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European trade in parts and components: searching (for a trade model for searching) for offshoring evidence

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Abstract

Recent empirical studies have been searching for evidence on and driving forces for offshoring. Typically, this search has been conducted by analysing gross trade flows related to offshored activities using gravity equations augmented by *ad hoc* measures of supply-side country differences. This paper suggests that gravity formulations of this sort are potentially mis-specified, due to theoretically unmotivated attempts of allowing for both complete and incomplete specialisation influences on gross trade flows within the same gravity framework. The paper suggests an alternative specification rooted in incomplete specialisation with complete specialisation as a natural limiting case. Results support evidence for offshoring activities across Europe, driven by supply-side country differences compatible with models of incomplete specialisation and trade. Further interpretation of the results in the spirit of Grossman and Rossi-Hansberg (2008) suggests the conjecture that the latest waves of offshoring activities from “old” to “new” EU members may have been more likely to hurt (low-skill) workers in the old EU than offshoring to east Asia.

JEL-Classification: F14, F16, L24

Keywords: Offshoring, gravity

1 Fragmentation, outsourcing, and offshoring

Fragmentation describes the deepening of the division of labour, as already illustrated in Adam Smith's example of the making of pins, by horizontally or vertically splitting the production process into distinct tasks. The division of labour encourages specialisation, deepening the division of labour thus increases incentives towards specialisation, based on either comparative advantage or economies of scale. To realise gains from fragmentation and specialisation, it may pay to break up the spatial concentration of production within a firm or even a single plant: 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.[1]

Apart from potential gains from specialisation, offshoring tasks implies costs of coordinating what is now an international production network rather than a firm or a plant. These coordination or *service link costs* typically entail costs of investment, communication and of trading inputs to and outputs of offshored tasks, i.e., intermediate products, such as parts and components. Straightforwardly, one would expect firms to offshore tasks whenever specialisation gains outweigh the implied service link costs, such that the volume of offshoring should increase with fragmentation, or with declining coordination costs, or with the strength of international incentives to specialisation.

The most noticeable incidents of offshoring have so far been registered 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 neighbours.[2] When considering the evidence of who offshores what to whom, it bears to keep in mind that fragmentation as much as declining service link costs represent technical progress, which is produced in only quite a few industrialised economies of the world.[3] I.e., it is rich country firms that offshore tasks, which tend to be routine, homogeneous, typically intensive in labour or even in low-skill labour (Breda et al., 2008; Kimura, 2006; Sinn, 2005). Case study evidence points to machine building, or capital goods production in general, as the industries experiencing offshoring most pronouncedly.

[1] Hummels et al. (2001) define the related notion of *vertical specialisation* 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. Recent strong growth in world trade (stronger than in world output) has mostly been due to increasing vertical specialisation implying very strong *growth in trade in intermediate goods* used for producing exports of (again) intermediate goods of a "higher" stage or final goods exports (Yi, 2003) in consequence of multilateral trade liberalisation.

[2] 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, basic features of international fragmentation are detected in chemical and material sectors (Kimura et al., 2008).

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

From this description of 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 EU-10, i.e. the central and east European post-2004 EU members (cf. Table B2 in the appendix) to specialise in labour-intensive tasks, the pre-2004 EU members (the EU-15) to specialise in capital-intensive tasks, generating two-way trade in intermediate goods across Europe. How then would production and trade patterns along stages of production in the presence of offshoring look like? As in Sinn (2005), one may assume that the further away from the final product, the less capital or skill intensive production processes are, giving way to a Heckscher-Ohlin type of pattern of trade in intermediate goods according to distance from the final product. Final products would then be assembled in capital rich countries. This picture, of course, may be wrong: assembling components to final products may well be labour rather than capital intensive. Also, new trade theory influences other than comparative advantages may play a role.

This paper is an attempt at contributing to the identification of evidence on and driving forces for offshoring activities. The next section deals with some theoretical background for offshoring, followed by a brief survey of empirical results identifying driving forces, which motivates the question of how to search for evidence on and driving forces for offshoring. Section 3 continues with presenting a typical example of such a search by analysing gross trade flows related to offshored activities using a gravity equation augmented by *ad hoc* measures of supply-side country differences. In section 4, we argue that gravity formulations of this sort are potentially mis-specified, due to theoretically unmotivated attempts of allowing for both complete and incomplete specialisation influences on trade within the gravity framework. In section 5, we suggest an alternative specification rooted in incomplete specialisation with complete specialisation as a natural limiting case. Results support evidence for offshoring activities across Europe, driven by supply-side country differences compatible with models of incomplete specialisation and trade. Further interpretation of the results in the spirit of Grossman and Rossi-Hansberg (2008) suggests the conjecture that recent waves of offshoring activities from “old” to “new” EU members may have hurt (low-skill) workers in the old EU more than offshoring to east Asia.

2 Some theoretical background

Egger and Egger (2005), Baldwin and Robert-Nicoud (2007), and Grossman and Rossi-Hansberg (2008) survey different approaches to modeling the potential determinants of offshoring loosely identified above. Both comparative advantage or economies of scale can be modelled to play a role: new trade theory approaches model imperfect competition on the level of intermediate goods (H. Egger and Falkinger, 2003; Fujita and Thisse, 2006; Hayakawa, 2007), economic geography models (Amiti, 2005; Robert-Nicoud, 2008) aim at resolving locations of component producers along the trade-off between agglomeration tendencies and factor prices. Most prominently, however, the rationalisation of patterns of production and trade in intermediate products in the presence of offshoring proceeds along traditional models of international trade, which explicitly model the costs of coordinating international production networks: without aiming at an exhaustive list, models of offshoring can be found to be grounded in Heckscher-Ohlin factor proportions models of trade (Arndt, 1997; Jones und Kierzkowski, 2001; Deardorff, 2001; H. Egger, 2002; H. Egger and Falkinger, 2002; Jones, 2000), in extended factor proportions models of both trade and FDI (Feenstra und Hanson, 1996), and in specific factor models (Kohler, 2004). Accordingly, international incentives to specialisation on tasks are given by country differences in terms of relative factor endowments or – absent factor price equalisation – factor prices, as recently 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- 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 for cost heterogeneity of offshoring across a continuum of tasks, Grossmann and Rossi-Hansberg demonstrate that costs of offshoring *versus* wage differences drive the international division of the production chain.[4] Offshoring may be attractive, if some factors can be hired more cheaply abroad than at home, but it also is costly, because remote performance of a task limits the opportunities for monitoring and coordinating workers.[5]

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

[5] Rossi-Hansberg (2008) also discuss the distributional implications of this new paradigm of trading tasks; see section 6 below.

3 Empirical results

Analysing a subset of offshored activities, i.e., U.S. inward *processing trade* with the EU,[6] Görg (2000, p. 418) concludes that "the distribution of fragmented production around the globe will be according to countries' comparative advantages." Right on the contrary, exploring textile and apparel trade, 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." Broadening the scope of analysis, Egger and Egger (2005) examine bilateral outward and inward processing exports and imports of the pre-1995 EU-12 economies. They first of all note that changes in outward processing imports are much more dynamic than changes in outward processing exports, perhaps due to increasing foreign processing activities. Distinguishing between groups of explanatory variables (size, relative factor endowments, other cost factors and infrastructure variables), the authors feel enabled to address the question of which type of model (factor proportions theory, new trade theory, or approaches stressing infrastructure expenditures) describes the data best. In the end, the authors find that real effective exchange rates and partner countries' level of 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. The authors interpret this as indicating that for the EU's specialisation in high-quality production stages, small variation in both size or comparative advantage are less relevant.

Considering wider measures than processing trade, de Simone (2007) finds a significant impact of trade in parts and components on the geographical distribution of industrial production across central and eastern Europe. Egger and Egger (2003) show that over the period of 1990–7 Austrian offshoring to central and eastern Europe and the former Soviet Union was extremely dynamic with an average annual increase of 10.7 per cent, with important roles for both declining tariffs and unit labour costs in the eastern economies. Studying east Asian versus European machinery parts and components trade, Kimura et al. (2007) interpret their results (see below) as indicating evidence for the existence of offshoring activities within international production networks in machinery in east Asia, but not so in Europe, driven by supply-side country differences.

How are these empirical results derived? Trade data are usually analysed within gravity frameworks where total export flows from country *j* to country *i* are related to both countries' incomes, all sorts of trade barriers, and occasionally to additional variables related to populations, incomes per capita, and/or the similarity between trading partners.[7] When searching for evidence for and determinants of offshoring, in virtually all papers mentioned above a gravity framework for analyzing gross trade flows related to offshoring

[6] *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.

[7] While empirical gravity approaches have been used with great success since the early sixties, theoretical foundations have been somewhat slower to come by. For a recent survey of the relevant literature, see Stack (2009).

activities (i.e., processing trade, trade in parts and components etc.) is set up that encompasses an eclectic combination of the determinants spelled out in competing theories to empirically determine, which of them is more important: e.g., apart from exporter and importer market sizes, supply-side country differences are supposed to catch factor proportions influences, similarity measures between countries are to reflect new trade theory or economic geography influences, where similarity measures may – as shown below – even be isomorphic to supply-side country differences. Finding significant influences in line with any trade theory on gross trade flows is taken to indicate evidence for the existence of offshoring activities. In addition, authors aim at testing the influences of various trade theories against each other within one and the same gravity specification.

3.1 A traditional augmented gravity account

We consider an example of the approach of analysing parts and components gross trade flows using a particular gravity equation augmented by supply-side country differences. A subsequent critique suggest that gravity formulations of this sort are mis-specified, due to *ad hoc* attempts of allowing for both complete and incomplete specialisation influences on gross trade flows within the gravity framework.

In Kimura et al. (2007), supply-side country differences are proxied by absolute values of differences in per capita incomes between exporter and importer countries to reflect wage differences within an augmented traditional gravity approach to search for evidence of offshoring in east Asian and European machinery separately for the years 1995 and 2003, respectively,

$$\log EX(PCM)_{ji} = \beta_0 + \beta_1 \log Y_j + \beta_2 \log Y_i + \beta_3 \log Dist_{ji} + \beta_4 Lan_{ji} + \beta_5 \log |y_j - y_i| + \varepsilon_{ji} \quad (1)$$

where $EX(PCM)_{ji}$ are exports of machinery parts and components from country j to i. The definition of machinery parts and components follows the authors' own classification of the underlying disaggregated UN ComTrade data. Y_j, Y_i are exporter and importer GDP, respectively; $Dist_{ij}$ is distance between the two capitals; Lan_{ji} is a common language dummy, and $|y_j - y_i|$ denotes the absolute value of the difference in per capita incomes.

Prior expectations on the first four coefficients are straightforward: β_1, β_2, $\beta_4 > 0$, $\beta_3 < 0$. As indicated, gravity frameworks set up for searching for evidence for and determinants of offshoring are often eclectic combinations of determinants spelled out in different trade theories. In line with this, prior expectations on the coefficient for per capita incomes differences, $|y_j - y_i|$, is formulated according to alternative trade theories:

- The existence of two-way trade driven by fragmentation and offshoring within international production networks *via* comparative/location advantages implies 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) implies a negative coefficient for the per capita income gap.

This procedure is in fact not at all confined to the offshoring part of the gravity literature.[8] In part, this may be due to a mixture of the success of incorporating new trade theories into factor proportions aspects (Helpman and Krugman, 1985; Helpman, 1987), which seems to suggest the possibility of differentiating between respective trade determinants within one unified approach, and a lack of differentiating between *gross* and *net* trade flows (see section 4.1).

Table 1: **Gravity regressions (OLS) for parts and components trade among selected East Asian and European countries**

	(1)	(2)	(3)	(4)	(5)	(6)
	East Asia		Europe			
	Parts and components of machinery				Parts and components of capital goods	
Explanatory variables:	1995	2003	1995	2003	1995	2003
Constant	–1.51	–6.02	-25.41^{***}	-21.32^{***}	-26.05^{***}	-19.62^{***}
	(–0.32)	(3.84)	(11.19)	(–8.85)	(–12.78)	(–8.02)
$\log Y_j$	0.67^{***}	0.69^{***}	1.16^{***}	1.02^{***}	1.14^{***}	0.96^{***}
	(5.58)	(6.90)	(34.39)	(20.40)	(24.17)	(17.72)
$\log Y_i$	0.17	0.46^{***}	0.86^{***}	0.86^{***}	0.92^{***}	0.85^{***}
	(1.31)	(4.18)	(17.20)	(14.33)	(19.58)	(15.61)
$\log \lvert y_j - y_i \rvert$	0.50^{***}	0.12	-0.14^{**}	–0.04	-0.16^{***}	–0.067
	(4.17)	(1.20)	(–2.33)	(–1.00)	(–3.53)	(–1.27)
$\log Dist$	-0.66^{***}	-0.63^{***}	-1.12^{***}	-1.25^{***}	-1.16^{***}	-1.23^{***}
	(–2.87)	(–3.32)	(12.44)	(–11.36)	(–12.03)	(–12.35)
Lan	1.07^{**}	1.65^{***}	0.22	-0.55^{***}	–0.065	–0.066
	(2.38)	(5.89)	(1.16)	(–3.06)	(–0.27)	(–0.27)
Observations	72	72	306	306	342	342
Adj. R-squared	0.54	0.52	0.79	0.71	0.79	0.71

Notes: to Tables 1–5: *t*-statistics in parentheses. * (**, ***) indicate significance at 10 (5, 1) per cent. (Parts and components of) capital goods always include (parts and components of) transport equipment. Transport equipment does not include passenger cars. For more details, see Appendix B. The cutoff-value for trade flows is 10,000$. Variables are defined in Appendix Table B3. Export flows, GDPs and the absolute income gap in nominal U.S. dollars.
Notes: Columns (1–4): *t*-statistics in parentheses are imputed from standard errors as presented in the original source (Kimura et al., 2007). Country samples: East Asia is JPN, HKG, KOR, SGP, IDN, MYS, PHL, THA, CHN (9 countries), Europe is AUT, BEL, CHE, DNK, ESP, FIN, FRA, GBR, GER, GRC, IRL, ITA, NLD, NOR, PRT, SWE; (CZE+ SVK), POL (18 countries).
Source: Kimura et al. (2007).
Columns (5–6): Country sample: Europe is AUT, BEL, CHE, DNK, ESP, FIN, FRA, GBR, GER, GRC, IRL, ITA, NLD, NOR, PRT, SWE; CZE, SVK, POL (19 countries).

[8] A typical example can be found in Rault et al. (2009, p. 1551): "Concerning the sign of the difference of GDP per capita, it is positive if the Heckscher-Ohlin (H-O) assumptions are confirmed. On the contrary, according to the new trade theory, the income per capita variable between countries is expected to have a negative impact." In the same spirit, see also P. Egger (2002).

Accordingly, the results of estimating (1), reproduced in columns (1–4) of Table 1, would indicate evidence for the existence of offshoring activities in machine building in east Asia, driven by supply-side country differences compatible with factor proportions models of incomplete specialisation and trade. European results would rather be interpreted to signal the existence of horizontal intra-industry trade in parts and components of machinery, driven by country similarity à la Krugman (1980).[9]

3.2 A critique of the traditional augmented gravity account

Both sample selection and the augmented traditional gravity specification chosen in (1) are open to criticism. Within Europe, there is significantly more variation in relative factor endowments or factor prices than represented in the European sample of Table 1: as a group, the ten new EU member states from central and eastern Europe (EU-10) feature significantly lower capital-labour endowments or wages than the longer standing EU members from western Europe (EU-15), while costs of coordinating production networks between west and east have declined substantially during the latters' process of opening up to the rest of the world during their transition from plan to market. One would thus expect high-wage EU-15 firms to offshore tasks in the production of capital goods to low-wage EU-10 countries. This, however, is little reflected in the Table 1 European sample, which includes only two EU-10 countries, i.e., Poland and Czechoslovakia (still as one country in Kimura et al., 2007; as two countries in our column (3) and (4) results). In fact, trade in parts and components is the most dynamic part of trade between the EU-15 and the EU-10.

As a first shot, high contributions of parts and components of capital goods to the export and import growth rates of EU-10 countries are an indication of offshoring activities with old EU members. This is exemplified in Figure 1, which allows a closer look at export growth by exporter and goods category to the German market. The main contribution to export growth to Germany from the majority of EU-10 countries indeed comes from parts and components of capital goods (including transport equipment), i.e., from involvement in offshoring activities of firms especially in the Czech Republic, Estonia, Hungary, Poland, and Slovakia.[10] Imports from Germany generally confirm the picture of a substantial two-way trade of the majority of EU-10 countries with Germany

[9] For the European sample, we can easily reproduce the Kimura et al. (2007) results given in columns (3) and (4) of Table 1 with our slightly wider concept of trade in parts and components of capital goods, rather than machinery parts and components. Columns (5) and (6) in Table 1 present our respective results, obviously closely matching the original Kimura et al. (2007) results.

[10] Also of interest in this respect is of course the development of Chinese exports to Germany over the same time: with 19 per cent, China's average annual real rate of export growth to Germany is the highest in our sample of countries between 1996 and 2004. While the contribution of parts and accessories is also important, the main driver of Chinese export growth to Germany is final capital goods, mostly as a result of assembly tasks offshored to China: China's involvement in offshoring has been deliberately encouraged by a selective trade policy granting preferential tariff treatment to assembly (Lemoine and Ünal-Kesenci, 2004).

in parts and components, taken to reflect German firms' offshoring production tasks to these countries.

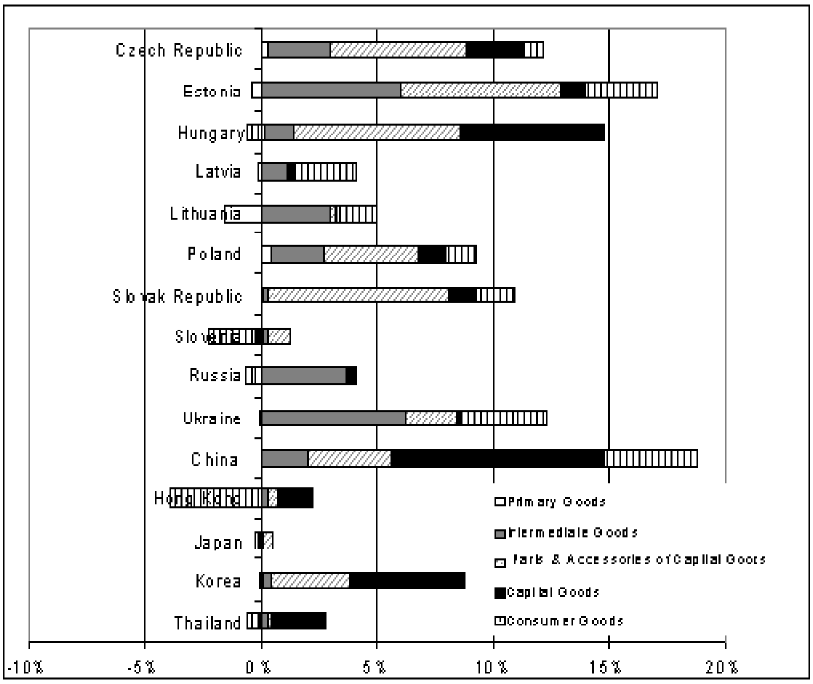

Figure 1: **Average annual real rates of change of exports to Germany, 1996–2004. Split into growth contributions of different goods categories**

Notes: Negative have to be subtracted from positive bars to obtain total growth rates. UN ComTrade data are re-classified according to the UN Classification by Broad Economic Categories; see Appendix B for further detail. *Parts and accessories* of capital goods include parts and accessories of transport equipment and are a subset of all intermediate goods. *Intermediate goods* are therefore all intermediate goods other than parts and accessories. I the etxt of this paper, BEC parts and accessories of capital goods are in – consistent with the use in the rest of the literature – referred to as *parts and components*.

Sourc:: Eck (2009).

With respect to the gravity specification, in terms of the three incentives towards off-shoring identified in section 1, to increase with fragmentation, with declining coordination costs, or with the strength of international incentives to specialisation, the approach (1) neglects the first two sources, which are due to technical progress. In addition, a traditional gravity approach may not be adequate: barriers to trade are captured by distances not treated as relative to the rest of the world, i.e. in terms of Anderson and van Wincoop's (2003) multilateral trade resistance. Analogously, country differences are reduced to differences in per capita incomes between exporter and importer countries, again without formulating specialisation incentives relative to the rest of the world (see section 5 below). Also, in so far as income differences are to proxy wage differences in absence of full factor price equalisation, measuring wage differences in dollars may not adequately reflect incentives to exploit these differences within Europe. What's more, potential tendencies towards factor price equalisation *via* trade call for instrumenting wage differences. Also, the authors do not make use of the panel structure of the data that are in fact available.

Perhaps most importantly however, it remains unclear, which model of trade could motivate the gravity specification (1), describing trade flows as log-linear in both country sizes and country income differentials. From the formulation of the prior expectations on the sign of the coefficient of supply-side country differences in equation (1), the specification is assumed to allow for testing competing theories of trade against each other. Testing the influences of various trade theories against each other within one and the same gravity specification presupposes that these theories can be reduced to the same gravity specification. But this view is not correct, as it neglects the fundamental differences of both approaches with respect to specialisation: factor proportions theories of trade are incomplete specialisation models, new theories of trade give way to complete specialisation. This difference results in fundamentally different gravity specifications: in fact, as will be argued below, the econometric model (1) does not describe the data well against any theoretical model of trade, i.e., it is mis-specified. Specifically, there is no reason to interpret a negative coefficient for the income gap, $|y_j - y_i|$, to signal new trade theory determinants of offshoring.

4 Trade, gravity, and specialisation

There is no scope for and also little sense in formulating gravity under complete specialisation, as is e.g. implied by new theories of trade, with per capita income differences when analysing gross trade flow in parts and intermediates for offshoring evidence. Doing so within incomplete specialisation models gives both scope and sense, however, in a specification different from equation (1) above.

4.1 Complete specialisation

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). According to Haveman and Hummels (2004), due to the adding-up constraints of countries' expenditure systems, for trade between more than two countries a combination of four assumptions suffices to derive the simplest possible gravity structure where gross bilateral trade in final goods is log-linear in both countries' incomes:

1. Trade is only in final goods;
2. trade is frictionless and balanced;
3. preferences over final goods are identical and homothetic;
4. each good is produced in and exported out of only one country.[11]

To see this, follow Haveman and Hummels (2004), and let C denote consumption, Y income, X output, with variables in nominal terms. Subscripts denote countries, superscripts denote goods. With identical and homothetic preferences, and assuming no trade barriers, each country i will consume a fixed income share θ^k of good k,

$$C_j^k = \theta^k Y_j \,, \qquad \sum_k \theta^k = 1 \tag{2}$$

This is also true for the word as a whole, $C_w^k = \theta^k Y_w$. Thus, each country consumes its income share $s_j = Y_j/Y_w$ of world consumption of each good. Worldwide, consumption equals production for each good, $C_w^k = X_w^k$, such that each country consumes its income share $s_j = Y_j/Y_w$ of world production of each good.

With complete specialization, $X_w{}^k = X_j^k$ for some j, such that imports to i from j are directly determined by consumption patterns, $IM_{ij}^k = s_i X_j^k$. Summing over all goods imported to i from j,

[11] Independent from the particular details on the supply side that give rise to complete specialization, whether by Armington-type assumed national product differentiation or endogenously emerging as in new theories of trade.

$$IM_{ij} = EX_{ji} = s_i \sum_k X_j^k = s_i Y_j = \frac{Y_i \, Y_j}{Y_w} \qquad (3)$$

Bilateral trade in final goods with complete specialisation is thus log-linear in both countries' incomes,

$$\log EX_{ji} = c + \log Y_j + \log Y_i \;, \quad c = -\log Y_w \qquad (4)$$

and there is no scope for "augmenting" the gravity equation, as in equation (1) by adding absolute values of differences in per capita incomes, $|y_j - y_i|$. Thus, negative coefficients for per capita income differences in augmented gross trade flow gravity equations simply cannot signal new trade theory influences on the data.

Part of the problem may be due to the success of incorporating new trade theories into factor proportions aspects (Helpman and Krugman, 1985; Helpman, 1987), which seems to suggest the possibility of differentiating between respective trade determinants within one unified approach, and a lack of differentiating between *gross* and *net* trade flows. In fact, Helpman (1987) assumes such a model with two countries, two factors and three differentiated goods. In the absence of factor price equalisation, each country produces two goods such that there is incomplete specialisation on the level of goods but complete specialisation on the level of variants, i.e., on the lowest level of aggregation, which is what counts. However, supply-side country differences do not influence gross trade flows, but do (negatively) influence the degree of intra-industry trade between countries: more supply-side different countries have lesser degrees of intra-industry trade with each other – simply because they are unlikely to overlap in terms of producing variants of the same good. Interestingly, however, the specification used in Helpman (1987) for analysing bilateral *net* or intra-industry trade flows can be found in gravity approaches analysing *gross* trade flows.

Accordingly, any sort of augmenting the simplest gravity relationship must be grounded in violating the assumptions (1) – (4) above.

4.1.1 Trade in intermediate goods

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 section 5 below, admitting trade also in intermediate goods results in generating multilateral gravity equations for individual goods net export flows that are log-linear in income (equation (17) below). With complete specialisation, it is again quite straightforward to decompose (17) into bilateral gross trade gravity relationships: again, with all values nominal, let production in country *j* be distributed over different goods,

$$X_j^k = \delta_j^k Y_j \;, \quad \sum_k \delta_j^k = 1 \qquad (5)$$

This is again also true for the world as a whole, $X_w^k = \delta_w^k Y_w$. According to (17) below, for each intermediate good, multilateral net imports of country *i* are $(\delta_w^k - \delta_i^k)Y_i$. With complete specialisation, each intermediate good is produced in exactly one country *j* such that,

$$\delta_i^k = 0 \Leftrightarrow \delta_w^k = \frac{X_w^k}{Y_w} = \frac{X_j^k}{Y_w} = \frac{X_j^k}{Y_w}\frac{Y_j}{Y_j} = s_j \delta_j^k \text{, for some } j \neq i \tag{6}$$

and,

$$IM_i^k = s_j \delta_j^k Y_i \text{ , } \quad \text{for some } j \neq i \tag{7}$$

As each good is exclusively supplied by one country, good *k* imports of country *i* from the world are in fact the good *k* imports of country *i* from some country *j*,

$$IM_{ij}^k = s_j \delta_j^k Y_i \text{ , } \quad \text{for some } j \neq i$$

Country *i* uses all intermediate goods supplied by country *j*,

$$IM_{ij} = EX_{ji} = s_j Y_i = \frac{Y_j Y_i}{Y_w},$$

which again reproduces (3), such that bilateral trade in intermediate goods with complete specialisation is log-linear in both countries' incomes, as with final goods trade. Introducing trade in intermediate goods does not on its own (i.e., under the assumption of full specialisation and identical homothetic technology) generate bilateral gravity equations augmented by (supply-side) country differences.

4.1.2 Trade frictions

Incorporating the typical monopolistic competition model iceberg type of trade costs, Bergstrand (1989) succeeds in theoretically motivating the inclusion of exporter-country capital-labour ratios in a gravity equation: production of two goods is either capital- or labour intensive. Trade costs are modelled as iceberg-type loss of output, i.e., trade costs are proportional to costs of production, and are thus also either capital- or labour-intensive for the two goods. Increasing the exporting country's capital-labour ratio then lowers the opportunity cost of exporting capital-intensive products *via* decreasing trade barriers for capital-intensive goods relative to labour-intensive goods. Accordingly, the simple gravity equation can be augmented for exports of capital (labour)-intensive goods to react positively (negatively) to the exporter's capita-labour ratio. Thus, this special treatment of trade barriers does imply the possibility of augmenting simple gravity by supply-side country characteristics, but not, however, by supply-side country differences between exporters and importers.

4.1.3 Heterogeneous or non-homothetic preferences

Allowing for different and/or non-homothetic preferences should be expected to result at best in motivating demand- rather than supply-side country differences. Nevertheless, for the sake of completeness, it is again Bergstrand (1989) to allow for non-homothetic preferences which results in the destination country's per capita income entering the gravity equation. The Linder-type implication is that countries with similar per capita incomes trade more with each other.

4.2 Incomplete specialisation

As illustrated above, following Hummels and Haveman (2004), for trade in final goods complete specialisation is the key to analytically deriving bilateral gravity equations. With the argument in 4.1.1, this conclusion carries over directly to trade in intermediate goods.

5 Trade in parts and components with incomplete specialisation

There is virtually no scope for augmenting the gravity equation (3) to describe bilateral gross trade flows under complete specialisation as implied by new trade theories, with per capita income differences. In addition, it also does not make much sense when analysing gross trade flow in parts and intermediates for offshoring evidence: while parts and components are often considered as "differentiated" products, much of this differentiation is in fact standardisation on demand, and does not reflect market power of the supplier but rather of the user. 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 analyse parts and components gross trade flows within an incomplete specialisation framework, compatible with factor proportions theories of trade that support supply-side country differences as driving trade theoretically.

In the following, we do so by extending the Haveman and Hummels (2004) approach for trade in final goods to allow for trade in intermediate goods, where the existence of intermediate goods will reflect horizontal or vertical fragmentation of production.

5.1 Multilateral trade with horizontal fragmentation

Again in line with Havemann and Hummels (2004), we assume that there are no trade frictions, all trade is balanced, there is no international lending. Production is horizontally fragmented in the spirit of Grossman and Rossi-Hansberg (2008), where firm-specific production technologies are available to all countries but used by firms in countries rather than by countries:[12] n tasks are carried out, each of which results in a tradable intermediate good, i.e. a part or component. One final good is assembled from these n parts or components. All production is subject to homothetic derived demands, such that all variables can again be studied in nominal terms: C is consumption or use, X production, and Y income, EX exports, IM imports. Subscripts denote countries, superscripts goods. Given the existence of n intermediate goods and neglecting primary inputs, value added Z is in each country j distributed over two stages of production:

$$Z_j^k = X_j^k = \delta_j^k Y_j \qquad \text{for } k = 1, ..., n \tag{8}$$

$$Z_j^{n+1} = X_j^{n+1} - \sum_{k=1}^{n} C_j^k = \delta_j^{n+1} Y_j, \qquad \sum_{k=1}^{n} \delta_j^k + \delta_j^{n+1} = 1 \tag{9}$$

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

$$\sum_{k=1}^{n} Z_j^k + Z_j^{n+1} = Y_j \tag{10}$$

With homotheticity in production,

$$C_j^k = \phi_j^k X_j^{n+1} \qquad \text{for } k = 1, ..., n \tag{11}$$

With (9) and (11), value added in producing the final good can be written as

$$\begin{aligned} Z_j^{n+1} = \delta_j^{n+1} Y_j = X_j^{n+1} - \sum_{k=1}^{n} C_j^k = X_j^{n+1} - X_j^{n+1} \sum_{k=1}^{n} \phi_j^k \\ = X_j^{n+1} \left(1 - \sum_{k=1}^{n} \phi_j^k \right) \end{aligned} \tag{12}$$

such that

$$X_j^{n+1} = \frac{\delta_j^{n+1} Y_j}{1 - \sum_{k=1}^{n} \phi_j^k} \tag{13}$$

(13) describes the output of the final good in country *j*. Demand is simply 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

$$\begin{aligned} NE_j^{n+1} = X_j^{n+1} - C_j^{n+1} = \frac{\delta_j^{n+1} Y_j}{1 - \sum_{k=1}^{n} \phi_j^k} - Y_j \\ = \left(\frac{\delta_j^{n+1}}{1 - \sum_{k=1}^{n} \phi_j^k} - 1 \right) Y_j \end{aligned} \tag{14}$$

For intermediate goods, output is given in (8) and use is in (11), which also holds for the world, $C_w^k = \phi_w^k X_w^{n+1}$. With final goods output as described in (13),

$$\frac{C_j^k}{C_w^k} = \frac{\phi_j^k}{\phi_w^k} \frac{\delta_j^{n+1} Y_j}{\delta_w^{n+1} Y_w} \frac{1 - \sum_k \phi_w^k}{1 - \sum_k \phi_j^k} \qquad \text{for } k = 1, \ldots, n$$

This expression can easily be simplified using two characteristics of world trade: first, we know from the world version of (14) that $1 - \sum_k \phi_w^k = \delta_w^{n+1}$, as world trade in final goods must be balanced. Second, world output of any good is equal to world use, such that

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

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

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

Country j's net exports of intermediate good k are thus described by

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

$$= \delta_j^k Y_j - \frac{\phi_j^k}{\phi_w^k}\frac{\delta_j^{n+1}}{1-\sum_k \phi_j^k}\delta_w^k Y_j = \left(\delta_j^k - \frac{\phi_j^k}{\phi_w^k}\frac{\delta_j^{n+1}}{1-\sum_k \phi_j^k}\delta_w^k\right)Y_j \tag{15}$$

As we are only interested in intermediate goods trade, we may simplify (15) by assuming balanced final goods trade for each single country,[13] such that

$$NE_j^k = \left(\delta_j^k - \frac{\phi_j^k}{\phi_w^k}\delta_w^k\right)Y_j\ , \qquad \text{for } k = 1, \ldots, n \tag{16}$$

On the basis of (16), countries export an intermediate good if they devote a greater share of value added to producing this good than the rest of the world ($\delta_j^k > \delta_w^k$), or if their intermediate good is more productive in terms of final output than the rest of the world ($\phi_j^k < \phi_w^k$). With firm-specific technologies, identically available everywhere in the world for offshoring activities, as assumed in Grossman and Rosssi-Hansberg (2008), this simplifies further to,

$$NE_j^k = \left(\delta_j^k - \delta_w^k\right)Y_j\ , \qquad \text{for } k = 1, \ldots, n \tag{17}$$

Summing over all k, j's exports of intermediate goods to the world are,

$$NE_j = Y_j\sum_{k=1}^{n}\left(\delta_j^k - \delta_w^k\right) \tag{18}$$

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

Suppose now that intermediate goods are indeed homogeneous. Then, goods are either exported or imported but not both, and positive NE_j indicates a country's exports. Selecting export items with positive net exports, country j's multilateral intermediate goods exports are,

$$EX_j = Y_j \sum_{k \in K_{EX_j}} (\delta_j^k - \delta_w^k) \qquad (19)$$

and are log-linear in income and a *specialisation pattern,* $\sum_{k \in K_{EX_j}} (\delta_j^k - \delta_w^k)$, exhibiting a unitary elasticity with respect to country of origin income, provided the specialisation pattern is uncorrelated with income. Analogously,

$$IM_j = Y_j \sum_{k \in K_{IM_j}} (\delta_w^k - \delta_j^k) \qquad (20)$$

5.2 Bilateral trade

With incomplete specialisation, it is not possible to analytically decompose (19) and (20) into bilateral trade relationships, as no analogue to the complete specialisation decomposition rule (6) can be applied. While trade indeterminacy can in principle be broken by trade barriers, gravity equations can nevertheless be generated as statistical relationships from (19) and (20). In particular, it is possible to formulate two conditions, subject to which bilateral trade relationships will be distributed in a statistical sense in a sample of countries.[14]

a) For bilateral trade to occur, countries' specialisation patterns as described in (19) and (20) must be complementary: there should at least be one k' that is both exported by country j and imported by country i.
b) Equations (19) and (20) describe countries' multilateral trade, i.e., the expected values of bilateral relationships. Thus, (19) and (20) 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 be expected to trade more with each other, the bilateral trade volume will increase with $Y_j \times Y_i$. Countries that are more specialised against the world average trade more in the average of all their bilateral relationships. Thus, in a sample of heterogeneous countries, countries more specialised *vis-à-vis* the world can be expected to trade more with each other, provided, their specialisation is complementary.

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

Incentives for incomplete specialisation and trade with parts and components are supply-side country differences in factor endowments and/or wages, where both can be proxied by average GDP per capita, y_j and y_i. Consistent with specialisation patterns described relative to the world, bilateral trade volumes can be expected to increase with relative supply-side country differences, $|y_j - y_w|\times|y_i - y_w|$, i.e., with the product of countries' respective supply-side differences against the world. In fact, this conforms to the procedure taken in Haveman and Hummels (2004) to describe incomplete specialisation influences on final goods trade. However, the problem with this formulation is the potential absence of complementary specialisation: relative supply-side country differences $|y_j - y_w|\times|y_i - y_w|$ predict large trade volumes also for countries that lack complementary specialisation. There are (at least) two ways of correcting for this by including additional variables: first, absolute supply-side country differences, $|y_j - y_i|$, can be introduced. Doing so additively, i.e. in a log-linear fashion within a gravity framework, however implies substitutability between countries' complementary specialisation and their relative supply-side country differences $|y_j - y_w|\times|y_i - y_w|$, which would actually again amount to mis-specifying gravity with respect to the underlying "model" conditions (a) and (b) above. Second, rather than modelling complementarity of countries' specialisation patterns and relative supply-side country differences as substitutes, a second possibility consists of selecting relative supply-side country differences for particular bilateral trade relationships by assigning dummies to bilateral trade relationships between countries that are known to be characterised by complementary specialisation by *a priori* information, e.g., on the basis of $y_j > y_w$ and $y_i < y_w$. Specifically, within a panel of EU-25 countries, bilateral trade in parts and components can be described by an augmented gravity equation, without accounting for trade barriers,

$$\log EX(PC)_{ji,t} = \beta_0 + \beta_1 \log\left(Y_{j,t} \times Y_{i,t}\right) + \beta_2 \log\left(\left|y_{j,t} - y_{w,t}\right| \times \left|y_{i,t} - y_{w,t}\right|\right) \qquad (21)$$
$$+ \beta_3 DumKomp_{ji} \times \log\left(\left|y_{j,t} - y_{w,t}\right| \times \left|y_{i,t} - y_{w,t}\right|\right)$$

where *DumKomp* equals one for trade relationships between a EU-15 and a EU-10 country, and zero otherwise.

6 Trade barriers and gravity specification for bilateral trade in parts and components with incomplete specialisation

6.1 Trade barriers

Traditional gravity approaches explicitly cope with different trade barriers, i.e., distance (to proxy transport costs), geographic contiguity, perhaps cultural proximity and the like. The current discussion on using gravity frameworks (Cheng and Wall, 2005; Baldwin and Taglioni, 2006), however, 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, i.e., for the intuitively appealing notion that bilateral trade barriers should always be measured – such as with supply-side country differences as trade incentives above – relative to the world: 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 (for formally linking this notion to gravity representing monopolistic competition models of trade, see Anderson and van Wincoop, 2003).

6.2 Gravity specification

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. 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, concluding the potential bias of fixed-effects gravity estimators to be rather small.[15] This is of specific concern with our data, which span only over a period of 13 years, too short a period for proper panel unit root testing, which is why we estimate the simple panel version of the above motivated gravity model,

[15] As for alternative dynamic panel estimators, the original Arellano and Bond (1991) performs poorly for persistent time series, while the Blundell and Bond (1998) system GMM estimator requires strict exogeneity of regressors, which is not fulfilled when variable such as income and trade are cointegrated.

$$\log EX(PC)_{ji,t} = \beta_0 + \beta_1 \log\left(Y_{j,t} \times Y_{i,t}\right) + \beta_2 \log\left(\left|y_{j,t} - y_{w,t}\right| \times \left|y_{i,t} - y_{w,t}\right|\right) + \beta_3 DumKomp_{ji} \times \log\left(\left|y_{j,t} - y_{w,t}\right| \times \left|y_{i,t} - y_{w,t}\right|\right) + c_{ij} + k_t + \varepsilon_{ij,t} \tag{22}$$

with time-invariant asymmetric country-pair specific (c_{ij}) as well as country-pair invariant time-specific (k_t) effects. Of course, this has the implication that no time-invariant parameters can be estimated. The time specific effects 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 US-$-denominated data are converted to euros. $EX(PC)_{ji}$ describes exports of parts and components of capital goods from country j to i. The definition of parts and components of capital goods follows the BEC categorisation of UN Statistics (for a full description of the data, see Appendix B); Y_j , Y_i, are exporter and importer GDP, respectively, and $|y_j - y_w|\times|y_i - y_w|$ are relative supply-side country differences proxied by per capita incomes. World average per capita incomes are computed from the sample described in Table B2, Appendix B.

Technical progress through decreasing service link costs can be represented by time effects. Nevertheless, as our motivation of offshoring in section 5 does not imply a high degree of substitutability but rather complementarity between technical progress and the possibility of using supply-side country differences, we model this by interacting the combined variable $DumKomp \times|y_j - y_w|\times|y_i - y_w|$ with time-period effects:[16] for this purpose, we divide the sample period into four sub-periods of (almost) equal length.

Finally, we allow for supply-side country differences to be represented by differences in factor endowments or factor prices, i.e., wages. Given that the specification (22) is rooted in models incomplete specialisation and trade, such as Heckscher-Ohlin, existing wage differences may be subject to factor price equalisation tendencies by the very offshoring trade they induce.[17] I.e., factor price differences may not be exogenous; we apply the simplest possible remedy in choosing lagged explanatory variables as instruments.

Before discussing results of estimating (22), we again demonstrate that (1) remains mis-specified, even if we remedy all points of criticisms voiced in sections 3.2 and apply remedies as formulated in section 5, except substituting (1) by our preferred specification (22). The results are given in Table 2, both for the original European sample of columns (1–4) of Table 1, and the EU-25. As argued extensively above, the specification in (1) is not generated by any theory of trade. Consequently, significantly negative coefficients for $\log|y_j - y_i|_{1992\text{–}5}$ in both columns 7 (Europe as defined for columns (1–4) of Table 1) and 8 (for EU-25) signal mis-specification in the sense that (7) and (8) do

[16] Navaretti and Venables (2004) among others show that only once fragmentation becomes possible, countries will start to engage in production-process wise vertical division of labor to utilize the advantage of location differences.

[17] Much of the offshoring literature is in fact on labour market effects; see most prominently Geishecker und Görg (2008).

not describe the data well, rather than signalling a dominating influence of new theories of trade upon the data.

Table 2: **Gravity regressions or parts and components trade among selected European countries, 1992–2004**
(TSLS with asymmetric country-pair specific and time-specific effects)

Explanatory variables:	(7) For the sample of countries in columns (1–4), Table 1	(8) For the EU-25
log Y_j	1.49***	1.62***
	(22.39)	(22.97)
log Y_i	0.88***	0.71***
	(13.21)	(10.24)
log $\lvert y_j - y_i \rvert_{1992\text{–}5}$	–0.095***	–0.19***
	(–4.28)	(–5.90)
log $\lvert y_j - y_i \rvert_{1996\text{–}8}$	–0.030	–0.021
	(–1.31)	(–0.63)
log $\lvert y_j - y_i \rvert_{1999\text{–}2001}$	0.027	0.079**
	(1.22)	(2.56)
log $\lvert y_j - y_i \rvert_{2002\text{–}4}$	0.069***	0.12***
	(3.08)	(3.76)
Observations (cross sections)	4,356 (342)	6,605 (552)
Adj. R-squared	0.95	0.95

Notes:: Column (7): Europe is AUT, BEL, CHE, DNK, ESP, FIN, FRA, GBR, GER, GRC, IRL, ITA, NLD, NOR, PRT, SWE; CZE, SVK, POL (19 countries). Column (8): EU-25; no specific effects reported.

6.3 Results

On the contrary, the specification (22) is explicitly rooted in incomplete specialisation. *A priori* expectations on coefficients are as follows: $\beta_1 > 0$; as equations (19) and (20) describe expected values of bilateral trade relationships, we may even expect β_1 to equal one, provided the extent of specialisation is uncorrelated with income. This expectation, however, is based on establishing bilateral gravity equations as statistical relationships, it is not theoretically derived. We cannot form an *a priori* expectation on β_2 without further information on the sample of countries: if the sample is sufficiently homogenous, with say all $y_i > y_w$, then there is no reason to assume the majority of country pairs to be complementarily specialised, in which case a higher $\lvert y_j - y_w \rvert \times \lvert y_i - y_w \rvert$ will generate less trade, such that $\beta_2 < 0$. Finally, with dummies *DumKomp* picking the "right" country pairs with complementary specialisation based on prior information, $\beta_3 > 0$. For the natural limiting case of complete specialisation, we would not find specialisation patterns to play any role, in which case $\beta_2 = \beta_3 = 0$. Results for estimating (22) on the EU-25 panel between 1992 and 2004 are given in Table 3.

Table 3: **Gravity regressions for trade among EU-25, 1992–2004**
(TSLS with asymmetric country-pair specific and time-specific effects)

		(9) Parts and components of capital goods	(10) Other intermediate goods	(11) Final goods (capital and consumer goods)
log Y_j Y_i		0.85^{***}	1.07^{***}	0.99^{***}
		(16.66)	(31.57)	(27.83)
log ($\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert$)		-0.11^{***}	-0.14^{***}	-0.07^{**}
		(–2.72)	(–5.10)	(–2.35)
	1992–95	0.29^{***}	0.19^{***}	0.14^{***}
		(4.57)	(4.93)	(2.86)
	1996–98	0.32^{***}	0.20^{***}	0.15^{***}
log ($\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert$)		(5.11)	(5.34)	(3.20)
for EU-15 / EU-10 pairs	1999–01	0.33^{***}	0.20^{***}	0.15^{***}
		(5.38)	(5.49)	(3.27)
	2001–04	0.34^{***}	0.20^{***}	0.16^{***}
		(5.56)	(5.46)	(3.35)
Observations (cross sections)		6,605 (552)	6,766 (552)	6,766 (552)
Adj. R^2		0.95	0.97	0.97

Notes:: no specific effects reported.

Table 3 results support 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 all three driving forces identified already in the first section: first, comparing coefficients β_2 and β_3 in the parts and components estimation (column 9, Table 3) points to supply-side country differences as driving offshoring activities across Europe compatible with models of incomplete specialisation and trade, specifically between original EU-15 and the ten accession countries, rather than within each of the two country groups. Second, technical progress in terms of declining service link costs – as captured by the sub-period dummies – appears to positively influence offshoring: for EU-15/EU-10 pairs, β_3 is increasing slowly over time. Third, when comparing trade between original EU-15 and the ten accession countries by broad economic categories across columns (7–9) in Table 3, trade in parts and components reacts about twice as elastic to supply-side country differences than trade in final goods: this is evidence for technical progress in terms of fragmentation to indeed yield increased incentives for specialisation.

Table 4 decomposes the influences specified in (22) on parts and components trade along the two margins of trade, i.e., along *extensive* (number of exported goods) *versus intensive* import margins (average volumes per exported good), based on the highly disaggregated nature of our original trade data (see Appendix B for data details).

Table 4: **Gravity regressions for parts and components trade among EU-25, 1992–2004**
(TSLS with asymmetric country-pair specific and time-specific effects)

		(12) Along the *extensive* margin	(13) Along the *intensive* margin
$\log Y_j Y_i$		0.57^{***}	0.28^{***}
		(22.51)	(6.61)
$\log (\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert)$		-0.14^{***}	0.026
		(–6.78)	(0.77)
	1992–95	0.21^{***}	0.083
		(6.58)	(1.61)
	1996–98	0.23^{***}	0.10^{*}
$\log (\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert)$		(7.24)	(1.86)
for EU-15 / EU-10 pairs	1999–01	0.23^{***}	0.10^{**}
		(7.45)	(2.06)
	2001–04	0.23^{***}	0.11^{**}
		(7.58)	(2.21)
Observations (cross sections)		6,605 (552)	6,605 (552)
Adj. R^2		0.95	0.91

Notes:: no specific effects reported. Extensive versus intensive margins of exports are defined in Table B3.

As TSLS is a linear operator, estimated coefficients given in columns (12) and (13) of Table 4 always sum up to the respective estimated coefficient in column (9) in Table 3. Table 4 results reveal that trade in parts and components due to offshoring activities across Europe is predominantly realised along the extensive margin. I.e., more offshoring of activities from the EU-15 to the EU-10 means predominantly offshoring of new activities rather than extending the scale of already offshored activities.

This distinction, however, may be of relevance for the labour market effects of offshoring, especially with respect to factor prices 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 labour market institutions, as suggested in Geishecker et al. (2008). Table 4 results may be related to an alternative explanation for internationally varying labour market effects of offshoring, however. Empirical work on labour 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, generalises Feenstra and Hanson (1996) by introducing task-specific trade costs that potentially limit 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 *cet. par.* implies a positive productivity effect in the source country, which appears strongest in those firms that have already offshored most, and which therefore carries the highest potential benefits for skill groups hit strongest by offshoring. Labour 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 rather than creating new offshoring relationships. In the terminology of recent theories of trade, existing offshoring relationships, in turn, get strengthened along the intensive margin, as opposed to strengthening along the extensive margin by new relationships. One might therefore suspect the unambiguous results of Geishecker and Görg (2008) to hold for offshoring relationships that get predominantly strengthened along the extensive, rather than along the intensive margin. This, in turn, seems to be the case for offshoring relationship between the EU-15 and the EU-10, i.e., the “old” and the “new” EU members.[18]

To illustrate that Table 4 results are not a “natural” finding, Table 5 repeats the estimation based on specification (22), but now over a larger sample, including on top of European economies also former member states of the Soviet Union and east Asian countries, including China. With respect to their respective trade relation with offshoring EU-15 countries, for this larger sample we have, however, only data on countries’ exports into the EU-15 but not on their imports from the EU-15.

Again, in Table 5 we also present results from decomposing the influences specified in (22) on parts and components trade along *extensive versus* the *intensive* margins. Results confirm that exports of parts and components from EU-10 to EU-15 countries are predominantly realised along the extensive margin, in stark contrast to parts and components exports from east Asia, including China.[19] Interpreting this trade data evidence in terms of underlying offshoring activities, extending offshoring of activities from the

[18] The *caveat* here, of course is Table 4 results are based on macro, rather than micro, i.e. firm level data, where, however, the macro trade data are quite disaggregated to represent some 90 million trade flows (see Appendix B).

[19] Part of this contrast may be due to a comparatively strong institutional trade liberalisation between the EU-15 and the EU-10 in the latters’ run-up to EU membership. Such an argument is made in Frensch (forthcoming), however, on the basis of recent complete specialisation models of heterogeneous firms and trade, such as Chaney (2008).

Table 5: **Gravity regressions for parts and components exports among a larger country panel, 1992–2004**
(TSLS with asymmetric country-pair specific and time-specific effects)

		(14) Export flows	(15) Along the *extensive* margin	(16) Along the *intensive* margin
log $Y_j\ Y_i$		0.82***	0.39***	0.43***
		(26.78)	(34.32)	(18.19)
log $\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert$		–0.10***	–0.060***	–0.045*
		(–3.50)	(–3.80)	(–1.95)
log $\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert$ for exports from EU-10 into EU-15	1992–95	0.50***	0.31***	0.19***
		(5.56)	(6.49)	(2.78)
	1996–98	0.53***	0.32***	0.21***
		(5.90)	(6.80)	(3.01)
	1999–01	0.54***	0.32***	0.22***
		(6.16)	(6.89)	(3.29)
	2001–04	0.54***	0.32***	0.23***
		(6.25)	(6.91)	(3.40)
log $\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert$ for exports from (HKG + KOR + THA + TWN) into EU-15	1992–95	0.22	–0.036	0.25**
		(1.63)	(–0.51)	(2.47)
	1996–98	0.21	–0.037	0.25**
		(1.62)	(–0.53)	(2.47)
	1999–01	0.21	–0.038	0.24**
		(1.64)	(–0.57)	(2.52)
	2001–04	0.20	–0.040	0.24**
		(1.59)	(–0.60)	(2.48)
log $\lvert y_j - y_w\rvert \times \lvert y_i - y_w\rvert$ for exports from CHN into EU-15	1992–95	0.43	0.015	0.41*
		(1.46)	(0.10)	(1.83)
	1996–98	0.44	0.017	0.43*
		(1.52)	(0.11)	(1.90)
	1999–01	0.45	0.015	0.43**
		(1.58)	(0.10)	(1.98)
	2001–04	0.47*	0.014	0.45**
		(1.65)	(0.10)	(2.08)
Observations (cross sections)		21,819 (2,256)	21,819 (2,256)	21,819 (2,256)
Adj. R^2		0.94	0.94	0.88

Notes: no specific effects reported. For the list of 55 exporters and 46 importers, see Table B2.

EU-15 to the EU-10 during 1992–2004 means predominantly offshoring of new activities, while extending offshoring from the EU-15 to east Asia takes place rather by expanding the scale of already offshored activities. In the spirit of the Grosssman Rossi-Hansberg (2008) approach outlined above, this would suggest the conjecture that recent waves of offshoring activities from “old” to “new” EU members might have been more likely to hurt (low-skill) workers in the old EU than offshoring to east Asia.

7 Conclusions

The paper started out stating that analysing gross trade flows related to offshored activities by using gravity equations augmented by *ad hoc* measures of supply-side country differences appear mis-specified, due to theoretically unmotivated attempts of allowing for both complete and incomplete specialisation influences on trade within the same gravity framework. The problem with complete specialisation, even when embedded into factor proportions theory, as in Helpman and Krugan (1985), is that analysing gross trade flows is simply not informative about the specific driving forces connected to new trade theories or economic geography. For that, analysing net or intra-industry trade is necessary, as strongly suggested in Helpman (1987), one of the rare attempts to structurally test new trade complete specialisation theories.[20]

On the other hand, pure incomplete specialisation à la Heckscher-Ohlin presumes that each good is produced in each country: with respect to offshoring activities, this is not necessarily true before offshoring! I.e., relevance points to incomplete specialisation theories that leave room for extensive margin adjustment, as in Grossman and Rossi-Hansberg (2008), where firms' decisions about offshoring are embedded in an environment of incomplete factor price equalisation, firm-level technologies, and cost heterogeneity of offshoring across a continuum of tasks.

Applying an appropriate gravity framework to a truly Europe-wide sample of countries results in finding evidence for offshoring activities across Europe, which result in two-way trade in parts and components driven by supply-side country differences compatible with models of incomplete specialisation and trade. In particular, the results do not contradict the Grossman-Rossi-Hansberg (2008) model, 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 by new relationships. Our results suggests the conjecture that this might have been the case recently when extending offshoring from the EU-15 to east Asia rather than in offshoring relationships between EU-15 and 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 liberalisation, or institutional variation especially with respect to the labour market (Geishecker et al., 2008). Another interesting topic, worthy of further research, is that service link costs are linked to the complexity of the coordination task, i.e., to 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 which increases in the variety of offshored tasks. These are worthwile topics to be studied in the future.

[20] It would be extremely helpful to reliably discriminate between horizontal, vertical (in terms of quality) intra-industry trade and such two-way trade as technologically rooted in stages of production. Appropriate trade data would have to distinguish between intermediate goods according to stages of production, e.g., by differentiating parts versus components rather than lumping them together as in this paper.

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Appendix A: Trade in intermediate goods with vertical fragmentation and incomplete specialisation

As in section 5, the following argument is developed along Haveman und Hummels (2004) for final goods. Specialisation is assumed to be incomplete, all goods are tradable. There are no trade frictions, all trade is balanced, there is no international lending. All variables are in nominal terms, as in section 5.1.

Production is vertically fragmented into n+1 *tasks* along the value chain: n tasks are carried out, using primary factors of production and 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 from now, 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. Accordingly, value added is distributed over the production of n intermediate and one final product,

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

Total income is spent on consumption of the final good,

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

With identical homothetic technology,

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

such that

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

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

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

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

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

Then, net exports out of country *j*,

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

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

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

(A4) and (A7) imply net exports of intermediate goods out of country *j*,

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

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

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

and total intermediate goods exports are – as in section 5, describing horizontal specialisation – log-linear in income and a pattern of specialisation,

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

Again, as long as income and specialisation pattern are uncorrelated, (A12) gives way to expectations on the behaviour of bilateral trade relationships in a sample of countries, to be represented by the estimation specification (22).

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) to be used at all aggregation levels (1-digit levels aggregate trade flows; 4- and 5-digit levels for distinguishing and counting SITC categories to define *extensive versus intensive* margins of trade flows). There are 3,121 *basic headings* or *basic categories* in the SITC, Rev.3, 2,824 at the 5-digit level and 297 at 4-digits, that are not disaggregated any further. The 3-digit group 334 (petroleum products), which is divided into eight final headings in SITC, Rev.3, is in fact not subdivided by many reporting countries, so we treat it as a single heading. This leaves 3,114 *basic categories*, as the level of aggregation of the SITC, Rev.3 to work with for defining 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.

SITC categories falling under BEC headings 51, 3, and 7 are excluded from our rearrangement into primary, intermediate, capital, and consumer goods for various reasons. 'Motor vehicles for the transport of passengers', SITC, Rev.3, heading 7812 (equivalent to BEC heading 51), cannot be divided into capital or consumer goods. Similar reasoning holds for motor spirits. By definition, intermediate goods should also include primary and processed fuels and lubricants other than motor spirit, but in this data set 'fuels and lubricants', which include 32 4- and 5-digit headings of the SITC, Rev.3, are not used, in part due to countries' incomparable reporting practices (see above). BEC 7, 'goods not elsewhere classified', comprises 14 basic headings of the SITC, namely, military equipment, including arms and ammunitions, special transactions, postal packages, etc., which are all excluded.

Table B1: **The structure of BEC**

1 Food and beverages 11 Primary 111 Mainly for industry 112 Mainly for household consumption 12 Processed 121 Mainly for industry 122 Mainly for household consumption **2 Industrial supplies not elsewhere specified** 21 Primary 22 Processed **3 Fuels and lubricants** 31 Primary 32 Processed 321 Motor spirit 322 Other	**4 Capital goods (except transport equipment) and parts and accessories thereof** 41 Capital goods (except transport equipment) 42 Parts and accessories **5 Transport equipment and parts and accessories thereof** 51 Passenger motor cars 52 Other 521 Industrial 522 Non-industrial 53 Parts and accessories **6 Consumer goods not elsewhere specified** 61 Durable 62 Semi-durable 63 Non-durable **7 Goods not elsewhere specified**

Source: Available online at http://unstats.un.org/unsd/class/family/family2.asp?Cl=10

Specifically, 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 – referred to as *parts and components*.

Country and period coverage

Trade data were extracted for 46 reporting importer countries, i.e. most of Europe, Central Asia and North America. Belgium and Luxembourg are treated as one country throughout as reported until 1998. The data cover 1992–2004 but not all countries report in each year (average: 40.15 countries report per year).

Table B2: **Reporter-countries, country codes, and trade data availability**

1	ALB	Albania (1996–2004)	17	GBR	United Kingdom (1992–2004)	33	NLD	Netherlands (1992–2004)
2	ARM	Armenia (1997, 1999–2000, 2002–4)	18	GEO	Georgia (1996–2004)	34	NOR	Norway (1992–2004)
3	AUT	Austria (1992–2004)	19	GER	Germany (1992–2004)	35	POL	*Poland* (1992–2004)
4	AZE	Azerbaijan (1996–2004)	20	GRC	Greece (1992–2004)	36	PRT	Portugal (1992–2004)
5	BEL	Belgium and Luxembourg (1992–2004)	21	HRV	Croatia (1992–2004)	37	ROM	*Romania* (1994–2004)
6	BGR	*Bulgaria* (1996–2004)	22	HUN	*Hungary* (1992–2004)	38	RUS	Russia (1996–2004)
7	BLR	Belarus (1998–2004)	23	IRL	Ireland (1992–2004)	39	SVK	*Slovakia* (1994–2004)
8	CAN	Canada (1992–2004)	24	ISL	Iceland (1992–2004)	40	SVN	*Slovenia* (1992–3, 1995–2004)
9	CHE	Switzerland (1992–2004)	25	ITA	Italy (1992–2004)	41	SWE	Sweden (1992–2004)
10	CYP	Cyprus (1992–2004)	26	KAZ	Kazakhstan (1995–2001, 2003–4)	42	TKM	Turkmenistan (1997–2000)
11	CZE	*Czech Republic* (1993–2004)	27	KGZ	Kyrgyzstan (1995–6, 1998–2004)	43	TUR	Turkey (1992–2004)
12	DNK	Denmark (1992–2004)	28	LTU	*Lithuania* (1994–2004)	44	UKR	Ukraine (1996–2002)
13	ESP	Spain (1992–2004)	29	LVA	*Latvia* (1994–2004)	45	USA	United States (1992–2004)
14	EST	*Estonia* (1995–2004)	30	MDA	Moldova (1994–2004)	46	YUG	Serbia and Montenegro (1996–2002, 2004)
15	FIN	Finland (1992–2004)	31	MKD	Macedonia (1994–2004)			
16	FRA	France (1992–2004)	32	MLT	Malta (1992–2004)			

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 55 separate exporters (the 46 reporter countries plus: Bosnia and Herzegovina, Tajikistan, Uzbekistan, China, Hong Kong, Japan, South Korea, Taiwan and Thailand)

Table B3: **Variables used in regressions**
(1) – (16) in Tables 1–5

Variable	Definition	Source	Notes
$EX_{ji,t}$	Exports from country *j* to country *i* at time *t* in current dollars	UN COMTRADE	Separately for parts and components of capital goods, other intermediate goods, and final goods. See Appendix B.
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*	Own computations on the basis of UN COMTRADE	Defined as a count measure over some 300 parts and components (out of all 3,114 SITC Rev.3) categories; see Text and Appendix B.
Intensive margin of $EX_{ji,t}$ *(PC)*	Intensity of parts and components exports from country *j* to country *i* at time *t*	Own computations on the basis of UN COMTRADE	Defined as average volumes of exported parts and components categories; see Text and Appendix B.
Y_j, Y_i	Export and import country GDP in current dollars	*World Development Indicators 2007*	
y_j, y_i	Export and import country GDP per capita in current dollars	*World Development Indicators 2007*	
y_w	World average GDP per capita in current dollars	Own computations on the basis of *World Development Indicators 2007*	"World" is defined by the 55 export countries in our database; see Appendix B.
$Dist_{ji}$	Distance between capitals of exporter and importer country	CEPII, available online at http://www.cepii.fr/anglaisgraph/bdd/distances.htm	For a discussion, see Mayer and Zignano (2006).
Lan_{ji}	Common language dummy for exporter and importer	CEPII, available online at http://www.cepii.fr/anglaisgraph/bdd/distances.htm	See Mayer and Zignano (2006).

Each reporting country's import data are given for 55 separate exporters (the 46 reporter countries plus: Bosnia and Herzegovina, Tajikistan, Uzbekistan, China, Hong Kong, Japan, South Korea, Taiwan and Thailand), where the Czech Republic, Slovakia and Macedonia are exporters countries only from 1993 on. These exporters generally account for 80–95 per cent of reported imports. Therefore, for the purposes of this paper, the 55 exporters constitute the world, and specifically, income per capita for the world as a whole is computed on the basis of the 55 exporters.

Given the level of disaggregation of the trade data, covering more than 3,000 different SITC items, traded between 46 importers and 55 exporters between 1992 and 2004, the original database consists of some 90 million observations.