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Incomplete specialization and offshoring across Europe

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Abstract

Research for evidence on offshoring activities and its driving forces has been done by analyzing gross trade flows related to offshoring using gravity equations augmented by *ad hoc* measures of supply-side country differences. We develop a specification grounded in incomplete specialization that views bilateral gravity equations as statistical relationships constrained on countries' multilateral specialization patterns. We apply this approach to an empirical analysis of the European trade in parts and components. Our results bring evidence that bilateral trade related to offshoring activities across Europe is driven by countries' multilateral specialization incentives that are expressed by specific supply-side country differences relative to the rest of the world.

JEL-Classification: F14, F16, L24

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1 Fragmentation, outsourcing, and offshoring: Introduction and motivation

Fragmentation and specialization[1] of production may bring additional gains after the break-up of the spatial concentration of production within a firm: firms may outsource tasks. The term *offshoring* describes the international aspect of this phenomenon, whether or not tasks leave the legal bounds of the firm.[2] A dominant feature of the literature analyzing empirically offshoring-related trade flows within the bilateral gravity framework is mis-specification of estimated models.[3] In this paper we contribute to the literature in two ways. First, we build a gravity model to identify driving forces for offshoring. We derive the motivation for offshoring based on supply-side country specific characteristics. Second, we test our model empirically: using a uniquely detailed and large data set, we analyze European trade in parts and components of capital goods. In our analysis we provide evidence that offshoring activities across Europe are driven by countries' relative (to the rest of the world) supply-side country differences compatible with models of incomplete specialization and trade.

Apart from potential gains from specialization, offshoring implies costs of coordinating an international production network rather than a single firm or plant. The coordination or *service link costs* typically entail costs of investment, communication, and *two-way trading* of the inputs into offshored tasks and resulting outputs, i.e., two-way trading of intermediate products, such as parts and components. It follows that one would expect firms to offshore tasks whenever specialization gains outweigh the implied

[1] Fragmentation describes the deepening of the division of labor—illustrated early on in Adam Smith's example of the making of pins—by horizontally or vertically splitting the production process into distinct tasks. The division of labor encourages specialization and the deepening of the division of labor thus increases incentives for specialization, based either on comparative advantage or on economies of scale.

[2] With respect to types of offshoring, Hummels et al. (2001) define the related notion of *vertical specialization* to occur when goods are produced in multiple, sequential stages: two or more countries provide value-added in the good's production sequence. At least one country must use imported inputs in its stage of the production process and some of the resulting output must be exported. The key aspect of vertical linkages is thus the use of imported intermediate inputs in producing goods that are again exported.

[3] We review the relevant literature in Section 2.

service link costs. Therefore, the volume of offshoring should increase with fragmentation, with declining coordination costs, or with the strength of international incentives to specialize.

The most noticeable incidents of offshoring have so far been in East Asia, as a consequence of fragmentation in Japanese production of electrical machinery, leading to strong increases in two-way trade in parts and components of electrical machinery between Japan and her neighbors.[4] When considering the evidence of who offshores what and to whom, one needs to keep in mind that fragmentation along with declining service link costs represent technical progress[5] that is produced in only a few industrialized economies (Keller, 2004). Hence, rich-country firms aim at offshoring tasks, which tend to be routine, homogeneous, and intensive in labor, even in low-skill labor (Breda et al., 2008; Kimura, 2006; Sinn, 2005). Case study evidence points to sectors of machine building or capital goods production as the industries experiencing the most pronounced offshoring.

From this description of the influences on offshoring, one would expect supply-side country differences to play a role, as in a factor-proportions setting. Specifically, across Europe one would expect the Central and Eastern European (CEE) countries that entered the EU in 2004 as new members (the EU-10) to specialize in labor-intensive tasks and the old EU members (the EU-15) to specialize in capital-intensive tasks. These tasks within the chain of production of capital goods would generate two-way trade in parts and components of capital goods across Europe. This process could be expected to be the most distinct during the European convergence process as well as supported by its beginning.[6]

In this paper we support the above reasoning by outlining a conceptual background for offshoring, and then briefly surveying the empirical results identifying offshoring driving forces. Then we theoretically motivate a gravity equation model to analyze

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[4] Fragmentation and offshoring in electrical machinery are the most salient, while intrasectoral input-output relationships across borders are weak in the transport equipment sector. In addition, the basic features of international fragmentation are detected in the chemical and material sectors (Kimura et al., 2008).

[5] This is in the spirit of the notion of capital goods variety describing an economy's state of technology, as proposed in Romer (1990) and tested in Frensch and Gaucaite Wittich (2009).

[6] On the earlier stage of the European integration among the EU-15 countries Chen and Novy (2011) show that during 1999-2003 cross-country trade integration was lower for those countries that joined the EU most recently and that have not abolishes physical border controls.

gross trade flows related to offshore activities, based on Haveman and Hummels (2004). Our specification is rooted in incomplete specialization, with complete specialization as a limiting case that views bilateral gravity equations as statistical relationships constrained on countries' multilateral specialization patterns within the international production chain. This view reveals countries' multilateral specialization incentives as driving bilateral trade related to offshore activities, corresponding to and competing with the role of multilateral trade resistance. Our results support the evidence for offshoring activities across Europe, driven by countries' multilateral specialization incentives, as expressed by relative (to the rest of the world) supply-side country differences. Further interpretation of the results in the spirit of Grossman and Rossi-Hansberg (2008) and Bergin et al. (2011) suggests links to the labor market effects in both "old" and "new" EU members.

The rest of the paper is organized as follows. Section 2 includes a conceptual background for offshoring and earlier empirical results. In section 3, we theoretically motivate a gravity equation model. We formulate our estimable specification and describe our data in section 4. Empirical results with a robustness analysis are presented in section 5, and then we finally provide conclusions in section 6.

2 Conceptual and empirical background

2.1 Approaches and empirics

In theoretical models, the potential determinants of specialization within the international production chain and offshoring include both comparative advantage and economies of scale. Approaches associated with new trade theory model imperfect competition on the level of intermediate goods (Egger and Falkinger, 2003; Fujita and Thisse, 2006; Hayakawa, 2007). Economic geography models (Amiti, 2005; Robert-Nicoud, 2008) aim at resolving the locations of component producers along with the trade-off between agglomeration tendencies and factor prices.

Most prominently, however, the rationalization of patterns of production and trade in intermediate products in the presence of offshoring proceeds using traditional models of international trade, which explicitly assume the existence of costs of coordinating international production networks. Models of offshoring can be found to be grounded in Heckscher-Ohlin factor proportions models of trade (Arndt, 1997; Jones and Kierzkowski, 2001; Deardorff, 2001; Egger, 2002; Egger and Falkinger, 2002), in extended-factor-proportions models of both trade and FDI (Feenstra and Hanson, 1996), and in specific-factor models (Kohler, 2004). Accordingly, international incentives for the specialization of tasks are given by country differences in terms of relative factor endowments or, absent factor price equalization, in terms of factor prices. This was proposed in Grossman and Rossi-Hansberg (2008), who identify individual tasks as prone to fragmentation and potential offshoring that may be part of the production processes of quite diverse products. From the point of view of capital-rich and / or skill-rich economies, this means that any routine task in any production can potentially be offshored. Assuming that firms are able to use their own technology whenever they opt to offshore parts of production and the cost of heterogeneity of offshoring across a continuum of tasks, Grossmann and Rossi-Hansberg (2008) demonstrate that the costs of offshoring *versus* wage differences drive the international division of the production chain.[7]

Empirical evidence that looks at offshoring determinants is mixed. Analyzing a subset of offshore activities in terms of the U.S. inward *processing trade* with the EU,[8] 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.” Egger and Egger (2005) examine bilateral outward and inward processing exports and imports of the pre-1995 EU-12 economies. They find that real effective exchange rates and partner countries’ level of corporate taxes on profits and earnings are key determinants of EU-12 outward and inward processing trade, while for outward processing trade, infrastructure variables in the partner country are also very important. Egger and Egger (2003) broaden the scope of the analysis and show that important roles for Austrian offshoring to the CEE and the former Soviet Union was played by declining tariffs and unit labor costs in the two regions. Marin (2006) presents empirical evidence for the role of institutional influences on offshoring across Europe, based on Austrian and German firms’ survey data. Finally, 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. Against the support from the previous literature, they interpret their results as indicating evidence for the existence of offshoring activities within international machinery production networks in East Asia, but not in Europe.

[7] Assuming firm-level technologies opens the possibility for activities not related to offshoring to be done subject to technological differences across countries. Thus, there need not be factor-price equalization, but on the contrary factor-price differences may exist to be exploited by offshoring activities.

[8] *Inward processing* imports are intermediate goods imports for further processing at home, after which goods are re-exported (as inward processing exports) under tariff exemption. *Outward processing* exports are intermediate goods exports to be further processed in a foreign country, after which goods are re-imported (as outward processing imports) under tariff exemption.

2.2 Gravity

When searching for evidence for and determinants of offshoring, in virtually all the papers mentioned above, a bilateral gravity framework for analyzing gross trade flows related to offshoring activities (i.e., processing trade, trade in parts and components, etc.) is set up in a way that encompasses an eclectic combination of the determinants spelled out in competing theories to empirically determine which of them is more important. Apart from exporter and importer market sizes, supply-side country differences or similarities, proxied by the absolute values of differences in per capita incomes or wages between exporter and importer countries, are supposed to catch factor-proportion influences relevant from the perspective of comparative advantages *versus* new trade theory or economic geography influences. As in Kimura et al. (2007), it is then tempting to formulate prior expectations on the coefficient for per capita income differences according to alternative trade theories: the existence of two-way trade driven by fragmentation and offshoring within international production networks *via* comparative / location advantages is assumed to imply a positive coefficient for the per capita income gap. The existence of horizontal intra-industry trade driven by new trade theories *à la* Krugman (1980) would imply a negative coefficient for the per capita income gap.[9]

Factor proportion theories of trade are incomplete specialization models while new theories of trade yield a complete specialization. Testing the influences of various trade theories against each other within the same gravity specification presupposes that these theories can be reduced to the same gravity specification. However, based on Haveman and Hummels (2004), we argue that gravity equations augmented by *ad-hoc* supply-side country differences are mis-specified since they neglect the key issue of specialization. To see this, consider that multilateral gravity equations describing a country's gross trade flows with the rest of the world can be shown to be expenditure equations for importers and allocation equations for exporters (Baldwin and Taglioni, 2006).

[9] This procedure is in fact not at all confined to the offshoring part of the gravity literature, for more detail, see Frensch, 2010a.

According to Haveman and Hummels (2004), due to the adding-up constraints of countries' expenditure systems, for a world with more than two countries a combination of four assumptions suffices to derive the simplest possible bilateral gravity structure. These conditions are: (i) trade is only in final goods, (ii) trade is frictionless and balanced, (iii) preferences over final goods are identical and homothetic, and (iv) each good is produced in and exported out of only one country, independent from the details on the supply side that give rise to this complete specialization. Under these conditions, bilateral trade is simply a log-linear equation in both countries' incomes, and there is no scope for "augmenting" the gravity equation, e.g. by adding absolute values of differences in per capita incomes.

Accordingly, any scope for augmenting the simplest gravity relationship means that the assumptions (i)–(iv) are violated. In reviewing the literature, Frensch (2010a) finds that violating any of the assumption (i)–(iii) while keeping the three others may result in a scope for augmenting the simple bilateral gravity equation by country characteristics, but never by country differences. Specifically, Harrigan (1995) suggests that theory predicts links between intermediate goods trade and the importer country's structure of production, expressed in terms of the capital-output ratio. However, the author finds his specified econometric model outperformed by a traditional, non-augmented gravity equation with importer country fixed effects. As shown in the next section 3, admitting trade also in intermediate goods does not on its own (i.e., under the assumptions of full specialisation, identical homothetic technology and frictionsless trade) generate bilateral gravity equations augmented by supply-side country differences. Thus, negative coefficients for per capita income differences in augmented gravity equations describing gross trade flows generated by outsourcing simply cannot indicate the presence of new trade theory influences on the data that would be rooted in complete specialization. In fact, as will follow from the analysis below, a gravity specification describing outsourcing-generated trade flows as log-linear in both country sizes and absolute country income differentials does not describe the data well against any theoretical model of trade, i.e., it is mis-specified.

3 Trade in parts and components with incomplete specialization

While parts and components are often considered as differentiated products, much of this differentiation is in fact standardization on demand, and need not reflect the market power of the supplier.[10] From this point of view, different parts and components are homogenous across potential suppliers from potentially different source countries, and some parts and components may well be exported by more than one country. Consequently, it might be more fruitful to analyze the parts and components gross trade flows within an incomplete specialization framework compatible with factor proportions theories of trade.

Under complete specialization analyzing gross trade flows is not informative about the specific driving forces connected to new trade theories or economic geography. This is true even when complete specialization is embedded into factor proportions theory as in Helpman and Krugman (1985). On other hand, pure incomplete specialization *à la* Heckscher-Ohlin presumes that each good is always produced in each country. However, with respect to offshoring activities, this is not necessarily true before offshoring. More relevant are incomplete specialization theories that leave room for extensive margin adjustment, as in Grossman and Rossi-Hansberg (2008). In their concept firms' decisions about offshoring are embedded in an environment of incomplete factor price equalization, firm-level technologies, and the cost heterogeneity of offshoring across a continuum of tasks.

For this, we extend the Haveman and Hummels (2004) approach of trade in final goods to allow for trade in intermediate goods subject to incomplete specialization, where the existence of intermediate goods will reflect the horizontal or vertical fragmentation of production. Our extension to intermediate goods – parts and components – is also appealing because Bridgman (2012) shows in a simulated three stage vertical specialization trade model with manufactured parts (along with raw materials and final goods) that falling trade costs explain much of the observed growth in overall and vertical specialization trade.

[10] Within Rauch's (1999) classification, these goods would be neither reference priced nor sold on an organized exchange.

3.1 Multilateral trade with horizontal fragmentation

Maintaining assumption (ii) from section 2.2, we assume that there are no trade frictions and all trade is balanced. Production is horizontally fragmented in the spirit of Grossman and Rossi-Hansberg (2008), where firm-specific production technologies are available to all countries but they are used by firms in these countries rather than by countries themselves.[11] Hence, n tasks are carried out, each of which results in a tradable intermediate good – a part or component. One final good is assembled from these n parts or components. Compatible with assumption (iii), all production is subject to homothetic derived demands, such that all variables can be studied in nominal terms: C is consumption or use, X production, Y income, EX exports, and IM imports. Subscripts denote countries, superscripts goods. Given the existence of n intermediate goods and neglecting primary inputs, value-added Z in each country j is distributed over two stages of production:

$$Z_j^k = X_j^k = \delta_j^k Y_j \qquad \text{for } k = 1, ..., n \tag{1}$$

and

$$Z_j^{n+1} = X_j^{n+1} - \sum_{k=1}^{n} C_j^k = \delta_j^{n+1} Y_j, \text{ with } \sum_{k=1}^{n} \delta_j^k + \delta_j^{n+1} = 1 \tag{2}$$

such that

$$\sum_{k=1}^{n} Z_j^k + Z_j^{n+1} = Y_j \ . \tag{3}$$

With homotheticity in production,

$$C_j^k = \phi_j^k X_j^{n+1} \qquad \text{for } k = 1, ..., n \ . \tag{4}$$

With (2) and (3), the value-added in producing the final good can be written as

$$Z_j^{n+1} = \delta_j^{n+1} Y_j = X_j^{n+1} - \sum_{k=1}^{n} C_j^k \, X_j^{n+1} - X_j^{n+1} \sum_{k=1}^{n} \phi_j^k$$

[11] Appendix A considers the alternative of vertical fragmentation.

$$= X_j^{n+1}\left(1 - \sum_{k=1}^{n} \phi_j^k\right) \qquad (5)$$

such that

$$X_j^{n+1} = \frac{\delta_j^{n+1} Y_j}{1 - \sum_{k=1}^{n} \phi_j^k} \quad . \qquad (6)$$

Equation (6) describes the output of the final good in country j. Demand is given by spending total income on the final good, $C_j^{n+1} = Y_j$. Accordingly, net exports of the final good are described by

$$NE_j^{n+1} = X_j^{n+1} - C_j^{n+1} = \frac{\delta_j^{n+1} Y_j}{1 - \sum_{k=1}^{n} \phi_j^k} - Y_j = \left(\frac{\delta_j^{n+1}}{1 - \sum_{k=1}^{n} \phi_j^k} - 1\right) Y_j \quad . \qquad (7)$$

For parts and components, output is given in (1) and use in (4), which also holds for the world as a whole, $C_w^k = \phi_w^k X_w^{n+1}$. With final goods output as described in (6),

$$\frac{C_j^k}{C_w^k} = \frac{\phi_j^k}{\phi_w^k} \frac{\delta_j^{n+1} Y_j}{\delta_w^{n+1} Y_w} \frac{1 - \sum_{k=1}^{n} \phi_w^k}{1 - \sum_{k=1}^{n} \phi_j^k} \quad , \quad \text{for } k = 1, \dots, n \quad .$$

This expression can be simplified using two characteristics of world trade: first, we know from the world version of (7) that $1 - \sum_{k=1}^{n} \phi_w^k = \delta_w^{n+1}$, as world trade in final goods must be balanced. Second, world output of any good is equal to world use, such that

$$C_j^k = \frac{\phi_j^k}{\phi_w^k} \frac{\delta_j^{n+1} Y_j}{Y_w} \frac{}{1 - \sum_k \phi_j^k} X_w^k$$

$$= \frac{\phi_j^k}{\phi_w^k} \frac{\delta_j^{n+1} Y_j}{Y_w} \frac{}{1 - \sum_k \phi_j^k} \delta_w^k Y_w$$

$$= \frac{\phi_j^k}{\phi_w^k} \frac{\delta_j^{n+1}}{1 - \sum_k \phi_j^k} \delta_w^k Y_j.$$

Country *j*'s net exports of part or component *k* are described by

$$NE_j^k = X_j^k - C_j^k, \qquad \text{for } k = 1, \dots, n$$

Hence,

$$NE_j^k = \delta_j^k Y_j - \frac{\phi_j^k}{\phi_w^k}\frac{\delta_j^{n+1}}{1-\sum_k \phi_j^k}\delta_w^k Y_j = \left(\delta_j^k - \frac{\phi_j^k}{\phi_w^k}\frac{\delta_j^{n+1}}{1-\sum_k \phi_j^k}\delta_w^k\right) Y_j \,. \qquad (8)$$

As we are only interested in parts and components trade, we may simplify (8) by assuming balanced final goods trade for each single country,[12] such that

$$NE_j^k = (\delta_j^k - \frac{\phi_j^k}{\phi_w^k}\delta_w^k)Y_j, \quad \text{for } k = 1, \dots, n \,. \qquad (9)$$

On the basis of (9), countries export a specific part or component if they devote a greater share of the value-added to producing this good than the rest of the world ($\delta_j^k > \delta_w^k$), or if their part or component is more productive in terms of final output than the rest of the world ($\phi_j^k < \phi_w^k$). With firm-specific technologies that are identically available everywhere in the world for offshoring activities, as assumed in Grossman and Rossi-Hansberg (2008), we can further simplify (9) to

$$NE_j^k = (\delta_j^k - \delta_w^k)Y_j, \qquad \text{for } k = 1, \dots, n \qquad (10)$$

Summing over all *k*, exports of parts and components of the country *j* to the world are

$$NE_j = Y_j \sum_{k=1}^{n}(\delta_j^k - \delta_w^k) \,. \qquad (11)$$

As parts and components are indeed homogeneous, they are either exported or imported but not both, and positive NE_j indicates a country's exports. Selecting export items with positive net exports into the set K_{EXj}, country *j*'s multilateral parts and components exports, are

$$EX_j = Y_j \sum_{k \in K_{EX_j}}(\delta_j^k - \delta_w^k) \qquad (12)$$

[12] Empirically, assuming balanced trade does not usually make a significant difference; see Helpman (1987).

As in Haveman and Hummels (2004) for trade in final goods, multilateral parts and components exports, generated by horizontal fragmentation and offshoring, are log-linear in income (Y) and a *specialization pattern*, $\left(\delta_j^k - \delta_w^k\right)$, and they exhibit a unitary elasticity with respect to country of origin income, provided the specialization pattern is uncorrelated with income. Analogously for imports,

$$IM_j = Y_j \sum_{k \in K_{IM_j}} (\delta_w^k - \delta_j^k) \ . \tag{13}$$

In the next section, we argue that countries' bilateral parts and components trade under incomplete specialization is driven by multilateral specialization incentives. These incentives exactly match multilateral specialization patterns in the form of deviations from the world average as described in equations (12) and (13). Specifically, the specialization patterns take the form of countries' deviations from capital-labor ratios (proxied by GDP per capita) or, absent factor price equalization, deviations of wages from the world average.

3.2 Bilateral trade

With complete specialization, each part or component is exclusively supplied by one country. Hence, good *k* imports of country *i* from the world are in fact the good *k* imports of country *i* from some country *j*. As country *i* uses all the parts and components supplied by country *j*, this decomposition of multilateral trade straightforwardly implies bilateral trade in parts and components with complete specialization as log-linear in both countries' incomes, as shown in Haveman and Hummels (2004) for trade in final goods.[13]

With incomplete specialization and costless trade, it is not possible to analytically decompose (12) and (13) into bilateral trade relationships. If there are multiple producers of an identical part or component willing to sell at the same price, importers will be indifferent between them and bilateral trade is indeterminate.

[13] Chaney (2008) demonstrates that bilateral gravity continues to hold under conditions of complete specialization, even when not every good produced is traded.

However, trade is not costless and the way to resolve the indeterminacy is by letting importers choose partners to minimize trade costs. For trade in final goods, this is pursued in Haveman and Hummels (2004), Bergstrand (1989), Eaton and Kortum (2002), and Chor (2010). Haveman and Hummels (2004) suppose that trade barriers are rising in distance so that importers of homogeneous goods buy only from the closest, and therefore cheapest, source of supply. For simplicity, they introduce a simulation to allow bilateral trade costs to become arbitrarily small while retaining the cost ranking of partners such that equilibrium prices are unaffected but bilateral indeterminacy is resolved.

By explicitly incorporating trade costs, Bergstrand (1989) was the first to succeed in analytically motivating bilateral gravity equations within an incomplete specialization multilateral world where the production of two goods is capital- or labor-intensive. Trade costs are modeled as iceberg-type loss of output, i.e., trade costs are proportional to the costs of production, and are thus also either capital- or labor-intensive for the two goods. Increasing the exporting country's capital-labor ratio then lowers the opportunity cost of exporting capital-intensive products *via* decreasing trade barriers for capital-intensive goods relative to labor-intensive goods. Accordingly, the simple gravity equation can be augmented for exports of capital (labor)-intensive goods to react positively (negatively) to the exporter's capital-labor ratio. This concept of explicitly modeling iceberg trade costs within an incomplete specialization multilateral world to motivate bilateral gravity equations augmented by origin country-specific characteristics is again taken up in Eaton and Kortum (2002) and especially in Chor (2010) who extends Eaton and Kortum's Ricardian model to also account for country differences in endowments and institutions.

However, within our offshoring context, we propose a different approach towards solving the bilateral trade indeterminacy in an incomplete specialization multilateral world. Specifically, as in Grossman and Rossi-Hansberg (2008), we refrain from any attempt to represent the costs of offshoring by iceberg costs (see also Marin, 2006, and Holweg et al., 2011). Rather, we will account for offshoring costs in terms of fixed effects only in the econometric model below. Thus, at this stage, we make no attempt to analytically solve the bilateral trade indeterminacy, but rather view bilateral trade equations as statistical relationships constrained on countries' multilateral specialization patterns. In fact, this view will help reveal countries' multilateral specialization incentives as driving bilateral trade, parallel to and competing with the role of multilateral trade resistance in bilateral trade.

In particular, it is possible to formulate two conditions, subject to which bilateral parts and components trade relationships will be distributed in a statistical sense in a sample of countries.[14] The conditions are:

I. For bilateral trade to occur, countries' specialization patterns as described in (12) and (13) must be complementary: there should be at least one *k* that is both exported by country *j* and imported by country *i*.

II. Equations (12) and (13) describe countries' multilateral trade, i.e., the expected values of bilateral relationships. Thus, (12) and (13) can be expected to be met on the average of all bilateral trading relationships.

These two conditions yield predictions for bilateral trade relationships: larger countries trade more in the average of all their trading relationships. In a sample of heterogeneous countries, larger countries can indeed be expected to trade more with each other. Hence, the bilateral parts and components trade volume will increase with the product of trading countries' incomes $Y_j \times Y_i$. Further, countries that are more specialized against the world average trade more in the average of all their bilateral relationships. Thus, in a sample of heterogeneous countries, countries more specialized *vis-à-vis* the world can be expected to trade more parts and components with each other provided that their specialization is complementary.

Incentives for incomplete specialization and trade with parts and components are supply-side country differences in factor endowments or wages, where capital-labor ratios can be proxied by average GDP per capita. Use of the specific variables raises some issues, though. First, although our theoretical background is grounded in incomplete specialization models such as Heckscher-Ohlin, the literature supplies ample motivations for the breakdown of factor price equalization across countries, be it for the

[14] This is also true for the vertical fragmentation case described in Appendix A.

presence of transport cost barriers or for technological differences in activities other than those related to outsourcing (Grossman and Rossi-Hansberg, 2008). Second, using GDP per capita proxy might create a problem at the estimation stage due to potential correlation with the dependent variable. For both reasons we prefere to employ data on wages in pairs of exporting (w_j) and importing (w_i) countries to accurately capture supply-side country differences and to use GDP per capita data for robust check. Consistent with specialization patterns described relative to the world, bilateral parts and components trade volumes can be expected to increase with the product of countries' respective supply-side differences against the world (w_w), i.e., $|w_j - w_w| \times |w_i - w_w|$. In fact, this conforms to the procedure in Haveman and Hummels (2004) to describe incomplete specialization influences on final goods trade.

However, the problem with the above formulation is the potential absence of complementary specialization: relative supply-side country differences $|w_j - w_w| \times |w_i - w_w|$ predict large trade volumes also for countries that lack complementary specialization. There are (at least) two ways of correcting for this by including additional variables. First, absolute supply-side country differences, $|w_j - w_i|$, can be introduced. However, doing so in a log-linear fashion within a gravity framework implies substitutability between countries' complementary specialization and their relative supply-side country differences $|w_j - w_w| \times |w_i - w_w|$, which would actually again amount to misspecifying parts and components gravity with respect to the underlying conditions I) and II) above. Second, rather than modeling the complementarity of countries' specialization patterns and relative supply-side country differences as substitutes, another possibility is to assign dummies to bilateral parts and components trade relationships between countries that are expected to be characterized by complementary specialization. This assignment is done based on *a priori* information about values of the supply side country differences, e.g., on the basis of $w_j > w_w$ and $w_i < w_w$.

Specifically, within a panel of EU-25 countries, bilateral trade in parts and components ($EX(PC)_{ji,t}$) can be described, without accounting for trade barriers, by

$$\log EX(PC)_{ji,t} = \beta_0 + \beta_1 \log(Y_{j,t} \times Y_{i,t}) + \beta_2 \log\left(\left|w_{j,t} - w_{w,t}\right| \times \left|w_{i,t} - w_{w,t}\right|\right) + \\ +\beta_3 Dummy(EU15/10)_{ji} \log\left(\left|w_{j,t} - w_{w,t}\right| \times \left|w_{i,t} - w_{w,t}\right|\right), \qquad (14)$$

where $DummyEU15/10$ equals one for trade relationships between an EU-15 and an EU-10 country and zero otherwise.

4 Trade barriers and gravity specification for bilateral trade in parts and components with incomplete specialization

4.1 Trade barriers

Traditional gravity approaches explicitly cope with different trade barriers, i.e., distance (to proxy transport costs), geographic contiguity, cultural proximity, and the like. However, the current discussion on using gravity frameworks (Cheng and Wall, 2005; Baldwin and Taglioni, 2006) recommends making use of the panel structure of available trade data, and specifically doing so by subsuming trade barriers under time-invariant country-pair specific as well as country-pair invariant time-specific omitted variables, to be controlled for by appropriate fixed effects. In terms of trade barriers, this procedure has the advantage over traditional procedures of also controlling for countries' multilateral trade resistance.[15] Hence, the procedure has the intuitively appealing notion that bilateral trade barriers should always be measured relative to the world, in a similar fashion as with supply-side country differences as trade incentives described above. An implication is that the higher the trade barriers of a country with the world for fixed trade barriers with a specific country, the more the country will be driven to trade with this specific country.

4.2 Gravity specification

The estimable specification is rooted in our model described in section 3 and accounts for the issues raised above in section 4.1. It takes the following simple form of a gravity model:

$$\log EX(PC)_{ji,t} = \beta_0 + \beta_1 \log(Y_{j,t} \times Y_{i,t}) + \beta_2 \log\left(\left|w_{j,t} - w_{w,t}\right| \times \left|w_{i,t} - w_{w,t}\right|\right) +$$

$$+\beta_3 Dummy(EU15/10)_{ji} \log\left(\left|w_{j,t} - w_{w,t}\right| \times \left|w_{i,t} - w_{w,t}\right|\right) + c_{ji} + k_t + \varepsilon_{ij,t}. \qquad (15)$$

[15] Anderson and van Wincoop (2003).

Specification (15) is estimated on unbalanced panel data with a mean time length of about 10 years.[16] In specification (15) we use time-invariant asymmetric country-pair specific effects (c_{ij}) to capture the fixed effects between exporting and importing countries that do not change over time.

Exogenous (to our model), technical progress through decreasing service link costs and fragmentation can be represented by time effects. Nevertheless, our motivation of offshoring does not imply a high degree of substitutability but rather complementarity between technical progress and the possibility of using supply-side country differences. Hence, we model this by interacting the combined variable $DummyEU15/10_{ji}\log\left(\left|w_{j,t}-w_{w,t}\right|\times\left|w_{i,t}-w_{w,t}\right|\right)$ with time-period effects. For this purpose, we divide the sample period (1992–2008) into five sub-periods of (almost) equal length.[17]

In order to obtain consistent estimates we employ a dynamic panel-data model following the approaches of Arellano and Bond (1991); Arellano and Bover (1995); Blundell and Bond (1998); and Blundell et al. (2000). The estimator is implemented in STATA 12 as a *xtdpd* command and it uses moment conditions in which the lagged levels of the dependent and predetermined variables serve as instruments for the differenced equation. We begin our estimation by performing 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-Bover-Blundell technique.

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[16] One drawback of using panel data lies in the potential non-stationarity of trade and income data, implying likely biased estimates with fixed effects models. However, since the mean time length of our panel is about 10 years the unit root is not a real issue. Also, by the very construction of gravity equations, bilateral trade is explained by a combination of countries' aggregate output, introducing cross-sectional correlation. Using cross-sectionally augmented panel unit root testing methods, Fidrmuc (2009) confirms that trade and income variables used in gravity regressions are integrated of order one. However, Fidrmuc (2009, p. 436) also finds that although fixed effects estimators may be biased, they are not only asymptotically normal and consistent with large panels but also perform "relatively well in comparison to panel cointegration techniques (FMOLS and DOLS)" in finite samples. The study concludes that the potential bias of fixed-effects gravity estimators are rather small.

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

As the test confirms the endogeneity of explanatory variables we proceed with instrumentation. We estimate the theoretically motivated specification (15) 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. This is done because some of the right hand side variables are correlated with the dependent variable. Specifically, let us note that GDP by standard identities contains corrections for international trade flows and therefore using a GDP measure, either in absolute values or scaled per capita values, would create problems even in a panel setting. 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. Our estimation approach controls for the potential endogeneity of explanatory variables and performs well even with low-order moving average correlations in error terms or predetermined variables as in Blundell and Bond (1998).

4.3 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. The data were obtained from the BACI database drawn from the United Nations COMTRADE data; details on the BACI database are provided by Gaulier and Zignago (2010). The definition of the parts and components of capital goods follows the BEC categorization of UN Statistics. The details on the data and variables used are given in Table 1.

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 (2010b), 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 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. The computations of both extensive and intensive margin measures are performed on the basis of the BACI Database described in Gaulier and Zignago (2010).

Table 1 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	BACI	Levels: 93,660 0.0 7.12e07 Logs: 6.36 0.0 18.1
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*	BACI, own computation	Levels: 65.1 0.0 629 Logs: 2.5 0.0 6.4
Intensive margin of $EX_{ji,t}$ *(PC)*	Intensity of parts and components exports from country *j* to country *i* at time *t*	BACI, own computation	Levels: 508.3 1.0 1.37e06 Logs: 3.8 0.0 14.1
Y_j, Y_i	Export and import, country GDP in current dollars	*World Development Indicators 2011*	Levels: 9.8e05 1172 1.4e07
y_j, y_i	Export and import, country GDP per capita in current dollars	*World Development Indicators 2011*	Levels: 20,504 260 93,017
y_w	World average GDP per capita in current dollars	*World Development Indicators 2011*, own computation	Levels: 16,662 10,042 25,566
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
p_i	Country population in millions	*World Development Indicators 2011*	Levels: 54.2 0.2 1,354

Further, Y_j and Y_i are exporter and importer GDP at current prices, respectively. Similarly we employ exporter and importer GDP per capita at current prices as an alternative measure of the supply-side country differences. Both GDP-related data were obtained from the World Development Indicators (accessed via the DCI database). Our primary measure of supply-side country differences is wages in exporting (w_j) and importing (w_i) countries and they are measured as the annual wage average in the manufacturing sector of the exporting (importing) country j (i) at the specific year t. For each country an average wage in the manufacturing sector in the local currency was converted into USD. The data were obtained from LABORSTA (International Labor Office statistical databases, http://laborsta.ilo.org/).

World GDP per capita at current prices and world average wage (w_w) is measured as the mean GDP per capita in the world and the mean wage in the world, respectively; the world is defined by our full reporting sample described in Appendix Table B.1. Analogously to a simple mean we also construct weighted averages of the world GDP per capita and wages 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 GDP per capita and wages, $|w_j - w_w| \times |w_i - w_w|$. Given that the specification (15) is rooted in models of incomplete specialization and trade, such as Heckscher-Ohlin, existing wage differences may be subject to factor price equalization tendencies by the very offshoring trade they induce.[18] 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.

The time-specific effects in (15) 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.

[18] Much of the offshoring literature is in fact on these labor market effects; see, e.g., Geishecker and Görg (2008).

5 Empirical Results

5.1 *A priori* expectations and benchmark results

Our key results are based on estimates from specification (15) that are explicitly rooted in incomplete specialization. Hence, we can form *a priori* expectations on some coefficients. Since the bilateral parts and components trade volume will increase with the product of trading countries' incomes we expect that $\beta_1 > 0$. As equations (12) and (13) describe the expected values of bilateral trade relationships, we may even expect β_1 to equal one, provided the extent of specialization is uncorrelated with income.

We cannot form an *a priori* expectation of β_2 without further information on the sample of countries: if the sample is heterogeneous in terms of complementary specialization, we expect $\beta_2 > 0$. If the sample is sufficiently homogenous, with, say, all $w_i > w_w$, then there is no reason to assume the majority of country pairs to be complementarily specialized. In this case higher deviations of both countries' specialization incentives from world averages, i.e., higher $|w_j - w_w| \times |w_i - w_w|$, will generate less parts and components trade, such that $\beta_2 < 0$.

Finally, if a complementary specialization can be derived from the data then the dummy variable $Dummy\mathrm{EU15/10}$ would capture the "right" country pairs with complementary specialization. In that case, and based on prior information, we expect $\beta_3 > 0$. For the natural limiting case of complete specialization, we would not find specialization patterns to play any role, in which case $\beta_2 = \beta_3 = 0$.

We introduce our benchmark results based on specification (15) in the first columns of Table 2 and 3 (flows), where we present the estimated coefficients for the dependent variables of bilateral parts and components trade introduced in section 4.3. Each table contains estimates for a specific variable described earlier that represent supply-side country differences: wages (Table 2) and GDP per capita to proxy capital-labor ratios (Table 3). Results for both types of variables are not materially different. Key fact is that our results provide evidence for offshoring activities generating 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.

Table 2 Parts and components exports, w=wages (simple world averages)

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

Notes to Tables 2–5: Variables are defined in Table 1. Fixed effects not reported, *t*-statistics in parentheses. * (**, ***) indicate significance at 10 (5, 1) percent.

Statistically significant coefficients β_1 demonstrate that larger countries trade more with each other. Second, negative coefficients β_2 confirm 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. However, comparing coefficients β_2 and β_3 points to relative supply-side country differences as driving offshoring activities across Europe compatible with models of incomplete specialization and trade, specifically between the original EU-15 and the ten accession countries (EU-10), rather than within each of the two country groups. Third, technical progress in terms of declining service link costs and ongoing fragmentation—as captured by the sub-period dummies—appears to positively influence offshoring: with the exception of the final sub-period, for EU-15 / EU-10 pairs, β_3 is increasing slowly over time. The slight decrease of the β_3 coefficients 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). As foreign-owned subsidiaries become a part of the innovation systems and 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.

Table 3 Parts and components exports, w=GDP per capita (simple world averages)

		Flows	Extensive Margin	Intensive Margin
log Y_j Y_i		0.728*** (0.019)	0.262*** (0.011)	0.465*** (0.013)
log ($\|w_j - w_w\| \times \|w_i - w_w\|$)		–0.069*** (0.027)	–0.020 (0.014)	–0.049*** (0.017)
log ($\|w_j - w_w\| \times \|w_i - w_w\|$) for EU-15 / EU-10 pairs	1992–1995	0.161*** (0.024)	0.108*** (0.014)	0.053*** (0.014)
	1996–1998	0.176*** (0.024)	0.117*** (0.014)	0.059*** (0.014)
	1999–2001	0.193*** (0.024)	0.124*** (0.014)	0.070*** (0.014)
	2002–2004	0.198*** (0.023)	0.126*** (0.013)	0.072*** (0.013)
	2005–2008	0.186*** (0.023)	0.110*** (0.013)	0.076*** (0.013)
N		33,034	33,034	33,034

5.2 Robustness

Tables 2 and 3 already confirm that the relative supply-side country differences that drive offshoring activities and generate trade in parts and components across Europe do not depend on the measurement of these differences, either as wages or as GDP per capita.

As already discussed in Debaere (2003), measuring world averages in relative supply-side country differences matters a lot. So far, world average wages and GDP per capita have been measured as simple averages in the world defined by our full reporting sample described in Appendix Table B.1. Tables 4 and 5 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 2 and 3. Hence, our results are also robust to this change in measurement.

Table 4 Parts and components exports, w=wages (population weighted world averages)

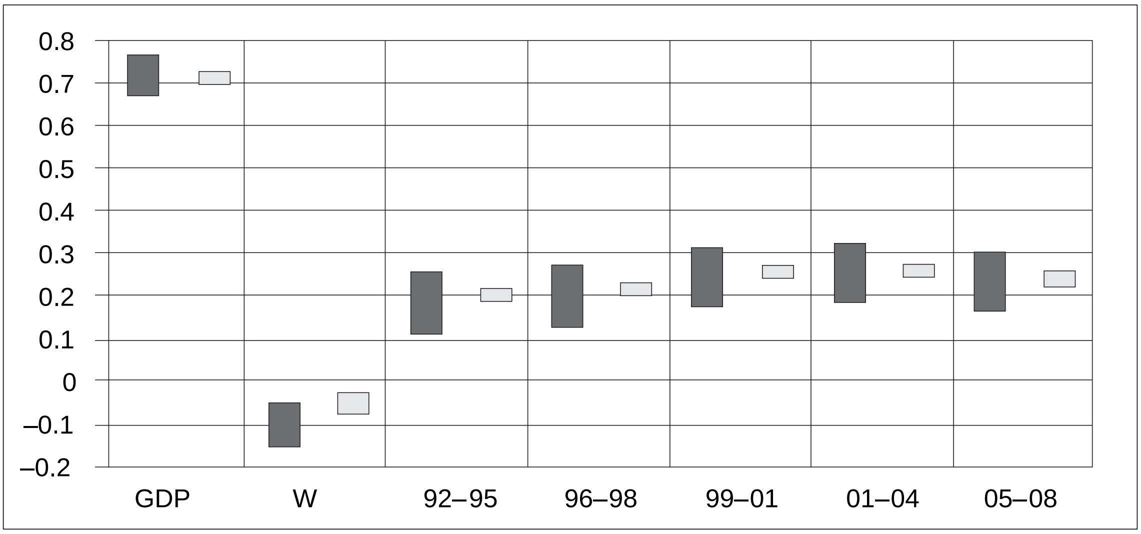
		Flows	Extensive Margin	Intensive Margin
log $Y_j Y_i$		0.711*** (0.007)	0.250*** (0.003)	0.462*** (0.006)
log ($\|w_j - w_w\| \times \|w_i - w_w\|$)		–0.052*** (0.012)	–0.015*** (0.005)	–0.037*** (0.011)
log ($\|w_j - w_w\| \times \|w_i - w_w\|$) for EU-15 / EU-10 pairs	1992–1995	0.200*** (0.009)	0.111***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

Finally, we complement our robustness results by a statistical comparison of the coefficients derived from the estimated specification (15) where wages serve as a measure for supply-side country differences. These are coefficients presented in Tables 2 (simple averages) and 4 (weighted averages). In Figure 1 we present the plots of the confidence intervals of the above coefficients. Dark and blank bars depict simple and weighted means, respectively. The shapes of the blank bars reflect the lower dispersion due to weighting. The three graphs in Figure 1 show that there is ample overlap of the confidence intervals of coefficients. Hence, our results are in a statistical sense robust to the world average measurement in terms of simple or weighted averages.

Table 5 Parts and components exports, w=GDP per capita (population weighted world averages)

		Flows	Extensive Margin	Intensive Margin
log Y_j Y_i		0.712*** (0.006)	0.256*** (0.002)	0.456*** (0.005)
log ($\lvert w_j - w_w \rvert \times \lvert w_i - w_w \rvert$)		–0.041*** (0.010)	–0.006 (0.004)	–0.035*** (0.009)
log ($\lvert w_j - w_w \rvert \times \lvert w_i - w_w \rvert$) for EU-15 / EU-10 pairs	1992–1995	0.172*** (0.006)	0.112*** (0.002)	0.060*** (0.005)
	1996–1998	0.187*** (0.005)	0.120*** (0.002)	0.066*** (0.005)
	1999–2001	0.203*** (0.005)	0.127*** (0.002)	0.077*** (0.005)
	2002–2004	0.207*** (0.005)	0.129*** (0.002)	0.078*** (0.005)
	2005–2008	0.197*** (0.005)	0.114*** (0.002)	0.083*** (0.005)
N		33,034	33,034	33,034

Figure 1 Comparison of confidence intervals for coefficients in specification (15)



Note: Confidence intervals are labeled in the following way: *GDP* denotes the coefficient of log Y_j Y_i and *W* denotes the coefficient of log ($\lvert w_j - w_w \rvert \times \lvert w_i - w_w \rvert$), where *w* stands for wages. The remaining confidence intervals refer to the coefficients of log ($\lvert w_j - w_w \rvert \times \lvert w_i - w_w \rvert$) for the EU15 / 10 dummy, computed over the specified time periods, i.e., 1992–1995 to 2005–2008.

5.3 Trade margins and further links to the offshoring literature

We decompose the influences on parts and components trade along the two margins of trade, i.e., along *extensive* (number of exported goods) versus *intensive* (average volumes per exported good) import margins, based on the highly disaggregated nature of our original trade data (see Appendix B for data details). This reveals that trade in parts and components due to offshoring activities across Europe is predominantly realized along the intensive margin in response to market size increases, but along the extensive margin in response to stronger relative supply-side country differences, i.e., more offshoring of activities from the EU-15 to the EU-10 in response to stronger relative supply-side country differences means predominantly the offshoring of new activities rather than the extending of the scale of already-offshore activities.

The above results provide important implications in terms of wages. According to Bergin et al. (2011), recent new offshoring from the EU-15 to the EU-10 may, *ceteris paribus,* have increased employment volatility in the new EU. The margin distinction, however, may also be of relevance for wages in the home country. 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 internationally varying labor market effects of offshoring, however. Empirical work on the labor market effects of offshoring has so far been 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, however, 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 service link 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 skill groups hit strongest by offshoring. Labor market effects to the disadvantage of skill groups hit strongest 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 margin, rather than along the intensive margin. With the *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 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 old EU offshoring elsewhere.[19]

[19] Preliminary results in Frensch (2010a) based, however, only on 1992–2004 data on countries’ exports into the EU-15 but not on their imports from the EU-15, suggest that exports of parts and components from east Asia, including China, to EU-15 countries are predominantly realized along the intensive margin, i.e. extending offshoring from the EU-15 to east Asia took place rather by expanding the scale of already offshored activities.

6 Conclusions

This study started by stating that analyzing gross trade flows related to offshore activities by using gravity equations augmented by *ad hoc* measures of supply-side country differences appear to be mis-specified, due to theoretically unmotivated attempts to allow for both complete and incomplete specialization influences on parts and components trade within the same gravity framework. On the other hand, pure incomplete specialization *à la* Heckscher-Ohlin presumes that each good is always produced in each country: with respect to offshoring activities, this is not necessarily true before offshoring. More relevant are incomplete specialization theories that leave room for extensive margin adjustment, as in Grossman and Rossi-Hansberg (2008), where firms' decisions about offshoring and trade in parts and components are embedded in an environment of incomplete factor price equalization, firm-level technologies, and the cost heterogeneity of offshoring across a continuum of tasks.

We develop an appropriate gravity framework, rooted in incomplete specialization, that views bilateral parts and components trade gravity equations as statistical relationships constrained on countries' multilateral specialization patterns. This gravity approach allows offshoring to increase with fragmentation, declining coordination costs, and multilateral incentives to specialization. On the other hand, offshoring declines with multilateral trade resistance.

We apply this framework to a truly Europe-wide sample of countries, while fully accounting for potential tendencies towards factor price equalization *via* trade, and find evidence for offshoring activities across Europe driven by countries' multilateral specialization incentives, as expressed by relative (to the rest of the world) supply-side country differences. In particular, the results do not contradict Grossman-Rossi-Hansberg (2008), and are thus compatible with the view that offshoring need not hurt (low-skill) workers, as long as offshoring relationships get strengthened along the intensive margin as opposed to the extensive margin. Our results, however, suggest that exactly this strengthening along the extensive margin by creating new relationships might have been happening recently when extending offshoring from the EU-15 to the EU-10.

Extensions of this paper may better reflect the influence of declining service link costs, so far proxied by sub-period fixed effects. More realistic attempts should aim at measuring trade liberalization or institutional variation especially with respect to the labor market (Geishecker et al., 2008). Another interesting topic worthy of further research is the connection between service link costs and the complexity of the coordination task, i.e., the variety of production processes and products involved. In the trade and production context, this implies an optimal level of offshoring; in the distribution context, this implies a skill premium that increases in the variety of offshored tasks.

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Appendix A

Trade in parts and components with vertical fragmentation and incomplete specialization

As in section 3, the following argument follows Haveman und Hummels (2004) for final goods. Specialization is assumed to be incomplete and all goods are tradable. There are no trade frictions and all trade is balanced. All variables are in nominal terms.

Production is vertically fragmented into n + 1 tasks along the value chain: n tasks are carried out, using inputs from the respective previous task, to produce tradable intermediate goods. In a final task, a tradable final consumer good is produced. Neglecting primary inputs, all production is according to firm-specific homothetic technologies available everywhere, i.e., we study the case of offshoring within the boundaries of the firm or within production networks. Accordingly, the value-added is distributed over the production of n intermediate and one final product,

$$Z_j^k = X_j^k - C_j^{k-1} = \delta_j^k Y_j, \quad k = 1, \dots, n+1 \quad . \tag{A1}$$

The total income is spent on the consumption of the final good,

$$\sum_k Z_j^k = Y_j = C_j^{n+1} \quad . \tag{A2}$$

With identical homothetic technology,

$$C_j^{k-1} = \phi^k X_j^k \tag{A3}$$

such that

$$X_j^k = \frac{\delta_j^k}{1-\phi^k} Y_j \quad . \tag{A4}$$

Again, (A3) is also true for the world,

$$\frac{C_j^{k-1}}{C_w^{k-1}} = \frac{X_j^k}{X_w^k} = \frac{\delta_j^k Y_j}{\delta_w^k Y_w} \quad . \tag{A5}$$

For the world as a whole, production equals consumption,

$$C_j^{k-1} = \frac{\delta_j^k Y_j}{\delta_w^k Y_w} X_w^{k-1} = \frac{\delta_j^k Y_j}{\delta_w^k Y_w} \frac{\delta_w^{k-1}}{1-\phi^{k-1}} Y_w \tag{A6}$$

such that

$$C_j^k = \frac{\delta_j^{k+1}}{\delta_w^{k+1}} \frac{\delta_w^k}{1-\phi^k} Y_j \quad . \tag{A7}$$

Then, net exports of parts and components out of country *j*,

$$EX_j^{n+1} - IM_j^{n+1} = X_j^{n+1} - C_j^{n+1} = (\frac{\delta_j^{n+1}}{1-\phi^{n+1}} - 1) Y_j. \tag{A8}$$

For the world as a whole, (A8) implies $\delta_w^{n+1} = 1 - \phi^{n+1}$, such that

$$EX_j^{n+1} - IM_j^{n+1} = \left(\frac{\delta_j^{n+1}}{\delta_w^{n+1}} - 1\right) Y_j = \frac{1}{1-\phi^{n+1}} (\delta_j^{n+1} - \delta_w^{n+1}) Y_j \ . \tag{A9}$$

(A4) and (A7) imply net exports of parts and components out of country *j*,

$$EX_j^k - IM_j^k = \frac{1}{1-\phi^k} (\delta_j^k - \frac{\delta_j^{k+1}}{\delta_w^{k+1}} \delta_w^k) Y_j \quad . \tag{A10}$$

With K_{E_j} as the set (or variety) of goods exported out of country *j*,

$$EX_j = Y_j \sum_{k \in K_{E_j}} \frac{1}{1-\phi^k} (\delta_j^k - \frac{\delta_j^{k+1}}{\delta_w^{k+1}} \delta_w^k) \tag{A11}$$

and total parts and components exports (as in section 3) are log-linear in income and a pattern of specialization,

$$log\, EX_j = log\, Y_j + log \sum_{k \in K_{EX_j}} \frac{1}{1-\phi^k} (\delta_j^k - \frac{\delta_j^{k+1}}{\delta_w^{k+1}} \delta_w^k) \ . \tag{A12}$$

Again, as long as the income and specialization pattern are uncorrelated, (A12) gives way to expectations on the behavior of bilateral trade relationships in a sample of countries, to be represented by estimation specification (15).

Appendix B

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 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/class/family/family2.asp?Cl=10) 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*.

Table B.1 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	HU N	*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. Reporter countries 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 (54 countries in all, on average accounting for above 90 percent of reported imports) constitute the "world" for the computation of our world averages.