Fragmentation and trade: A network perspective

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Abstract

International fragmentation of production generates trade in intermediate inputs. Using data from the UN Comtrade Database according to the BEC (rev. 3) classification, we construct matrixes of bilateral trade separately for exchange of final capital goods and intermediate inputs thereof for 85 countries in 1995 and 2004. Analysis of regular equivalence gives clustering of countries into core and three tiers of (semi)periphery of the international production networks. Estimates of the gravity equation do not reveal significant differences in determinants of trade in the final goods and their intermediate inputs. However, we show that determinants of intra-product trade differ along the divisions derived from the network analysis.

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1. Introduction

Globalization of production is in a full swing. International trade in intermediate inputs is extensive and rapidly growing (Feenstra 1998, Hummels, et al. 2001, Yeats 2001, Kaminski and Ng 2001, Fontagné, et al. 2005 and Srholec 2006a,b) as the world economy becomes tightly knitted by international production networks (Ernst and Kim 2002, Gereffi, et al. 2005). The deepening fragmentation of production, which generates the intra-product trade in inputs, has important theoretical implications and welfare effects (Jones 2001, Arndt and Kierzkowski 2001, Antras and Helpman 2004) [1] Intra-product trade puts comparative advantage and specialization back to the centre of the analysis, after the emphasis on monopolistic competition and scale economies. Although the welfare effects are generally positive, some corners of the world economy and segments of the society, such as unskilled workers in the advanced countries, might come out worse off. It makes the traditional view on trade as an exchange of (differentiated) final goods increasingly unbearable. From empirical perspective, patterns and determinants of trade in intermediate inputs may differ from trade in final goods, making the distinction urgent in applied research. Still evidence on the scale and scope of international production networks and their implication for trade remains limited.

Unlike the existing empirical papers on intra-product trade, we look at the patterns of bilateral intra-product trade between countries from a network perspective and attempt to compare the factors driving trade in final and intermediate product in an econometric framework. Using data from the UN Comtrade Database according to the BEC (rev. 3) classification, we construct matrixes of trade between countries separately for exchange of final capital goods and intermediate inputs thereof for 85 countries in 1995 and 2004. Social network analysis is applied on the dataset. Analysis of regular equivalence gives clustering of countries into core and three tiers of (semi)periphery of the international production network. Furthermore, we estimate gravity equations separately for trade in final capital goods and their intermediate inputs matters. We also examine whether determinants of intra-product trade differ according to the grouping of countries derived from the network analysis and whether the intra-product trade is related to cross-country differences in productivity, technology, skills and institutions. Section 5 provides conclusions.

2. The dataset

At the empirical front, two approaches to identify intra-product trade have emerged. Input-output tables can be utilized to measure trade in intermediate inputs (Hummels et al. 2001) or trade in final goods can be separated from intermediate inputs, such as manufacturing parts and components, at a detail level of classifications of trade by commodities (Ng and Kaminski 2001, Yeats 2001). We follow the latter approach. However, unlike most of the previous studies, we do not use the taxonomy put forward by Yeats (2001, pp. 111-112), which is selective and defined only in SITC (rev. 2), but utilize the comprehensive new evidence on

[1] Some aspects of fragmentation of production have also been described in the literature as industrial differentiation (Young 1928) or vertical disintegration (Rosenberg 1963) and in the international context as integration of trade and disintegration of production (Feenstra 1998), vertical specialization (Hummels et al. 2001), intra-product trade (Arndt and Kierzkowski 2001), “slicing up the value chain” (Krugman 1995) or simply (global) outsourcing at the firm level (Kogut 1985, Antras and Helpman 2004). “Intra-product” trade and trade in “intermediate inputs” are used interchangeably in this paper.

trade in intermediate products available from the UN Comtrade Database. Our data is based on the UN classification of products by Broad Economic Categories (BEC, rev. 3), which have been constructued to distinguish between trade in final capital goods and intermediate inputs thereof in SITC (rev, 3) and HS (2002) classifications for the purpose of national accounts. Although the BEC classification has been used rather sporadically in the literature on trade so far (see for instance Srholec 2006ab), it is well positioned to provide a new standard for the research of intra-product trade.

A dataset of bilateral trade for a balanced sample of 85 countries in 1995 and 2004 have been constructed using data from the UN Comtrade Database (composition of the sample is given in Table 1). [2] Only independent (sovereign) countries are included in the analysis, with the only exception of Hong-Kong, which is monitored separately from the mainland China. Some very small countries (less than 200,000 USD in exports and/or less than 200,000 inhabitants) were further excluded from the sample (such as most of the Caribbean archipelagos, etc.) Taiwan could not be included due to missing data in the UN Comtrade database.[3]

3. A network perspective of intra-product trade

A majority of the existing empirical studies on intra-product trade is limited to description of basic trends and structure of trade separately for final and intermediate products (Feenstra 1998, Yeats 2001, Kaminski and Ng 2001, Fontange, et al. 2005). Another limitation is that these studies looked only at aggregate trade flows. It is useful to analyse intra-product trade using bilateral trade matrixes, because inputs are often imported from a different country to which they are later passed downstream the value chain. Aggregated data hide important patterns of triangular (and multilateral) "chain" links between countries in the international production networks. Structural characteristics of these relationships derived from network analysis may provide new insights into the literature on intra-product trade.

From the network perspective, countries are the actors (or nodes) of the network, and the amount of bilateral trade represents strength of a directed (export or import) links between them. Social network analysis focuses on the relations between actors (not the individual actors and their attributes). A key issue is how the actor is embedded within a structure and how the structure emerges from the relations between individual parts.

A number of mathematical and statistical tools, essentially based on matrix algebra, have been developed for the social network analysis (for an overview see Hanneman 2001, Carrington, et al. 2005). One of them is structural analysis of the network, which provides various measures of individual roles and overall network structure. The number, strength and structure of connections that actors have determine their role in the network and provides a basis for their (dis)similarity to other actors. Some actors are predominantly "sources" with

[2] It was not possible to construct full time series for such a large sample, because data according to the BEC (rev. 3) is missing in the UN Comtrade Database for many countries in 1996 and other years.

[3] South Africa includes Namibia in 1995 (a custom union), but only data for South Africa is available in 2004 (Namibia is missing). Similarly only data for the Belgium-Luxembourg custom union is available in 1995, so that data for these countries were added together in 2004 as well (the diagional "domestic" exchange between Belgium and Luxembourg was omitted in the 2004 sample). For the Philippines, Russia and Ukraine the data is missing in 1995, but it is available in 1996. To keep these countries in the analysis, we use their bilateral trade in 1996 instead of 1995 in the initial period

important outgoing connections, while other are “sinks” that mostly receive links in the network. Other actors can be “transmitters” that both send a receive, but with different strengths and to different actors. Analogy to trade relations makes most sense in the presence of advanced division of labour in production networks among countries. Some countries may be predominantly exporters of intermediate inputs, while others mainly import inputs and assemble final products from them (possibly for an export market). Still other countries may harbour labour intensive processing plants, which put them in a position of the transmitter of intermediate inputs in the production network (importing large amounts of a components and exporting the same product to a different country down the value chain, such as Malta, the Phillipines or Costa Rica in electronics).

One of the prime interest of network analysis is in the “sub-structures” that are present in the network since there may be a structural basis for stratification of the network. Rather than being truly global the international production networks might be composed of multiple sub-networks (trading blocks) that are substantially more integrated within than with actors in other blocks. A tightly knitted core and a loosely connected periphery of the network also may emerge from the analysis. Sub-structures of the network are important to understand how individual countries are embedded in the network. Some may act as “bridges” between blocks, while others (some “locals”) may conduct most of their trade within a single area. It may have important consequences for trade and ultimate economic development of a country to be deeply integrated into a particular block or remain peripherial (to the international production sharing).

Structural or regular equivalence can be used for measuring positional proximity in a network. Structural equivalence is the more restrictive method. It requires that actors have identical patterns of connections to the same other third actors, i.e. countries are structurally equivalent, if they trade similar amounts with the same partners. Since the method only looks at correlations between the rows and columns of the matrix, and neighbour tend to trade more with each other, the estimated similarity often follows geographical proximity of countries, which is too narrow view to capture different role of countries in the network (rather than their spatial clustering).

Regular equivalence, based on the REGE algorithm, is less restrictive (Wasserman and Faust 1994, pp. 473-482). Actors are regularly equivalent if they have identical ties to and from actors that are themselves regularly equivalent. It does not refer to relations to specific other actors, but only to recursively equivalent actors (actors that play the same role in the network). In other words, two countries can be regularly equivalent and yet trade with different countries. For instance, consider trade in oil between four countries: Norway exports oil to Denmark and Iran exports oil to China (lets assume for simplicity that it is not economical to ship oil from Norway to China and from Iran to Denmark). Structural equivalence will identify four roles: Norway as an exporter to Denmark; Denmark as importer from Norway, Iran as an exporter to China and China as an importer from Iran. On the other hand, regular equivalence will identify only two roles: exporters and importers of oil. Regular equivalence provides a method for identifying general “roles” from the patterns of connections and therefore allows us to identify more general characteristics of the network.

Table 1 shows clustering of countries according to regular equivalence and their centrality – so-called “coreness”– in the trade in intermediate inputs of capital goods. It is organized column-wise for results in 1995 and row-wise for results in 2004. Regular equivalence suggests three broad clusters of countries (see Appendix for tree diagrams). It often provides clustering of countries by their role as a core and a periphery of the network, which has been previously used to study hierarchical structure of the world trading system (Snyder and Kick 1979, Smith and White 1992). The measure of coreness is reassuring for this interpretation of the results (for details on coreness see Everett and Borgatti 2005). Since average coreness of the first group of countries – in the upper left part of the table – is substantially higher than for others, we refer to it as the "core" of the network. Coreness of the second broad cluster of countries suggests that it represents a "semiperiphery". A brief look at the tree diagrams reveals that this cluster can be further divided into two large groups with mean coreness of those in the "1st semiperiphery" more than ten times higher than countries in the "2nd semiperiphery". [4] The remaining countries are peripherial for the intra-product trade (all of them have coreness equal to zero at four decadil places).

In the diagonal can be found countries that did not change their roles in the network over the decade. Twelve countries forged the core in both periods. All of the G7 countries, four newly industriazed countries from East Asia – Hong Kong, Korea, Malaysia and Singapore - and Mexico are included. In 2004 these have been joined by China, the Benelux countries and Spain. The increasing role of China in the global production sharing has been well documented in the literature and lift of the the latter countries obviously reflects the deepening intergration of the European production systems.

Enlarging of the European Common Market is also reflected in shifts of countries from the 2nd to the 1st semiperiphery. In 1995 the latter was populated by medium-size industrialized countries from all corners of the world, Brazil and three rising manufacturing bases from the ASEAN group (Indonesia, the Philippines and Thailand) were already in this group. Over the decade a number of countries, which joined the EU over the nineties as well as during the recent enlargement, joined this group. Also India, Portugal, Russia, South Africa and Turkey appear in the 1st semiperiphery in the latter period, which underlines the increasingly global reach of production networks. Note that only countries from the 1st simiperiphery managed to entre core of the network, so these in this cluster nowadays are the prime candidates to join the core in the future.

In the 2nd semiperiphery remain countries on the east and south borders of the enlarding EU and some countries from Latin America. At the periphery of the international production networking – the network "isolates" - are mainly African and other low-income countries. Small countries, which exports are not based on manufactures, such as Iceland, Oman and Maledives also come out peripherial.

[4] Appendix 1 suggests that another group consisting from Estonia, Kazakhstan, Russia and Ukraine should be distinguished within the semiperiphery in 1995. Although it might be questioned using a strict criteria, for the sake of simplicity we include these four countries into the 2nd semiperiphery. It proved to be useful for analytical purposes, because these countries behave similarly in the rest of the analysis. Note that this decission has no effect on results for the gravity equations in the next section.

Table 1: Clustering of countries according to regular equivalence in the network of trade in intermediate inputs in 1995 and 2004

			1995			
Coreness			0.2333	0.0368	0.0032	0
			Core	1st semiperiphery	2nd semiperiphery	Periphery
2004	0.2135	Core	Canada France Germany Hong Kong Italy Japan Korea Malaysia Mexico Singapore United Kingdom United States	China Belgium-Luxembourg Netherlands Spain		
2004	0.0253	1st semiperiphery		Australia Austria Brazil Indonesia Ireland Israel Philippines Sweden Switzerland Thailand	Czech Rep. Denmark Finland Hungary India Norway Poland Portugal Russia Slovakia South Africa Turkey	
2004	0.0023	2nd semiperiphery			Algeria Argentina Chile Colombia Croatia Egypt Estonia Greece Malta Morocco New Zealand Romania Slovenia Tunisia Ukraine Venezuela	Costa Rica Lithuania
2004	0	Periphery			Kazakhstan	Bangladesh Bolivia Burkina Faso Cameroon Cyprus Ecuador El Salvador Guatemala Iceland Jordan Kyrgyzstan Latvia Macedonia Madagascar Malawi Maldives Mauritius Moldova Nicaragua Oman Panama Paraguay Peru Togo Uganda Uruguay Zambia Zimbabwe

It is important to realize, however, that architercture of the network portrayed by the regular equivalence does not necessarily follow regional patterns or size and income differences among countries, but primarily shows the roles played by actors in the network. Differences along these lines are relevant but not trivial for the core-periphery clustering. Size seems to be important, but Argentina and Ukraine are in the 2nd semiperiphery, Bangladesh in the periphery, while Hong Kong and Singapore are found firmly in the core. Income per capita also matters because it increases in tandem with industrialization, advance division of labour and therefore participation in internalization production networks (for open economies). However, China and Mexico are the core countries, while India, Russia and Argentina are not.

Table 2 provides more details on bilateral trade along these divisions in 2004. Most of the international trade in intermediate inputs was concentrated within the core. Intra-regional trade between the sixteen core countries accounted to two-thirds of the total. Another fifteen percent was trade from the core to the 1st semiperiphery and eleven percent the other way around. The rest of the matrix accounts only for eight percent. It confirms that in value terms there is a strong core of the system and role of most countries is rather marginal from the perspective of the whole network.

A network can be described by density of the connections. Density is defined as the proportion of connections that are present to all connections that could be present. A fully saturated network has density 1 (or 100%). Table 2 shows that except from trade with(in) the periphery the networks of intra-product trade are close to be saturated. Besides further illuminating the distinction between the core and the periphery, the density is also important for selection of the estimation method (OLS vs. tobit regression) in the next section.

Table 2: Trade in intermediate inputs between groups of countries in 2004

Trade in intermediate inputs in bln. USD

	Core	1st semiperiphery	2nd semiperiphery	Periphery	Total
Core	982	223	33	8	1,246
1st semiperiphery	162	41	9	3	215
2nd semiperiphery	12	5	1	1	19
Periphery	0	0	0	0	1
Total	1,157	269	43	11	1,481

Density of connections in %

	Core	1st semiperiphery	2nd semiperiphery	Periphery	Total
Core	100	99	99	94	98
1st semiperiphery	100	100	99	93	97
2nd semiperiphery	97	87	70	48	72
Periphery	67	40	26	18	35
Total	88	77	69	59	71

So far we have not examined the relative importance of trade in intermediate inputs (of capital goods) in international trade. Table 3 provides proportions relative to total trade in capital goods (the other part is trade in final capital goods) and relative to total trade. Nearly half of the total trade in capital goods is trade in their inputs. And about one fifth of the total world trade is in the intermediate inputs of capital goods. Similar proportions are naturally found for the largest amounts of trade in the core and 1st semiperiphery. These shares tend to decrease as we move away from the core. It is strong pattern both row- and column-wise for specialization in terms of total trade as well as row-wise for the share of intermediate inputs in total trade in capital goods. However, the highest values for the latter indicator appear in exports from the 2nd semiperiphery. Although the amount of trade in this direction (and its share in their total trade of these countries) remains relatively small, international production sharing may be an important device for export-driven industrialization of these countries.[5]

Table 3: Importance of trade in intermediate inputs between groups of countries in 2004

% of intermediate inputs in trade in capital goods

	Core	1st semiperiphery	2nd semiperiphery	Periphery	Total
Core	46	46	36	23	45
1st semiperiphery	49	41	35	33	46
2nd semiperiphery	61	50	36	26	54
Periphery	31	37	37	32	34
Total	47	45	36	25	46

% of intermediate inputs in total trade

	Core	1st semiperiphery	2nd semiperiphery	Periphery	Total
Core	22	22	16	10	22
1st semiperiphery	15	12	11	8	14
2nd semiperiphery	7	9	5	4	7
Periphery	1	1	3	1	1
Total	20	19	14	9	20

[5] Averages of these proportions for these groups of countries does not systematically differ from the unweighted percentages presented in Table 3 (i.e. large countries do not drive the unweighted figures).

4. Determinants of intra-product trade

Mapping of trade in intermediate inputs provides important insights into the architecture of the system and roles played by invididual countries. A different perspective is needed to shed futher light into factors driving globalization of production. How can we explain the patterns of bilateral intra-product trade? Does trade in intermediate inputs differ from trade in final products? And does the clustering of countries that came out from the network analysis provide explanations along these lines? We turn to these questions now.

A simpe gravity equation, where the volume of trade between two countries is proportional to size of their product and inversely related to the distance between them, is the natural starting point of the analysis. Another factors have been shown to be relevant elements of gravity equations. Like most other studies, we also include dummy variables for contingent countries, for a common culture proxied by a commong language and a dummy for historical/institutional factors given by a common colonial history. It is well known that the gravity equation can have underpinning from different theories of international trade (xxx the paper in JPE)… Although a comprehensive discussion on testing different theoretical aspects of intra-product trade goes beyond the scope of this paper (and will be a subject of a different paper), nothing prevent us from exploiting the theoretical flexibility of the gravity equation by exploring explanatory power of various differences between counties. Our specification is the following:

$$X_{ij} = \alpha_i + \beta_1 GDP_i + \beta_2 GDP_j + \beta_3 D_{ij} + \beta_4 C_{ij} + \beta_5 L_{ij} + \beta_5 H_{ij} + \beta_6 GAP_{ij} + \varepsilon_{ij}$$

where i the country of origin, j is the destinationa country, X_{ij} is export from i to j, GDP_i and GDP_j is gross domestic product (USD) of the countries i and j, D_{ij} is the geographical distance between the most important cities (in terms of population) in the two countries, C_{ij} is a dummy equal one, if the countries share a common border (adjacency), L_{ij} is a dummy equal one, if the trading partners share a common official language, H_{ij} is a dummy equal one, if the countries have been governed by the same colonizer over a long period and ε_{ij} is the error term. Our prime interest is in the coefficient for GAP_{ij}, which refers to various differences between the trading partners in terms of productivity, technology and institutions (defined as the absolute value of the difference between the trading partners). Except of the dummies, all the variables are in natural logarithms, so that the estimated parameters can be interpreted as elasticities. Sources for the variables are listed in Appendix 3.

Table 4 reports estimates of the gravity equation separately for the bilateral trade in final capital goods and their intermediate inputs in 1995 and 2004.[6] Coefficients of the traditional variables used in gravity equations came out with expected signs and are statistically significant at 1% level; with the only exception of the adjacency dummy. Although there are generally no problems of multicollinerity (mean VIF = 1.10), a modest correlation between distance and the adjacency dummy (R = -0.39) seem to be driving results for the latter variable.[7] The coefficients for the gap in GDP per capita (PPP) are positive and highly significant across the board, which indicates that countries with widely different income per

[6] A sample of 85 countries implies a total number of bilateral trade links (withour the diagonal) equal to 7,140, but only 6,972 observations can be utilized for the estimates because of lacking the data for GDP per capita in Maldives in the World Bank's World Development Indicators 2006.

[7] We keep the variable in the model, because it comes out significant later on.

capita tend to trade more with each other than the basic gravity model predicts. Our expectation that vertical division of labour between rich and poor countries is important is confirmed by the results. Furthermore, magnitude of the coefficients tend to decrease over time, although the overall explanatory power of the model increases. Since we do not observe notable shifts in relative magnitude of the coefficients over time, we further estimate the regressions only for the latest period (see the tables below).

As has been shown by the network density (see Table 2), not all possible connections are present, particularly in the periphery. Since the data are truncated from below at zero, and in the full sample twenty-nine percent of the observations are zeros, we have also used a tobit model to estimate the gravity equations. A comparison of the OLS and the tobit estimates (the left and right parts of Table 4) confirms that the coefficients obtained from the OLS estimates are biased downwards. So we put more weight to the tobit estimates, although interpretation of the results remains the same.

Intra-product trade is generated by firms integrated in production networks. At the micro level, evidence on the increasing globalization of production is abound in the management and business literature (Gereffi, et al. 2005). Organization of production which emerges from international fragmentation is often described as "global production networks" (Ernst and Kim 2002). For a trade analyst, the important insight from this literature is that suppliers and customers of final products organize their relationship differently from firms vertically integrated by exchange of intermediate inputs downstream the value chain. It has been also pointed out that micro heterogeneity of firms, such as diversity in organization of their business abroad, has important consequences for the extent of international trade and investment (Helpman, et al. 2004). Organizational, technological and other differences between producer-user and producer-producer interactions at the micro level should be reflected in different patterns of trade in final goods and intermediate inputs at the aggregate level.

At a first glance, the coefficients estimated for trade in final goods and intermediate inputs seem to differ much, still a formal test may prove otherwise. To test whether these coefficients are statistically different, we conduct the Wald test with the null hypothesis that all coefficients are identical. As reported in the last row in Table 4, the null hypothesis cannot be rejected in both periods, which suggests that the regime of trade in final goods does not differ from the intra-product trade.[8]

[8] The Wald test was performed using *suest* and *testparm* commands in Stata 9.2., which are incompatible with the tobit estimate.

Table 4: Estimates of the gravity equation for all countries in 1995 and 2004

	OLS				Tobit			
	Final capital goods		Intermediate inputs thereof		Final capital goods		Intermediate inputs thereof	
	1995	2004	1995	2004	1995	2004	1995	2004
Constant	-65.92***	-67.63***	-65.14***	-70.34***	-95.48***	-88.22***	-98.01***	-93.00***
	(65.14)	(66.86)	(64.57)	(71.04)	(53.52)	(54.89)	(53.33)	(58.01)
$GDP_{importer}$	1.24***	1.25***	1.23***	1.30***	1.70***	1.55***	1.73***	1.62***
	(47.87)	(50.13)	(47.58)	(53.11)	(41.13)	(42.78)	(40.76)	(45.06)
$GDP_{exporter}$	2.53***	2.54***	2.52***	2.57***	3.36***	3.09***	3.47***	3.18***
	(113.32)	(113.96)	(112.55)	(115.92)	(76.88)	(82.04)	(76.55)	(84.54)
Distance	-2.35***	-2.19***	-2.40***	-2.11***	-3.14***	-2.63***	-3.28***	-2.57***
	(39.31)	(38.77)	(40.48)	(37.65)	(33.73)	(32.15)	(34.61)	(31.86)
Adjacency	0.41	0.18	0.48	0.25	-0.37	-0.22	-0.27	-0.15
	(1.29)	(0.62)	(1.58)	(0.84)	(0.74)	(0.49)	(0.53)	(0.34)
Common language	2.43***	2.16***	2.09***	1.87***	3.59***	2.90***	3.14***	2.56***
	(14.01)	(13.23)	(11.40)	(11.20)	(13.67)	(12.41)	(11.71)	(11.09)
Common colonizer	2.28***	1.50***	2.09***	1.59***	3.80***	2.19***	3.75***	2.41***
	(6.21)	(4.36)	(5.79)	(4.84)	(8.75)	(5.70)	(8.44)	(6.33)
GDP per $capita_{gap}$	0.31***	0.27***	0.27***	0.23***	0.60***	0.48***	0.57***	0.45***
	(6.69)	(6.15)	(5.92)	(5.33)	(8.82)	(7.99)	(8.19)	(7.54)
F / Wald χ^2	3,628.31	3,046.94	3,733.44	3,376.88	6,479.72	6,696.18	6,512.34	6,979.54
R^2	0.65	0.67	0.66	0.68	..	..	..	..
N	6,972	6,972	6,972	6,972	6,972	6,972	6,972	6,972
Wald test final vs. inputs	0.000	0.000	..	..	..	..	..	..

Note: Absolute value of robust t-statistics in brackets; *, **, *** denote significance at the 10, 5 and 1 percent levels. The null hypothesis in the Wald test is that all coefficients in the estimates for final capital goods and intermdiate inputs are identical.

A hierarchical grouping of countries according to their roles in international production sharing has been suggested by the regular equivalence. To examine whether the coefficients differ along the division between the core and the (semi)periphery, we estimate the same gravity equations separately for trade between (and within) the groups of countries derived from the network analysis. We draw the main dividing line between the core and "the rest of the world" (ROW), which refers to countries in the (semi)periphery (the 1st and 2nd semiperiphery jointly with the periphery in Table 1). The model is estimated for intra-core and intra-ROW trade as well as for trade between these two broad groups of countries separately in the direction from the core to the ROW and vice a versa.

Table 5 gives results of tobit estimates. [9] Significantly different coefficients are obtained for the sub-samples. The income gap comes out significant only for intra-ROW trade and for exports of intermediate inputs from the core to the ROW. In the latter estimate the coefficient is smaller than for the full sample, while the opposite holds for the former.[10] The coefficient is not statistically different from zero in the other regressions, which means that trade between these groups of countries is within the prediction of the basic gravity equation. An important outcome is that location advantages, proxied by the gap variable, boost exports of intermediate inputs from core to the periphery, but are not related to trade in final capital goods in the same direction, which is another indication that determinants of these two types of trade differ (and also verifies validity of the core-periphery divide).

GDP of exporters, importers and distance between them remain highly significant and with the correct sign, although magnitude of the coefficients varies greatly across the board. The estimated elasticity of trade to distance is rapidly increasing row-wise, which suggests that distance, and associated trade costs, are more important for exports in the (semi)periphery. It seems that opportunities to trade for the peripherial countries can be substantially improved by lowering the effect of distance (for example by investment into infrastructure, more exploiting of scale economies, etc.). Another support for trade being more sensitive to cost differences in the periphery might be derived from the gap variable. A reason why the gap came out significant particularly in those three estimates can be that low wages (and therefore price-based competitiveness) tend to appear in tandem with low income per capita. So that the differences in prices matters for exports in the periphery, but other than price factors are driving globalization of production in the core countries. However, such an interpretation of the gap variable remains rather speculative until the indicator of unit labour costs provides similar results.

[9] OLS estimates are reported in Appendix 4. The results differ noticeably only for the ROW-core and ROW-intra estimates because a significant number of "zeros" is present in these sub-samples.

[10] Note that the intra-ROW trade obviously dominates results fo the full sample because two-thirds of the observations are in this sub-sample, though two-thirds of the amount of trade is within the core.

Table 5: Estimates of the gravity equation by regions in 2004 (tobit model)

	Final capital goods				Intermediate inputs thereof			
	Intra-core	Core-ROW	ROW-core	Intra-ROW	Intra-core	Core-ROW	ROW-core	Intra-ROW
Constant	-8.76***	-33.86***	-56.89***	-107.22***	-4.25	-36.09***	-63.82***	-113.26***
	(2.95)	(12.56)	(12.41)	(37.17)	(1.41)	(13.44)	(13.12)	(39.73)
$GDP_{importer}$	0.63***	1.23***	1.10***	1.67***	0.50***	1.38***	1.01***	1.74***
	(9.62)	(22.98)	(9.53)	(24.33)	(7.43)	(26.04)	(8.25)	(26.01)
$GDP_{exporter}$	0.63***	1.08***	2.44***	3.99***	0.55***	0.96***	2.82***	4.12***
	(9.63)	(15.88)	(26.83)	(54.03)	(8.30)	(14.17)	(29.11)	(56.22)
Distance	-0.65***	-1.08***	-2.23***	-3.49***	-0.53***	-1.08***	-2.34***	-3.40***
	(7.31)	(10.65)	(13.03)	(28.84)	(5.84)	(10.66)	(12.94)	(28.91)
Adjacency	0.56	-0.09	-1.35	-0.42	0.61*	-0.12	-1.78	-0.25
	(1.57)	(0.13)	(1.20)	(0.67)	(1.68)	(0.18)	(1.50)	(0.41)
Common language	0.37	0.59**	1.82***	4.37***	0.57**	0.90***	1.79***	3.72***
	(1.57)	(2.19)	(4.03)	(12.12)	(2.35)	(3.38)	(3.76)	(10.58)
Common colonizer	1.35**	0.28	-0.46	2.38***	2.27***	0.25	-0.83	2.70***
	(2.29)	(0.54)	(0.52)	(4.35)	(3.79)	(0.48)	(0.89)	(5.05)
GDP per $capita_{gap}$	0.03	0.06	-0.08	0.55***	0.06	0.18**	-0.01	0.52***
	(0.61)	(0.72)	(0.56)	(6.06)	(1.10)	(2.08)	(0.02)	(5.86)
Wald χ^2	211.13	748.27	811.11	3,703.62	168.78	796.73	869.08	3,911.59
N	240	1,088	1,088	4,556	240	1,088	1,088	4,556

Note: Absolute value of robust t-statistics in brackets; *, **, *** denote significance at the 10, 5 and 1 percent levels. ROW is rest of the world. ROW refers to countries, which clustered in the 1st and 2nd semiperiphery and the periphery.

Apart from measuring productivity, GDP per capita is often used as a proxy for other aspects of (under)development, such as the level of technology for instance. Many other factors – correlated to the level of economic development – might be found to be associated to the extent of intra-product trade. To obtain a better idea on what factors may be lurking behind the significant coefficient of the income gap, we reestimate the gravity equations using a battery of indicators for differences in technology, skills and institutions. Table 6 summarizes tobit coefficients for these factors if the various gaps are introduced into the equation instead of the differences in income per capita. Logarithmic transformation of the absolute difference between countries is used only for the indicators on per capita basis. For space considerations, coefficients of the other variables in the estimate are not reported (available from the author upon request). See Appendix 3 for overview of the indicators.[11]

First, we look at direct measures on technology gap. Among the growing number of available technology indicators, we choose research and development expenditure (% of GDP), the number of USPTO patents per capita (per capita) and the number of science and engineering articles per capita (per capita).[12] On a worldwide basis, these indicators tend to be highly correlated to each other (and also to GDP per capita), so it is not surprising that for the full sample all of them give similar results. Some differences emerge in the sub-samples. Divides in patenting are significant in all of the estimates, articles are not relevant only for the intra-core trade, while gaps in R&D spending came out significant for the latter and the intra-ROW trade. Altogether technology gaps seem to boost intra-product trade between countries.

Second, we explore differences between countries in skills (or human capital) represented by average years of primary, secondary and tertiary education in population. There is a sharp contrast between results in the full sample for the differences in technology and skills. Although wide gaps in technology between exporter and importer lead into large intra-product trade, it is the opposite for differences in primary and tertiary education. Looking at the sub-samples, the negavite coefficient is sustained and significant for the differences in primary education with the only exception of intra-core trade, where there are probably a little cross-country differences. Universal primary education seems to be a must for countries to participate in the international production sharing. On the other hand the coefficient of tertiary education turns into positive and significant for the intra-core sub-sample, which again manifests the different mechanism of intra-product trade in the core and other countries.

It has been pointed out that the prevailing varieties of capitalism in the world economy may represent “institutional comparative advantage” and induce trade (and direct investment) between countries (Hall and Soskice 2001). So finally, we examine explanatory power of various institutional indicators constructed in the “governance matters” dataset by Kaufmann, et al. (2005) and the index of democracy based on constitutional rules by Marshall and Jaggers (2003).[13] A mixture of significantly positive and negavite coefficients comes out

[11] Since there are missing data for some of these variables, the number of observations (and therefore composition of the sample) differs across these estimates (see Appendix 3 for the number of missing countries).
[12] One had to be added to patents per capita before the log transformation because some countries have no patents at the USPTO. In order to suppress the “home country advantage” of United States in the USPTO patent counts, we adjusted scores for this country downwards based on a comparison between the Japanese and the United States patents registered at the European Patent Office (see Archibugi and Coco 2004, p. 633).
[13] For an extended discussion on the difference between institutions and governance see Fagerberg and Srholec (2005).

from the estimation. It apears that all else equal these is less intra-product trade between politically stable and unstable countries. However, coeffiicients for the other variables tend to change sings depending on the (sub)sample, which suggests that there is a lot of diversity in how these factors influence trade between the core and the periphery. More research is needed to shed further light into these results.

Table 6: Estimates of the gravity equation for intermediate inputs in 2004: Coefficients of variables for gaps in technology, skills and institutions (tobit model)

	Intermediate inputs thereof				
	All countries	Intra-core	Core-ROW	ROW-core	Intra-ROW
R&D	0.53***	0.37***	-0.01	0.14	0.57***
	(6.81)	(2.80)	(0.05)	(0.70)	(5.33)
Patents	0.58***	0.27***	0.30***	0.41***	0.63***
	(14.40)	(3.62)	(5.39)	(4.06)	(10.87)
Articles	0.59***	0.03	0.21***	0.38***	0.58***
	(12.36)	(0.35)	(3.44)	(3.65)	(8.30)
Primary education	-0.48***	-0.23	-0.22**	-0.76***	-0.46***
	(6.54)	(1.55)	(2.47)	(4.33)	(4.27)
Secondary education	0.14*	0.15	0.09	-0.25	0.39***
	(1.78)	(1.37)	(1.07)	(1.47)	(3.13)
Tertiary education	-1.34***	0.74***	-0.13	0.57	-0.24
	(4.43)	(2.80)	(0.43)	(0.98)	(0.39)
Voice	-0.23**	0.49***	0.36***	-0.34*	-0.57***
	(2.46)	(4.52)	(3.32)	(1.74)	(4.04)
Corrupt	0.42***	0.20*	-0.05	-0.08	0.42***
	(5.50)	(1.77)	(0.55)	(0.48)	(3.69)
Gov effectiveness	0.26***	-0.01	-0.05	-0.83***	0.30**
	(3.03)	(0.06)	(0.51)	(4.38)	(2.32)
Political stability	-0.17*	0.27	-0.30**	-1.07***	-0.16
	(1.74)	(1.20)	(2.53)	(5.01)	(1.18)
Regulatory quality	-0.02	0.55***	-0.01	-0.92***	-0.16
	(0.25)	(3.55)	(0.11)	(4.61)	(1.17)
Rule of law	0.26***	0.05	0.01	-0.68***	0.35***
	(3.00)	(0.35)	(0.06)	(3.65)	(2.75)
Democracy	-0.10***	0.08***	0.05***	-0.05*	-0.20***
	(7.96)	(5.42)	(3.19)	(1.79)	(10.28)

Note: Absolute value of robust t-statistics in brackets; *, **, *** denote significance at the 10, 5 and 1 percent levels. ROW is rest of the world.

5. Conclusions

Intra-product trade can be analyzed by distinguishing trade in final goods from their intermediate inputs. Using data from the UN Comtrade Database according to the BEC (rev. 3) classification, we have constructed matrixes of bilateral trade separately for these types of trade for a balance sample of 85 countries in 1995 and 2004. Analysis of regular equivalence suggested clustering of these countries into core and three tiers of (semi)periphery of the international production networks. Estimates of the gravity equation did not reveal significant differences in determinants of trade in the final goods and their intermediate inputs. However, we found that determinants of intra-product trade differ along the divisions derived from the network analysis. Intra-product trade within the core is not related to cross-country differences in productivity, technology, skills or institutions. On the other hand, intra-product exports from the core to the rest of the world as well as intra-peripherial trade is correlated to the differences.

Our results suggest that globalization of production within the core countries is driven by different factors than the spread of production networks outside of the core. More research is needed to examine whether the definition of the core is robust to sample composition and whether similar differences in the regression results can be obtained for geographical or other clustering of countries (such as the commonly used divide between developed and developing countries). Analysis of the aggregate data for capital good may hide important differences at the industrial level. It remains a challenge for the future research to investigate whether patterns of trade in final goods and intermediate inputs differ in the context of specific industries, such as the highly globalized production of electronics.

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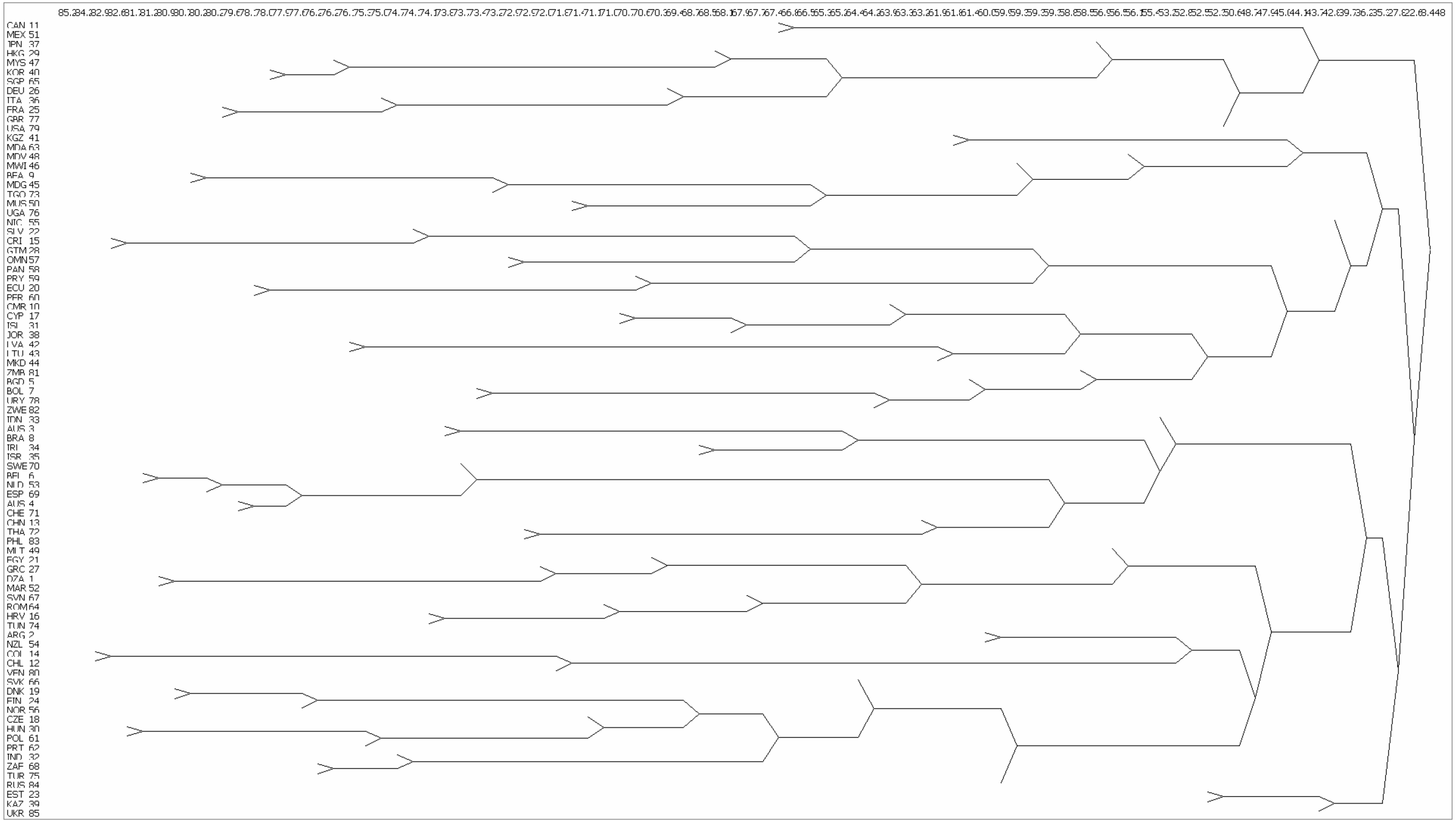
Appendix 1: Tree diagram – regular equivalence in 1995



Note: Countries are identified by ISO3 codes.

Appendix 2: Tree diagram – regular equivalence in 2004

Note: Countries are identified by ISO3 codes.

Appendix 3: Sources of variables used in the gravity estimates

Indicator	*Scaling*	*Source*	*Years*	*Number of missing countries*
Gross domestic product (GDP)	USD	World Bank (World Development Indicators 2006)	1995, 2004	0
GDP (PPP, constant 2000 USD)	per capita			1
Geographical distance and the dummies for adjacency, common official language and a common colonizer	km and a dummy	CEP II datasets	Fixed	0
Gross domestic expenditure on research and development (R&D)	% of GDP	World Bank (World Development Indicators 2006), OECD (MSTI Database), RICYT and national sources	The latest year available	18
USPTO patents	per capita	OECD Patent Database (based on the USPTO)	2004	0
Science and engineering articles	per capita	U.S. National Science Foundation (Science and Engineering Indicators 2006)	2003	17
Average primary, secondary and tertiary schooling years in population:	years	Barro and Lee (2000)	2000	19
Voice and Accountability, Control of Corruption, Government Effectiveness, Political Stability, Regulatory Quality, Rule of Law	Index (-2.5 to 2.5)	Kaufmann, et al. (2005)	2004	0
Index of democracy and autocracy	index (-10 to 10)	Marshall and Jaggers (2003) - Polity IV Dataset	2003	4

Note: See the original sources for definitions of the variables.

Appendix 4: Estimates of gravity equation by regions in 2004 (OLS)

	Final capital goods				Intermediate inputs thereof			
	Intra-core	Core-ROW	ROW-core	Intra-ROW	Intra-core	Core-ROW	ROW-core	Intra-ROW
Constant	-8.69***	-33.28***	-51.27***	-66.16***	-4.18	-35.45**	-55.77***	-68.63***
	(3.08)	(10.37)	(13.36)	(43.14)	(1.41)	(11.33)	(13.72)	(45.64)
$GDP_{importer}$	0.63***	1.21***	1.00***	1.12***	0.49***	1.37***	0.90***	1.15***
	(8.45)	(19.01)	(9.67)	(26.30)	(6.71)	(21.17)	(8.25)	(28.45)
$GDP_{exporter}$	0.63***	1.07***	2.29***	2.74***	0.55***	0.95***	2.59***	2.76***
	(11.20)	(13.35)	(31.17)	(77.37)	(7.97)	(12.14)	(33.08)	(79.49)
Distance	-0.65***	-1.07***	-2.11***	-2.61***	-0.53***	-1.07***	-2.18***	-2.49***
	(9.63)	(11.87)	(16.02)	(36.04)	(7.45)	(11.67)	(15.84)	(35.08)
Adjacency	0.57**	-0.07	-1.13*	0.53	0.61*	-0.10	-1.48**	0.68*
	(2.05)	(0.22)	(1.73)	(1.49)	(1.92)	(0.26)	(2.39)	(1.94)
Common language	0.37	0.58***	1.68***	2.67***	0.56**	0.89***	1.59***	2.15***
	(1.43)	(2.91)	(4.38)	(12.20)	(2.07)	(4.47)	(3.85)	(9.60)
Common colonizer	1.34***	0.28	-0.23	1.07***	2.27***	0.24	-0.56	1.18***
	(3.11)	(0.34)	(0.23)	(2.64)	(4.95)	(0.29)	(0.57)	(3.10)
GDP per $capita_{gap}$	0.03	0.06	-0.11	0.29***	0.06	0.17**	-0.04	0.25***
	(0.58)	(0.68)	(0.91)	(5.11)	(1.09)	(1.99)	(0.35)	(4.58)
F	68.81	94.54	232.41	1,715.94	46.84	99.66	238.08	1,916.86
R^2	0.59	0.51	0.56	0.60	0.51	0.53	0.59	0.62
N	240	1,088	1,088	4,556	240	1,088	1,088	4,556

Note: Absolute value of robust t-statistics in brackets; *, **, *** denote significance at the 10, 5 and 1 percent levels. ROW is rest of the world. ROW is rest of the world.