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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 the 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 tradeoffs 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 conducted along the extensive margin but (ii) the potential to intensify the trade and international production network in new EU members has not been exhausted yet.

1. Introduction

Worldwide trade in intermediate goods now comprises 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. In order to do 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 set of data on European trade in parts and components of capital goods.

While empirical gravity approaches have been used with great success since the early 1960s, their theoretical foundations have emerged somewhat later.[1] As

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

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, come 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 data on bilateral trade patterns in capital and consumer goods among old and new European Union (EU) members. Our interest in trade patterns in parts and components 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 the so-called "European Agreements" with the European Union in December 1991.[2] Subsequently, they strove to establish a workable framework for international trade and cooperation 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 with the addition of virtually all of the remaining 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 to 1999 underwent a lengthy and thorough screening process leading to EU accession; some CEE countries followed at later dates. The CEE countries finalized their accession process by becoming full EU members on 1 May 2004, when the first group of CEE countries joined the EU, followed by the second group in 2007.

EU integration impacted international trade between old and new EU members even before the actual enlargement. First, association agreements signed in the early 1990s were found to have a positive and significant impact on trade flows between the transition and EU countries (Caporale *et al.*, 2009; Egger and Larch, 2011). Second, despite existing economic differences among the countries, the new EU members quickly became an important part of the EU-wide manufacturing and distribution network (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 the potential overall gains from trade. Further, lowering the fixed cost of trade during European integration prompted trade to increase (Frensch, 2010).

The above-mentioned features are relevant to the composition and characteristics of EU members' trade and correlate with the empirical fact that OECD trade in intermediate goods grew 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%. As of 2006, the ratio of intermediate goods in manufacturing to total trade flows in Europe was on average 52% and

[2] The first four countries are the Czech Republic, Hungary, Poland and Slovakia. In the text, the old EU (EU-15) countries are sometimes referred to as Western Europe. New EU members that joined the EU in 2004 and later (EU-10) are often referred to as Eastern Europe. The detailed grouping is given in *Appendix Table C1*.

in the new EU members it was even higher, reaching well above 60% (Miroudot *et al.*, 2009, Tables 7 and 10).

The 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 gained from innovations embodied in imported goods.[3]

It is appealing to analyze the sets of new and old EU countries also from another theoretical perspective. The EU is a functioning free trade area and its strong tariff reduction has been shown to be trade creating (Eicher and Henn, 2011). The 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. Furthermore, despite a gradual catching-up process, the new EU members still exhibit lower price levels for a 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 the methodological framework and the above-mentioned arguments and facts on the patterns of trade in intermediate goods, we hypothesize that trade 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 Eastern and Western 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 tradeoffs 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 conducted along the extensive margin (representing the variety of goods). We interpret this in terms of *ex ante* and *ex post* choices of location for investments in production networks: location choices

[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 of multinationals (through FDI), who dominate the innovation process in the 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%. Furthermore, they show that import competition has a pronounced effect on average productivity.

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 ratios 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 the paper.

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 coordination costs, 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) comprehensively surveys the relevant literature on gravity approaches and important empirical contributions. For that, we outline below only the key issues that are relevant to our paper. The theoretical literature related to our paper is not extensive. While some theoretical approaches associated with the new trade theory model of 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 firms in low-wage countries 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 manufacturing 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 US 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 exporting and importing 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 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

We present our methodological framework in this section. 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 present 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 in Nunn (2007) for example, 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 modeling: 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 for setting up a production network was made *ex ante*. Therefore, some parts and components may be produced in and exported by more than one country in equilibrium.[5]

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

We follow this view and make the aspect of *ex ante* versus *ex post* choice of investment location 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* decisions on choosing investmetn locations for 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 *t* 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 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 to where to source a particular part or component among 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 setup, 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

[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.

case, this means that potentially many countries can be suppliers to locations within one country and each customer country is indifferent to all potential supplier countries except itself, again motivating random rationing *à la* Deardorff (1998) to decompose countries' multilateral gravity (in a similar vein, 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. The model 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.

Assumption 3—trade balance. Imports of country j are equal to exports, $I_j = E_j$. The 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 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 defined by the stage of production. Parts and components as well as final capital goods and transport equipment are all 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 the CEE countries' exports as well as the other way around. Assumption 3 enables us to concentrate on the 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 the 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 the 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, $E_j = I_j \propto Y_j \left(w_j - w_{world} \right)$. The analogous holds for country i with a relatively low wage-rental ratio, such that $E_i = I_i \propto Y_i \left(w_{world} - w_i \right)$.

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 the 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 domestic parts or components to foreign ones, but are indifferent between all foreign-produced parts or components. Hence, country *i's* imports of a specific part or component k from country j 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 $Y_i Y_j \left(w_j - w_{world}\right)\left(w_{world} - w_i\right)$, as $\sum_j E_j^k$ is identical for all countries. As countries' deviations from the 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 the form of the deviations of their wage-rental ratios from the world average, $E_{ji} \propto Y_j Y_i \left(w_j - w_{world}\right)\left(w_{world} - w_i\right)$, provided that bilateral wage-rental ratio deviations have opposite signs.

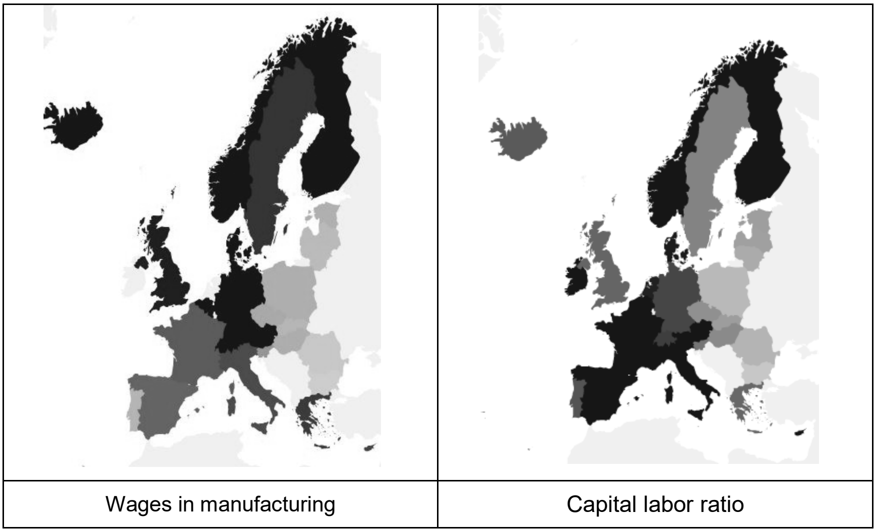
Result 2 has implications for the complementarity of specialization among countries. The benefits of trade would materialize only if the countries' specializations are mutually beneficial.

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, $\left|w_j - w_{world}\right| \times \left|w_i - w_{world}\right|$, we are able to isolate the trade volumes also for those countries that lack complementary specialization. We could resolve this strictly based on a *priori* information about $w_j > w_{world}$

Figure 1 Geographical Distribution of Country-Specific Differences in Manufacturing across Europe, 2008



Notes: 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.

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 ratios 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 the key direction of the European trade pattern is currently 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. In comparison with the traditional procedures, this has the advantage 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 country j with respect to the world, the more 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:

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

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 ten years. We proxy wage-rental ratios by wages and capital-labor ratios, acknowledging much lower variation in interest rates than in both wage-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

[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. Furthermore, 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 rise with distance.

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

[9] Our model does not contain a capital-rental part. Basically, capital rentals do not differ much across Europe, so variation in wages more or less mimics the 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 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 a stronger assumption about the error term distribution (see Hsiao *et al.*, 2002).

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 using 2008 as the final year of our sample, 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 apparent 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 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 the 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 comprising ***exports from*** country j 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 components out of all 3,114 of the SITC Rev.3 categories. Our third measure, along the intensive margin, represents the *intensity of exports of parts and components* from country j to country i at time t. The intensive margin is defined as the average volumes of exported parts and components categories.

[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 also employ the xtdpd command, which can fit models with low-order moving-average correlation in the idiosyncratic errors or predetermined variables with a more complicated structure than allowed for by the xtabond command. The results were quite similar and thus 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; the results are not reported.

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

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 the wage-rental parameter, we use two proxy variables. The first one is wage, as this variable is frequently 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 average wage in the respective manufacturing sector in a specific year *t*. For each country, the average wage in the manufacturing sector in local currency was converted to USD. The world average wage (w_{world}) is measured as the mean wage in the world; 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 the capital-labor ratio. Data on the capital-labor ratio are taken from Penn World Tables, 8.1 and the ratio is defined as *clr* = *ck/emp*, where *ck* = capital stocks at current PPP (in 2005 USD million) 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, $\left|w_j - w_{world}\right| \times \left|w_i - w_{world}\right|$. 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 a 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 specification (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 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 $\left|w_j - w_{world}\right| \times \left|w_i - w_{world}\right|$, will rather generate less parts and components trade, so 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 $DummyEU15/10_{ji} \log\left(\left|w_{j,t} - w_{world,t}\right| \times \left|w_{i,t} - w_{world,t}\right|\right)$ 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 differing 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-mentioned idea of intra-European specialization. For the natural limiting case of complete specialization, we would not find that specialization patterns 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 *Tables 1* and *2* (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 provide information about the driving forces previously identified in the first section.

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)	(0.021)
	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

Notes: Variables are defined in *Table B1*. 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: 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 ($\lvert clr_j - clr_{world}\rvert \times \lvert clr_i - clr_{world}\rvert$)	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.

First, the statistically significant coefficient β_1 demonstrates that larger countries trade more with each other. Second, the negative coefficient β_2 confirms that, in fact, our sample of European countries on average 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 of specialization incentives across Europe, which becomes evident once we compare the coefficient β_2 with the 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 Eastern and Western Europe react with an elasticity rising 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 2*, 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: in *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 parts and components trade flows 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, coefficients γ_s increase slowly over time for the EU-15/EU-10 pairs. The slight decrease of the γ_5 coefficient in the final 2005–2008 sub-period might indicate that the EU-10 countries are catching up with the EU-15, so supply-side country differences between both groups, relative to the world, are becoming less pronounced. This may well be affected by the technological progress in the EU-10 countries, which is closely linked to foreign direct investment and multinationals (Uzagalieva *et al.*, 2012; Hanousek *et al.*, 2011). As foreign-owned subsidiaries become part of the innovation systems and the industrial structure of the EU-10 countries, they promote overall technological growth in the region, which that further contributes to its catching up with the EU-15.

Finally, we also assessed the confidence intervals of the coefficients estimated from specification (1) and verified that the sum of the coefficients associated with the development of 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, the world average wages and capital-

[13] Note that this result would not confirm the 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 require a zero rather than a negative coefficient β_2!

Table 3 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 ($\lvert w_j - w_{world}\rvert \times \lvert w_i - w_{world}\rvert$)	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

Notes: Variables are defined in *Table B1*. 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 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 ($\lvert clr_j - clr_{world}\rvert \times \lvert clr_i - clr_{world}\rvert$)	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.

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 3* 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 workforce data are unavailable on the scale of our full sample. The results are not materially different from those reported in *Tables 1* and *2*. 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 3*), from about 15% $(\beta_2 + \gamma_1)$ to about 21% $(\beta_2 + \gamma_4)$. In the 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 with 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 *2* (simple averages) and *Tables 3* 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 and 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 tradeoffs 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 the *extensive* (variety of exported goods) versus *intensive* (average volumes per exported good) margins. Based on the significance of factor proportion 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* investment location choice situations in production networks, which corresponds to our trade margins point of view.

In summary, 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 investment decisions involving the setting up of new international capital goods production networks or deepening 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 the values of coefficients in the second and third columns of *Tables 1–4*, reveal that trade in parts and components across Europe is not conducted 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 of 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 involving setting up or deepening 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 involving 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 involving setting up or extending European capital goods production networks (extensive margin). However, one distinction emerges. In the case of the extensive margin (second columns in *Tables 1–4*), the coefficients γ_s increase slowly over time but exhibit a slight decrease in the final 2005–2008 sub-period (γ_5). However, in the case of the intensive margin (third columns in *Tables 1–4*), the coefficients γ_s increase 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 has not been exhausted yet and provides further room for deepening trade or international production networks. This is in full accordance with the previous evidence presented 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 involving 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 in *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 Western European to Eastern European firms, we may conclude from the literature cited in Section 2 that this is what happens regularly as foreign engagement in Eastern European firms is substantial and positively impacts their efficiency (Hanousek *et al.*, 2015). Accordingly, but largely as a conjecture, we may interpret trade in parts and components between Eastern and Western 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 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 previously identified in Feenstra and Hanson (1996), are thus counterbalanced and may even be overcome under certain conditions. Firms that have already offshored most of their tasks are increasingly likely to strengthen already-existing relationships rather than create new offshoring relationships. In our trade terminology, existing offshoring relationships get strengthened in turn along the intensive margin, as opposed to being strengthened 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 strengthened predominantly 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 Grossman 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 the offshoring of old EU members elsewhere.

7. Conclusions

We view bilateral parts and components trade gravity equations as relationships conditional on countries’ incomplete multilateral specialization patterns, taking into account the specifics of the economic geography of Europe. Differently 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 that the average bilateral European parts and components trade relationship is 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 the conclusion of Kimura *et al.* (2007) regarding East Asia, we take this as evidence for the existence of international production networks across Europe, driven by tradeoffs between wages or capital-labor ratios and coordination costs.

Our results also reveal that parts and components trade across Europe is predominantly conducted 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 the EU-10 countries has not been 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 may have hurt (low-skill) workers in the old EU.

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,

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

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,

$$C_j^k = \phi^k X_j^{N+1} \quad , \qquad \text{for } k = 1, \dots, N \tag{A4}$$

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

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

(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

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

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

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

Analogously, we can write

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

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

Table C1 Import-Reporting Countries, Country Codes, and Trade Data Availability

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

Notes: 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.

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.

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