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"Trade in parts and components across Europe"

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Trade in parts and components across Europe

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Abstract

Based on the factor-proportion gravity framework we build a model that identifies driving forces for trade in parts and components. We test our model empirically by using a detailed and large European data set. We show that trade in parts and components is driven by relative supply-side country differences, proxied by wages and capital labor ratios. The pattern is compatible with models of incomplete specialization and trade. We take our results as evidence for the existence of international East-West production networks in Europe, driven by trade-offs between wages, capital labor ratios and coordination costs. Our results also reveal that (i) in response to stronger relative wage differences trade in parts and components across Europe is predominantly realized along the extensive margin but (ii) potential to intensify the trade and international production network in new EU members is not exhausted yet.

JEL-Classification: C23, F14, F23

Keywords: International trade, production networks, gravity model, panel data, European Union

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1. Introduction

Worldwide trade in intermediate goods is now more than two thirds of total trade (IMF, 2013). A number of studies, reviewed in the next section, link trade in intermediate goods, and specifically trade in parts and components of capital goods (an important subset of intermediate goods), to the existence of production networks. For doing so, they adopt gravity frameworks with a variety of trade determinants to analyze the phenomenon. In this paper, we contribute to this literature in two ways. Our first contribution is methodological: we motivate a theory-guided gravity approach to identify driving forces for trade in parts and components. Second, we test our model empirically by using a detailed and large data set of European trade in parts and components of capital goods.

While empirical gravity approaches have been used with great success since the early sixties, their theoretical foundations have been somewhat slower to come.[1] As a result, bilateral gravity frameworks for analyzing gross trade flows are still often set up as eclectic combinations of determinants to test for influences beyond partner incomes and trade barriers. As our first contribution we show that *ad hoc* augmented gravity equations, specifically those augmented by absolute supply-side country differences or similarities, run into conflict with the supposed theoretical foundations, i.e., they are misspecified. As a remedy we extend the approach of Haveman and Hummels (2004) to formulate an estimable specification of bilateral gravity on the basis of country-specific supply-side differences relative to the world average.

In order to test the validity of our model we chose the data on bilateral trade patterns in capital and consumer goods among old and new European Union (EU) members. Our interest in parts and components' trade patterns among the old and new EU members is driven by the new opportunities for specialization and trade created by the European integration process. After embarking on the uneasy path of economic transformation, the first four Central and Eastern European (CEE) countries that would become EU members signed in December 1991 the so-called "European Agreements" with the European Union.[2] Subsequently, they strove to establish a workable framework for international trade and co-operation in order to facilitate the transition process and in March 1993 they established the Central European Free Trade Area (CEFTA; Kocenda and Poghosyan, 2009). CEFTA was later enlarged by virtually all of the rest of the CEE countries and helped to remove barriers to trade among its members as well as with the EU. Many CEE countries applied for EU membership in 1995–1996 and from 1998–1999 underwent a lengthy and thorough screening process towards EU accession; some CEE countries followed at later dates. The CEE countries finalized their process as full EU members on May 1, 2004 when the first round of CEE countries joined the EU followed by a second round in 2007.

EU integration has impacted international trade between old and new EU members even before actual enlargement. First, association agreements signed in the

[1] For a survey of the relevant literature, see Stack (2009).

[2] The first four countries are the Czech Republic, Hungary, Poland, and Slovakia. In the text the old EU (EU-15) countries are sometime referred as Western Europe. New EU members that joined the EU in 2004 and later (EU-10) are often referred as Eastern Europe. The detailed grouping is given in Appendix Table C.1.

early 1990s were found to have a positive and significant impact on trade flows between the transformation and EU countries (Caporale et al., 2009; Egger and Larch, 2011). Second, despite existing economic differences among countries, the new EU members quickly became an important part of the EU-wide manufacturing and distribution web (Kaminski and Ng, 2005). In this respect Egger et al. (2008) show that the larger the difference in relative goods and factor prices of two integrating countries before integration, the larger are the potential overall gains from trade. Further, lowering the fixed cost of trade during European integration has prompted trade to increase (Frensch, 2010).

The above features are relevant to the composition and characteristics of EU members' trade and correlate with the empirical fact that OECD trade in intermediate goods has been growing at a pace of about 6.2% a year for much of the period under research (1992-2008); the growth rate was slightly higher in Europe and highest in new EU members, often above 10%. Share of intermediate goods in manufacturing to total trade flows in Europe as of 2006 was on average 52% and in the new EU members it was even higher, reaching the proportions well above 60% (Miroudot et al., 2009; Table 7, Table 10).

Direct benefits resulting from the increased availability and choice of the traded parts and components are likely to be complemented by less obvious advantages. Coe and Helpman (1995) theoretically show that trade can function as a channel to diffuse technology, which is also quite important in the case of intermediate goods with higher value added. Añón Higón and Stoneman (2011) provide empirical evidence for welfare growth in the economy through the benefits from innovations embodied in imported goods.[3]

The set of new and old EU countries is appealing to analyze also from another theoretical perspective. The EU is a functioning free trade area and its strong tariff reduction was shown to be trade creating (Eicher and Henn, 2011). New EU members were accepted to the free trade area after their accession in 2004 and 2007, but they were already removing trade barriers before and during their accession process (Egger and Larch, 2011). Hence, we analyze a set of countries that impose no barriers on trade among themselves and for this reason the data are not contaminated by differences in tax/tariff regimes or customs rules. Further, despite a gradual catching-up process the new EU members still exhibit lower price levels for number of goods (Égert, 2011) that along with lower labor costs may represent types of potential comparative advantages that could prove relevant for specialization and bilateral EU trade patterns during the period under research.[4]

Based on the scope of methodological framework and the above arguments and facts on the patterns of the trade in intermediate goods we hypothesize that trade

[3] Añón Higón and Stoneman (2011) show the effect of innovations via imports in five old EU countries. This indirect innovation effect is likely to materialize in the new EU countries as well and can be further paired with a direct effect caused by the innovation activities by multinationals (through FDI), who dominate the innovation process in new EU economies, as shown in Uzagalieva et al. (2012).

[4] Auer et al. (2012) show that when non-European exporters from low-wage countries capture 1% of a European market, producer prices decrease by about 3%. Further, they show that import competition has a pronounced effect on average productivity.

in parts and components across Europe (i) should increase with the countries' size, (ii) its volume should be related to the extent of supply-side country differences relative to the world, (iii) its volume should increase with the extent of complementary specialization between countries, and (iv) such increase should be paired with the degree of specialization between the new and old EU countries. By assessing our hypotheses we aim to fill the existing gap in the literature on international trade.

In accordance with the predictions of our model, we provide evidence that trade in parts and components of capital goods between East and West Europe is driven by relative supply-side country differences, compatible with models of incomplete specialization and trade. We take our results as evidence for the existence of international East-West production networks in Europe, driven by trade-offs between wages or capital labor ratios and coordination costs. Our results also reveal that parts and components trade across Europe in response to stronger relative wage or capital labor ratio differences is predominantly realized along the extensive margin (representing the variety of goods). We interpret this in terms of *ex ante* and *ex post* location choice investments in production networks: location choices for setting up or extending (i.e., adding new products to) European capital goods production networks react more elastically to relative country differences in wages or capital labor ratio than deepening international production networks, i.e., intensifying trade within an established partner-product network.

The rest of the paper is organized as follows. Section 2 includes a review of the conceptual background and relevant literature for analyzing fragmentation-induced trade in parts and components together with earlier empirical results. In section 3, we motivate a factor-proportions based gravity equation for parts and components trade to refine the approach taken in Kimura et al. (2007). Next, we develop our empirical model by controlling for potentially omitted variables from outside our hypothesized approach, i.e., full multilateral trade costs and other influences. We also relate our gravity specification to the literature. We describe our data in section 5, formalized hypotheses and empirical results are presented in section 6. Section 7 concludes.

2. Review of the related literature

Fragmentation describes the deepening of the division of labor by splitting production into distinct tasks. Fragmentation increases incentives towards specialization but requires breaking up the geographical concentration of production. Hence, firms specialize within the supply chain, potentially by joining international production networks or even offshoring individual tasks. Apart from potential gains, fragmentation-induced specialization within networks implies costs of coordination, i.e., costs of investment, communication, and two-way trading of intermediate products. Hence, the international scale of production networking should increase with fragmentation, with declining coordination costs, or with the strength of international incentives to specialize.

Stack (2009) surveys comprehensively the relevant literature on gravity approaches and important empirical contributions. For that, below we outline only the key issues that are relevant to our paper. Theoretical literature related to our paper is

not expansive. While some theoretical approaches associated with new trade theory model imperfect competition on the level of intermediate goods (Egger and Falkinger, 2006; Fujita and Thisse, 2006), most models of production networks are grounded in factor-proportions trade models (Jones and Kierzkowski, 2001; Deardorff, 2001; Egger, 2002; Egger and Falkinger, 2003), in extended-factor-proportions models of both trade and FDI (Feenstra and Hanson, 1996), or in specific-factor models (Kohler, 2004). Assuming firm-specific technologies and cost heterogeneity of offshoring across a continuum of tasks, Grossman and Rossi-Hansberg (2008) demonstrate that the costs of offshoring versus wage differences drive the international division of labor along the production chain.

We observe that low wage country firms specialize in tasks that tend to be routine, homogeneous, and intensive in low-skilled labor (Breda et al., 2008; Kimura, 2006). Case study evidence points to machine building and capital-goods production in general experiencing the most pronounced international production networking (Kimura et al., 2007 and 2008; IMF, 2013). Empirical evidence that looks at potential determinants of specialization along the international production chain is mixed. Analyzing U.S. inward processing trade with the EU, Görg (2000, p. 418) concludes that "the distribution of fragmented production around the globe will be according to countries' comparative advantages." Exploring textile and apparel trade, however, Baldone et al. (2001, p. 102) find that "there is no evidence that the choice of the processing country by EU firms is due to pre-existing comparative advantages".

Kimura et al. (2007) study East Asian *versus* European machinery parts and components trade within an augmented traditional gravity approach, where the absolute values of differences in per capita incomes between exporter and importer countries reflect supply-side country differences. Finding positive coefficients for the absolute values of differences in per capita incomes for East Asian trade but negative ones for European trade, they interpret their results as indicating evidence for the existence of international machinery production networks in East Asia, but not so in Europe. The authors argue that European machinery parts and components trade is better explained by a horizontal product differentiation model. In our contribution, we will explicitly challenge this latter conclusion, based on (i) a more refined gravity framework, (ii) more data to reliably distinguish trade flows across Europe, (iii) by using panel estimation techniques for testing our hypotheses, and (iv) by testing our gravity framework also along both margins of trade.

3. A gravity framework for trade in parts and components with incomplete specialization

In this section we bring our methodological framework. At first we cover the conceptual background of how the intermediate goods are modelled. We also link the intermediate goods trade to the issues related to production networks. Next, we outline our gravity framework of incomplete specialization. In the third part we bring forth the model of bilateral trade.

3.1 Background and link to production networks

As outlined in section 2, intermediate goods, and especially parts and components of capital goods, are sometimes modelled as differentiated products within monopolistic competition models of trade. This may rest on a literal interpretation of parts and components' featuring prominently among Rauch's (1999) "differentiated goods" that are neither sold on organized exchanges nor have reference prices within his three-way classification. Quite a different interpretation of this class of goods is, as e.g. in Nunn (2007), in terms of relation specificity: much of the assumed differentiation of parts and components is in fact customization on demand within production networks (Antràs and Staiger, 2012). The particular interpretation of differentiation has important consequences for the market structure aspect of trade modelling: Levchenko (2007) demonstrates the compatibility of relation specificity with a pure factor proportions, incomplete specialization approach to trade. From this point of view, *ex post* differentiated parts and components may be viewed as homogenous across potential suppliers from potentially different source countries where the investment location choice of setting up a production network were made *ex ante*. Therefore, some parts and components may in equilibrium be produced in and be exported by more than one country.[5]

We follow this view and make the aspect of *ex ante* versus *ex post* location choice investment an important basis for the interpretation of some of our results. Kimura et al. (2007) interpret their machinery trade flow analysis as indicating evidence for or against the existence of international machinery production networks. Extending this argument to the margins of trade, first, changes along the extensive margin of parts and components trade (i.e., changes in the variety of parts and components traded by adding more products to a network) correspond to reactions to *ex ante* location choice investment decisions of setting up or extending international capital goods production networks. Second, changes along the intensive margin (average traded volume of parts and components) represent responses to *ex post* decisions of deepening international production networks, i.e., intensifying production and trade within an established partner-product network.

Different parts of trade may result from different sources of trade (Evenett and Keller, 2002). To let the data speak, we will analyze parts and components gross trade flows within an incomplete specialization factor proportions framework, allowing for complete specialization as a limiting case.

3.2 Multilateral trade

We follow the literature by basing our derivation of bilateral gravity equations on two distinctions (see especially Deardorff, 1998; Evenett and Keller, 2002; Haveman and Hummels, 2004): complete *versus* incomplete specialization and trade incentives *versus* trade costs.

A full theoretical derivation of bilateral gravity in the presence of trade costs is so far limited to complete specialization. In a factor proportions framework, we first have to answer how incomplete specialization can arise in the presence of trade costs in a world comprised of $j = 1,\ldots, J$ countries with equal technologies, two factors of

[5] For the specific relevance of this discussion to the European case, see also Coe et al. (2008).

production (capital K and labor L), one final good, and many homogenous intermediate goods $k = 1,\ldots, N$. With zero trade costs, destination-country customers are indifferent from where to source a particular part or component between all supplier countries, including their own, resulting in random rationing *à la* Deardorff (1998). While there is no higher dimensional factor proportions theory with trade costs upon which to rest our gravity derivation, we put a multi-country, multi-product, two-factor framework into an intermediate goods trade extension of Haveman and Hummels' (2004) description of incomplete specialization as our starting point, assuming infinitesimally small border costs.[6] We argue that what we thus add in terms of trade cost structure upon the seamless world qualitatively fits European realities: rather than assuming that countries are ordered like pearls on a thread, we see many small countries encircled by all the other equidistant small countries. In this set-up, foreign distance need not matter more for international trade than domestic distance. In consequence, pure distance effects are of second order as compared to border effects, even within the EU context (see Cheptea, 2013). In our homogenous goods case, this means that potentially many countries can be suppliers to locations within one country, and each customer country is indifferent among all potential supplier countries except itself, again motivating random rationing *à la* Deardorff (1998) to decompose countries' multilateral gravity (in a similar spirit, see Armenter and Koren, 2014). In accordance with the above we make the following assumptions for deriving our gravity framework of incomplete specialization in the presence of small border costs that is formally presented in Appendix A.

Assumption 1 – technology. Production is horizontally fragmented. N tasks are carried out, using two factors of production (capital K and labor L), each of which results in a tradable intermediate good – a part or component. One final good is assembled from these N parts or components. All production is subject to homothetic derived demands.

Assumption 2 – trade costs. We assume infinitesimally small border costs but no further trade costs.

Assuming infinitesimally small – rather than zero – border costs is necessary for making specialization incentives matter when deriving our gravity framework. We will loosen this assumption in the final econometric specification by adding specific effects to take account of the full trade-off between incomplete-specialization forces and all service-link costs that is behind much of the theoretical motivation for the fragmentation-induced trade cited in section 2.

[6] In their original notation, Haveman and Hummels' (2004) econometric specification of bilateral trade is $\ln M_{ij} = \alpha + \beta_1 \ln Y_i Y_j + \beta_2\, kldif_i + \beta_3\, kldif_j + \varepsilon_{ij}$, where $kldif_i = \left|\frac{k_i}{l_i} - \frac{k_{world}}{l_{world}}\right|$. I.e., larger countries are expected to trade more with each other, separately controlling for their capital-labour ratios, each relative to world averages.

Assumption 3 – trade balance. Imports of country j are equal to exports, $I_j = E_j$. Trade balance holds separately for parts and components trade as well as for final goods trade.

As witnessed by case studies summarized in IMF (2013), Central and Eastern European (CEE) firms are present in all stages of production of capital goods and transport equipment. This means that specialization along the value chain within European production networks is not by a stage of production. Parts and components as well as final capital goods and transport equipment are all being produced everywhere. This implies strong bilateral trade flows in parts, components, and final capital goods across Europe and results in substantial Western European value added being present in exports of the CEE countries as well as the other way round. Assumption 3 enables us to concentrate on influence of the factor proportions in the early stages of the production and trade pattern. At the same time we avoid the problem of having to deal with gross trade data of final goods which include substantial double-counting and thus overstate the amount of domestic value-added in exports (Johnson, 2014).

As argued in Appendix A, combining a simple accounting exercise over expenditure and production relationships with results from previous literature, these assumptions suffice to motivate our first result.

Result 1. Country j, with a relatively high wage-rental ratio w_j, will export capital-intensive parts and components to the world, and import labor-intensive parts and components. The volume of this trade is proportional to country income Y_j and the deviation of j's wage-rental ratio from the world average, $E_j = I_j \propto Y_j(w_j - w_{world})$. The analogous holds for country i, with a relatively low wage-rental ratio, such that $E_i = I_i \propto Y_i(w_{world} - w_i)$.

The result 1 does not differ from similar results on finished goods. However, it is a reasonable outcome for intermediate goods and when tested empirically (see Section 6.1) it is shown to be valid.

3.3 Bilateral trade

For bilateral trade to occur, countries' specialization patterns must be complementary. Hence, there must be at least one part or component k that is both exported by country j and imported by country i. For this, trading countries' deviations from world average wage-rental ratios must be opposite, i.e., one country must feature a relatively high wage-rental ratio, the other a relatively low wage-rental ratio.

Now we make use of Deardorff's (1998) random choice argument, which in the context of our specific accent on the economic geography of Europe states that a country's customers, due to infinitesimally small border effects, prefer their home part or component to foreign ones, but are indifferent between all foreign-produced parts or components. Hence, imports of country i from country j of a specific part or component k are given by country i's worldwide imports of k times country j's share

in worldwide exports of k, $I_{ij}^k = I_i^k \frac{E_j^k}{\sum_j E_j^k}$. Together with Result 1, for any two countries j (relatively high wage-rental ratio) and i (relatively low wage-rental ratio), the expected volume of this trade is proportional to $Y_i Y_j (w_j - w_{world})(w_{world} - w_i)$, as $\sum_j E_j^k$ is identical for all countries. As countries' deviations from world average wage-rental ratios continue to predict trade in the multi-product case (see Appendix A), we can state our second result.

Result 2. Bilateral trade in parts and components is conditional on countries' multilateral specialization. The volume of bilateral trade can be expected to be proportional to both countries' incomes and relative supply-side country differences in form of the deviations of their wage-rental ratios from world average, $E_{ji} \propto Y_j Y_i (w_j - w_{world})(w_{world} - w_i)$, provided bilateral wage-rental ratio deviations have opposite signs.

The result has implication for complementarity of specialization among countries. The benefits of the trade would materialize only if the countries' specializations are mutually beneficial.

4. Empirical specification

4.1. Outline

For any pair in a sample of heterogeneous European countries we reformulate Result 2 in terms of absolute values. Based on the product of the relative wage-rental differences in absolute values, $|w_j - w_{world}| \times |w_i - w_{world}|$, we are able to isolate the trade volumes also for those countries that lack complementary specialization. We could solve this strictly based on *a priori* information about $w_j > w_{world}$ and $w_i < w_{world}$. Being especially interested in East-West trade flows across Europe, we present the geographical distribution of manufacturing wages and capital labor ratio across Europe in Figure 1. The map confirms the existence of the East-West dichotomy of wages as well as in capital labor ratios across Europe. We therefore introduce a trade relationship specific dummy variable, *DummyEU*15/10, that equals one for all bilateral East-West or West-East trade relationships in Europe (and zero otherwise). This econometric step is further supported by the fact that currently the key direction of the trade European pattern is along the East-West axis (Hanousek and Kočenda, 2014).

Traditional gravity approaches explicitly cope with different trade barriers, i.e., distance, geographic contiguity, etc. The relevant discussion on using gravity frameworks (Baldwin and Taglioni, 2006; Baltagi et al., 2014) recommends making use of the panel structure of available trade data. The specific purpose is to incorporate trade barriers under time-invariant country-pair-specific and country-pair-invariant time-specific omitted variables to be controlled for by appropriate fixed effects. This has the advantage over the traditional procedures of also controlling for countries' multilateral trade resistance (Anderson, 2011), with the intuitively appealing notion that bilateral trade barriers should always be measured relative to the

world, in a similar fashion as trade incentives as described above: given fixed trade barriers between countries *j* and *i*, then the higher the trade barriers of a country *j* with respect to the world, the more the country *j* will be driven to trade with country *i*. [7]

The estimable specification rooted in our approach then takes the following gravity model form:

$$\begin{aligned}\log\ EX(PC)_{ji,t} &= \beta_0 + \beta_1 \log\left(Y_{j,t} \times Y_{i,t}\right) + \\ &+\beta_2 \log\left(\left|w_{j,t} - w_{world,t}\right| \times \left|w_{i,t} - w_{world,t}\right|\right) + \\ &+\sum_{s=1}^{5} \gamma_s Dummy(EU15/10)_{ji,s} \log\left(\left|w_{j,t} - w_{world,t}\right| \times \left|w_{i,t} - w_{world,t}\right|\right) + \\ &+ c_{ji} + k_t + \varepsilon_{ij,t} \qquad (1)\end{aligned}$$

Exogenous (to our model), technical progress through decreasing coordination costs and ongoing fragmentation are represented by time effects.[8] Thus, our combination of specific effects amounts to assuming that multilateral trade resistance may vary across country pairs while coordination costs (e.g., communications costs) do not, but are specific to types of goods, in our case to parts and components, as suggested in Keller and Yeaple (2013). Nevertheless, our motivation of fragmentation and the trade it induces does not imply a high degree of substitutability but rather complementarity between technical progress and the possibility of using supply-side country differences.[9] Hence, we model this by interacting the combined variable $DummyEU15/10_{ji} \log\left(\left|w_{j,t} - w_{world,t}\right| \times \left|w_{i,t} - w_{world,t}\right|\right)$ with time-period effects. For this purpose, we divide the sample period (1992–2008) into five sub-periods of (almost) equal length.[10]

4.2. Estimation strategy

Specification (1) is estimated on unbalanced panel data with a mean time length of about 10 years. We proxy wage-rental ratios by wages and capital labor ratios,

[7] In general, researchers prefer using a pairwise fixed-effects model because individual effects could be correlated with the explanatory variables; this can lead to inconsistent estimates, especially in a dynamic setting. Further, pairwise fixed effects estimation has an advantage by eliminating potential omitted variable bias. Using country pair fixed effects is also consistent with Haveman and Hummels (2004) assumption that, although trade costs can be arbitrarily small, they are rising with distance.

[8] Navaretti and Venables (2004), among others, show that fragmentation is a necessary condition for countries starting to engage in production-process involving vertical division of labour to utilize the advantages of location differences.

[9] Our model does not contain capital rental part. Basically, capital rentals do not differ much across Europe, so that variation in wages mimics more or less variation in wage-rental ratios. Because of very low EU variation in capital rental, the capital rental cost effects are captured by the time fixed effects in the equation (1).

[10] We did not estimate these subsamples separately because we would have to deal with the time dynamics in short panel data settings that requires stronger assumption about the error term distribution (see Hsiao at al , 2002).

acknowledging much lower variation in interest rates than in both wager-rental variables across Europe.

As the test confirms the endogeneity of explanatory variables we proceed with instrumentation. We estimate the theoretically motivated specification (1) in a panel setting with fixed effects plus instrument variables a) to overcome the problems of omitting-variables bias and b) to control for time-invariant endogeneity and selection bias.[11] This is done because some of the right-hand-side variables are correlated with the dependent variable. The reason is that, by construction, the unobserved panel-level effects are correlated with potentially endogenous independent variables that cause standard estimators to be inconsistent. Therefore, in our estimation we adopt the approach of Arellano and Bond (1991) to control for the potential endogeneity of explanatory variables.

5. Data

Bilateral trade in parts and components $EX(PC)_{ji}$ describes the exports of parts and components from country *j* to country *i* over the period 1992–2008. By constraining our sample to 2008, we avoid the noisy impact of the economic crisis from 2009 onward on the dynamics of the trade patterns evolving against the background of the European convergence process; it is evidenced that regular international trade flows were severely affected during the global financial crisis (Chor and Manova, 2012) along with capital inflows to new EU countries (Globan, 2015). The data were compiled from the United Nations COMTRADE database. The definition of the parts and components of capital goods follows the BEC categorization of the UN Statistics. Our data cover 24 EU countries, which leads to 552 (23 x 24) importer-exporter country pairs.[12] Our data do not contain zero-trade flows; hence, we do not need to apply the two-stage estimation procedure suggested in Helpman et al. (2008). Details on data and variables used are provided in Appendices B and C.

In our estimation we employ three different measures of bilateral trade in parts and components. First, we measure the trade flows of how much country *j* exports to country *i*, which is identical to how much country *i* imports from country *j*. Then, following Frensch (2010), we measure bilateral trade along the extensive and intensive margins. Hence, our second measure, trade along the extensive margin, represents the *variety* of parts and components of capital goods exported from country *j* to country *i* at time *t*. It is defined as a count measure over some 300 parts and

[11] We perform a Hausman-type specification test to assess the potential endogeneity of the explanatory variables by comparing a standard fixed effects model with the Arellano-Bond technique. In order to obtain consistent estimates we employ a dynamic panel-data model following the approach of Arellano and Bond (1991) in which the lagged levels of the dependent and predetermined variables serve as instruments for the differenced equation. The estimator is implemented in STATA 12 using the xtabond command. We have also employed the xtdpd command that can fit models with low-order moving-average correlation in the idiosyncratic errors or predetermined variables with a more complicated structure than allowed for xtabond command. The results were quite similar and hence we present those corresponding to the classical Arellano-Bond estimator (updated xtabond2 procedure). We also performed standard FE and OLS for robustness checks, but these methods are inferior to the one we employ; results are not reported.

[12] Belgium and Luxembourg are treated as one country. Cyprus and Malta are not included due to limited data.

components out of all 3,114 of the SITC Rev.3 categories. Our third measure, along the intensive margin, represents the *intensity* of parts and components exported from country j to country i at time t. The intensive margin is defined as the average volumes of exported parts and components categories.

Further, Y_j and Y_i are exporter and importer GDP at current prices, respectively, obtained from the World Development Indicators (accessed via the DCI database).

For our measure of supply-side country differences in wage-rental parameter we use two proxy variables. The first one is wage as this variable is much used in the literature we reviewed earlier in Section 2. Wages in exporting (w_j) and importing (w_i) countries are measured as the annual wage average in the respective manufacturing sector at a specific year t. For each country, the average wage in the manufacturing sector in local currency was converted to USD. World average wage (w_{world}) is measured as the mean wage in the world, respectively; the world is defined by our full reporting sample described in the notes to Appendix Table C1. The data were obtained from LABORSTA (International Labor Office statistical databases, http://laborsta.ilo.org/). The second measure is capital labor ratio. Data on capital labor ratio are taken from Penn World Tables, 8.1 and it is defined as *clr=ck/emp*. Where *ck* = capital stocks at current PPP (in millions 2005 USD) and *emp* = number of employees (in millions).

Analogous to a simple mean we also construct weighted averages of world wages and world capital labor ratios in which population sizes (p_i) serve as weights. Population data were obtained from World Development Indicators. With these variables we construct relative supply-side country differences in wages and capital labor ratios, $|w_j - w_{world}| \times |w_i - w_{world}|$. Given that specification (1) is rooted in factor-proportion models of incomplete specialization and trade, existing wage or capital labor ratio differences may be subject to factor price equalization tendencies by the very trade they induce. As factor-price differences may not be strictly exogenous, we follow Arellano and Bond (1991) and apply the simplest possible remedy in choosing the second lags of the explanatory variables as instruments. Since the estimation is performed on differenced equation the input data are stationary. We also check that we do not have an identification problem due to potential correlation.

The time-specific effects in (1) also control for each year's data using a different *numéraire* since GDP and trade values are all current (Baldwin and Taglioni, 2006), where original USD-denominated data are converted to euros.

6. Empirical results

6.1. A priori *expectations and benchmark results*

Our key results are based on estimates from specification (1) that are explicitly rooted in incomplete specialization. Hence, we can form *a priori* expectations on some coefficients and formulate testable hypotheses.

Hypothesis 1: The bilateral parts and components trade volume will increase with the product of trading countries' incomes; formally we test whether $\beta_1 > 0$.

Hypothesis 2: The volume of trade is related to the extent of supply-side country differences relative to the world.

We form an *a priori* expectation about the value of β_2 based on the further information on the sample of countries. We performed a check on our data and the set is sufficiently homogenous: in terms of wages and capital labor ratios, these are mostly larger than average. Then there is no reason to assume the majority of country pairs to be complementarily specialized. In this case, increasing deviations of both countries' specialization incentives from world averages, i.e., higher $|w_j - w_{world}| \times |w_i - w_{world}|$, will rather generate less parts and components trade, such that $\beta_2 < 0$.

Hypothesis 3: The volume of trade will increase with the extent of truly complementary specialization between countries; formally we test whether $\gamma_s > 0$.

If a complementary specialization can be derived from the data then the dummy variable *Dummy*EU15/10 in specification (1) would capture the "right" country pairs with complementary specialization, as we expect *a priori*, on the basis of the geographical distribution of manufacturing wages and capital labor ratios across Europe in Figure 1. Since the interactive term $DummyEU15/10_{ji} \log(|w_{j,t} - w_{world,t}| \times |w_{i,t} - w_{world,t}|)$ is estimated separately for five sub-periods over the period 1992–2008, we obtain five coefficients γ_s. This set of coefficients enables us to capture the dynamic effects.

Hypothesis 4: The volume of trade will increase with the degree of specialization between the new and old EU countries.

Hypothesis 4 is assessed via the net effect of the relative supply-side country differences that is captured by the sum of the coefficients ($\beta_2 + \gamma_s$). A positive value of the sum favors the above idea of intra-European specialization. For the natural limiting case of complete specialization, we would not find specialization patterns to play any role, in which case $\beta_2 = \gamma_s = 0$. In fact, complete specialization is in principle compatible with both (new) new theories of trade, based on monopolistic competition models of trade as well as Heckscher-Ohlin with trade costs or for substantial differences in endowments. However, Debaere and Demiroglu (2003) find evidence of similar factor endowments among large parts of our country sample, to potentially enable them to produce the same set of goods. Heckscher-Ohlin-based simulation results in Haveman and Hummels (2004) with infinitesimally small trade costs changing the ordering of minimum cost suppliers without changing prices give rise to incomplete specialization in the sense of more than one country in the world producing and exporting one particular good to the rest of the world and each supplier country supplying a particular good to more than one customer country. On this basis, we will interpret the limiting case of $\beta_2 = \gamma_s = 0$ as complete specialization based on

monopolistic competition models of trade, indicating trade in variants of differentiated products rather than in different homogenous products.

We introduce our benchmark results based on specification (1) in the first columns of Table 1 and 3 (flows), where we present the estimated coefficients for the dependent variables of bilateral parts and components trade introduced in section 4.1. The key fact is that our results provide evidence for trade in parts and components of capital goods due to the existence of multinational production networks across Europe, and inform about the driving forces identified already in the first section.
First, the statistically significant coefficient β_1 demonstrates that larger countries trade more with each other. Second, the negative coefficient β_2 confirms that our sample of European countries on average in fact features a rather homogeneous specialization pattern in the international production chain as compared to the world average.[13]

This average pattern fails to reveal the significant role for specialization incentives across Europe, as becomes evident once we compare the coefficient β_2 with always significantly positive and much larger coefficients γ_s. The sums of the coefficient pairs β_2 and γ_s ($\beta_2 + \gamma_1$ for the first period 1992–1995, $\beta_2 + \gamma_2$ for the second period 1996–1998, etc.) show that relative supply-side country differences do drive trade in parts and components across Europe. This trade is compatible with models of incomplete specialization and trade, but only between the original EU-15 and the ten accession countries (EU-10), rather than within each of the two country groups. Specifically, measuring relative supply-side country differences by wages (Table 1, first column), parts and components trade flows between East and West Europe react with an elasticity growing from about 8% ($\beta_2 + \gamma_1$) to some 15% ($\beta_2 + \gamma_4$). When we employ the capital labor ratios as a measure of the relative supply-side country differences (Table 3, first column), the elasticity growth is lower (from about 1% ($\beta_2 + \gamma_1$) to about 4% ($\beta_2 + \gamma_4$)). This is quite natural: from Figure 1 we can see that differences in wages are somewhat larger than differences in capital labor ratios and therefore, trade flows react more elastically to the factor exhibiting larger country differences (i.e. wages). In any event, based on the evidence, bilateral trade flows in parts and components between old and new EU members appear to be driven by incomplete specialization motives.

Third, technical progress in terms of declining coordination costs and ongoing fragmentation – as captured by the sub-period dummies – appears to positively influence trade in parts and components: with the exception of the final sub-period, for EU-15/EU-10 pairs, coefficients γ_s are increasing slowly over time. The slight decrease of the γ_5 coefficient in the final 2005–2008 sub-period might indicate that EU-10 countries catch up with the EU-15 so that supply-side country differences between both groups, relative to the world, become less pronounced. This may well be affected by the technological progress in the EU-10 countries that is closely linked to foreign direct investment and multinationals (Uzagalieva et al., 2012; Hanousek et al., 2011). As foreign-owned subsidiaries become a part of the innovation systems and

[13] Note that this result would not confirm results in Kimura et al. (2007) in that European trade in parts and components is based on monopolistic competition models of trade, indicating trade in variants of differentiated products rather than in different homogenous products: with our specification, this would ask for a zero rather than a negative coefficient β_2!

the industrial structure of the EU-10 countries, they promote overall technological growth in the region that further contributes to catch-up with the EU-15.

Finally, we also assesses the confidence intervals of the coefficients estimated from specification (1) and verified that the sum of the coefficients associated with development of the specialization ($\beta_2 + \gamma_s$) is statistically greater than zero for all five periods. This property of the coefficients directly implies that specialization patterns of the EU-15 and EU-10 countries were complementary during the period under research.

6.2. Robustness

As discussed in Debaere (2003), measuring world averages in relative supply-side country differences matters a lot. So far, world average wages and capital labor ratios have been measured as simple averages in the world defined by our full reporting sample described in the notes to Appendix Table C1. Tables 2 and 4 (first column) display the results of a modified world average measurement. We now employ an average that is weighted by countries' populations, as comparable work force data are unavailable on the scale of our full sample. The results are not materially different from those reported in Tables 1 and 3. Hence, our results are robust to this change in measurement. Specifically, when population-weighted averages are used the trade flows react with even larger elasticity growth to differences in wages (Table 2), from about 15% ($\beta_2 + \gamma_1$) to about 21% ($\beta_2 + \gamma_4$). In case of capital labor ratios, the β_2 coefficient is statistically insignificant and precludes proper assessment. However, as it is almost zero, we may say that the trade flows react with smaller elasticity growth to differences in capital labor ratios (Table 4), from about 2% ($\beta_2 + \gamma_1$) to more than 4% ($\beta_2 + \gamma_4$)

We complement our robustness results by a statistical comparison of the coefficients derived from the estimated specification (1). We assess the confidence intervals of the coefficients presented in Tables 1 and 3 (simple averages) and Tables 2 and 4 (weighted averages); details are available but not reported. All coefficients are within a reasonable range so that they enable comparable inference. The weighted coefficients exhibit lower dispersion due to weighting. Hence, our results are in a statistical sense robust to the world average measurement in terms of simple or weighted averages.

6.3. Trade margins and links to production networks

The results of the previous section provide evidence that the East-West part of European trade in parts and components is driven by trade-offs between location advantages and coordination costs, relative to the rest of the world. As Kimura et al. (2007) do for East Asia, we take this as evidence for the existence of supply chains in the form of international, specifically East-West, production networks across Europe.

Based on the highly disaggregated nature of our original trade data (see Appendix C for details) we can decompose the influences on parts and components trade along the two margins of trade, i.e., along *extensive* (variety of exported goods) versus *intensive* (average volumes per exported good) margins. On the basis of the

significance of factor proportions forces we analyze the margins of homogenous, rather than differentiated, products. Hence, our margin results are not rooted in models of firm heterogeneity and trade but rather have the structural explanation laid out in section 3: the potential relation specificity of investment in production networks implies an important distinction between *ex ante* and *ex post* location choice investment situations in production networks which corresponds to our trade margins point of view.

To sum, the extensive margin of trade represents the variety of parts and components traded, while the intensive margin describes how intensively each of the parts and components is traded. The difference in both margins of trade has important implications with respect to production networks. First, changes along the extensive margin of trade translate into the variety of parts and components traded by adding more products to a network. These changes are reactions to the investment decisions of setting up new international capital-good production networks or extending the existing ones; these decisions are made *ex ante*. Second, changes along the intensive margin (average traded volume of parts and components) represent responses to *ex post* decisions on either deepening international production networks or intensifying production and trade within an already established partner-product network.

Our results, specifically values of coefficients in the second and third columns of Tables 1 - 4, reveal that trade in parts and components across Europe is not realized along the intensive margin (third columns) in response to market size increases, but predominantly along the extensive margin (second columns) in response to stronger relative supply-side country differences. The latter result signals that choices on sources from which to add new products to European capital goods production networks are driven by relative country differences in wages and capital labor ratios. In this sense, choices on setting up or extending European capital goods production networks, i.e., location choices, are driven by relative country differences in wages and capital labor ratios.

The intensive margin results state that choices on traded volumes within existing parts and components trade relationships respond less elastically to relative country differences in wages and capital labor ratios. This implies that deepening production networks, i.e., intensifying trade within an established partner-product network (intensive margin), responds less elastically to relative country differences in wages and capital labor ratios than location choices on setting up or extending European capital goods production networks (extensive margin). However, one distinction emerges. In case of extensive margin (second columns in Tables 1 - 4) the coefficients γ_s are increasing slowly over time but exhibit a slight decrease the final 2005–2008 sub-period (γ_5). However, in case of intensive margin (third columns in Tables 1 - 4) the coefficients γ_s are increasing slowly over the whole researched period without any decline in the final 2005–2008 sub-period (γ_5). This indicates that for the EU-10 countries the potential to catch up with the EU-15 is not exhausted yet and provides further room for deepening trade or international production networks. This is in full accord with previous evidence brought by Uzagalieva et al. (2012) that the technological progress in the EU-10 countries is closely linked to activities based on foreign direct investment.

The results thus constitute evidence that our postulated relation between trade margins and *ex ante* and *ex post* investment situations in production networks is appropriate. Different elasticities in margin responses to relative country differences indicate that (in terms of customization upon demand) *ex post* differentiated parts and components indeed appear to be more homogenous across potential suppliers from potentially different source countries than *ex ante* investment decisions of setting up a production network. This, in turn, justifies our deriving gravity within an incomplete specialization framework with complete specialization as a limiting case, which allows for different forces of trade being at work *ex ante* versus *ex post* location choices.

6.4. Further conjectures on links to offshoring

While our results cannot constitute evidence for outright offshoring of labor-intensive tasks from West European to East European firms, we may conclude from the literature cited in section 2 that this is what happens regularly as foreign engagement in East European firms is substantial and positively impacts their efficiency in large (Hanousek et al., 2015). Accordingly, but largely as a conjecture, we may interpret trade in parts and components between East and West Europe as being offshore related, yielding important implications of our margin results. Estimating Mincer-type wage equations augmented by offshoring treatment effects to firm-level data, Geishecker and Görg (2008) demonstrate that offshoring low-skill tasks decreases the wages of German low-skill employees. Comparing wage and employment effects across countries features significant differences in this respect, which may be motivated by different labor market institutions, as suggested in Geishecker et al. (2008).

Our results may be related to an alternative explanation for the internationally varying labor-market effects of offshoring. Empirical work on the labor-market effects of offshoring was at first mainly guided by the theoretical framework of Feenstra and Hanson (1996), in which offshoring is costless or uniformly costly across discrete sets of tasks, predicting the effects indeed identified in Geishecker and Görg (2008). More recent theoretical work generalizes Feenstra and Hanson (1996) by introducing task-specific trade costs that potentially limit the offshoring of a continuum of tasks (Grossman and Rossi-Hansberg, 2008). More offshoring of low-skill tasks, made possible by decreasing coordination costs over all tasks, then *ceteris paribus* implies a positive productivity effect in the source country, which appears strongest in those firms that have already offshored the most, and which therefore carries the highest potential benefits for the skill groups hit hardest by offshoring. The labor market effects that disadvantage the skill groups hit hardest by offshoring, as already identified in Feenstra and Hanson (1996), are thus counterbalanced and may even be dominated under certain conditions. Firms that have already offshored most tasks are increasingly likely to strengthen already-existing relationships rather than create new offshoring relationships. In our trade terminology, existing offshoring relationships, in turn, get strengthened along the intensive margin, as opposed to strengthening along the extensive margin by new relationships.

One might therefore suspect the unambiguous results of Geishecker and Görg (2008) to hold for offshoring relationships that get predominantly strengthened along the extensive rather than along the intensive margin. With the major *caveat* of our using disaggregated macro rather than micro data, this, in turn, seems to be the case for the offshoring relationship between the EU-15 and the EU-10, i.e., the "old" and the "new" EU members. In the spirit of the Grosssman and Rossi-Hansberg (2008) approach, this would suggest the conjecture that recent waves of offshoring activities from "old" to "new" EU members might have hurt (low-skill) workers in the old EU, perhaps more so than extending old EU offshoring elsewhere.

7. Conclusions

We view bilateral parts and components trade gravity equations as relationships conditional on countries' incomplete multilateral specialization patterns, taking account of the specifics of the economic geography of Europe. Different from previous literature, we apply our framework to a truly Europe-wide sample of countries, while fully accounting for potential tendencies towards factor price equalization via trade.

We find no evidence for the average bilateral European parts and components trade relationship to be driven by countries' multilateral specialization incentives, as expressed by relative (to the rest of the world) wage differences. However, we do find this evidence for parts and components trade relationships between EU-15 and EU-10 countries, together with a positive influence for technical progress in terms of declining coordination costs and ongoing fragmentation and a negative impact of multilateral trade resistance. Analogous to Kimura et al. (2007)'s conclusion on East Asia, we take this as evidence for the existence of international production networks across Europe, driven by trade-offs between wages or capital labor ratios and coordination costs.

Our results also reveal that parts and components trade across Europe is predominantly realized along the extensive margin in response to stronger relative wage differences (while the reaction to capital labor ratios is less elastic). We interpret this in terms of *ex ante* and *ex post* investment situations in production networks. Location choices for setting up or extending (adding more products to) European capital goods production networks are stronger than those for deepening international production networks, i.e., intensifying production and trade within an established partner-product network. Still, our results show that the potential to deepen the trade and international production network specifically in EU-10 countries is not exhausted yet.

Finally, in as much as international production networks across Europe are shaped by the outright offshoring of labor-intensive tasks from West to East, our results support the conjecture that offshoring activities from "old" to "new" EU members would have hurt (low-skill) workers in the old EU.

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Table 1: Exports of parts and components: Wages

			Flows	Extensive Margin	Intensive Margin
log Y_j Y_i		β_1	0.718*** (0.023)	0.254*** (0.013)	0.464*** (0.014)
log ($\lvert w_j - w_{world}\rvert \times \lvert w_i - w_{world}\rvert$)		β_2	-0.101*** (0.020)	-0.040*** (0.010)	-0.061*** (0.013)
log ($\lvert w_j - w_{world}\rvert \times \lvert w_i - w_{world}\rvert$) for EU-15 / EU-10 pairs	1992–1995	γ_1	0.183*** (0.036)	0.104*** (0.020)	0.079*** (0.021)
	1996–1998	γ_2	0.202*** (0.036)	0.117*** (0.019)	0.085*** (0.021)
	1999–2001	γ_3	0.241*** (0.035)	0.145*** (0.019)	0.096*** (0.020)
	2002–2004	γ_4	0.251*** (0.034)	0.157*** (0.018)	0.094*** (0.020)
	2005–2008	γ_5	0.230*** (0.033)	0.132*** (0.018)	0.099*** (0.020)
N			27,354	27,354	27,354

Note: Variables are defined in Table B.1. The simple average wage is used as a proxy for the world average wage. Fixed effects not reported; standard errors are in parentheses. *, **, and *** indicate significance at 10, 5, and 1 percent levels, respectively.

Table 2: Exports of parts and components: Population weighted wages

			Flows	Extensive Margin	Intensive Margin
log Y_j Y_i		β_1	0.711*** (0.007)	0.250*** (0.003)	0.462*** (0.006)
log ($\lvert w_j - w_{world}\rvert \times \lvert w_i - w_{world}\rvert$)		β_2	-0.052*** (0.012)	-0.015*** (0.005)	-0.037*** (0.011)
log ($\lvert w_j - w_{world}\rvert \times \lvert w_i - w_{world}\rvert$) for EU-15 / EU-10 pairs	1992–1995	γ_1	0.200*** (0.009)	0.111*** (0.004)	0.089*** (0.008)
	1996–1998	γ_2	0.217*** (0.008)	0.123*** (0.003)	0.095*** (0.007)
	1999–2001	γ_3	0.257*** (0.007)	0.152*** (0.003)	0.105*** (0.007)
	2002–2004	γ_4	0.260*** (0.008)	0.161*** (0.003)	0.100*** (0.007)
	2005–2008	γ_5	0.234*** (0.008)	0.133*** (0.003)	0.101*** (0.007)
N			27,354	27,354	27,354

Note: Variables are defined in Table B.1. The population weighted average wage is used as a proxy for the world population weighted average wage. Fixed effects not reported; standard errors are in parentheses. *, **, and *** indicate significance at 10, 5, and 1 percent levels, respectively.

Table 3: Exports of parts and components: Capital/labor ratios

			Flows	Extensive Margin	Intensive Margin
log $Y_j\ Y_i$		β_1	0.772*** (0.007)	0.312*** (0.003)	0.470*** (0.005)
log ($\lvert clr_j - clr_{world}\rvert \times \lvert clr_i - clr_{world}\rvert$)		β_2	-0.011* (0.007)	-0.017*** (0.003)	0.005 (0.005)
log ($\lvert clr_j - clr_{world}\rvert \times \lvert clr_i - clr_{world}\rvert$) for EU-15 / EU-10 pairs	1992–1995	γ_1	0.025*** (0.005)	0.023*** (0.003)	0.003 (0.003)
	1996–1998	γ_2	0.036*** (0.005)	0.031*** (0.003)	0.006* (0.003)
	1999–2001	γ_3	0.051*** (0.005)	0.038*** (0.003)	0.013*** (0.003)
	2002–2004	γ_4	0.049*** (0.005)	0.035*** (0.003)	0.014*** (0.003)
	2005–2008	γ_5	0.046*** (0.005)	0.025*** (0.003)	0.021*** (0.003)
N			27,371	27,371	27,371

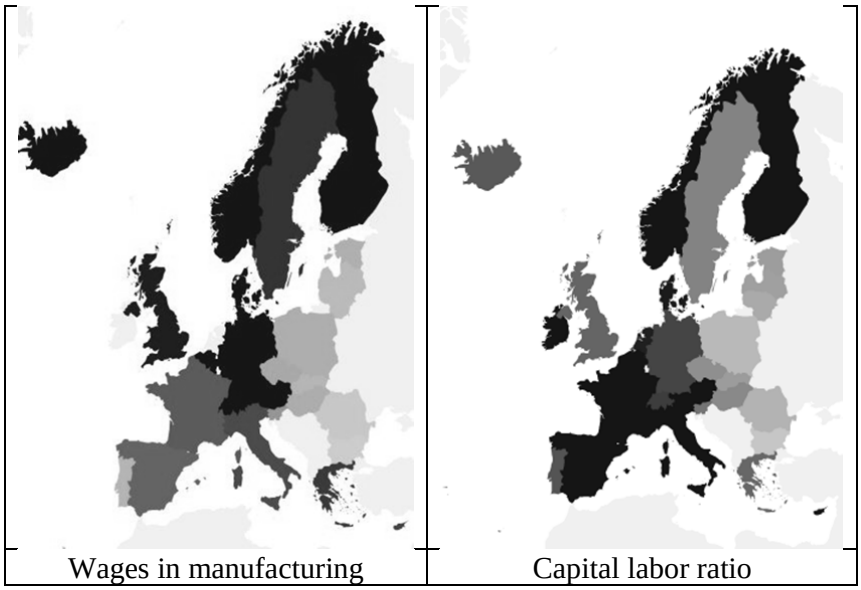
Notes: Capital labor ratio is taken from Penn World Tables, 8.1 and is defined as clr=ck/emp. Where *ck* =capital stocks at current PPP (in millions 2005 USD) and *emp* =number of employees (in millions). The simple average capital/labor ratio is used as a proxy for the world capital/labor ratio. Fixed effects are not reported; standard errors are in parentheses. *, **, and *** indicate significance at 10, 5, and 1 percent levels, respectively.

Table 4: Exports of parts and components: Population weighted capital/labor ratios

			Flows	Extensive Margin	Intensive Margin
log $Y_j\ Y_i$		β_1	0.767*** (0.007)	0.308*** (0.003)	0.470*** (0.006)
log ($\lvert clr_j - clr_{world}\rvert \times \lvert clr_i - clr_{world}\rvert$)		β_2	0.002 (0.007)	-0.003 (0.003)	0.002 (0.006)
log ($\lvert clr_j - clr_{world}\rvert \times \lvert clr_i - clr_{world}\rvert$) for EU-15 / EU-10 pairs	1992–1995	γ_1	0.023*** (0.005)	0.020*** (0.003)	0.002 (0.003)
	1996–1998	γ_2	0.034*** (0.005)	0.028*** (0.003)	0.005* (0.003)
	1999–2001	γ_3	0.048*** (0.005)	0.035*** (0.003)	0.013*** (0.003)
	2002–2004	γ_4	0.046*** (0.005)	0.032*** (0.003)	0.014*** (0.003)
	2005–2008	γ_5	0.043*** (0.005)	0.021*** (0.003)	0.020*** (0.003)
N			27,354	27,354	27,354

Notes: Capital labor ratio is taken from Penn World Tables, 8.1 and is defined as clr=ck/emp. Where *ck* =capital stocks at current PPP (in millions 2005 USD) and *emp* =number of employees (in millions). The population weighted average capital/labor ratio is used as a proxy for the world capital/labor ratio. Fixed effects are not reported; standard errors are in parentheses. *, **, and *** indicate significance at 10, 5, and 1 percent levels, respectively.

Figure 1. Geographical distribution of country-specific differences in manufacturing across Europe, 2008



Note: Average wages in manufacturing as of 2008. Local currency data from LABORSTA (International Labor Office statistical databases, http://laborsta.ilo.org/), converted into USD. The capital/labor ratio is computed from the PWT8.0 as *cap/emp*, i.e., as capital stock at current PPPs (in millions of 2005 USD) over the number of persons engaged (in millions). Higher wages and higher ratios are indicated by darker shading. Maps were created by a web interface at http://www.openheatmap.com.

Appendix A: Gravity and incomplete specialization in the presence of small border costs

We start by extending the Haveman and Hummels' (2004) derivation of (A10) below to the intermediate goods case: according to Assumption 1, production is subject to homothetic derived demands, such that all variables can be studied in nominal terms: *C* is consumption or use, *X* production, *Z* value added, *Y* income, *E* exports, and *I* imports. Subscripts denote countries, superscripts goods. With two stages of production, there are *N* intermediate goods and one final product (*N*+1); δ_j^k denotes the share of a part or component *k* in total nominal value-added in country *j*. Then,

$$Z_j^k = X_j^k = \delta_j^k Y_j \qquad \text{for } k = 1,\ldots, N \tag{A1}$$

and

$$Z_j^{N+1} = X_j^{N+1} - \sum_{k=1}^{N} C_j^k = \delta_j^{N+1} Y_j \tag{A2}$$

such that

$$\sum_{k=1}^{N} Z_j^k + Z_j^{N+1} = Y_j \text{ , as } \sum_{k=1}^{N} \delta_j^k + \delta_j^{N+1} = 1 \tag{A3}$$

With Assumption 1, parameters ϕ^k represent the reciprocal productivities of parts and components, to describe derived demands in nominal terms,

$$C_j^k = \phi^k X_j^{N+1} \text{ , for } k = 1, \ldots, N. \tag{A4}$$

Value-added in producing the final good can then be written as

$$Z_j^{N+1} = X_j^{N+1} - X_j^{N+1} \sum_{k=1}^{N} \phi^k = X_j^{N+1}\left(1 - \sum_{k=1}^{N} \phi_j^k\right) \tag{A5}$$

such that

$$X_j^{N+1} = \frac{\delta_j^{N+1} Y_j}{1 - \sum_{k=1}^{N} \phi^k} \ . \tag{A6}$$

(A6) describes the output of the final good in country *j*. Final demand is given by spending total income on the final good, $C_j^{N+1} = Y_j$. With infinitesimally small border costs, exports are always identical to net exports, and final good exports are

$$E_j^{N+1} = X_j^{N+1} - C_j^{N+1} = \frac{\delta_j^{N+1} Y_j}{1 - \sum_{k=1}^{N} \phi^k} - Y_j = \left(\frac{\delta_j^{N+1}}{1 - \sum_{k=1}^{N} \phi^k} - 1\right) Y_j. \tag{A7}$$

Parts and components output is given in (A1) and use in (A4), which also holds for the world as a whole, $C_{world}^k = \phi^k X_{world}^{N+1}$. With (A6) we obtain

$$\frac{C_j^k}{C_{world}^k} = \frac{\delta_j^{N+1} Y_j}{\delta_{world}^{N+1} Y_{world}}, \text{ for } k = 1,\ldots,N. \tag{A8}$$

(A8) can be simplified. First, the world version of (A7) implies that $1 - \sum_{k=1}^{N} \phi^k = \delta_{world}^{N+1}$, as world trade in final goods must always be balanced. As we are only interested in parts and components trade, we assume balanced final goods trade for each single country (Assumption 3), such that $1 - \sum_{k=1}^{N} \phi^k = \delta_j^{N+1}$, for each country. Further, world output of any good is always equal to world use, such that

$$C_j^k = \frac{Y_j \delta_{world}^k Y_{world}}{Y_{world}} = \delta_{world}^k Y_{world} \tag{A9}$$

Again, with infinitesimally small border costs, exports are always identical to net exports, and country *j*'s exports of part or component *k* are

$$E_j^k = (\delta_j^k - \delta_{world}^k) Y_j, \qquad \text{for } k = 1, \ldots, N, \tag{A10}$$

which is isomorphic to equation (6) in Haveman and Hummels' (2004) description of final goods trade. I.e., countries export a specific part or component if they devote a greater share of the value-added to producing this good than does the rest of the world.

We interpret the multilateral gravity equation (A10) between country *j* and *world* as a bilateral gravity equation. Then, using the argument put forward in Evenett and Keller (2002, p. 286), in a 2×2×2 factor proportions setup: if country *j* is relatively capital-rich and part or component *k* is capital intensive, value-added δ_j^k is positively related to country *j*'s capital-labor ratio $\kappa_j = (K/L)_j$, and δ_{world}^k is inversely related to *world*'s capital-labor ratio, κ_{world}. Hence, the volume of trade in *k* increases in the difference between capital-labor ratios, $(\kappa_j - \kappa_{world})$, such that

$$E_j^k \propto Y_j(\kappa_j - \kappa_{world}). \tag{A11}$$

Analogously, we can write

$$I_i^k \propto Y_i(\kappa_{world} - \kappa_i) \tag{A12}$$

for relatively labor-rich country *i* importing the capital-intensive *k* and exporting a labor-intensive part or component.

According to Ethier (1985), the Heckscher-Ohlin theorem carries through to the case of more than two goods, such that specialization patterns between countries *j* and *world* and countries *world* and *i* continue to be shaped by differences in factor endowment ratios in terms of correlations. In the multi-good, multi-country and two-factor version of Heckscher-Ohlin, Deardorff (1979) derives a chain proposition according to which the capital-intensity of exported commodities declines with the capital-labor endowment ratio of the exporting country if there are unequal factor prices, as long as there is no connection between trade in final goods and intermediate goods.

Different factor prices are the rule in our context due to infinitesimally small home country effects. We can therefore generalize (A11) and (A12) to the extent that country *j* will export the more capital intensive parts and components if *j* is capital-richer than *world* or if its wage-rental ratio is higher than that in *world*. As the analogous reasoning can be applied to labor-rich country *i*, this establishes Result 1.

Appendix B: Descriptive statistics

Table B1. Definitions of variables and descriptive statistics

Variable	Definition	Source	Average, min, max
$EX_{ji,t}$ *(PC)*	Exports of parts and components of capital goods from country *j* to country *i* at time *t* in current dollars	UN Comtrade	Levels: 93,660 0.0 7.12e07
Extensive margin of $EX_{ji,t}$ *(PC)*	Variety of parts and components of capital goods exported from country *j* to country *i* at time *t*	UN Comtrade, own computation	Levels: 65.1 0.0 629
Intensive margin of $EX_{ji,t}$ *(PC)*	Intensity of parts and components exports from country *j* to country *i* at time *t*	UN Comtrade, own computation	Levels: 508.3 1.0 1.37e06
Y_j, Y_i	Export and import country GDP in current dollars	*World Development Indicators 2011*	Levels: 9.8e05 1172 1.4e07
w_j, w_i	Average wage in manufacturing in export and import countries in current dollars	LABORSTA, ILO database, available online at http://laborsta.ilo.org/ plus country statistical offices	Levels: 1,272 405 3,561
clr_i, clr_j	Capital labor ratio (*clr*), defined as *clr*=*ck*/*emp*. *ck*=capital stocks at current PPP (in millions 2005 USD), *emp*=number of employees (in millions)	Penn World Tables, 8.1	Levels: 57,195 561 439,443
p_i	Country population in millions	*World Development Indicators 2011*	Levels: 54.2 0.2 1,354

Appendix C: Commodity classifications, country, and time coverage

Commodity classifications

SITC

All our trade data are reported according to the Standard International Trade Classification, Revision 3 (SITC, Rev.3). Data are used at all aggregation levels (1-digit-level aggregate trade flows; and 3,114 entries at the 4- and 5-digit levels. We use *basic categories* to distinguish and count SITC categories for the definition of the *extensive versus intensive* margins of trade flows).

BEC

The United Nations Statistics Division's *Classification by BEC* (*Broad Economic Categories*, available online at: http://unstats.un.org/unsd/trade/BEC%20Classification.htm) allows for headings of the SITC, Rev.3 to be grouped into 19 activities covering primary and processed foods and beverages, industrial supplies, fuels and lubricants, capital goods and transport equipment, and consumer goods according to their durability. The BEC also provides for the rearrangement of these 19 activities (on the basis of SITC categories' *main* end-use) to approximate the basic System of National Accounts (SNA) activities, namely, primary goods, intermediate goods, capital goods, and consumer goods.

Specifically, the BEC permits the identification of a subset of about 300 intermediate goods used as inputs for capital goods, i.e. parts and accessories of capital goods. In this paper, consistent with the use in the rest of the literature, these are referred to as *parts and components* of capital goods.

Table C1. Import-reporting countries, country codes, and trade data availability

1	AUT	Austria (1992–2008)	9	FRA	France (1992–2008)	17	LVA	*Latvia* (1995–2008)
2	BEL	Belgium and Luxembourg (1992–2008)	10	GBR	United Kingdom (1992–2008)	18	NLD	Netherlands (1992–2007)
3	BGR	*Bulgaria* (1996–2008)	11	GER	Germany (1992–2008)	19	POL	*Poland* (1992–2008)
4	CZE	*Czech Republic* (1993–2008)	12	GRC	Greece (1992–2008)	20	PRT	Portugal (1992–2008)
5	DNK	Denmark (1992–2008)	13	HUN	*Hungary* (1992–2008)	21	ROM	*Romania* (1992–2008)
6	ESP	Spain (1992–2008)	14	IRL	Ireland (1992–2008)	22	SVK	*Slovakia* (1993–2008)
7	EST	*Estonia* (1995–2008)	15	ITA	Italy (1992–2008)	23	SVN	*Slovenia* (1995–2008)
8	FIN	Finland (1992–2008)	16	LTU	*Lithuania* (1995–2008)	24	SWE	Sweden (1992–2008)

Note: Belgium and Luxembourg are treated as one country. EU-15 underlined; EU-10 in *italics*. Each reporting country's import data are given for all reporter countries for the indicated time period. For the computation of our world averages, the "world" consists of the EU countries in the table plus: Albania, Armenia, Azerbaijan, Bosnia & Herzegovina, Belarus, Canada, Switzerland, Cyprus, Georgia, Iceland, Kazakhstan, Kyrgyzstan, Moldova, Macedonia, Malta, Norway, Russia, Tajikistan, Turkmenistan, Turkey, Ukraine, Uzbekistan, the U.S., China, Hong Kong, Japan, South Korea, Taiwan, and Thailand. Hence, the "world" encompasses 54 countries that on average account for more than 90 percent of reported imports.