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Vertical Intra-Industry Trade and Product Fragmentation in the Auto-Parts Industry

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Abstract A distinctive feature of present globalization is the development of international production sharing activities, i.e. production fragmentation. The increased importance of fragmentation in world trade has created an interest among trade economists in explaining the determinants of intra-industry trade (IIT) in intermediate goods. In this study, the extent of IIT in Austria's auto-parts trade is analyzed by decomposing Austria's auto-parts trade into one-way trade, vertical IIT, and horizontal intra-industry trade IIT. Then, the development of vertical IIT in the auto-parts industry is examined as an indicator for international fragmentation of the production process between Austria and its 29 trading partners, and various country-specific factors suggested by the fragmentation literature are tested using panel econometrics as well as more recent data from 1996 to 2006. The results show that a substantial portion of IIT in the Austrian auto-parts industry is vertical IIT, and the econometric results mainly support the hypothesis drawn from the fragmentation theory. In particular, the findings show that the extent of Austria's vertical IIT in auto-parts is positively correlated with average market size, differences in per capita GDP, and foreign direct investment, while it is negatively correlated with distance.

Keywords vertical intra-industry trade · fragmentation · Austrian auto-parts industry · panel data techniques

JEL Classification F-14 · F-15

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1 Introduction

A distinguishing feature of present economic globalization is fragmentation of production.[1] As world markets have become increasingly integrated in the last few decades due to developments in transportation and communication technologies, the degree of product fragmentation (i.e. production sharing) has increased across countries, leading to an increase in trade in intermediate goods as goods are designed, produced and assembled in different locations.

Despite the increase in the intermediate goods trade, the empirical literature on this fragmentation has provided only descriptive statistics on the importance of the trade in intermediate goods induced by international fragmentation of the production process (Feenstra 1998; Hummels et al. 1999; Yeats 2001; Kimura and Ando 2005; Kaminski and Ng 2005; Ando 2006). In contrast, with the exception of Görg (2000), Jones et al. (2005), Egger and Egger (2005), and Kimura et al. (2007), there have been few empirical studies into the shortcomings of fragmentation.

One of the empirical problems in these studies has been how to measure the degree of fragmentation. Lloyd (2004) argues that vertical product differentiation can take place because of product stage separation. Ando (2006) argues that vertical intra-industry trade (IIT) in intermediate goods, resulting from production sharing activities seems to be best way to see the extent of fragmentation for a particular industry.[2] Hence, following Ando (2006), the goal of this paper is to calculate the indices of vertical IIT in the auto industry between Austria and its 29 trading partners, and to analyze the determinants of vertical IIT, which is used in this study as a proxy for the extent of fragmentation.[3]

The Austrian auto-parts industry is chosen for several reasons. First of all, the auto industry is often regarded as one of the most fragmented industries. Due to this fragmentation, Austria's export and import levels of auto-parts have been continually increasing. The nominal value of auto-parts imported into Austria more than doubled from $ 5.3 billion in 1996 to $ 12.7 billion in 2006 (Fig. 1c). Likewise, Austria's auto-parts exports increased significantly from $ 5.3 billion in 1996 to $ 12.9 billion in 2006. This increase in trade in auto-parts implies that IIT has become more prevalent in this sector in Austria.[4] Second, Austria is ranked amongst the world's top twenty in terms of auto-parts exports and imports.[5] Historically, Austria is known as a supplier of auto-parts, largely due to the fact that more than 10 automobile production facilities, including BMW, Skoda, Volkswagen, Audi, Fiat, Renault, and Hyundai Kia,[6] are located close to the Austrian border. The auto industry is also the most important manufacturing and export sector for Austria, representing 5.3% of Austria's total manufacturing, 10.3% of total Austrian

[1] Product fragmentation can be defined as division of production processes into different locations across different countries.

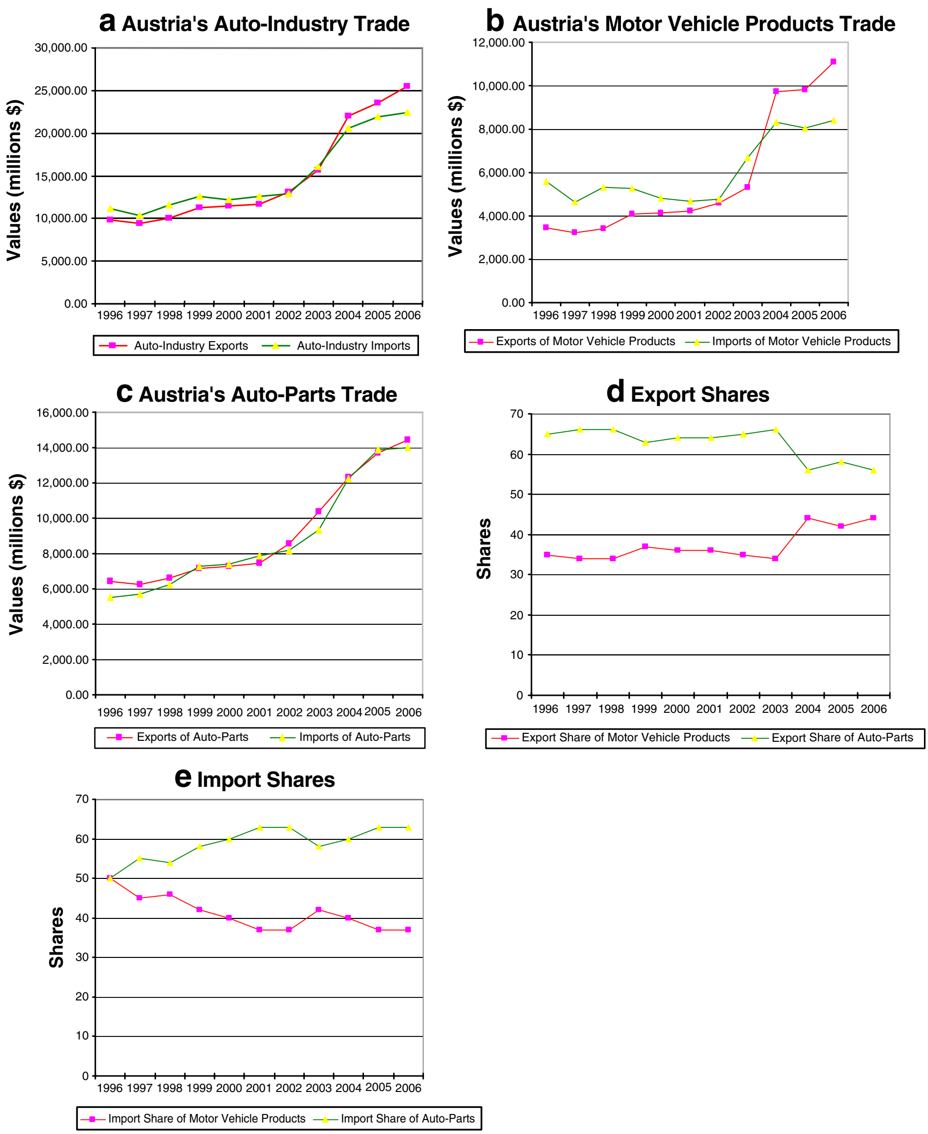
[2] IIT is defined as the simultaneous export and import of products which belong to the same statistical product category. IIT of goods with a certain range of unit-price differentials between exports and imports is classified as horizontal IIT, while the rest is classified as vertical IIT.

[3] Several empirical studies have analyzed the determinants of VIIT in the motor vehicle and auto-parts industry (Becuwe and Mathieu 1992; Ito and Umemoto 2004; Umemoto 2005; Montout et al. 2002). However, the drawback of these empirical studies is that they do not incorporate hypotheses stemming from newly developed fragmentation literature.

[4] In the auto industry, global production networks involve intra industry trade both at the level of final products, and of intermediate goods.

[5] A 2006 Survey by the Office of Aerospace and Automotive Industries' Automotive Team ranks Austria among the top 20 countries in terms of auto-parts exports in the world in 2003.

[6] Table 11 lists automotive assembly plants close to Austria by country.



Source: Authors' own calculations

Fig. 1 Austria's auto industry trade with the world, 1996–2006

manufacturing exports and 9.9% of total Austrian manufacturing imports,[7] as can be seen in Table 10.

Finally, major structural changes have taken place in the Austrian auto industry brought about by the accession of the Central and Eastern economies into the European Union (EU).

[7] For a more detailed picture of the Austrian auto industry, see ABA-Invest in Austria (2002) and Mosser and Bruner (2007).

This may impact on the pattern and determinants of the Austrian auto-parts trade[8] and, given its crucial importance to the Austrian economy, this is an appropriate case with which to study fragmentation.

Using finely disaggregated international trade data, this paper examines the recent changes in trade patterns in the auto-parts industry in Austria, particularly by breaking down the figures into inter-industry trade, vertical IIT and horizontal IIT. As there has been no previous study which has investigated the Austrian experience in this strategically important industry, this paper seeks to fill the void.

Vertical IIT was used as an indicator of fragmentation between Austria and its 29 trading partners for the period 1996 to 2006. In particular, various country-specific factors suggested by the fragmentation literature initiated by Jones and Kierzkowski (1990) were tested by utilizing newly developed panel data techniques.[9] This study, unlike previous literature, is able to provide valuable information about the structure and determinants of vertical IIT as an indicator of the fragmentation process in the Austrian auto-parts industry.

The major findings can be summarized as follows. Vertical IIT dominated trade flows in auto-parts during the period 1996–2006, and hypotheses drawn from the fragmentation literature help to explain vertical IIT, with the findings suggesting in particular that the extent of Austria's vertical IIT in auto-parts is positively correlated with average market size, differences in per capita GDP, and outward foreign direct investment (FDI), while it is negatively correlated with distance. These findings support the claim that IIT in the Austrian trade in auto-parts is mainly a case of international fragmentation of vertical production chains.

This paper is organized as follows: Section 2 offers a brief explanation of developments in Austria's auto industry trade. Section 3 surveys empirical methodologies on the measurement of fragmentation, outlines the methodology for the measurement of IIT, as well as analyzing the patterns of IIT in the Austrian auto industry. Section 4 presents the economic model and the determinants of vertical IIT, while also addressing the key issue of estimation. Section 5 presents the empirical results. Section 6 contains concluding remarks.

2 Developments in the Austrian auto industry trade

In this section, we describe the extent, nature and dynamics of Austria's auto industry trade with 29 OECD countries using data in the Harmonized System (HS). Table 6 lists the countries used in the calculations.

The global automobile industry has been undergoing significant structural transformation in recent years.[10] Automakers in the USA and Europe, with General Motors (GM),

[8] As shown in Bhattacharya (2007), Austria's trade links with Central and Eastern Europe have gathered momentum in recent years. In particular, the Central and Eastern European countries' share of Austria's total exports rose from 12.5% in 1991–1995 to 18% in 2001–2005, while its share of total exports increased from 8% in 1991–1995 to 14% in 2001–2005. According to Bhattacharya (2007), the shift in the commodity composition of exports and imports as well as the enormous increase in manufacturing products implies that intra-industry trade resulting from outsourcing activities has become much more important than before in Austria's trade with the region. See also Egger et al. (2001).

[9] IIT in intermediate goods does not seem to be fully explained by the traditional trade models of IIT developed by Krugman (1980), and Helpman and Krugman (1985). On the other hand, fragmentation theory seems to be more appropriate for analyzing trade in intermediate goods.

[10] For a more complete analysis of trends in the auto industry, see Sadler (1999), Diehl (2001), Corswant and Fredriksson (2002), Lall et al. (2004), and Cooney and Yacobucci (2005).

Ford, Toyota, Honda, Volkswagen, Audi, and Daimler Chrysler as notable examples, have been outsourcing an increasing proportion of automotive production to developing countries and emerging economies in order to reduce production costs. By outsourcing we mean that automakers have started to buy parts from outside suppliers rather than producing them within their own organization. This reduction in vertical integration allows auto manufacturers to buy parts from the most suitable suppliers, a situation that typically results in lower unit costs.

Most of the giant automotive manufacturers have also recently merged with or acquired other companies with the intention of gaining access to markets where they did not previously have a significant presence, or to avoid bankruptcy as the world automobile market contracted during the financial crisis in 2009. The merger between the Renault Corporation and Nissan Motors, and the acquisitions of Land Rover and Jaguar by India's Tata Motors are just two examples. In further moves of this nature, Chrysler has now formed an alliance with Fiat, with the Italian firm taking an initial 20% stake in the US carmaker, while GM initially offered to sell 55% of its European subsidiaries Opel and Vauxhall to Magna International in 2009. Volkswagen AG and Porsche AG have agreed in principle to the creation of an integrated car manufacturing group.

Finally, another trend is the increasing use of entire sub-assemblies ('modules') rather than individual components. For instance, rather than supplying only the fuel tank for a given model, a tier 1 supplier may now supply the entire fuel supply system,[11] and manufacturers have also started to require their tier 1 suppliers to provide modular components (standard) that can be used on several vehicle models worldwide. By using modules or preassembled units for several vehicle models, automakers are able to cut production costs and reduce their in-house parts operations.

These changes have permanently altered the relationship between motor vehicle manufacturers and auto-parts suppliers in the global auto industry. Motor vehicle manufacturers have forced their tier 1 manufacturers to become systems integrator-suppliers of modules or systems, and tier 1 manufacturers have been required to increase their role in the design, research and development of modules and systems. Auto-parts manufacturers have responded by consolidating their operations worldwide, since they need to have the financial and managerial resources to comply with these new and specific requirements from the motor vehicle manufacturers. In preparation for the greater reliance on modules or systems, tier 1 suppliers have been encouraged to form their own strategic partnerships with lower tier suppliers, as well as managing the sourcing of auto-parts from tier 2 and tier 3 suppliers.

European and North American automakers, in an attempt to consolidate their activities, have started to shift their production bases to emerging markets such as Latin America, China, and other markets in Southeast Asia. In response, auto-parts suppliers have established component plants close to assembly plants, or entered into joint ventures with local manufacturers to cope with the greater use of just-in-time delivery systems. This demand for proximity in module supply has been a major factor in the emergence of global mega auto-parts manufacturers such as Delphi, Visteon, Bosch and Magna.

The following detailed analysis will show that these changes have also had major effects on the structure of the Austrian auto industry. Historically, Austria reputation was as a supplier of automotive components, largely as a result of there being more than 10

[11] The auto industry has organized itself into several tiers. Tier 1 sells directly to automakers or original equipment manufacturers (OEM), which assemble the final product. Tier 2 supply parts to tier 1, and those that sell parts to tier 2 are known as tier 3, etc. moving down the value chain. The term "tier" describes products rather than an entire firm, so that some firms may be tier 1 on one product and tier 2 on another.

automobile production facilities located close to Austria's borders. Austria specialized particularly in the development and production of power trains, engines, and transmissions, which accounted for around 40% of auto-parts production.[12]

In line with global trends, the Austrian motor vehicle and auto-parts industry has experienced major changes during the last few decades. There has been a shift away from production of auto-parts towards assembly operations. Austria's new role in the auto assembly industry has made this industry a vital part of the national economy, and with about 300,000 motor vehicles produced each year (Fig. 4)[13] the trade data confirms the increased importance of final assembly relative to auto-parts production. In addition, given the new role of tier 1 suppliers in the research and development of modules or systems, many Austrian auto-parts manufacturers have had no option but merge with an existing multinational auto-parts manufacturer to stay competitive in the global market.[14]

Outsourcing has also led to a change in the factor intensity of the auto-parts industry in Austria. In recent years there has been a shift towards high-skill, intensive production,[15] and this implies that Austria, despite the outsourcing of low-skill production stages to neighboring countries, seems to have been able to maintain its competitive position. This is largely the result of a relatively abundant supply of skilled labor in Austria. In this way, outsourcing has had a significant positive impact on the demand for workers with high education, while it has had a negative impact on the demand for workers with lower education.

The global trends that have shaped and are still affecting the Austrian auto industry over the last two decades have also had a major impact on the international pattern of the Austrian auto industry trade. Austria's total trade (exports & imports) in this sector increased significantly from $20.9 billion in 1996 to $47.8 billion in 2006, a 228% increase during this period (Fig. 1a). In particular, the trade figures show that Austria changed from being a net importer of motor vehicle products to being a net exporter in 2002, and has remained so since that time.

By contrast, Austria remained a net exporter of auto-parts in 2006 despite an increase in imports (Fig. 1c). The export shares of motor vehicle products as a proportion of total automotive exports increased from 35% to 45%, whereas the import shares of motor vehicle products dropped from 50% to 37% during the sample period (Fig. 1d and e). However, the export of auto-parts as a proportion of total exports has fallen steadily from 65% in 1996 to 55% in 2006. In turn, the import share of auto-parts as a proportion of total imports has grown substantially, from 50% in 1996 to 63% in 2006, as shown in Fig. 1d and e. Moreover, imports have been the most rapidly growing component of the auto-parts trade. Over the period 1996–2006 Austria's auto-parts exports to OECD countries grew by 10% per annum on average, while its total imports grew by 12% a year on average. Consequently, Austria's trade surplus in this sector has declined steadily in recent years.

[12] More than 250 auto-parts producers including General Motors Powertrain, BMW Motoren, Magna Steyr, and MAN Nutzfahrzeuge supply components for the motor vehicle industry in Austria (see Table 10).

[13] For instance, Magna Steyr, a subsidiary of Magna International and one of the leading auto-parts manufacturer in Austria, have assembled a total of more than 200,000 vehicles for various automakers on a contract basis, such as Daimler-Chrysler (Chrysler Voyager, Grand Voyager, Jeep Grand Cherokee, Jeep Commander), BMW (X3 Sports Activity), Saab (9-3 Cabriolet), and Mercedes-Benz (G-Class). Recently, Magna Steyr signed an agreement with BMW to manufacture the Mini series beginning in the year 2010. Further, Aston Martin has agreed a deal with Magna Steyr for the production of its forthcoming Rapide sedan in Austria starting at the end of 2009.

[14] Currently, there are around 80 international auto-parts manufacturers, such as Delphi Packard Austria, Bosch, Magna International, and Johnson Controls, which coordinate their Eastern European operations from their bases in Austria.

[15] The employment effects of outsourcing which had their origin in the accession of new Member states to the EU are also present in other Austrian manufacturing sectors. See Bhattacharya (2007).

This finding is definitely consistent with the frequently asserted views of globalization, particularly with respect to outsourcing.

The geographical pattern of Austria's trade in auto-parts has undergone a change which mirrors the change in trade between 1996 and 2006. Table 1 presents data on Austria's auto-parts trade by individual partner country for the 29 OECD member countries, plus two

Table 1 Austria's auto-parts trade by countries (Values is in millions of $ and share is in percent)

Countries	1996				2006			
	Exports		Imports		Exports		Imports	
	Value	Share	Value	Share	Value	Share	Value	Share
Australia	18.40	0.29	0.37	0.01	220.95	1.53	77.46	0.55
Belgium	0.00	0.00	0.00	0.00	260.99	1.81	67.34	0.48
Canada	53.88	0.84	74.10	1.34	206.39	1.43	196.73	1.41
Czech Republic	73.91	1.15	62.06	1.12	379.86	2.64	476.85	3.41
Denmark	26.53	0.41	16.81	0.30	70.00	0.49	35.71	0.26
Finland	29.25	0.46	50.67	0.92	44.09	0.31	319.67	2.28
France	117.39	1.83	285.86	5.16	385.92	2.68	490.15	3.50
Germany	3,663.97	57.16	2,923.58	52.81	6,589.95	45.77	7,035.48	50.25
Greece	8.51	0.13	0.74	0.01	176.52	1.23	0.76	0.01
Hungary	351.77	5.49	194.32	3.51	539.68	3.75	280.14	2.00
Iceland	1.07	0.02	0.00	0.00	2.40	0.02	1.27	0.01
Ireland	3.59	0.06	12.19	0.22	21.54	0.15	13.32	0.10
Italy	153.54	2.40	443.20	8.01	682.54	4.74	867.56	6.20
Japan	54.46	0.85	67.53	1.22	138.63	0.96	282.98	2.02
Korea	12.59	0.20	10.20	0.18	51.73	0.36	195.48	1.40
Luxembourg	0.00	0.00	0.00	0.00	3.98	0.03	30.32	0.22
Mexico	24.30	0.38	12.51	0.23	37.42	0.26	52.04	0.37
Netherlands	66.18	1.03	97.94	1.77	107.63	0.75	259.70	1.85
New Zealand	2.45	0.04	1.29	0.02	8.39	0.06	0.56	0.00
Norway	12.03	0.19	0.99	0.02	29.42	0.20	13.15	0.09
Poland	29.47	0.46	6.23	0.11	651.27	4.52	139.91	1.00
Portugal	41.03	0.64	22.83	0.41	109.93	0.76	61.23	0.44
Slovak Republic	33.38	0.52	10.69	0.19	301.24	2.09	122.63	0.88
Spain	478.13	7.46	43.16	0.78	728.74	5.06	218.05	1.56
Switzerland	68.11	1.06	50.90	0.92	184.92	1.28	178.49	1.27
Sweden	76.25	1.19	44.58	0.81	167.53	1.16	101.05	0.72
Turkey	9.50	0.15	22.40	0.40	49.69	0.35	72.23	0.52
United Kingdom	242.15	3.78	130.54	2.36	618.52	4.30	209.36	1.50
USA	303.85	4.74	743.95	13.44	510.58	3.55	979.56	7.00
Core	5,433.36	84.78	5,021.43	90.71	11,321.29	78.63	11,635.38	83.12
Periphery	522.33	8.15	308.21	5.56	1,959.16	13.61	1,143.8	8.18
OECD	5,955.69	92.92	5,329.66	96.28	12,992.10	90.23	12,715.30	90.81

Authors' own calculations based on OECD's ITCS International Trade by Commodity Database-Harmonized System, 1996 groups of countries (core and peripheral) during the period analyzed. The geographical composition of this trade reveals a few important, empirical facts.

First, as seen in Table 1, almost 90% of Austria's auto-parts trade occurred with the 29 OECD member countries. Among them, Germany remained one of the top trading partners of Austria during the study period. In 2006, exports to Germany accounted for 45% of total Austrian auto exports, and Austrian imports from Germany accounted for 50% of total Austrian auto-parts imports. The Austrian auto-parts industry has traditionally been linked to German auto-makers, however, the interdependence between the Austrian and German auto industries is changing. Over the last decade, in response to increased competition, German auto-makers have begun to source more parts from cheaper production locations, especially Central and Eastern European countries.[16] In order to meet the increased price competition associated with the opening up of Central and Eastern European countries, several auto-parts suppliers in Austria deployed some of their labor-intensive production and assembly operations to low-cost locations, particularly the Czech Republic, Slovakia, Slovenia, Hungary, and Poland. As a result, the German share of Austria's auto-parts trade has declined notably thanks to rising German imports from these locations in recent years. Germany's share of Austria's auto-parts exports declined from 57% in 1996 to 45% in 2006. In the meantime, Germany's role in Austria's auto-parts imports declined, from 52% in 1996 to 50% in 2006, as shown in Table 1. German auto-makers who established assembly operations in Eastern and Central Europe, such as Opel in Poland, Volkswagen in the Czech Republic and Slovak Republic, and Audi in Hungary, were followed by German auto-parts suppliers such as Bosch in the Czech Republic.[17] As a result, suppliers in Central and Eastern Europe have gained a sizable market share in both the import and export of German auto-parts at the expense of suppliers from Austria.

In 2006, Austria's major export destinations behind Germany were Spain (5.06%), Italy (4.74%), Poland (4.52%), and the United Kingdom (4.30%) (see Table 1). Interestingly, most of these countries are from outside the advanced OECD area, and have become increasingly attractive hosts for German automakers over the past two decades. For instance, Spain and Poland have important shares in Austria's auto-parts exports mainly because of Volkswagen's engagement in these countries with Seat, a subsidiary of the Volkswagen Group in Spain, as an example.

However, in the case of imports, the other top five suppliers of auto-parts to Austria in 2006 were the USA (7%), Italy (6.20%), France (4%), the Czech Republic (3.41%), and Japan (2.02%), as shown in Table 1. The rapid growth of USA's exports to Austria is primarily a reflection of increased production at the Magna Steyr facility in Graz, where several vehicles are assembled for various US automakers as mentioned above.

Second, the share of periphery countries in Austria's auto-parts trade has increased substantially at the expense of core countries in recent years. As seen in Table 1, the patterns and dynamics of this trade differ for core and periphery countries.[18] Examining core countries first, Table 1 shows that of the share of Austria's trade represented by core countries, particularly Germany, exports dropped from 84% in 1996 to 78% in 2006, whereas imports dropped from 90% to 83% during the same period. In contrast, in the share taken by periphery countries, such as Poland and the Slovak Republic, exports and imports increased from around 8% in 1996 to 13% in 2006 and from 5% to 8%, respectively. It seems that for this industry, the entrance of new member states to the EU, which enabled

[16] For details, see Nunnenkamp (2005).

[17] For details see Diehl (2001) and Nunnenkamp (2005).

[18] Table 6 lists core/periphery categorizations of countries used in the analysis.

both Austrian and European multinationals to set up motor vehicle assembly plants there, coupled with geographical proximity, may have had a decisive impact on the pattern of Austria's auto-parts trade over the past decade.[19]

3 Measurement of intra-industry trade in the Austrian auto industry

This section presents a brief survey of empirical methodologies on the measurement of fragmentation, and outlines the methodology for measurement of IIT.

3.1 Fragmentation

Fragmentation can be defined as division of the production process into different locations across different countries. A number of studies have attempted to measure the degree of fragmentation. These studies can be divided into four groups based on their methods as well as the data sources employed.[20]

The first group measures the degree of fragmentation by employing input-output (I–O) data tables, which provide information on the interrelationship between industries, including imported intermediate goods use and the export of each industry's output (See Feenstra and Hanson 1996, 1997; Campa and Goldberg 1997; Hummels et al. 1998). It is difficult to capture the degree of fragmentation with the available I–O tables due to the fact that these tables do not include information on whether the goods produced with the imported intermediate goods are exported to third countries.

The second group of studies such as Görg (2000), Graziani (2001), and Egger and Egger (2005) measure fragmentation by using outward processing trade (OPT) and inward processing trade (IPT) statistics.[21] Although this method definitely provides some insights about the level of fragmentation, it has one major shortcoming: that it covers only a few products. Thus, this method will underestimate the degree of fragmentation.

Another method used in the literature to measure the degree of fragmentation is intra-firm trade statistics (See Andersson and Fredriksson 2000; Borga and Zeile 2004; Chen et al. 2005; Kimura and Ando 2005). Fragmentation can lead to intra-firm trade between different production locations within the same organization of vertically organized Multinational Enterprises (MNEs) from advanced countries, which often establish an affiliate in a developing country to produce labor-intensive intermediate goods, which are then exported back to its home base for assembly.[22] Despite the fact that intra-firm trade statistics clearly establish the link between fragmentation and MNEs, proving it to be better than the other two methods, it has two major shortcomings that make the employment of this method rare in the empirical literature. First, it is difficult to distinguish between

[19] The increased trade in auto-parts with Central and Eastern Europe is accompanied by a substantial expansion of Austria's outward FDI stocks in the region. See, for example, Nunnenkamp (2005) and Bhattacharya (2007).

[20] For a more detailed discussion on the empirical analysis of fragmentation see Egger et al. (2001).

[21] IPT is the duty relief procedure allowing goods to be imported into a country for processing and subsequent export outside the country without payment of duty, while OPT involves intermediate goods exports for further processing in a foreign country where the goods are shipped back to the home country under tariff exemption.

[22] For instance, Chen et al. (2005) found that a significant portion of U.S. exports of manufactured goods carried out by U.S. multinationals which are sent to foreign manufacturing affiliates of the U.S. multinationals have mainly consisted of materials and components for further processing or assembly: the share of U.S. exports to foreign affiliates for further manufacturing increased from 15.6% in 1977 to 22% in 1999.

horizontally integrated and vertically integrated MNEs with the available data. Second, detailed information on intra-firm trade is available only for a few countries such as the U.S. and Japan, which limits analysts when making international comparisons on the degree of fragmentation across different countries and industries.

Lastly, some analysts suggest using international trade statistics to estimate the degree of fragmentation by simply calculating the volume of trade in parts and components (See Yeats 2001; Kaminski and Ng 2005; Kimura et al. 2007) or the intra-industry trade index (Kol and Rayment 1989; Schüler 1995; Ando 2006) in intermediate goods. Yeats (2001) evaluates the magnitude and growing importance of global production sharing in international trade by looking at the items classified as components and parts within the machinery and transport equipment group of the Standard International Trade Classification System (SITC 7). The major disadvantage of this approach is that many parts related to the above groups come under different headings.[23] Hence, this method also clearly fails to capture the degree of fragmentation for a particular industry.

As suggested by Jones et al. (2002) and Ando (2006), international fragmentation generates a two-way trade in intermediate goods between countries, which may exchange intermediate goods for intermediate goods, both of which are within the same industry classification. There are three possibilities that lead to the two-way exchange of intermediate goods: horizontal trade in similar products with differentiated varieties (e.g. the exchange of small-sized radiators for large-sized radiators); trade in vertically differentiated goods distinguished by quality (e.g. the exchange of high-quality fuel pumps for lower-quality fuel pumps); and vertical specialization that involves the exchange of technologically linked products.[24]

Horizontal IIT arises when there is a two-way trade in intermediate goods that are similar in terms of quality, costs, and capital/labor techniques, but which have different characteristics or technological specifications. Firms engage in trade in horizontally differentiated intermediate goods because some imported intermediates fit their production specifications better. Horizontal IIT in intermediates originates from economies of scale, product differentiation, and demand for input varieties.[25] Countries with similar factor endowments and incomes are likely to engage in horizontal IIT.

By contrast, vertical IIT represents trade in similar products of different qualities, but they are no longer the same in terms of unit production costs and factor intensities. Falvey and Kierzkowski (1987) have shown that IIT in vertically differentiated goods occurs because of factor endowment differences across countries. In particular, Falvey and Kierzkowski (1987) suggest that the amount of capital relative to labor used in the production of vertically differentiated goods indicates the quality of an item. As a consequence, in an open economy, higher-quality products are produced in capital abundant countries, whereas lower-quality products are produced in labor abundant countries. This will give rise to intra-industry trade in vertically differentiated goods: the capital abundant country exports higher-quality varieties, and the labor abundant country exports lower-quality products. The models of vertical IIT predict that the share of vertical IIT will increase as countries' income and factor endowments diverge.

However, vertical IIT would also reflect trade as a result of back-and-forth transactions in vertically fragmented production networks in the same commodity heading (Lloyd 2004;

[23] For instance, transport equipment group 78 does not include parts such as automotive tires, electronics, instruments, glass parts, or rubber parts, which are recorded under different headings.

[24] See Türkcan (2009) for more on this issue.

[25] For a more detailed discussion of trade in horizontally differentiated intermediate goods, see Ethier (1982).

Jones et al. 2005; Ando 2006). Consider the production of an engine for a German automobile. The engine itself consists of many production stages and components, such as cylinder block, spark plugs, valves, connecting rods, crankshafts, fuel pumps, cast iron parts, and various small parts. As an example, some of these parts, such as connecting rods, cast iron parts, cylinder heads, and various parts are all recorded under the product group HS (840991), parts for spark-ignition type engines. Suppose that some of these components which are part of the spark-ignition type engines are imported into Germany from Austria under the product group HS (840991). At the first stage, German firms produce the components of spark-ignition type engines and export these components to Austria under the product group HS (840991). At the second stage, the assembly of parts of spark-ignition type engines bound for the German market takes place in Austria. At the final stage, the assembled parts of spark-ignition type engines which are imported from Austria under the product group HS (840991) are used in the production of spark-ignition type engines, and subsequently in the production of passenger cars in the German auto manufacturing plants. As a result, this type of exchange appears as IIT in intermediate goods in trade statistics if the processing in Austria does not change the product's statistical category. Thus, vertical IIT in intermediates is defined as trade in inputs belonging to the same industry but located at different stages on the production spectrum.[26] Multi-stage vertical specialization stems from the differences in factor costs across countries.[27]

In the trade literature, it is common to divide total IIT into two parts: IIT in horizontally differentiated goods and IIT in vertically differentiated products by comparing unit values of exports relative to imports because the determinants of both types of IIT appear to be quite different and need to be assessed. In a similar way to final goods, this method has also been adopted by several recent papers including Schüler (1995), Montout et al. (2002), Ito and Umemoto (2004), Umemoto (2005), Ando (2006), Wakasugi (2007) to distinguish horizontal IIT from horizontal IIT in intermediate goods. In this context, intra-industry trade is classified as horizontal IIT when the unit value of exports relative to unit value of imports lies within a specified range. Conversely, if the relative unit values lay outside this range, IIT is defined as vertical, which may capture not only trade in intermediate goods with different quality, but also trade in technologically linked intermediate goods.

Vertical IIT can reflect multi-stage trade as a result of back-and forth transactions in vertically fragmented production networks in the same commodity heading because vertical specialization definitely generates unit value differences across technologically related exported and imported intermediates. Therefore, vertical IIT could be used as an indicator of international fragmentation within the same product category. This empirical approach is clearly supported by the recent findings by Jones et al. (2002), Ando (2006), and Kimura et al. (2007) that the rapid increase in vertical IIT mainly originates from vertical linkages in production rather than trade in quality differentiated goods. [28]

[26] Notice that exchanges of intermediates against intermediates (such as in our case, exports of parts of spark-ignition type engines and imports of assembled spark-ignition type engines) may result in one-way trade due to fact that trade leads to changes in a product's statistical category. However, the current analysis is internationally not so highly disaggregated such as 10-digit level, as to exclude this form of trade.

[27] A number of studies, such as Feenstra and Hanson (1997) and Arndt (1997), have employed the Heckscher-Ohlin model to explain the pattern of vertical specialization in intermediates. In these models, the degree of vertical specialization will increase as countries' incomes and factor endowments diverge.

[28] Horizontal IIT through fragmentation would also be present if imported parts and components were exported with small unit price differentials embodied in the local market. However, this kind of trade does not seem to be important in Austria's auto-parts trade.

Thus, following Ando (2006), this paper uses unit-price differentials between exported and imported intermediate goods as a criterion for distinguishing trade in horizontally differentiated intermediate goods from trade in technologically linked intermediate goods. We should, however, bear in mind that trade flows classified as vertical IIT could partially reflect international fragmentation of production in the same commodity heading.

3.2 Methodology of measuring intra-industry trade

IIT is defined as the simultaneous export and import of products which belong to the same statistical product category. According to Fontagne and Freudenberg (1997), three types of bilateral trade flows may occur between countries: inter-industry trade (i.e. one-way trade), vertical IIT, and horizontal IIT. This section presents empirical methodology for measuring IIT and its components.

The most widely used method, known as the unadjusted Grubel-Lloyd (G-L) index for computing IIT, as developed by Grubel and Lloyd (1971),[29] is given by the following ratio:

$$IIT_{jkt} = \frac{\left(X_{ijkt} + M_{ijkt}\right) - \left|X_{ijkt} - M_{ijkt}\right|}{\left(X_{ijkt} + M_{ijkt}\right)} \tag{1}$$

where X_{ijkt} and M_{ijkt} are Austria's exports and imports of product i of industry j with country k at time t. The value of this index is zero if all trade is inter-industry trade, while it is equal to 1 if it is wholly IIT.

In recent years, an alternative method has been suggested by Fontagne and Freudenberg (1997), Fontagne et al. (1997), and Fontagne et al. (2006). They seek to disentangle bilateral trade flows into one-way trade (OWT), two-way trade in vertically differentiated goods (TWTV), and two-way trade in horizontally differentiated goods (TWTH).[30] As Fontagne and Freudenberg (1997) point out, the G-L index gives us the problem of having two different explanations for the same majority trade flow (such as exports): the inter-industry part of the majority flow by traditional trade theory, and the intra-industry part of the majority flow by the new trade theories. To avoid this problem, Fontagne and Freudenberg (1997) proposed a new criterion: that trade in a product is considered to be two-way trade when the value of the minority flow represents at least 10% of the majority flow. Otherwise, both exports and imports are regarded as inter-industry trade.[31]

Given the criticisms of Fontagne and Freudenberg (1997) concerning the measurement of intra-industry trade, we apply both the G-L type trade decomposition and the Fontagne and Freudenberg's method to Austria's auto-parts trade in order to examine bilateral trade

[29] The traditional G-L index is negatively correlated with a large overall trade imbalance. With national trade balances, the level of IIT in a country will be clearly underestimated. To avoid this problem, Grubel and Lloyd (1975) proposed another method to adjust the index by using the relative size of exports and imports of particular goods within an industry by weight.

[30] Empirical studies using the Fontagne and Freudenberg's (1997) method are Montout et al. (2002), Ito and Umemoto (2004), Umemoto (2005), and Ando (2006).

[31] Fontagne et al. (2006) compare between the G-L index and the two-way trade index using regression analysis in a quadratic form for all country pairs in the world in 2000 and find that the fit between two indices is good, but the two-way index is considerably larger than the G-L index. As pointed by Fontagne and Freudenberg (1997), a degree of caution must be used when comparing and interpreting the G-L index and the two-way trade index because these two methods are complementary rather than substitutes. The former method deals with the intensity of overlap, while the later method calculates the relative importance of each type of trade in total trade.

flows in their component parts of inter-industry trade, horizontal IIT and vertical IIT.[32] These two methods which are used to measure intra-industry trade are briefly described in the following subsections.

3.2.1 The Grubel-Lloyd type trade decomposition

As indicated above when dealing with the problems of the unadjusted G-L index, this paper computes the extent of intra-industry trade between Austria and its trading partners by employing the adjusted G-L index, defined as:

$$IIT_{jkt} = \frac{\sum_{i=1}^{n}\left(X_{ijkt} + M_{ijkt}\right) - \sum_{i=1}^{n}\left|X_{ijkt} - M_{ijkt}\right|}{\sum_{i=1}^{n}\left(X_{ijkt} + M_{ijkt}\right)} \tag{2}$$

where X_{ijkt} and M_{ijkt} are Austria's exports and imports of product i of industry j with country k at time t. Hence, IIT_{jkt} computes the export and import flows with country k in industry j, adjusted or weighted according to the relative share of the trade flows in the i products included in j. The adjusted G-L index is equal to one if all trade is IIT, and is equal to1 if all trade is inter-industry trade.

The first step toward computing the G-L index is to select auto-parts (intermediate products) in the bilateral trade data. Bilateral trade flows used in this paper are classified at the 6-digit level of the Harmonized System (HS), which are used to construct the G-L index for each trading partner. In the end, 92 items are considered as auto-parts from the 6-digit level of HS.[33]

Once the auto-parts products have been selected for our study, we break total IIT into its two components of horizontal IIT and vertical IIT by using the method suggested by Abd-el-Rahman (1991), Greenaway et al. (1995).

Assuming that the price differentials between export prices and imports prices outside a certain range reflect multi-stage trade, IIT is considered as horizontal if the export and import values differ by less than 25 %, and when this is not the case, it is considered to be vertical;[34]

$$\frac{1}{1.25} \leq \frac{P^X_{ijkt}}{P^M_{ijkt}} \leq 1.25 \tag{3}$$

where P^X_{ijkt} and P^M_{ijkt} represent the unit value of Austria's exports and imports respectively, while indices i refer to the product, j the industry, k the partner country in year t.

[32] This method is called "the decomposition-type threshold method" by Ando (2006).

[33] Following Klier and Rubenstein (2006), we employ the list provided by the Office of Aerospace and Automotive Industries' Automotive Team, part of the U.S. Department of Commerce's International Trade Administration in order to select the motor vehicle products and auto parts from the trade data. That team's definition of motor vehicle products and auto parts can be found at http://www.ita.doc.gov/td/auto.html.

[34] The choice of 25 % is arbitrary. In trade literature, two common values are often employed, 15% and 25%. Greenaway et al. (1995), and Fontagne and Freudenberg (1997)'s empirical analysis suggest that the results are not very sensitive to the range chosen. The 15% threshold is generally used and considered to be appropriate when the unit value differences reflect only differences in quality. However, in case of production fragmentation the 15% threshold could be too wide and 25% threshold is considered to be more appropriate. Taking these considerations into account, this paper uses a rather narrower measure of vertical IIT in intermediates to more accurately measure the degree of international fragmentation.

After we identify whether intra-industry trade of product *i* is horizontal IIT or vertical IIT by using Eq. 3, the amount of horizontal (or vertical) IIT is calculated using the Eq. 2 at a 6 digit product level of HS items, and thereafter summed over all 6-digit level comprising a particular industry.

Note that there may be some products with IIT which cannot be classified as either HIIT or VIIT due to missing unit value data. We have labeled these as non-classified IIT. Following discussion made by Ando (2006) and Fontagne et al. (2006), products with no unit value should be included in the calculation of the G-L index. Otherwise, the actual share of intra-industry trade may have been underestimated for countries where the unit values of a large number of products were not available. Thus, IIT in auto parts can divided into three components in this method; HIIT, VIIT, and non-classified IIT.

3.2.2 The decomposition-type threshold method

For the sake of comparison, an alternative method developed by Fontagne and Freudenberg (1997) and Fontagne et al. (1997) is also employed to break down total trade into three types: one-way trade (OWT), two-way trade in horizontally differentiated goods (TWTH), and two-way trade in vertically differentiated goods (TWTV). In this method, there are three steps to compute the share of each type of trade. In order to differentiate between OWT and two-way trade (TWT), the first step of our analysis is to determine the degree of trade overlap. Trade in a product is considered to be TWT when the value of minority flow of trade represents at least 10% of the majority flow of trade and as OWT, otherwise:[35]

$$\frac{Min\left(X_{ijkt}, M_{ijkt}\right)}{Max\left(X_{ijkt}, M_{ijkt}\right)} \geq 0.1 \tag{4}$$

where X_{ijkt} and M_{ijkt} are Austria's exports and imports of product *i* of industry *j* with country *k* at period *t*.[36]

After determining trade flows as being TWT, the second step is to distinguish trade in horizontally differentiated goods from trade in vertically differentiated goods by following the method from Abd-el-Rahman (1991) and Greenaway et al. (1995) as briefly outlined in the previous section. Therefore, TWT is classified as TWTH if the export and import unit values differ by less than 25%, i.e. if Eq. 3 holds, and as TWTV otherwise.

Finally, the share of each type of trade is defined as follows:

$$S_{jkt}^{Z} = \frac{\sum_{i=1}^{N}\left(X_{ikt}^{Z} + M_{ikt}^{Z}\right)}{\sum_{i=1}^{N}\left(X_{ikt} + M_{ikt}\right)} \tag{5}$$

where S_{jkt}^{Z} stands for either one-way trade (OWT_{jkt}), horizontal two-way trade ($TWTH_{jkt}$), or vertical two-way trade ($TWTV_{jkt}$), while indices *Z* refer to one of three trade categories depending on the corresponding trade type, *i* referring to the product, *j* the industry, *k* the partner country in year *t*.

[35] Unfortunately, the G-L method still considers the minority flow below this 10 % threshold as two-way trade when the calculated G-L index is greater than zero.

[36] Most previous studies such as Umemoto (2005) used 10% as a benchmark, though there are some studies which use different benchmark values such as Montout et al. (2002). In our study, the 10% benchmark is employed.

Using Eq. 5, the shares of the three trade types (OWT, TWTH, and TWTV) at country level are calculated for the trade in auto-parts. Note that some products have no information on quantities. Thus, it is not possible to determine whether two-way trade of such products is vertical or horizontal. These products in our data set are classified as "non-classified two-way trade". Consequently, TWT in auto parts can be divided into three components in this method; TWTH, TWTV, and non-classified TWT.

3.3 Evidence of IIT in the Austrian auto industry

Using the two approaches outlined in the previous section, we compute measures of IIT in the auto industry as a whole as well as separately for motor vehicle products, and auto-parts between Austria and OECD, for the period 1996 to 2006. At the more aggregated level, summary results are presented in Fig. 2 for horizontal intra-industry trade (HIIT), vertical intra-industry trade (VIIT) and total intra-industry trade (IIT) along with measures for inter-industry trade using the first approach; and in Fig. 3 for horizontal two-way trade (TWTH), vertical two-way trade (TWTV), total two-way trade (TWT), and one-way trade, using the second approach.

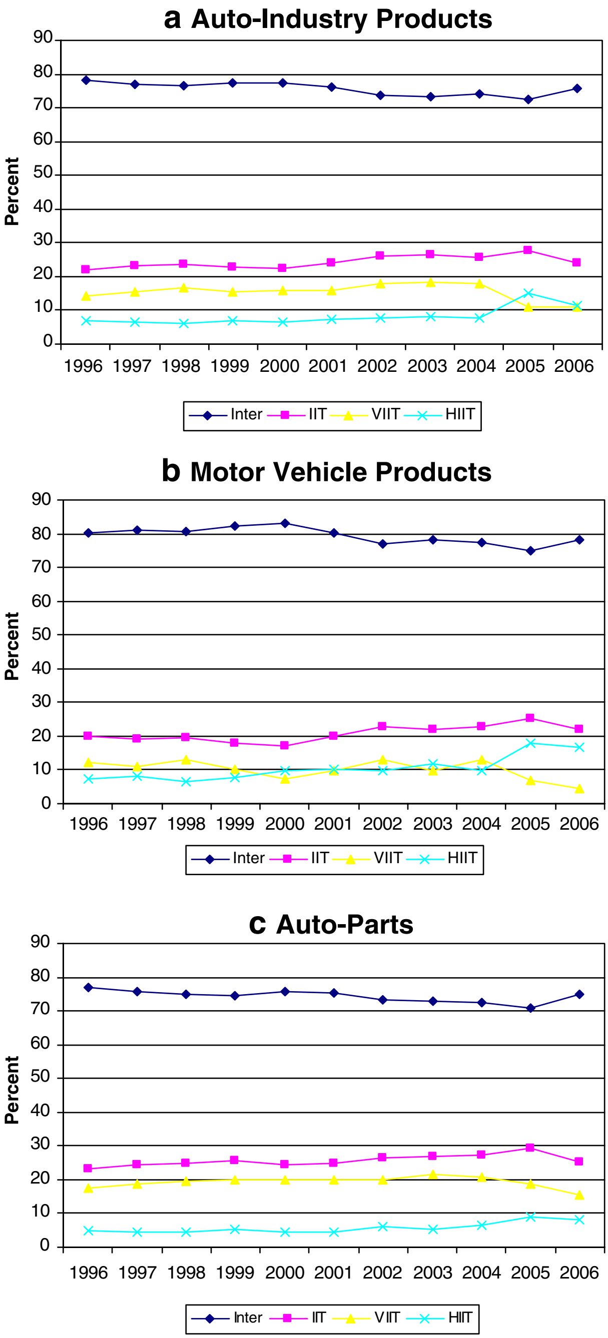
As can be seen from Fig. 2, three points are worth noting. First, the auto industry as a whole, as well as separately for the motor vehicle products and auto-parts, exhibits a substantial level of inter-industry trade.[37] However, the overall Grubel-Lloyd measure of intra-industry trade (IIT) in the auto industry, motor vehicle products, and auto-parts industry has increased in recent years, respectively, from around 21% in 1996 to 24% in 2006, 19% to 21%, and 23% to 25%.

Second, the relative significance of vertical IIT on the total IIT of auto industry product groups and auto-parts has dropped marginally from 14% in 1996 to 10% in 2006, 17% to 15%, respectively.[38] In the meantime, the corresponding share in motor vehicle products has also declined from 12% to 4%. In other words, vertical IIT in auto-parts still dominates trade flows in auto-parts during the period considered, while trade in motor vehicle products trade flows are overwhelmingly horizontal (Fig. 2).

A high degree of vertical IIT in the auto-parts industry is suggestive of the substantial contribution of fragmentation to trade between Austria and OECD countries. On the other hand, the increasing importance of horizontal IIT, particularly in motor vehicle products, is closely linked with the ongoing structural changes in the Austrian auto industry, where there has been a shift from production of auto-parts to motor vehicle production. IIT in finished goods (motor vehicle products) tends to reflect more exchange in horizontally differentiated goods based on varieties. The outcome is not surprising since trade in motor

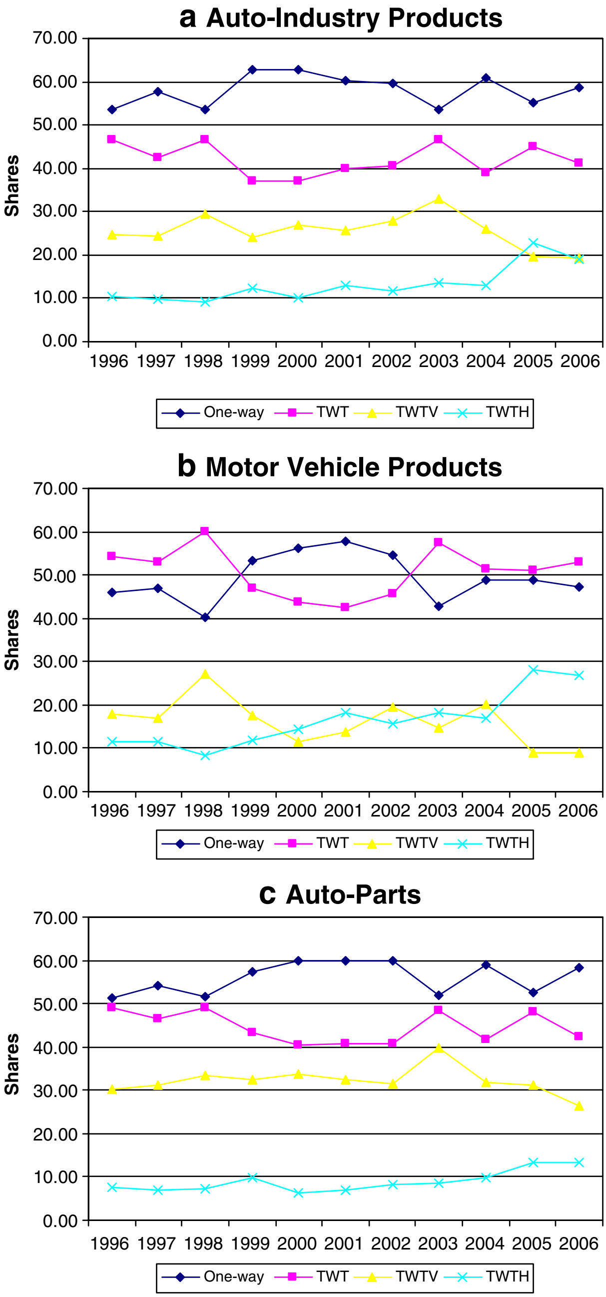
[37] Similarly, Ando (2006) provided empirical evidence that the auto industry trade in East Asia is mainly one-way trade thanks to import substituting policies in these developing countries, although vertical IIT has become important for auto-parts in recent years. On the other hand, Montout et al. (2002) demonstrated the importance of IIT in NAFTA's auto parts trade, which represents approximately 70% of total trade in the 1990 s. Similarly, Jones et al. (2002) also found that the degree of IIT between the USA and Mexico in auto-parts rose substantially, from 67% in 1992 to 85% in 1999. However, Lall et al. (2004) argue that in the auto industry, fragmentation is more constrained than in other sectors, such as the electronics sector. While the auto industry has separable stages of production and parts with different scale, skill and technological needs whose production can be located in different countries, many components, such as body and chassis parts, are heavy, thus making their processing more suitable for relocation in closer areas rather than in distant areas, which in turn reduces the degree of intra-industry trade.

[38] As seen in Fig. 2, except in 2006, the degree of VIIT in auto-parts has continuously increased since 1996. The reason for a drop in 2006 is due to the fact that missing data are often encountered in the last quarter of 2006.



Source: Authors' own calculations

Fig. 2 Development of intra-industry trade in Austria's auto industry-G-L index (%), 1996–2006.



Source: Authors' own calculations

Fig. 3 Development of intra-industry trade in Austria's auto industry—decomposition method (%), 1996–2006.

vehicle products accounts for a significant portion of total auto industry trade in recent years.

Finally, as evident in Fig. 2, the degree of IIT in auto-parts is much larger than in motor vehicle products. In addition, horizontal IIT is lower in the auto-parts trade compared with the motor vehicle trade. However, the Austrian auto industry exhibits a high level of vertical IIT in parts, while it has a relatively low level of vertical IIT in motor vehicle products. Both the recent developments in the auto-parts industry and the importance of vertical IIT in auto-parts suggest that Austrian auto-parts suppliers are locating their production stages to take advantage of differences in labor costs across countries.

Furthermore, in almost all product groups (auto industry products, motor vehicle products, and auto-parts), traditional G-L indices and two-way trade shares obtained from the decomposition method display a reasonably similar pattern (Fig. 3). However, quantitatively the results of the decomposition type of threshold method measure for two-way trade are systematically higher than G-L index results, consistent with the findings of Fontagne et al. (2006).

The nature and dynamics of Austria's intra-industry trade in auto-parts is further studied by breaking down the traditional G-L indices and two-way trade shares obtained from decomposition method for each trading partner for the period 1996 to 2006.[39] Overall, two important findings emerge from the calculations of Austria's IIT indices for the auto industry. Our first finding is that there are wide variations in intra-industry trade indices and two-way trade shares across partner countries (Tables 2 and 3). As we can see in Table 2, in 2006 it was found that Germany had the highest values of IIT in auto-parts, 58%, followed by France, Italy, Sweden, and Hungary.[40] On the other hand, Table 2 reveals that the highest measure of horizontal IIT is seen for Germany again (28% in 2006).

The United Kingdom, the Czech Republic, Ireland, and France are other important partner countries with a high degree of horizontal IIT. However, when looking at vertical IIT in 2006, we see that Sweden has the highest degree of vertical IIT in auto-parts (36%), but there are other partner countries with rather high degrees of vertical IIT, such as France, Hungary, Germany, and Japan. From the figures in Table 2 we conclude that intra-industry trade indices are relatively higher for developed countries such as Germany, France, Italy, Sweden and the United Kingdom, and also for Austria's neighbor countries such as Hungary, Slovak Republic, and the Czech Republic.

The second important finding is that the degree of vertical IIT remained stable for periphery countries, declining marginally from 21% in 1996 to almost 20% in 2006 (Table 2),[41] while in core countries it declined mildly from 15% to 13% (Table 2)[42] over the

[39] From Tables 2 and 3, one can see that several countries such as Belgium, Iceland, and others, have extremely low levels of intra-industry trade in 1996, and also large changes in the levels of IIT from 1996 to 2006. These values are not in line with the values expected for a developed country such as Belgium. The low levels of IIT and large changes in IIT can be primarily explained by the fact that there are many missing or unrecorded observations in the OECD's International Trade Commodity Statistics (ITCS) database, particularly in 1996.

[40] Likewise, Fontagne et al. (2005) showed that Germany and Austria are the two trading partners in the world having one of the highest shares of IIT in their manufacturing products trade: 77% in 2000.

[41] For similar results see Fidrmuc (2000), who showed that the level of IIT in EU trade with Austria dropped from 69% in 1990 to 66% in 1996.

[42] For similar results see Fidrmuc (2000), who showed that the level of IIT in EU trade with Austria dropped from 69% in 1990 to 66% in 1996.

Table 2 Development of intra-industry trade in Austria's auto-parts industry-G-L index, 1996–2006

Countries	1996				2006			
	Inter	IIT	VIIT	HIIT	Inter	IIT	VIIT	HIIT
Australia	94.75	5.25	2.33	0.00	96.26	3.74	1.63	0.23
Belgium	100.00	0.00	0.00	0.00	81.22	18.78	10.69	7.01
Canada	65.54	34.46	25.91	8.09	83.08	16.92	13.15	2.58
Czech Republic	49.82	50.18	41.59	8.37	57.85	42.15	16.22	24.56
Denmark	66.64	33.36	23.52	8.09	71.48	28.52	17.05	4.35
Finland	85.57	14.43	12.63	1.14	93.22	6.78	3.68	2.68
France	67.25	32.75	25.69	6.69	47.48	52.52	31.63	19.03
Germany	44.73	55.27	37.70	17.57	41.30	58.70	27.73	28.88
Greece	79.63	20.37	16.97	2.34	99.11	0.89	0.42	0.32
Hungary	79.96	20.04	19.34	0.62	57.78	42.22	30.96	9.42
Iceland	100.00	0.00	0.00	0.00	91.63	8.37	5.44	0.11
Ireland	90.98	9.02	6.94	0.00	66.63	33.37	9.21	23.56
Italy	62.68	37.32	20.77	16.41	54.62	45.38	23.41	20.78
Japan	81.74	18.26	12.63	4.95	71.24	28.76	27.59	0.31
Korea	84.99	15.01	11.08	1.07	95.24	4.76	3.95	0.53
Luxembourg	100.00	0.00	0.00	0.00	97.25	2.75	1.98	0.64
Mexico	97.01	2.99	2.47	0.20	84.49	15.51	6.03	9.27
Netherlands	60.00	40.00	33.53	5.97	64.47	35.53	22.44	11.27
New Zealand	77.23	22.77	21.53	0.00	92.07	7.93	0.97	0.03
Norway	88.03	11.97	8.72	0.85	79.10	20.90	18.98	1.64
Poland	79.40	20.60	12.67	6.95	78.31	21.69	13.96	7.28
Portugal	90.01	9.99	8.66	0.99	90.43	9.57	7.56	1.62
Slovak Republic	62.37	37.63	37.11	0.00	66.12	33.88	31.58	1.27
Spain	95.51	4.49	2.89	1.49	76.49	23.51	13.42	8.50
Switzerland	65.86	34.14	22.75	10.66	69.84	30.16	20.57	7.89
Sweden	49.32	50.68	33.79	15.94	56.65	43.35	36.67	3.66
Turkey	77.78	22.22	16.49	5.26	65.27	34.73	25.71	7.44
United Kingdom	73.35	26.65	24.01	2.15	62.01	37.99	10.62	25.67
USA	62.20	37.80	21.43	16.15	78.18	21.82	16.82	3.62
Core	78.46	21.54	15.66	5.03	76.81	23.19	13.82	7.67
Periphery	74.39	25.61	21.61	3.57	68.30	31.70	20.74	9.87
Mean	76.98	23.02	17.35	4.89	74.79	25.21	15.52	8.07

Author's calculation based on OECD's ITCS International Trade by Commodity Database-Harmonized System 1996

same period.[43] As we mentioned previously, the importance of vertical IIT between Austria and periphery countries was largely due to high and increasing flows of German FDI into these countries over the period, which is directly related to the internationalization of production.

[43] Similarly, Umemoto (2005) illustrated that higher-income countries, such as EU countries, experienced a sharp decline in vertical IIT in auto-parts whereas low-income countries, such as East Asian countries, experienced a sharp increase in vertical IIT during the late 1990 s.

Table 3 Development of intra-industry trade in Austria's auto-parts industry—decomposition method (%), 1996–2006

Countries	1996				2006			
	One-way	TWT	TWTV	TWTH	One-way	TWT	TWTV	TWTH
Australia	90.41	9.59	6.05	0.00	93.11	6.89	1.55	0.55
Belgium	0.00	100.00	0.00	0.00	69.28	30.72	16.95	13.29
Canada	59.33	40.67	29.35	11.00	70.37	29.63	23.67	5.92
Czech Republic	22.12	77.88	64.31	13.34	35.03	64.97	30.77	30.06
Denmark	48.76	51.24	34.64	14.44	54.49	45.51	25.47	9.19
Finland	76.02	23.98	18.99	4.59	89.34	10.66	6.57	3.23
France	38.86	61.14	48.24	12.63	27.06	72.94	45.10	24.94
Germany	21.45	78.55	53.78	24.76	7.95	92.05	48.48	38.98
Greece	60.54	39.46	36.59	2.42	99.03	0.97	0.78	0.00
Hungary	47.95	52.05	51.17	0.77	20.10	79.90	48.90	28.24
Iceland	0.00	100.00	0.00	0.00	86.92	13.08	10.30	0.00
Ireland	87.45	12.55	10.54	0.00	39.14	60.86	11.63	48.55
Italy	29.31	70.69	42.01	28.60	24.52	75.48	41.28	32.43
Japan	72.14	27.86	19.37	8.12	60.98	39.02	36.64	0.57
Korea	75.13	24.87	20.32	0.00	93.68	6.32	5.53	0.23
Luxembourg	0.00	100.00	0.00	0.00	95.52	4.48	4.14	0.17
Mexico	99.44	0.56	0.00	0.00	73.00	27.00	9.70	17.05
Netherlands	44.05	55.95	47.07	7.89	35.25	64.75	45.52	15.50
New Zealand	5.65	94.35	90.81	0.00	90.71	9.29	1.30	0.15
Norway	84.74	15.26	11.19	0.00	63.55	36.45	33.76	2.61
Poland	63.35	36.65	21.03	14.42	58.98	41.02	26.92	12.77
Portugal	92.90	7.10	6.81	0.09	84.57	15.43	11.55	3.41
Slovak Republic	43.96	56.04	55.83	0.00	44.22	55.78	52.95	1.70
Spain	92.47	7.53	5.97	1.31	62.06	37.94	17.61	17.51
Switzerland	45.61	54.39	36.43	17.22	44.52	55.48	38.16	16.14
Sweden	14.98	85.02	55.71	27.61	30.46	69.54	62.31	3.65
Turkey	62.34	37.66	26.83	10.24	51.03	48.97	37.62	7.86
United Kingdom	58.33	41.67	37.64	3.44	32.85	67.15	18.24	45.91
USA	44.91	55.09	37.66	16.99	44.50	55.50	44.70	7.42
Core	49.70	50.30	28.22	7.87	60.86	39.14	23.97	12.62
Periphery	56.53	43.47	36.53	6.46	47.06	52.94	34.48	16.28
Mean	51.11	48.89	29.94	7.58	58.01	41.99	26.14	13.38

Author's own calculation based on OECD's ITCS International Trade by Commodity Database-Harmonized System 1996

These figures clearly show that the important pattern of IIT in the Austrian auto-parts industry is still vertical IIT, not horizontal IIT, although the degree of horizontal IIT in auto-parts has, on average, doubled during the same period, from around 4% to 8%.

The importance of vertical IIT, particularly with periphery countries, confirms that Austria's trade in auto-parts mainly involves the exchange of technologically linked intermediates rather than the exchange of different varieties of the same intermediates.[44] Hence, the numbers obtained here clearly prove that low wages in periphery countries have a decisive impact on the pattern of Austria's trade in auto-parts, in line with the predictions of the Heckscher-Ohlin theory that vertical IIT tends to be high between countries that are different in terms of their factor endowments. In brief, these results therefore support the claim that that Austria's intra-industry trade in auto-parts is mainly induced by international fragmentation of vertical production chains, in addition to intra-industry trade of auto-parts with different qualities.

4 The empirical model, the determinants of vertical IIT, and estimation

4.1 The empirical model

Using annual data from 1996–2006, the following logit transformation model is proposed to explain the determinants of vertical IIT in bilateral auto-parts trade between Austria and its 29 trading partners:

$$\ln\left(\frac{y_{kt}}{1-y_{kt}}\right) = \alpha_k + \mu_t + \beta_m Z_{kt} + \beta_d DIST_k + \beta_E EU15_k + \varepsilon_{kt} \tag{6}$$

where y_{kt} stands for either $VIIT_{kt}$ or $TWTV_{kt}$ between Austria and its trading partner country (k), Z_{kt} is a set of m country-specific variables, $DIST_k$ represents the geographic distance and $EU15_{kt}$ indicates whether the trading partners are members of the EU, α_k is the country effect, $k = 1.....,K$, μ_t is the time effect, $t = 1.....,T$, and finally ε_{kt} is the white noise disturbance term distributed randomly and independently.

In the present study, two different concepts of the vertical IIT index between Austria and its trading partners (k) are used for the purpose of comparison: the vertical intra-industry trade index ($VIIT_{kt}$) based on the Grubel-Lloyd type trade decomposition method, and the share of two-way trade in vertically differentiated goods ($TWTV_{kt}$) based on the decomposition-type threshold method.

In analyzing the determinants of IIT, many earlier studies apply either a linear function or log-linear function by ordinary least squares to the IIT index. However, OLS estimation of a linear or log-linear function may predict values of IIT that lie outside the theoretically feasible range since the G-L index or two-way trade share index vary between zero and one. Thus, a number of studies such as Caves (1981) have used a logit transformation of the IIT index to correct this problem because the logit transformation will simply drop observations with zero values for the dependent variable. As a result, the logit transformation of the dependent variables has been used to analyze the determinants of vertical IIT in the Austrian auto-parts industry.

4.2 The determinants of vertical intra-industry trade

In terms of the explanatory variables, several country-specific variables suggested by the fragmentation literature are considered to investigate the determinants of vertical IIT in the auto-parts industry.[45]

[44] Gabrisch and Segnana (2007) also found that the shares of vertical IIT between Austria and candidate countries in 1993 and 2000 were 22% and 42%, respectively. The sharp increase in vertical IIT clearly indicates how rapidly vertical IIT became an essential element of trade between Austria and neighboring periphery countries.

[45] The definitions and sources of explanatory variables are explained in Appendix A and Table 7.

Economic size (GDP) Jones and Kierzkowski (2005) claim that IIT in intermediate goods tends to increase with the bilateral market size of the two countries due to economies of scale in service link activities. In addition, larger markets also support more varieties and qualities to be traded (Lancaster 1980). Thus, the larger the international market the larger the opportunities for production of differentiated intermediate goods and the larger the opportunities for trade in intermediate goods. As a result, vertical IIT in the auto-parts industry is expected to be positively related to the average market size of Austria and its trading partner, denoted as GDP_{kt}.

Differences in market size (DGDP) Grossman and Helpman (2005) show that a trading partner's market size encourages greater degrees of fragmentation between two countries. Firms are more likely to find a trading partner with the appropriate skills that match their needs in large host markets. This suggests a negative relationship between the bilateral trade in intermediate goods and differences in market sizes.[46] On the other hand, there are also reasons to believe that large markets are more likely to be served by local production due to the fact that the availability of local input producers in the host country should reduce the dependence on the imports of intermediate goods from the home country.[47] Consequently, the difference in market size ($DGDP_{kt}$), measured by the absolute difference of total GDP between Austria and its trading partners, could have uncertain effects on vertical IIT.

Differences in per capita GDP (DPGDP) Our empirical model also includes differences in per capita GDP as a measure of differences in factor endowments between Austria and its trading partners. Helpman (1984) shows that vertical type trade increases with differences in relative factor endowments. Assuming that fragmentation typically occurs with vertical type FDI, IIT in intermediate goods would be expected to be high when there are large differences in relative factor endowments across trading countries.

Likewise, Feenstra and Hanson's (1997) model of outsourcing predicts that fragmentation is more likely to take place between countries with dissimilar factor endowments. Previous studies such as Egger and Egger (2005) and Kimura et al. (2007) have used per capita income differences to measure the effect of the differences in factor endowments on fragmentation. Following the same logic, in the current study differences in factor endowments are proxied by the absolute value of the difference in per capita GDP between Austria and its trading partners ($DPGDP_{kt}$), which is expected to be positively related to the share of vertical IIT. On the other hand, the differences in per capita GDP may also capture the differences in infrastructure endowment and worker skills between countries, which would be reflected in lower shares of vertical IIT. Therefore, the relationship between vertical IIT and the differences in per capita GDP could be either positive or negative depending on which effect dominates.

Foreign direct investment (FDI) FDI will also influence the share of vertical IIT. Firms through their FDI activities have established extensive production and distribution networks

[46] By contrast, Falvey and Kierzkowski (1987) have demonstrated that vertical IIT is positively associated with differences in market size, reflecting differences in factor endowments. At first sight, the expectation of a negative coefficient on the differences in market size appears to be contrary to the expectations of Falvey and Kierzkowski (1987). However, in the present study, vertical IIT is used as a proxy to measure the degree of fragmentation of production, instead of two-way exchanges of quality-differentiated products trade.

[47] See Andersson and Fredriksson (2000) for a more detailed discussion on the relationship between a host country's market size and intra-firm imports of imported intermediate goods.

to take advantage of differences between countries over the last two decades. Recent evidence suggests that the establishment of such networks has ultimately led to a surge in intermediate goods trade. Vertical models by Helpman (1984) and Helpman and Krugman (1985) predict a complementary relationship between FDI and trade, given the fact that affiliates in the host country perform final assembly or processing stages using imported intermediate goods from the parent firms. Likewise, Feenstra and Hanson's (1997) model predicts that the growth of the capital stock in the host country encourages the flow of intermediate goods between two countries for further processing. Thus, there is a positive relationship between vertical IIT and FDI. Austria's stocks of outward FDI into sample countries, FDI_{kt}, is used to test this hypothesis.[48]

Geographical distance (DIST) The relevance of service-link costs for vertical IIT is also investigated. According to Jones (2001), reductions in service-link costs should encourage the international fragmentation of production across countries.[49] However, measures of service-link costs are not widely available. Service-link costs consist of transport costs, telecommunication costs, coordination costs, and others. Among various components of service-link costs, transportation costs between production sites are the most visible portion of service link costs, and transportation costs are typically assumed to be a linear function of geographical distance. For instance, Kimura et al. (2007) claim that geographical distance between countries can be viewed as indicative of service-link costs, particularly the transportation and telecommunication costs. Hence, geographical distance between the capital cities of Austria and its trading partners, $DIST_k$, is used as a proxy for service-link costs. The vertical IIT is expected to be negatively associated with distance ($DIST_k$) between Austria and its trading partner.[50]

The remaining variables that influence vertical IIT are the bilateral exchange rate and dummy variable for the countries belonging to the EU.

The bilateral exchange rate (EXCH) The bilateral exchange rate ($EXCH_{kt}$) is included in our model to control the effects of exchange rate changes on the degree of vertical IIT between Austria and its trading partners. Changes in exchange rates may have an important impact on the international outsourcing decisions of firms across countries. Traditionally, it is expected that an appreciation of a country's currency boosts imports and lowers exports. In the case of international fragmentation of production, however, an appreciation of the home country's currency (i.e., a decline in the price of foreign inputs) may cause firms or affiliates abroad to use locally produced inputs of the host country rather than those of the home country. Subsequently, this suggests a negative impact from an appreciation of the home's currency on the flows of intermediate goods across countries. However, the negative

[48] A temporal causality between outward FDI stocks and trade may also exist in the other direction. There appears no consensus among researchers in the literature on this issue. For instance, the results reported in Alguacil and Orts (2002) and Türkcan (2007) suggest a causal relationship running from FDI to trade In contrast, Pfaffermayr (1994) indicates that the causality between FDI and trade runs significantly in both ways.

[49] In the same way, Krugman and Venables (1995), and Venables (1996) found that the volume of trade in intermediate goods is greater the lower the transportation costs between countries.

[50] The magnitude of this effect on vertical IIT could be different across different product groups: final and intermediate goods. Considering trade in intermediate goods, small changes in transportation costs have a major effect on fragmentation decisions because of multiple border-crossing involved in the value added chain. In contrast, distance is less likely to affect the final goods trade in which goods pass the border once only.

response of the home country's intermediate goods exports to exchange rate appreciation tends to disappear when a foreign affiliate requires a large share of imported inputs from the home country for further processing. As a result, one cannot make a definitive assessment of the effect of exchange rate changes on the extent of fragmentation across countries.[51] However, a possible negative relationship in the empirical results implies that a depreciation of the domestic currency will increase the share of vertical IIT between Austria and its trading partners.

EU dummy (EU15) It is generally accepted that economic integration will increase the share of vertical IIT due to specialization, division of labor, product differentiation, economies of scale, and reduction of trade barriers between member countries. In our case, we have used the dummy variable for countries belonging to the EU before the 2004 enlargement ($EU15_k$) which takes a value 1 if both Austria and its trading partner are members of the EU and zero otherwise.[52] Regional integration is expected to have a positive influence on the share of vertical IIT.

4.3 Estimation

In estimating the determinants of vertical IIT in the auto parts industry between Austria and its 29 trading partners, a number of estimation techniques are applied to Eq. 6 in order to ensure the robustness of the results. The results for two different concepts of vertical IIT index ($VIIT_{kt}$ and $TWTV_{kt}$) using these estimators are reported in Tables 4 and 5.

First, Eq. 6 is estimated with the pooled ordinary least squares (OLS) with a White heteroscedasticity correction. However, it has been shown that pooled OLS can lead to biased results because it ignores unobserved cross-country heterogeneity. For example, there are good reasons to believe that unobserved individual factors such as legal, cultural, and institutional factors are difficult to observe, and they most likely affect bilateral trade flows between any pair of countries.

Using a panel data approach allows us to account for such effects. The most commonly employed panel models, which monitor the existence of such effects are the fixed effects model (FE) and the random effects model (RE). The FE model is particularly appropriate in the presence of cross-country heterogeneity because it allows for unobserved factors that explain the bilateral trade flows between two countries, and leads to unbiased and efficient results.

However, a shortcoming of the FE is that it is not able to compute coefficients for time-invariant variables such as distance or the regional integration dummy because those variables are dropped within transformation. In order to tackle this problem most researchers advocate the implementation of the RE model, since it allows parameter estimation of time-invariant regressors within the panel data framework. However, as noted

[51] For instance, the results of Arndt and Huemer (2005) indicate that U.S trade flows become much less sensitive to exchange rate changes as fragmentation induced trade expands. Similarly, Thorbecke (2008) recently investigated the impact of exchange rate volatility and changes in the bilateral exchange rate on fragmentation of the electronic component industry in East Asia, and found that the flow of these goods in East Asia is very sensitive to exchange rate volatility, but not to changes in bilateral exchange rates. In contrast, Swenson (2000) analyses the sensitivity of firms located in the U.S. foreign trade subzones to a dollar depreciation, and found a decline in the use of imported inputs in production by the U.S. firms as a response to depreciation.

[52] The EU dummy consists of Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, and the United Kingdom.

Table 4 Determinants of vertical intra-industry trade in Austria's auto-parts industry, 1996–2006

Independent variables	Pooled OLS	Fixed effects	FGLS	HT
GDP_{kt}	0.500 (2.17)[b]	0.722 (0.18)	1.088 (15.63)[a]	0.465 (2.14)[b]
$DGDP_{kt}$	−0.945 (−1.41)	0.404 (0.07)	−3.363 (−17.38)[a]	−0.928 (−1.39)
$DPGDP_{kt}$	1.291 (4.18)[a]	−0.420 (−0.09)	2.384 (11.73)[a]	1.301 (4.17)[a]
FDI_{kt}	0.130 (4.00)[a]	−0.027 (−0.37)	0.130 (6.58)[a]	0.130 (3.95)[a]
$EXCH_{kt}$	−0.026 (−0.73)	−0.080 (−0.63)	0.043 (1.94)[c]	−0.027 (−0.75)
$DIST_k$	−0.409 (−4.44)[a]		−0.663 (−14.98)[a]	−0.410 (−4.42)[a]
$EU15_k$	−0.565 (−4.82)[a]		−0.109 (−2.02)[b]	−0.567 (−4.80)[a]
Constant	−25.81 (−3.63)[a]	−16.101 (−0.29)	−51.282 (−15.90)[a]	−25.155 (−3.61)[a]
R-squared	0.44	0.003		0.44
F-statistics	20.37[a]	0.16		19.99[a]
Wald statistic: χ^2 (8)			860.03[a]	
Wooldridge test for autocorrelation: F (1,24)			0.730	
LR-test for heteroscedasticity: χ^2(27)			173.11[a]	
Chow test of FE vs OLS: F (32,179)		14.49[a]		
Breusch-Pagan test of RE vs OLS: χ^2 (1)			233.68[a]	
Hausman test of RE vs FE: χ^2 (7)			9.46	
Hausman test of HT vs FE: χ^2(7)				5.39
Hansen overid. test: χ^2(1)				0.001
# of groups		28	28	
# of observations	220	220	220	220

The dependent variable is the logit transformation of $VIIT_{kt}$, Grubel-Lloyd index in vertically differentiated products. Heteroskedasticity-consistent t-statistics (White-Newey) are reported in the first, second, and last columns

[a] Statistical significance at 1% levels

[b] Statistical significance at 5% levels

[c] Statistical significance at 10% levels

by Egger and Pfaffermayr (2004), the RE estimates are inconsistent when regressors are correlated with the error term.

In order to overcome the bias of the RE model, theoretical econometric and empirical studies recommend the use of the Hausman-Taylor procedure (HT) for panel data with time-invariant variables and correlated unit effects (See Hausman and Taylor 1981; Egger and Pfaffermayr 2004). Hausman and Taylor (1981) suggest an instrumental variable approach to estimate the coefficients of time-invariant variables by generalized least squares (GLS) to deal with the endogenity of some of regressors.[53]

In order to obtain efficient and consistent estimates for all parameters in (6), the HT approach consists of four steps. In brief, the first step of the HT approach is to obtain within estimator of β

[53] For a detailed explanation of the estimation strategy, see Greene (2003).

Table 5 Determinants of two-way trade in vertically differentiated goods in Austria's auto-parts industry, 1996–2006

Independent variables	Pooled OLS	Fixed effects	FGLS	HT
GDP_{kt}	0.781 (1.98)[b]	2.217 (0.40)	1.814 (11.40)[a]	0.774 (1.95)[c]
$DGDP_{kt}$	−1.549 (−1.26)	−1.432 (−0.17)	−5.226 (−10.54)[a]	−1.527 (−1.24)
$DPGDP_{kt}$	1.556 (2.90)[a]	−2.756 (−0.40)	2.093 (7.65)[a]	1.564 (2.84)[a]
FDI_{kt}	0.180 (3.098)[a]	0.079 (0.66)	0.102 (4.17)[a]	0.179 (3.90)[a]
$EXCH_{kt}$	−0.029 (−0.61)	−0.170 (−1.35)	−0.009 (−0.32)	−0.031 (−0.64)
$DIST_k$	−0.509 (−3.81)[a]		−0.883 (−14.10)[a]	−0.510 (−3.77)[a]
$EU15_k$	−0.657 (−4.28)[a]		−0.340 (−3.56)[a]	−0.661 (−4.22)[a]
Constant	−34.834 (−3.07)[a]	−30.089 (−0.40)	−64.436 (−13.24)[a]	−33.160 (−3.02)[a]
R-squared	0.42	0.01		0.41
F-statistics	16.48[a]	0.42		15.75[a]
Wald statistic: χ^2 (8)			527.40[a]	
Wooldridge test for autocorrelation: F (1,24)			3.054[c]	
LR-test for heteroscedasticity: $\chi^2(27)$			148.08[a]	
Chow test of FE vs OLS: F (32,179)		10.32[a]		
Breusch-Pagan test of RE vs OLS: χ^2 (1)			137.90[a]	
Hausman test of RE vs FE: χ^2 (7)			3.56	
Hausman test of HT vs FE: $\chi^2(7)$				1.08
Hansen overid. test: $\chi^2(1)$				0.001
# of groups		28	28	
# of observations	220	220	220	220

The dependent variable is the logit transformation of $TWTV_{kt}$, the share of two-way trade in vertically differentiated products. Heteroskedasticity-consistent t-statistics (White-Newey) are reported in the first, second, and last columns

[a] Statistical significance at 1% levels

[b] Statistical significance at 5% levels

[c] Statistical significance at 10% levels

but they may not be efficient. Note that this procedure, however, eliminates the time-variant variables from the model. The second step is to form the within group residuals from the within regression at the first step, and then regress them on the time-variant variables using a set of time-varying exogenous variables and time-variant exogenous variables as instruments. This provides a consistent estimator of time-invariant variables.

In the third step, using residuals from both overall and within estimates, the components of variance of the dependent variable are estimated. The estimated variance components are then used to form the weight for feasible generalized least squares (GLS) by forming the estimate of θ. In the final step, the estimate of θ is used to perform a GLS transformation on each of the variables at step 2. After transforming the variables by θ, the HT estimates of the coefficients of the model are then obtained by performing an instrumental regression on the

GLS-transformed model using deviations of time-varying variables from their means as instruments.

The advantage of the HT approach is that it allows us to estimate the coefficients of time-invariant variables using instruments from inside the model. However, it is quite difficult to find appropriate internal instruments to estimate all model coefficients because the individual effects are unobserved. Following Egger and Pfaffermayr (2004), the explanatory variables are divided into two groups: the doubly exogenous (i.e. uncorrelated with the unobserved effects) and the singly exogenous ones (correlated with the unobserved effects). Hausman and Taylor (1981) suggest using economic intuition to decide which group a variable belongs to. In our case, it is appropriate to assume the distance and regional integration dummy as doubly exogenous, and the remaining ones as singly exogenous variables. The doubly exogenous variables are then used to instrument for the singly exogenous variables such as GDP and FDI. The validity of the choice of instruments can be tested by performing a Hansen test of over-identifying restrictions, which is distributed as chi-squared. As shown in Table 4 and 5, the Hansen test for over-identifying restrictions does not reject the null hypothesis that our choice of instruments are valid for both concepts of the vertical IIT index.

To find the appropriateness of the HT approach, several statistical tests are performed.[54] First, we test whether we need to use panel data techniques in the first place, to using the Chow test for fixed effects and the Breusch-Pagan (BP) test for random effects. As reported in Tables 4 and 5, the Chow test confirms the appropriateness of the FE model over the pooled OLS whereas the Breusch-Pagan test advocates the use of the RE model over the pooled OLS. Consequently, the question of model selection arises. To decide whether the FE model or the RE model is appropriate, the Hausman specification test can be applied under the null hypothesis that individual effects are uncorrelated with the other regressors in the model. As evident in the third columns of Tables 4 and 5, the resulting Hausman test statistics in both regressions strongly indicate that the RE model should be preferred over the FE model.[55]

Finally, the Hausman specification test is applied to the FE and the HT method to determine if the instrumental variable technique eliminates the correlation between individual effects and other regressors in the model.[56] The reported values of 5.39 and 1.08 in Tables 4 and 5 are much smaller than the critical value of 12.59, so the results suggest that, of the two alternatives considered here, the HT method is more efficient for

[54] As suggested by the tests for heteroscedasticity the likelihood ratio test (LR) and serial correlation (the Wooldridge test) reported in Tables 4 and 5, pooled OLS, the FE model, and the HT model are conducted using the Newey-West method which generates robust standard errors in the presence of autocorrelation within panels, and heteroscedasticity across panels. In addition, the RE model is estimated using the feasible generalized least squares (FGLS) method in order to account for heteroscedasticity and autocorrelation. Besides addressing the problem of heteroscedasticity and autocorrelation, collinearity among independent variables is also examined and reported in the Appendix, Table 9. After an examination of collinearity among explanatory variables in Table 9, it is found that none of the explanatory variables is strongly correlated with the others.

[55] Test statistics of 9.46 and 3.56 for both concepts of vertical IIT index are much smaller than the critical value of a chi-squared with six degrees of freedom (12.59).

[56] Someone might argue that if we cannot reject the hypothesis that individual effects are uncorrelated with the other regressors in the model, then there is no need to apply the HT model. However, Baltagi et al. (2003) show that there is a substantial bias in the RE estimators when there are time-invariant variables, and also endogenity among the regressors. Hence, they conclude that inference based on the RE estimators can be seriously misleading even when there is no correlation between the explanatory variables and the individual effects.

both concepts of vertical IIT index. Hence, in the remainder of the analysis discussion of the results for both concepts of vertical IIT will focus on those obtained using the HT method.

5 Empirical results

The regression results from the HT method, reported in Tables 4 and 5, generally support the hypothesis drawn from the theoretical literature models of fragmentation. In addition, as can be seen from the results in Tables 4 and 5, the estimated coefficients are qualitatively the same for $VIIT_{kt}$ and $TWTV_{kt}$, suggesting that the results are robust across both specifications of the vertical IIT index.[57] In particular, the results show that the market size variable (GDP_{kt}) turns out to have a positive and significant association with vertical IIT, as predicted by the theory. As suggested by Jones and Kierzkowski (2001), a greater level of market size promotes a greater degree of fragmentation due to increasing returns to scale in service-link activities. This is in accord with the result of Jones et al. (2005), and Kimura et al. (2007).

Contrary to the theoretical expectations of Grossman and Helpman (2005), the variable representing difference in size between trading partners ($DGDP_{kt}$) exerts a negative but statistically insignificant impact on both $VIIT_{kt}$ and $TWTV_{kt}$. On the other hand, differences in GDP per capita ($DPGDP_{kt}$) are shown to have a positive and significant effect on both $VIIT_{kt}$ and $TWTV_{kt}$, consistent with the predictions of both Helpman and Krugman's (1985) and Feenstra and Hanson's (1997) theoretical models that the volume of vertical trade or outsourcing tends to increase with greater differences in factor endowments between two countries.[58]

As noted earlier, however, differences in per capita GDP also capture the differences in location advantages such as the existence of supporting industries, public infrastructure, favorable policy environment, skilled labor, and industrial agglomeration, which would be reflected in lower shares of vertical IIT.[59] Given the fact that there are small differences in location advantages in the sample of countries included in the study, it is not surprising that the effect of location advantages on vertical IIT become minimal, and consequently the findings of a positive and significant impact of differences in per capita GDP implies that labor cost differences are most important in explaining the share of VIIT in the auto-parts industry than location advantages.[60]

The FDI variable (FDI_{kt}) has a significant positive effect on both $VIIT_{kt}$ and $TWTV_{kt}$, confirming our hypothesis that FDI stimulates the exchange of intermediates. This result is

[57] Although we do not report the detailed results here, we also checked the sensitivity of our results with respect to outliers. We consider a HS product as an outlier if its unit value in any year is more than two standard deviations away from the population mean. Where outliers were obvious they were replaced by average values for that 6-digit category. Excluding these outliers from the dataset did not influence the key coefficients of interest relating vertical IIT. Overall, it is concluded that the results seem to be robust to extreme outliers.

[58] This result regarding the positive relation between the trade induced by fragmentation and per capita income differences is similar to previous studies by Borga and Zeile (2004), Egger and Egger (2005), and Zeddies (2007).

[59] Cooney and Yacobucci (2005) suggest that the key determinant for location choices of auto-parts firms would be the location of the assembly plant itself and the associated transport infrastructure.

[60] For instance, Kimura et al. (2007) reports that the machinery parts and components trade in Europe is discouraged by difference in GDP per capita, as a proxy for both differences in wages and location advantages, while their influence on East Asia appears to be positive.

consistent with the theoretical expectation that vertical type FDI complements rather than substitutes for trade in intermediate goods. Similar findings also emerge in Görg (2000), Blonigen (2001), and Türkcan (2007). Thus, the results confirm the view that Austria has started to engage in back-and-forth transactions in auto-parts with Eastern and Central European countries.[61] It has been mentioned earlier that since the opening up of the Eastern European Economies at the beginning of the nineties, FDI by the Austrian automobile industry in Central and Eastern Europe, particularly in auto-parts, has increased significantly.[62] Egger et al. (2001) show that relocation of production stages from Austria to these countries (outsourcing) has increased the level of intra-firm trade in intermediate goods over the period 1990–1998. At the industry level, they observed that outsourcing to Eastern and Central European countries is most pronounced in the transport equipment industry, and the growth rate of intra-firm trade in this industry is substantially higher than the average growth of intra-firm trade in total manufacturing from these countries.

Moreover, our results indicate that the distance variable ($DIST_k$) as a proxy for service-link costs shows, as expected, a negative and significant relationship with both concepts of vertical IIT index. According to this result, transportation costs significantly hamper the fragmentation of production across countries, verifying the hypothesis developed by Jones and Kierzkowski (2001) that cross-border outsourcing is more favorable if service-link costs are lowered.[63]

Furthermore, the findings also suggest that many auto makers require auto-parts suppliers to be located near their plants because of the “just-in-time” manufacturing model. A large portion of Austria’s exports and imports of auto-parts are in the body and chassis parts categories that are heavy or bulky, encouraging their production location to be close to assembly plants. And so, the negative and significant coefficient of the distance variable also points to the importance of the just-in-time production model in Austria’s auto-parts industry.[64]

Regarding the impact of regional integration on vertical IIT in intermediate goods, the coefficients for $EU15_k$ are negative and statistically significant in both models. In other words, there is no statistical evidence to support the hypothesis that increasing regional integration between Austria and its trading partners has a positive impact on the auto-parts trade. This finding is consistent with Egger and Pfaffermayr (2002) who found that the latest enlargement of the EU (Austria, Finland, and Sweden) does not lead to positive integration effects on the intra-core volume of trade. In this regard, Egger and Pfaffermayr (2002) point out that further enlargement of the EU should increase intra-EU periphery trade volumes at the expense of the intra-EU core.

According to Egger and Pfaffermayr (2002), Austria is a prime example where companies have begun to locate the relatively labor intensive stages of auto-parts production to new member states from Eastern and Central Europe since 2004, thereby reducing the volume of trade in auto-parts trade between Austria and West European

[61] A number of MNEs in the auto industry such as Magna, Renault, or Volvo have chosen Austria as the headquarters for their Eastern and Central European operations.

[62] See Bhattacharya (2007).

[63] Jones et al. (2005) and Kimura et al. (2007) report similar findings for the relationship between service-link costs and trade in intermediate goods.

[64] Cooney and Yacobucci (2005) claim that distance may limit China’s role in the U.S. auto industry as a major supplier for auto-parts producers (particularly the original equipment industry) using the “just-in-time” production model.

countries (Table 1).[65] The rapid expansion of trade with East and Central European countries, therefore, might partly explain the negative influence of the EU15 dummy on vertical IIT in the auto-parts industry during the period considered.

Finally, the coefficient for bilateral exchange rate changes ($EXCH_{kt}$) appears to have a negative but statistically insignificant impact on $TWTV_{kt}$, a result similar to the previous studies by Arndt and Huemer (2005) and Thorbecke (2008), who also did not find any link between exchange rate changes and trade volumes induced by fragmentation.

6 Conclusions

The increased importance of fragmentation in world trade has created an interest among trade economists in explaining the determinants of intra-industry trade in intermediate goods. This study looks at the Austrian auto-parts industry IIT in a way that that represents the following improvements over previous studies.

First, the pattern of IIT and its components in the Austrian auto-parts industry is carefully examined with the application of different methods to measure IIT between Austria and its 29 trading partners. Second, the development of vertical IIT in the Austrian auto-parts industry is analyzed as an indicator for fragmentation, and various country-specific factors suggested by the fragmentation literature are tested using panel econometrics techniques.

The results show that a substantial part of intra-industry trade in the auto-parts industry between Austria and its trading partner is vertical IIT. This is suggestive of the substantial contribution made by fragmentation to trade between Austria and OECD countries. The second important finding is that the degree of vertical IIT remained stable for periphery countries, while it declined rapidly over the same period for core countries. The importance of vertical IIT between Austria and periphery countries was largely due to high and increasing flows of German FDI into these countries over the period, which is directly related to the internationalization of production.

Using the HT method, the econometric results obtained here generally support the hypotheses drawn from the fragmentation literature. The estimated coefficients are outstandingly similar and robust across the various estimation methods for both concepts of vertical IIT index. In particular, the extent of Austria's vertical IIT in auto-parts is positively correlated with average market size, differences in per capita GDP, and outward FDI, while it is negatively correlated with distance. Furthermore, the negative relationship between the magnitude of vertical IIT and the EU dummy needs further investigation, as this result is contrary to the expectation of a positive relationship between the two variables.

The results in this paper leave several issues for further research. First of all, we have employed the unit values technique to separate vertical trade from horizontal trade at the commodity level. This method has one drawback: it is difficult to track an intermediate good once it is imported using the currently available trade data. Trade data used in this paper provide information only on the export and import values and quantities of a given input. The imported input could be used primarily for the production of a final good that is later consumed by local consumers, or it could be used in the production of

[65] Before the latest enlargement of the EU, the Austrian auto-parts industry had traditionally been linked to the German automobile industry.

other intermediate goods or final goods that are later exported back to the original country or to other countries. It may be worthwhile to investigate this link in more detail in a future study to confirm whether 25% differences between unit values of exports and imports truly reflects value-added activities. Furthermore, it may be beneficial to separate countries under study into two groups based on their GDPs, because selected trading partner countries have enormous differences in factor endowments, production technologies, and incomes.

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Appendix A: Definitions of auto-parts industry trade and explanatory variables

Definition of auto-parts industry trade

The annual bilateral trade flows data in the 6-digit HS (Harmonized System 1996) used in this study were obtained from the OECD's International Trade Commodity Statistics (ITCS). There are about 6,784 items at the 6-digit level of the HS. For the measurement of IIT in the automobile industry, we chose to identify 18 items as motor vehicle products, and 92 items as auto parts from the 6-digit level of HS.

This database provides detailed annual bilateral trade data for commodity exports and imports in value ($US at current prices) and quantities at the 6-digit level of the HS. Unit values at the 6-digit product level of the HS are then constructed as the value of imports and exports of the product divided by the corresponding quantities. In this source, export values are recorded on a f.o.b. basis, while import values are recorded on a c.i.f. basis. Following Ando (2006), we multiplied the export values by 1.05 in order to adjust the discrepancy between export and import values. Thus, calculated unit price differentials do capture a trade in the auto industry that is entirely due to differences in quality or international fragmentation.

Definition of explanatory variables

Country-level variables for Austria and the 29 OECD countries are mainly retrieved from the OECD database that can be downloaded from http://www.sourceoecd.org. The full list of countries included in the analysis is shown in Table 6. In addition, we divided our sample of countries into core and peripheral countries using the categorization drawn up by the World Bank.

Market size (GDP_{kt}) is proxied by the log of the average GDP of Austria and its trading partner, expressed in current US dollars. In addition, $DGDP_{kt}$ is the log of the absolute difference in market size, expressed in current US dollars. In line with Balassa and Bauwens (1987), we calculated the difference in market size as:

$$DGDP_{kt} = 1 + \frac{[w \ln w + (1 - w) \ln(1 - w)]}{\ln 2}$$

Table 6 Countries included in the analysis

Core	Periphery
Australia	Czech Republic
Belgium	Hungary
Canada	Mexico
Denmark	Poland
Finland	Slovak Republic
France	Turkey
Germany	
Greece	
Iceland	
Ireland	
Italy	
Japan	
Korea	
Luxembourg	
Netherlands	
New Zealand	
Norway	
Portugal	
Spain	
Switzerland	
Sweden	
United Kingdom	
USA	

Countries that we consider in this study account for roughly 90 % of the Austrian automotive trade. Core and Periphery indicate the countries that are classified as core countries and periphery countries, respectively

where $w = \frac{GDP_{ht}}{GDP_{ht}+GDP_{kt}}$, h and k are Austria and its trading partners, respectively. This index obtains a value between 0 and 1, and increases as the relative inequality between two countries increases.

The log of the absolute difference in per capita GDPs of Austria and its trading partner k is defined as $DPGDP_{kt} = |PGDP_{ht} - PGDP_{kt}|$, expressed in current US dollars.

Moreover, FDI_{kt} is the log of Austria's outward FDI stock into its trading partner k, measured in current US dollars. As a measure of multinational activity in the host countries, outward FDI stock data is chosen rather than outward FDI flows since stock data is more complete than the flows data. Some researchers argue that outward FDI stock is an imperfect proxy for multinational activity because multinational companies may also engage in many activities in the host countries which one would not expect to have any relationship with fragmentation of production, such as real estate investment. Nonetheless, considering the limited availability of data, outward FDI stock data may be best available proxy.

$DIST_k$ is the log of direct distance between Austria's capital and its trading partner's capital, and is taken from the CEPII's Distance Database that can be downloaded from http://www.cepii.fr. Finally, the bilateral exchange rate in this study is defined as the number of foreign currency units per unit of domestic currency, so that $EXCH_{kt}$ falls with depreciation of the domestic currency, namely the Euro. The explanatory variables, their predicted signs, and their sources are summarized in Table 7. Table 8 provides the summary statistics for different concepts of the IIT index and explanatory variables, while Table 9 presents the correlation matrix between explanatory variables.

Table 7 Variable definitions, expected signs, and sources

Variable definition	Expected signs	Sources
GDP_{kt}=Average GDP between Austria and its trading partner	+	Source OECD Annual National Accounts
$DGDP_{kt}$=Absolute difference of GDP between Austria and its trading partner	+/−	Source OECD Annual National Accounts
$DPGDP_{kt}$=Absolute difference of per capita GDP between Austria and its trading partner	+/−	Source OECD Annual National Accounts
FDI_{kt}=Outward FDI stocks from Austria into its trading partner	+	Source OECD International Direct Investment Yearbook Statistics
$DIST_k$=The distance between Austria and its trading partner	−	CEPII's Distance Database: http//www.cepii.fr/anglaisfraph/bdd/distances.htm.
$EXCH_{kt}$=Bilateral exchange rate between the Austria and its trading partner	+/−	Source OECD OECD Stat Beta Version
$EU15_k$=Regional integration dummy, 1 if the trading partner belongs to European Union, else 0	+	

Table 8 Summary statistics of different concepts of intra-industry trade index and explanatory variables

Variable	Mean	St. deviation	Minimum	Maximum	Observations
$VIIT_{kt}$	0.19	13	0.00	0.89	319
$TWTV_{kt}$	0.32	22	0.01	0.99	319
GDP_{kt}	26.60	0.86	25.39	29.38	319
$DGDP_{kt}$	0.23	0.24	0.00	0.84	319
$DPGDP_{kt}$	10.86	0.18	10.43	11.45	319
FDI_{kt}	5.37	2.22	−0.23	9.22	220
$DIST_k$	7.35	1.29	4.08	9.81	319
$EXCH_{kt}$	1.39	2.00	−2.24	7.35	319

All variables are in log form except VIIT and TWTV

Table 9 Correlation matrix between explanatory variables

Variables	GDP_{kt}	$DGDP_{kt}$	$DPGDP_{kt}$	FDI_{kt}	$DIST_k$	$EXCH_{kt}$	$EU15_k$
GDP_{kt}	1.000						
$DGDP_{kt}$	0.578 (0.000)	1.000					
$DPGDP_{kt}$	0.072 (0.198)	0.292 (0.000)	1.000				
FDI_{kt}	0.172 (0.010)	0.189 (0.004)	0.144 (0.031)	1.000			
$DIST_k$	0.355 (0.000)	0.257 (0.000)	0.143 (0.010)	−0.468 (0.000)	1.000		
$EXCH_{kt}$	−0.128 (0.021)	0.074 (0.184)	−0.273 (0.000)	−0.097 (0.149)	−0.025(0.656)	1.000	
$EU15_k$	−0.044 (0.433)	−0.099 (0.075)	0.315 (0.000)	0.130 (0.053)	−0.233 (0.000)	−0.542 (0.000)	1.000

p-values are reported in parentheses

Appendix B: Key figures and stats for the auto industry in Austria

Table 10 Auto industry statistics in Austria-2006

Production of Motor Vehicles (MV)	274,932
Production of Passenger Cars	248,059
As a Share of Total Manufacturing	5.3%
As a Share of Total Manufacturing Exports	10.3 %
As a Share of Total Manufacturing Imports	9.9%
Employment in Manufacture of MV, Trailers and Semi-trailers (34, ÖNACE Based)	33,108
Employment in Manufacture of MV (341, ÖNACE Based)	16,444
Employment in Manufacture of Bodies (Coachwork) for Motor vehicles; Manufacture of Trailers and Semi-trailers (342, ÖNACE Based)	3,467
Employment in Manufacture of Parts and Accessories for MV and their Engines (343, ÖNACE Based)	13,197
Number of Enterprises in Manufacture of MV, Trailers and Semi-trailers (34, ÖNACE Based)	279
Number of Enterprises in Manufacture of MV (341, ÖNACE Based)	29
Number of Enterprises in Manufacture of bodies (coachwork) for Motor Vehicles; Manufacture of Trailers and Semi-trailers (342, ÖNACE Based)	173
Number of Enterprises in Manufacture of Parts and Accessories for MV and their Engines (343, ÖNACE Based)	77

Total motor vehicles number includes passenger cars, light commercial vehicles, heavy trucks and coaches & buses

Derived from Statistics Austria and European Automotive Manufacturers' Association (ACEA) websites

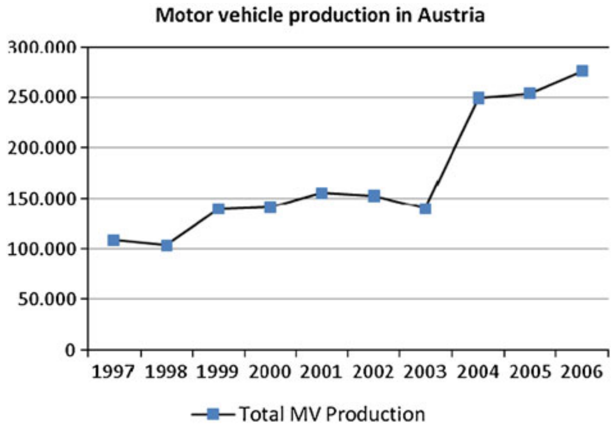
Table 11 Automotive assembly plants near Austria by country

Country	Plant location	Manufacturer	Country	Plant location	Manufacturer
B-Belgium	Antwerp	GM Europe	H-Hungary	Esztergom	Fiat,Alfa, Lancia
B-Belgium	Genk, Gent	Ford Europe	H-Hungary	Szentgotthard	Fiat-GM Powertrain
B-Belgium	Brussels	Volkswagen AG	H-Hungary	Esztergom	GM Europe
CZ-Czech Republic	Kolin	PSA Peugeot Citroen	H-Hungary	Esztergom	Suzuki
CZ-Czech Republic	Kolin	Toyota	H-Hungary	Gyor	Volkswagen AG
CZ-Czech Republic	Mlada Boleslov, Vrchlabi, Kvafiny	Skoda	I-Italy	Torino, Verona, Milan, Maranello, Modena, Suzzara, Mirafiori, Chivasso, Sant Giorgio Canavese	Fiat, Alfa, Lancia
CZ-Czech Republic	Mlada Boleslav, Kvasiny, Vrchlabi	Volkswagen AG	I-Italy	Torino	Fiat-GM Powertrain
F-France	Hambach	Daimler AG	I-Italy	Bairo Canavese	Ford Europe

Table 11 (continued)

Country	Plant location	Manufacturer	Country	Plant location	Manufacturer
F-France	Valenciennes	Fiat,Alfa, Lancia	I-Italy	Bologna, Modena	Lamborghini
F-France	Sochaux, Mulhouse, Valenciennes	PSA Peugeot Citroen	I-Italy	Bairo Canavese	Mitsubishi
F-France	Douai, Flins, Sandouville, Villeurbanne, Batilly, Maubeuge	Renault, Nissan	I-Italy	Sant' Agata	Volkswagen AG
F-France	Hambach	Smart	NL-Netherlands	Born	Mitsubishi
F-France	Onnaing	Toyota Motor Europe	PL-Poland	Tychy, Bielsko-Biala	Fiat, Alfa, Lancia
F-France	Dorlisheim	Volkswagen AG	PL-Poland	Tychy	Fiat-GM Powertrain
D-Germany	Ingolsdat, Neckarsulm	Audi	PL-Poland	Gliwice	GM Europe
D-Germany	Munich, Regensburg, Landshut, Dingolfing, Leipzig	BMW	PL-Poland	Poznan	Volkswagen AG
D-Germany	Sindelfingen, Untertürkheim, Ulm, Ratstatt, Ludwigsfelde, Bremen, Osnabrück, Düsseldorf	Daimler AG	SK-Slovak Republic	Zilina	Hyundai
D-Germany	Bochum	Fiat-GM Powertrain	SK-Slovak Republic	Trnava	PSA Peugeot Citroen
D-Germany	Cologne, Saarlouis	Ford Europe	SK-Slovak Republic	Bratislava	Volkswagen AG
D-Germany	Rüsselsheim, Kaiserslautern, Eisenach, Bochum	GM Europe	SLO-Slovenia	Novo Mesto	Renault, Nissan
D-Germany	Zuffenhausen, Leipzig	Porsche AG	BIH-Bosnia Herzegovina	Sarajevo	Volkswagen AG
D-Germany	Wolsfurg, Hanover, Salzgitter, Kassel, Braunschweig, Dresden, Mosel, Ingolstadt, Neckarsulm, Ludwigsfelde, Emden, Rheine	Volkswagen AG	SRB-Serbia	Kragujewac	Zastava-Fiat
H-Hungary	Gyor	Audi			

Derived from ABA-Invest in Austria and European Automotive Manufacturers' Association (ACEA) websites



Source: Derived from International Organization of Motor Vehicle Manufacturers (OICA) websites.

Fig. 4 Motor vehicle production in Austria (units), 1997–2006.

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