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Suggested Citation: Görg, Holger (2000) : Fragmentation and trade: US inward processing trade in the EU, Weltwirtschaftliches Archiv, ISSN 0043-2636, Mohr, Tübingen, Vol. 136, Iss. 3, pp. 403-422

This Version is available at:

<https://hdl.handle.net/10419/2491>

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Fragmentation and Trade: US Inward Processing Trade in the EU

By

Holger Görg

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I. Introduction

The increasing “globalization” of the world economy over the last decades has attracted much interest in the recent academic literature (see, for example, Arndt 1997). Most scholars seem to agree that the increasing levels of international trade in goods and services and the increasing international mobility of capital are two signs of this rapid globalization. Other economists, such as Jones and Kierzkowski (1990, 2000) and Venables (1999), also point to the increasing possibilities of international fragmentation, i.e., the splitting up of vertically integrated production processes into separate components, which enable a more rapid globalization of the world economy. If production processes are fragmented, there is scope for international trade in intermediate products as well as for the emergence of multinational companies, with plants in different countries producing different components which are then traded between plants within the multinationals.

The possibilities created by fragmentation have received considerable attention in the recent literature, with most of the literature to-date being concerned with theoretical issues, analyzing these mainly from the point of view of the international trade literature using Ricardian and Heckscher–Ohlin type models (see Deardorff 1998, 2000; Jones and Kierzkowski 2000). Complementing this work, this paper undertakes, to the best of our knowledge for the first time, an empirical study of the

Remark: I am grateful to James McCarthy and Adrian Redmond of the Central Statistics Office of Ireland for help with the Eurostat data. Thanks are due to Marius Brühlhart, Henryk Kierzkowski, Gerard O'Reilly, Frances Ruane, an anonymous referee, and participants at the IESG conference at Warwick University, April 1999, and the EARIE conference in Turin, September 1999, for helpful comments on an earlier draft of the paper. Any remaining errors are mine. Financial support from the Faculty of Business and Management at the University of Ulster is gratefully acknowledged.

extent and the determinants of fragmentation in US trade with the EU. Data available from Eurostat enable us to analyze US trade with the EU in intermediate goods, which are processed in the EU and then re-exported to destinations outside the EU. This type of trade, which we use as a proxy for the extent of fragmentation, is named "inward processing trade" (IPT). We are interested in the determinants of fragmentation and, specifically, why a particular EU member state receives inward processing trade into a particular sector.

The paper is structured as follows. Section II discusses the empirical background for our study and presents some descriptive data on the extent of US inward processing trade in the EU. Section III discusses the determinants of fragmentation and specifies an empirical model of the determinants of the distribution of US IPT across EU countries. Section IV presents the results of an econometric estimation of the model, using panel data for the period 1988–1994, while Section V summarizes the main results of the paper and draws some conclusions.

II. Empirical Background

In order to measure fragmentation it is helpful to note that fragmentation can take place across borders or domestically, and it can be inter-firm or intra-firm. In the case of intra-firm fragmentation, domestic fragmentation leads to the emergence of domestic multi-plant firms, while international fragmentation leads to intra-firm trade between plants within the same multinational company (MNC). In the case of inter-firm fragmentation, international fragmentation leads to inter-firm trade.

This paper is concerned with international fragmentation, i.e., trade in fragmented products across national borders. There have been, to the best of our knowledge, only a few empirical studies, presenting descriptive statistics on the importance of trade as a means of fragmentation. See, for example, Feenstra (1998) for fragmentation in the US, Kierzkowski (2000) and Baldone et al. (1997) for Central and Eastern European countries, and Ruane and Görg (2000) for Ireland.

One indicator of trade in fragmented components (rather than final goods) is the extent of trade which is devoted to trading intermediate goods which are processed abroad and are then shipped back to the home country for final production (see Kierzkowski 2000). Such data are available for the EU, where Eurostat collects information on outward and inward processing trade (OPT/IPT) in EU member states. Outward processing is the customs arrangement allowing goods to be temporar-

ily exported from EU territory for processing, and the resultant products to be released for free circulation in the EU with total or partial relief from import duties. Inward processing is the duty relief procedure allowing goods to be imported into the EU for processing and subsequent export outside the EU without payment of duty. Thus, IPT data enable us to establish to what extent countries in the EU are bases for fragmentation and they, therefore, give a good indication of the extent of fragmentation across borders. Unfortunately, the data do not allow us to distinguish between intra-firm trade, i.e., trade between different plants within a multinational company, and inter-firm trade, i.e., trade between different firms.

We focus on the US as a source for IPT because the US is a major trading partner of EU countries. According to Eurostat data, roughly 19 per cent of total imports from outside the EU were sourced from the US and 18 percent of total extra-EU exports from the EU were directed towards the US in 1994.¹ Furthermore, as with many empirical studies, constraints on the data used for the empirical estimation below favour the focus on the US as a source for fragmentation.

We analyze the development of US inward processing trade over the period 1988–1994. The focus on this period is mainly due to data constraints, but the exclusion of earlier years also allows us to ignore possible changes in inward processing trade following the introduction of the Single European Market. While the Single Market was not completed before 31 December 1992, the Single European Act, which introduced the commitment to achieve the Single Market by the end of 1992, came into effect in 1987. One may, therefore, expect market players to have anticipated the effects of the Single European Market at least from that point onwards (Aristotelous and Fountas 1996).

Table 1 presents data on US IPT as a percentage of total imports from the US for the 12 EU member states. The percentage for the EU 12 as a whole increased slightly between 1988 and 1994, perhaps reflecting a trend towards greater fragmentation of production over that period (see also Baldone et al. 1997; Kierzkowski 2000). This trend is particularly striking for the peripheral countries, where the percentage of IPT increased from around 14 per cent to 24 per cent of US imports.²

¹ 1994 is the latest year for which the data used in the empirical estimation below are available. This implies that all data relate to the EU 12, i.e., the twelve member states that formed the EU prior to the accession of Austria, Finland and Sweden in 1995.

² Peripheral countries are defined as Greece, Ireland, Portugal and Spain. Belgium, Denmark, France, Germany, Italy, Luxembourg, the Netherlands and the UK are seen as core countries.

Table 1 – *US IPT as Percentage of US Imports by Country (per cent)*

	1988	1994
Belgium/Luxembourg	12.5	16.9
Denmark	8.3	11.5
France	29.8	31.1
Germany	13.1	16.7
Greece	12.0	4.0
Italy	9.9	11.1
Ireland	23.7	44.1
Netherlands	24.1	14.0
Portugal	4.6	6.2
Spain	10.3	11.9
UK	16.3	18.6
Core	18.1	18.9
Periphery	13.7	23.7
EU 12	17.7	19.8

Source: Calculated from Eurostat, *Intra- and Extra-EU Trade* (combined nomenclature). CD-ROM.

Table 2 – *US IPT as Percentage of US Imports by Sector (per cent)*

	1988			1994		
	EU 12	Core	Periphery	EU 12	Core	Periphery
Food, Drink & Tobacco	5.0	5.9	1.5	4.4	5.2	0.8
Chemicals	16.2	15.7	20.1	16.0	14.7	28.1
Leather	29.5	13.8	78.2	21.7	11.4	62.3
Rubber	18.3	18.5	16.1	12.4	12.3	13.0
Cork & Wood	4.2	4.4	1.9	2.4	2.6	0.4
Paper	8.8	8.6	11.4	13.7	14.4	5.2
Textiles	11.0	10.3	17.1	11.0	9.6	24.9
Non-metallic Minerals	3.7	3.3	13.9	6.7	4.2	53.0
Metals	21.9	21.6	26.4	19.2	19.5	16.4
Metal Manufacturing	19.6	18.1	34.3	17.4	15.8	32.9
Industrial Machinery	27.8	29.8	8.1	34.6	36.4	11.7
Electronics	15.5	15.1	18.1	21.0	17.5	46.2
Transport Equipment	32.1	34.8	12.5	24.8	27.6	4.6
Other Manufacturing	10.5	10.5	9.8	10.3	9.6	17.3
Total	17.7	18.1	13.7	19.8	18.9	23.7

Source: See Table 1.

Increasing IPT inflows can be observed for almost all member states with the exception of Greece and the Netherlands. The most notable increase in IPT (by roughly 20 percentage points) is evident for Ireland, which may suggest that Ireland has become an increasingly attractive host for fragmented production over that period (Ruane and Görg 2000).

Table 2 presents the distribution of US IPT across manufacturing sectors for the EU. Note that there are fairly high percentages of IPT for the Leather and Textiles sectors, particularly in the EU periphery. Given that inward processing trade allows the circumvention of tariff barriers, one may expect this type of trade to be affected by the corresponding patterns of tariffs. While it is arguably not very meaningful to calculate tariffs for such highly aggregated sectors as used in this paper,³ inspection of the range of nominal and effective rates of protection calculated by Greenaway (1988) and Ennew et al. (1990) shows that Leather and Textiles are sectors which include products that are subject to high rates of protection. One may therefore expect inward processing trade in these sectors to be a means to overcome high tariff barriers. Note, however, that IPT is not confined to these sectors; there are high percentages of IPT for other sectors, most notably Industrial Machinery and Transport Equipment as well.

The patterns of IPT differ for core and peripheral countries. Turning to the core countries first, the table shows that the Metals, Industrial Machinery, and Transport Equipment sectors receive the highest percentages of US IPT, and this has not changed by much between 1988 and 1994. The sectoral distribution of US IPT in peripheral countries, however, has altered over the period. While the Leather sector receives the highest percentages of US IPT in both 1988 and 1994 (perhaps due to high rates of protection for particular goods in the sector), the Non-metallic Minerals and Electronics sectors have become the second- and third-largest recipients of US IPT in 1994. In particular in the Electronics sector, this development may reflect the impact of falling coordination costs for production in that sector. New technological developments have led to an increasing “weightlessness” of production in this sector (Quah 1996) which, combined with falling communications and transport costs, have extended the tradability of electronics products.

³ Girma et al. (1999) argue that an aggregation of tariff rates across sectors may be misleading as it does not take into account differences in tariffs across products. See also Barrell and Pain (1999).

III. Determinants of Fragmentation

Fragmentation of production is possible if intermediate products can be easily traded.⁴ Reductions in transport costs as well as improvements in communications over the last decades mean that trade has become easier and less costly, allowing fragmentation to occur (Harris 2000; Jones and Kierzkowski 2000). This leads to a re-organization of the production process, whereby the production of components can be re-allocated around the globe.

The issue of interest in this paper is what determines the allocation of fragmentation across countries, i.e., how companies decide on the host country for the production of fragmented components. If the EU were one homogenous producer market, we would expect fragmented production to be randomly distributed across member states. If US producers perceive differences across locations in the EU, however, we would expect systematic differences in the distribution of fragmentation across EU countries.

As argued above, fragmentation of production can lead to intra-firm trade between different plants within the same multinational companies. This process has recently been formalized by Venables (1999). If transport costs are low, a firm may find it profitable to locate the production of intermediate goods or the assembly of the final product to a low-wage country, which is effectively a fragmentation of production leading to intra-firm trade.⁵ This argument also implies, however, that a country which is host to a large stock of multinational companies may also be likely to be a base for fragmentation, as MNCs may re-locate the production of components to countries where they already have subsidiaries. In other words, a large part of intra-firm trade between plants within the same multinational may be trade in fragmented components.

There are, of course, other explanations as to why a country could be a base for fragmentation even without involving multinational companies. For the production of an integrated product where both the intermediate good *A* and the final output *B* are produced using labour and capital inputs, Venables (1999) shows in a partial equilibrium analysis that, in a two-country setting, a reduction in transport costs can lead to

⁴ Venables (1999) shows that fragmentation is impossible if transport costs are very high, and becomes possible as transport costs are reduced.

⁵ Zhang and Markusen (1999) also discuss vertical multinationals which fragment production through "locating skilled-labor-intensive phases of operation in a skilled-labor-abundant country and unskilled-labor-intensive or resource-intensive phases in suitable locations" (p. 234).

a relocation of production. Depending on their respective capital intensities, either the production of *A* or *B* will move to the low-wage economy to exploit factor cost differences between countries. A country with relatively low labour costs may, therefore, be more likely to be a host for the production of fragmented components than a country with high labour costs.

Jones and Kierzkowski (2000) argue that fragmented production allows greater possibilities for the exploitation of gains from specialization. The production of components can be dispersed globally according to countries' comparative advantages. This implies that a country with a comparative advantage in sector *i* is more likely to be a host for fragmented production in that sector than another country, *ceteris paribus*. In the conventional framework, differences in factor endowments across countries are the source for different comparative advantages.

The literature leaves us, therefore, with three predictions for the empirical analysis. Other things being equal, we would expect a country *i* to attract the production of fragmented components in sector *j* if it has (i) a large stock of MNCs, (ii) low labour costs and (iii) a comparative advantage in that sector. This leads to the following empirical model:⁶

$$IPT_{ijt} = \alpha_0 + \alpha_1 FDI_{ijt} + \alpha_2 WAGE_{ijt} + \alpha_3 CA_{ijt} + \mu_i + v_j + \varepsilon_{ijt}, \quad (1)$$

where the dependent variable IPT_{ijt} is defined as the ratio of US IPT to total imports from the US in country *i* and sector *j* at time *t*. FDI_{ijt} is the stock of US foreign direct investment in country *i* and sector *j* at time *t* as a percentage of GDP, $WAGE_{ijt}$ is a sectoral labour cost variable and CA_{ijt} is a proxy for a country's comparative advantage in a sector. The term μ_i is a country-specific time-invariant and unobservable effect, such as culture or language, v_j is a sector-specific time-invariant unobservable effect (for example, the level of technology), and ε_{ijt} is the remaining period-specific error term, assumed to be independent across countries, sectors, and over time.⁷

⁶ As pointed out above, tariffs may also have a role to play in determining the total level of inward processing trade. However, tariffs are not included in the empirical model for two main reasons. First, tariffs may affect each member state equally since there is no independent trade policy of individual EU countries. Second, as pointed out above, it is doubtful whether a calculation of tariff rates at such a highly aggregated level is meaningful.

⁷ We also experimented with the inclusion of time-specific effects in the empirical model, but statistical tests showed that the inclusion of these effects was not appropriate.

There is a possible problem with the model in (1) in that *FDI* may itself be positively influenced by a country's comparative advantage (Milner and Pentecost 1996) and the level of labour costs (Barrell and Pain 1996). In order to overcome this difficulty, we estimate an auxiliary equation

$$FDI_{ijt} = \beta_0 + \beta_1 CA_{ijt} + \beta_2 WAGE_{ijt} + e_{ijt} \quad (2)$$

and use the residual e_{ijt} from this regression as a proxy for US FDI.⁸ In other words, the residual reflects the share of US foreign direct investment that is not explained by either comparative advantage or labour costs and is, therefore, employed as a proxy for FDI_{ijt} in (1).

IV. Econometric Estimation

1. Data

Data for the dependent variable and the comparative advantage variable are taken from the Eurostat CD-ROM: *Intra- and Extra-EU Trade (combined nomenclature)*, which provides intra- and extra-EU trade statistics for all member states. The empirical measurement of comparative advantage is problematic, and this fact has been discussed extensively in the literature (see, for example, Deardorff 1980 and Ballance et al. 1987). The main problem is that comparative advantage depends on relative autarkic prices, which are not observable post-trade. However, only post-trade events can be measured empirically. Therefore, several post-trade indicators of "revealed comparative advantage" have been suggested in the literature, which can be assumed to give a reasonably good approximation of actual comparative advantages.

We calculate two measures of revealed comparative advantage, namely

$$CA1_{ijt} = (X_{ijt} - M_{ijt}) / (X_{ijt} + M_{ijt}), \quad (3)$$

i.e., the net trade ratio, which has been used as a measure of revealed comparative advantage in recent papers by Lundbäck and Torstensson (1998), Milner and Pentecost (1996) and Neven (1990). Also, we calculate the simple ratio of exports over imports,

$$CA2_{ijt} = X_{ijt} / M_{ijt}, \quad (4)$$

as used by Driffield and Munday (2000).

⁸ See Kokko (1994: 283) for a similar exercise.

Data on labour costs are available from the US Department of Labor. They report hourly compensation costs for production workers in manufacturing for 31 countries and 40 manufacturing industries. We use an index for relative labour costs, i.e., labour costs in the EU country relative to the US, as a proxy for *WAGE*.⁹

Finally, the data on US foreign direct investment are taken from data available from the US Department of Commerce. The data relate to US FDI stocks in manufacturing and services industries, which are collected by the US Department of Commerce for more than 50 countries. *FDI* is calculated as the ratio of US FDI stocks by sector *j* over GDP in country *i* at time *t*. GDP data for EU member states are taken from Eurostat statistics.¹⁰

2. Results

We estimate (1) and (2) with data for 14 manufacturing sectors for the period 1988–1994. The results for estimating the auxiliary regression in (2) using OLS are presented in the Appendix. Equation (1) was estimated using fixed-effects panel data regression techniques as described by Baltagi (1995). The fixed-effects model was deemed preferable for the estimation of country-specific effects to a random-effects specification because we follow a specific set of countries over time. While the fixed-effects model purges country-specific effects, we include sectoral dummies in the estimation to control for sector-specific effects as specified in the equations above. All estimations are performed in Stata 6.0.

Table 3 presents the results of the estimation of (1) using available data for all EU countries. We estimate four alternative specifications: Columns 1 and 2 use *CA1* as the measure of comparative advantage and show the results of the estimation without and with sectoral dummies, respectively. Columns 3 and 4 include *CA2* as independent variable and also show results excluding and including dummy variables for sectors, respectively. As the F-statistics show, the hypothesis of identical country-specific effects can be rejected in all four specifications. Also, the

⁹ One may argue that the *CA1* and *CA2* variables are correlated with the *WAGE* variable. In a correlation analysis we found only a very weak correlation (correlation coefficient equal to 0.35 between *CA1* and *WAGE* and 0.05 between *CA2* and *WAGE*). The correlation coefficient between *CA1* and *CA2* is 0.63.

¹⁰ We use lagged variables for all right-hand side variables. In the case of the revealed comparative advantage measures, this is partly because of the possible endogeneity between *CA1* or *CA2* and the dependent variable, if data for the same year were used.

Table 3 – *Econometric Results for Estimation for All EU Countries*

Variable	(1)	(2)	(3)	(4)
CA1	0.1223 (0.0185)***	0.1365 (0.0185)***	–	–
CA2	–	–	0.0097 (0.0043)**	0.0135 (0.0041)***
FDI	4.8113 (1.2453)***	7.2519 (1.2506)***	5.3566 (1.2647)***	7.9046 (1.2670)***
WAGE	–0.0013 (0.0003)***	0.0006 (0.0004)*	–0.0011 (0.0003)***	0.0007 (0.0004)*
Sector 1	–	–0.0150 (0.0230)	–	–0.0141 (0.0234)
Sector 2	–	0.0812 (0.0244)***	–	0.0717 (0.0248)***
Sector 3	–	–0.0046 (0.0250)	–	–0.0091 (0.0255)
Sector 4	–	0.0615 (0.0233)***	–	0.0542 (0.0237)**
Sector 5	–	–0.0190 (0.0239)	–	–0.0442 (0.0241)*
Sector 6	–	0.0708 (0.0253)***	–	0.0406 (0.0250)
Sector 7	–	0.0426 (0.0235)*	–	0.0354 (0.0238)
Sector 8	–	0.0694 (0.0236)***	–	0.0770 (0.0240)***
Sector 9	–	0.1968 (0.0254)***	–	0.1916 (0.0258)***
Sector 10	–	0.1351 (0.0243)***	–	0.1336 (0.0248)***
Sector 11	–	0.1315 (0.0239)***	–	0.1241 (0.0242)***
Sector 12	–	0.1332 (0.0237)***	–	0.1186 (0.0240)***
Sector 13	–	0.1225 (0.0266)***	–	0.1054 (0.0268)***
CONSTANT	0.27470 (0.0292)***	0.0135 (0.0447)	0.2394 (0.0294)***	–0.0106 (0.0460)
# of observations	736	736	736	736
F ($H_0: \alpha_n = 0$)	20.05	13.82	10.37	11.80
F ($H_0: \mu_i = \mu_n$)	4.82	5.22	5.20	5.07
F ($H_0: v_j = v_k$)	–	11.69	–	12.12
R ²	0.12	0.26	0.08	0.26

Note: Fixed-effects panel data estimation, standard error in parentheses. – ***, **, * denote statistical significance at the 1 per cent, 5 per cent, 10 per cent level, respectively. – With 11 countries, 14 sectors, and 7 years one may expect 1,078 observations. The smaller number of observations is due to missing values in the data for some of the independent variables.

hypothesis of identical sector-specific effects can be rejected, and hence the specifications including sectoral dummies, i.e., columns 2 and 4, are preferred. The results for the specifications in columns 2 and 4 are very similar in their magnitudes and confidence levels.

The *FDI* variable turns out to have a positive and statistically significant coefficient. Note that this variable is measured as a percentage, which makes the interpretation of the coefficient straightforward. For example, in the specification in column 2, an increase in FDI stocks by one percentage point leads to an increase in US IPT of 7.3 percentage points, *ceteris paribus*. The results indicate that the presence of US foreign direct investment in the EU member country has a positive impact on US inward processing trade in the respective country. This suggests that US multinationals in the EU are engaged in intra-firm trade, i.e., they ship intermediate products to their affiliates in the EU. These affiliates process the intermediate goods and re-export them to destinations outside the EU, either back to the parent company in the US or for final consumption or further processing to other locations world-wide. In other words, this proportion of production is not intended to serve the European market, which is in contrast with the frequently asserted opinion that US multinationals in the EU locate there in order to establish a base to serve the European market (Balasubramanyam and Greenaway 1992; Aristotelous and Fountas 1996). While our results do, by no means, contradict this assertion, they do suggest, however, that the use of the affiliate in the EU as a base for fragmentation is also an important factor. This finding clearly deserves further research.

The *WAGE* variable is also statistically significant and positive in the preferred specifications. This implies that higher labour costs seem to make a particular sector in a country more attractive for US inward processing trade; a result that may seem odd at first sight. However, if we think of the *WAGE* variable as a proxy for different skill levels in different sectors, the result does appear reasonable. Higher-skilled labour can be expected to be paid higher wage rates than low-skilled labour. The results may, hence, indicate that sectors with higher skill levels, i.e., higher levels of human capital, receive higher levels of US IPT, *ceteris paribus*.

As regards comparative advantage, *CA1* and *CA2* produce statistically significant and positive coefficients in the preferred specifications. This suggests that, controlling for the level of US FDI, the wage rate, and other sector- and country-specific effects, a country which has a revealed comparative advantage in the production of a good also attracts US inward processing trade into this sector. This finding is in line with

the prediction of international trade theory regarding the dispersion of fragmentation around the globe (see Jones and Kierzkowski 2000). Since the dependent variable and the CA variables are measured in percentage terms, the interpretation of the coefficient is straightforward. For the results reported in column 2, an increase in CA1 by one percentage point will lead to an increase in US IPT by 0.1 percentage points, *ceteris paribus*.

The regression also includes thirteen sectoral dummies, keeping the "Other Manufacturing" sector as a base comparison. The results in column 2 show that only sectors 1, 3 and 5 (Food, Drink & Tobacco; Leather; Cork & Wood) are not statistically significantly different from the base sector, while all other sectoral dummies have statistically significant positive coefficients. The results for the specification in column 4 are very similar, the only difference being that the coefficient for Sector 5 (Cork & Wood) is statistically significant negative (albeit only at the 10 per cent level) while the coefficient for Sector 7 (Textiles) is not statistically significant. These results reflect that production in some sectors may be more likely to be fragmented than in others. For example, electronics production (such as manufacturing of PCs) may easily be fragmented, whereas the production of wooden furniture can be assumed to be less likely to be split up into various components due to bulky inputs.

In order to shed some more light on the issue of why a particular EU member state receives US IPT into a particular sector, we divide our sample of countries into core and peripheral countries. The latter sample consists of data for Greece, Ireland, Portugal and Spain, while the former contains data for the other eight member states (Belgium, Denmark, France, Germany, Italy, Luxembourg, Netherlands, UK). As Görg and Ruane (1999) find, production activities of US companies show different patterns in EU core and peripheral countries. While US companies in core countries are dispersed across all manufacturing sectors, peripheral countries show evidence of sectoral specialization, i.e., US companies are concentrated in a small number of industrial sectors rather than being dispersed across the whole spectrum of manufacturing sectors. Therefore, we may expect that there are different determinants of US IPT in the core and periphery as well. If a large share of IPT is intra-firm trade, IPT will be more sectorally specialized in peripheral countries and may, therefore, be more strongly influenced by the stock of FDI or comparative advantage, *ceteris paribus*.

Table 4 presents the results for the estimation of (1), using data for core countries. As in the estimation reported in Table 3, we can reject the hypothesis of identical country-specific and sector-specific effects

Table 4 – *Econometric Results for Estimation for EU Core Countries*

Variable	(1)	(2)	(3)	(4)
CA1	0.1008 (0.0203)***	0.0791 (0.0211)***	–	–
CA2	–	–	0.0401 (0.0088)***	0.0329 (0.0090)***
FDI	–5.7839 (2.3414)**	–0.5436 (2.6312)	–6.0844 (2.3559)**	–0.8448 (2.6439)
WAGE	–0.0013 (0.0002)***	0.0005 (0.0004)	–0.0012 (0.0002)***	0.0005 (0.0004)
Sector 1	–	–0.0153 (0.0229)	–	–0.0160 (0.0229)
Sector 2	–	0.0670 (0.0253)***	–	0.0716 (0.0253)***
Sector 3	–	0.0178 (0.0248)	–	0.0206 (0.0249)
Sector 4	–	0.0348 (0.0232)	–	0.0367 (0.0232)
Sector 5	–	0.0150 (0.0232)	–	0.0107 (0.0233)
Sector 6	–	0.0776 (0.0251)***	–	0.0763 (0.0251)***
Sector 7	–	0.0058 (0.0233)	–	0.0072 (0.0233)
Sector 8	–	0.0121 (0.0241)	–	0.0126 (0.0241)
Sector 9	–	0.1360 (0.0262)***	–	0.1375 (0.0262)***
Sector 10	–	0.1049 (0.0246)***	–	0.1065 (0.0246)***
Sector 11	–	0.1602 (0.0243)***	–	0.1609 (0.0243)***
Sector 12	–	0.0813 (0.0238)***	–	0.0831 (0.0239)***
Sector 13	–	0.1360 (0.0279)***	–	0.1386 (0.0279)***
CONSTANT	0.2793 (0.0283)***	0.0225 (0.0504)	0.2301 (0.0298)***	–0.0213 (0.0506)
# of observations	523	523	523	523
F ($H_0: \alpha_n = 0$)	20.14	11.26	18.82	11.18
F ($H_0: \mu_i = \mu_s$)	7.13	8.70	7.50	8.98
F ($H_0: v_j = v_k$)	–	8.66	–	8.90
R ²	0.09	0.20	0.08	0.19

Note: Fixed-effects panel data estimation, standard error in parentheses. – ***, **, * denote statistical significance at the 1 per cent, 5 per cent, 10 per cent level, respectively.

and we, therefore, prefer the specifications including sectoral dummies as reported in columns 2 and 4. Inspection of Table 4 shows that, in contrast to the results reported in Table 3, only the coefficients of the comparative advantage variables are statistically significant. In other words, the presence of US FDI, or the level of labour costs in a sector, do not seem to explain the location of US inward processing trade across core countries, other things being equal. However, a country's comparative advantage does have a positive effect on its receiving US IPT. In terms of sectoral dummies, sector 2 (Chemicals), sector 6 (Paper) and sectors 9–13 have statistically significantly positive coefficients. It is worthy of note that especially sectors 2 and 9–13 are mainly high-technology sectors, and the results suggest that these sectors are more likely to show fragmented production than other (low-technology) sectors.

The results in Table 5 relate to the estimation of (1), using data for EU peripheral countries only. The test statistics for $F(H_0: \mu_i = \mu_x)$ show that the hypothesis of identical country-specific effects cannot be rejected for the estimations in columns (1) and (3) and the fixed-effects model may, hence, not be appropriate in this case. We also estimated the specifications in columns (1)–(4), using simple OLS, which yielded similar results.¹¹ To maintain consistency we, therefore, report the results of the fixed-effects estimation in Table 5. The F-test for the significance of sectoral dummies allows us to reject the hypothesis of identical sector-specific effects, which implies that columns (2) and (4) show the results for the preferred specifications.

The results show that the presence of US foreign direct investment has a positive impact on the location of US IPT in a peripheral country. This suggests that the possibility of fragmented production may be at least one of many factors that attract US FDI into a particular sector in an EU peripheral country. However, as Table 4 shows, this does not seem to be an important factor for US IPT in core countries. These results suggest that US multinationals use their affiliates in peripheral countries in part as a base for processing intermediate goods, which are then shipped to destinations outside the EU. As pointed out above, this finding does not reject the view that US firms locate in EU countries to service the EU market, it merely suggests that not all of the output produced is being sold within the European market.

The *WAGE* variable is also statistically significant and positive, as in Table 3. This implies that higher labour costs seem to make a particular sector in a country more attractive for US inward processing trade,

¹¹ These results are not reported here but can be obtained from the author upon request.

Table 5 – *Econometric Results for Estimation for EU Periphery Countries*

Variable	(1)	(2)	(3)	(4)
CA1	0.1078 (0.0358)***	0.0888 (0.0378)**	–	–
CA2	–	–	0.0059 (0.0061)	0.0144 (0.0053)***
FDI	6.1786 (1.8472)***	6.7594 (1.6380)***	6.4323 (1.8693)***	7.0219 (1.6332)***
WAGE	0.0037 (0.0013)***	0.0024 (0.0013)*	0.0047 (0.0012)***	0.0025 (0.0013)*
Sector 1	–	–0.0524 (0.0466)	–	–0.0512 (0.0464)
Sector 2	–	0.0954 (0.0481)**	–	0.0785 (0.0463)*
Sector 3	–	–0.0529 (0.0505)	–	–0.0603 (0.0502)
Sector 4	–	0.1039 (0.0464)**	–	0.0947 (0.0456)**
Sector 5	–	–0.1490 (0.0511)***	–	–0.1853 (0.0527)***
Sector 6	–	–0.0102 (0.0538)	–	–0.0414 (0.0482)
Sector 7	–	0.1219 (0.0470)**	–	0.1149 (0.0464)**
Sector 8	–	0.1916 (0.0458)***	–	0.1944 (0.0453)***
Sector 9	–	0.3062 (0.0520)***	–	0.3062 (0.0518)***
Sector 10	–	0.1479 (0.0532)***	–	0.1358 (0.0522)***
Sector 11	–	0.0177 (0.0517)	–	–0.0092 (0.0470)
Sector 12	–	0.1815 (0.0493)***	–	0.1631 (0.0474)***
Sector 13	–	0.0035 (0.0533)	–	–0.0251 (0.0484)
CONSTANT	–0.0644 (0.0813)	–0.0444 (0.0918)	–0.1516 (0.0786)*	–0.0682 (0.0294)
# of observations	213	213	213	213
F ($H_0: \alpha_n = 0$)	9.7	11.56	7.61	11.76
F ($H_0: \mu_i = \mu_n$)	0.73	2.35	1.28	3.55
F ($H_0: v_j = v_k$)	–	11.08	–	12.26
R ²	0.28	0.56	0.25	0.56

Note: Fixed-effects panel data estimation, standard error in parentheses. – ***, **, * denote statistical significance at the 1 per cent, 5 per cent, 10 per cent level, respectively.

ceteris paribus. Furthermore, the results show that, ceteris paribus, a country's revealed comparative advantage has a positive effect on the level of US IPT in peripheral countries. Inspection of the sectoral dummies shows that there are also some differences to the results in Table 4. While sectors 2, 9, 10 and 12 show statistically significant coefficients (as in Table 4), the coefficients for sectors 4, 7 and 8 are also statistically significant and positive in Table 5. Sector 5 has a statistically significant negative coefficient, while the coefficients for sectors 6, 11 and 13 are statistically insignificant. These differences between core and peripheral countries suggest that the location of a sector matters. For example, while production in the Industrial Machinery sector in core countries is more likely to be involved in fragmentation than the average (as measured by Other Manufacturing), this does not seem to be the case in peripheral countries.

V. Conclusions

Advances in communications and transportation technologies have increased the possibilities of fragmentation in production, i.e., the splitting up of the production process into various components. This allows the relocation of the production of components around the globe, taking into account different country characteristics. The purpose of this paper is to analyze the extent of US fragmentation, measured as inward processing trade, in the EU and the determinants of the distribution of US IPT across EU member countries.

Our empirical analysis of US inward processing trade in EU countries gives support to the prediction of international trade theory, namely, that the distribution of fragmented production around the globe will be according to countries' comparative advantages. We find that a country's comparative advantage has a positive effect on its receiving US IPT. We also find that, in peripheral countries, the stock of US FDI has a positive effect on US IPT, suggesting that at least part of the inward processing trade going into peripheral countries is intra-firm trade between different plants of the same multinational company. Furthermore, the extent of US IPT into peripheral countries is positively related to their wage rates relative to the US. This may suggest that US IPT moves to countries with high skill levels, as proxied by higher wage rates. The stock of US FDI and the wage rate do not seem to affect US IPT in core countries, however.

The results in this paper, which should be seen as a first step towards analyzing empirical data in an area that has not received much atten-

tion heretofore, clearly leave a number of issues for further research. For example, the positive relationship between FDI stocks and inward processing trade in peripheral countries indicates that it may be worth investigating whether FDI is intended to service local markets or whether its purpose is to shift parts of the production process to locations with lower labour costs, as postulated by Venables (1999) and Zhang and Markusen (1999). Furthermore, the positive relationship between the relative wage rate and US IPT needs further investigation, as this result is contrary to the expectation of a negative relationship between the two variables.

On a more general level, it may be worthwhile to investigate further the impact of advances in communications and transportation technologies, and the resulting cost reductions on fragmentation. Liberalization of services, both at national and international levels, may also be expected to have had an impact on these costs. While it was not possible to include a measure of such costs in the analysis in this paper, due to data constraints, it should be an interesting issue for further research to investigate this link in more detail.

Appendix

Table A1 – *Econometric Results for FDI Equation*

Variable	(1)	(2)	(3)	(4)	(5)	(6)
CA1	0.0041 (0.0009)***	–	–0.0000 (0.0005)	–	0.0034 (0.0020)*	–
CA2	–	0.0002 (0.0002)	–	–0.0000 (0.0002)	–	0.0005 (0.0004)
WAGE	–0.0001 (0.0000)***	–0.0001 (0.0000)**	–0.0000 (0.0000)**	–0.0000 (0.0000)**	0.0003 (0.0000)***	0.0003 (0.0001)***
CONSTANT	0.0072 (0.0008)***	0.0055 (0.0008)***	0.0033 (0.0005)***	0.0033 (0.0005)***	–0.0080 (0.0025)***	–0.0110 (0.0022)***
Number of observations	736	736	523	523	213	213
F ($H_0: \alpha_n = 0$)	12.66	3.47	2.24	2.24	42.54	41.59
R ²	0.03	0.01	0.01	0.01	0.28	0.28

Note: Standard error in parentheses. – ***, **, * denote statistical significance at the 1 per cent, 5 per cent, 10 per cent level, respectively. Columns (1) and (2) report results of the estimation, using data for all EU countries, columns (3) and (4) using data for EU core countries, columns (5) and (6) using data for EU peripheral countries.

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Abstract: Fragmentation and Trade: US Inward Processing Trade in the EU. – Fragmentation, which refers to the splitting up of a previously integrated production process into separate components, is seen as one of the reasons for the increasing globalization of the world economy. This paper undertakes an empirical study of the extent of US inward processing trade (IPT) in the EU, which we use as a proxy for fragmentation in trade. We also provide empirical evidence on the determinants of the distribution of US IPT across manufacturing sectors in the twelve EU member states. Our results give support to the importance of comparative advantage for the sectoral distribution of US IPT. Also, we find that the labour costs and the level of US FDI stocks affect US IPT in EU peripheral countries, while they do not seem to have any impact on EU core countries. JEL no. F14, L14.

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Zusammenfassung: Die Aufspaltung von Produktionsprozessen und internationaler Handel: Die Lohnveredelung amerikanischer Unternehmen in der EU. – Die Fragmentation, die sich auf die Aufspaltung von bislang vertikal integrierten Produktionsprozessen bezieht, wird als einer der Gründe für die zunehmende Globalisierung der Weltwirtschaft gesehen. Dieser Artikel unternimmt es, empirisch den Umfang der Lohnveredelung amerikanischer Unternehmen in der Europäischen Union zu untersuchen, bei der amerikanische Unternehmen im Rahmen ihrer weltweiten Strategie zunächst Zwischenprodukte in die EU-Länder importieren, dort in Tochterfirmen weiter veredeln und dann wieder aus den EU-Ländern exportieren. Aufgezeigt wird die empirische Evidenz von Determinanten, die die Verteilung der Lohnveredelung über die Industriesektoren in den zwölf EU-Mitgliedstaaten bestimmen. Die Ergebnisse bekräftigen die Bedeutung der komparativen Vorteile für die sektorale Verteilung der Lohnveredelung. Außerdem zeigt sich, dass die Lohnkosten und der Bestand amerikanischer Direktinvestitionen die Lohnveredelung amerikanischer Unternehmen in den Ländern am Rande der EU beeinflussen, während sie für die Kernländer nicht von Bedeutung sind.
