351	0.406	0.514	0.311	0.559	0.614	0.412	0.659
Number of countries	29	29	29	29	29	29	29	29	29

Robust t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 5. Income Convergence

The model

The econometric model is a standard cross-sectional growth equation where the initial per capita income is included additively and in interaction with the total foreign value-added embodied in each country exports (and normalized by GDP). The existence of a beta-convergence is tested by estimating a negative regression coefficient associated with the initial per capita income. The model controls for standard determinants of long term growth: investment ratio, human capital, and macroeconomic policies and instability proxied by the inflation rate. The foreign value-added in exports is also accounted for in the specifications.

The baseline takes the following form:

$$g_i = -\beta \ln Y_{i,1995} + \phi_1 fva_i + \mathbf{X}_i'\Gamma + \varepsilon_i, \qquad [1]$$

where *g* is the average annual growth rate in each country *i*, $Y_{i,1995}$ is the real initial per capita in 1995, *fva* is the within-country average of the total foreign value-added embodied in each country's *i* exports (scaled by GDP), and **X** is the matrix of standard determinants of growth rate: investment ratio, human capital, and inflation rate, both measured as averages over 1995-2009. $-\beta$ measures the convergence effect which suggests that growth is affected by diminishing returns as countries starting with low initial income should growth faster than others.

The model [1] can be amended to account for the contribution of the foreign value-added to the speed of income convergence by allowing the coefficient β to be conditional on the size of the foreign value-added. The proposed specification which follows previous works on the estimation of non-linearities in income convergence process (Slaughter, 2001; Abiad et al., 2009) is as follows:

$$g_i = -\left(\beta_1 + \beta_2 fva_i\right) \ln Y_{i,1995} + \phi_1 fva_i + \mathbf{X}_i'\Gamma + \varepsilon_i, \qquad [2]$$

where β_1, and β_2 are strictly positive.

Sample and data

All the variables are drawn from Penn World table 7.1., except the inflation rate (World Development Indicators) and the value-added trade export series which are computed by the authors using the WIOT. All the variables are computed as averages over 1995-2009, except for the initial income variable which is measured at the beginning of the period in 1995.

Annex Table 2. Supply Chains and Income Convergence

Dependent variable: Average real per capita GDP growth Period: 1995-2009	OLS (1)	OLS (2)	IV [a] (3)	IV [b] (4)
Initial real per capita income (in 1995, log)	-0.0244***	-0.0217***	-0.0243***	-0.0212***
	(-5.565)	(-4.632)	(-6.061)	(-5.077)
Initial income * Foreign value-added in exports		-0.0262*		-0.0267**
		(-2.007)		(-1.974)
Foreign value-added in exports (over GDP)	0.0567***	0.328**	0.0552***	0.328**
	(6.619)	(2.413)	(6.213)	(2.365)
Investment ratio	0.0689	0.0743	0.0688	0.0740
	(1.222)	(1.291)	(1.342)	(1.446)
Years of schooling in the tertiary	0.0343***	0.0329***	0.0342***	0.0324***
	(5.155)	(4.986)	(5.545)	(5.551)
ln (100+inflation rate)	-0.0158	-0.0141	-0.0158	-0.0140
	(-0.589)	(-0.543)	(-0.646)	(-0.609)
Intercept	0.294*	0.257	0.293*	0.254*
	(1.781)	(1.614)	(1.947)	(1.809)
First-stage identification tests				
F-stat of the instrumentation equation of foreign value-added			80.79	461.50
F-stat of the instrumentation equation of foreign value-added*Initial income				396.80
P-value of the joint significance of initial income coefficients			0.000	0.000
Observations	34	34	34	34
R-squared	0.661	0.684	0.661	0.683

Robust t-statistics in parentheses. [a] The foreign value-added embodied in cou
*** p<0.01, ** p<0.05, * p<0.1