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Fragmentation, Vertical Intra-Industry Trade, and Automobile components

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Abstract

By analyzing vertical intra-industry trade (VIIT) within Portugal's automobile parts and components industry, this study adds new empirical evidence for the international fragmentation of the production process. For trade partner countries, we choose the EU countries, the BRICs, and the US during the period 1995 to 2005. From panel data analysis, the empirical evidence supports the notion that shorter geographical distance, dissimilar income levels, and dissimilar endowments between two economies lead to a higher VIIT of automobile components. In addition, our results also confirm the hypothesis that automobile (assembly) production in each country promotes higher VIIT of auto parts, while economic integration in the style of the European Union and similarity in culture do not magnify the VIIT of the parts and components industry. We conclude that income differences between trade partner countries are an important driver via the international fragmentation of production of a higher VIIT. However, a call for a geographically closer vertical linkage by the agglomeration effect for large domestic automobile production leads a firm to keep the entire production process within a country and may deter this income-difference effect

1. Introduction

By observing reallocation of fragmented parts of production across national borders by multinational corporations, research works accumulates on the topic of fragmentation literature.[1] International fragmentation of production process, consequently, leads to new component trade between two units, located in different countries, of multinational corporations. In a particular case of international outsourcing, a multinational in home country may conduct the first process of manufacturing and send intermediate parts and components to a foreign plant for the second stage of processing and receive finished components for the final assembly at home. This resulting two way trade with price differentials, arising from value-added in a foreign firm, between export and import will be classified as vertical intra-industry trade (VIIT). VIIT is two-way trade in the same industry with a price gap between two directions. The trade in automobile components is a good example of this type of trade. In this study we examine to what extent the index of VIIT is related to the degree of international fragmentation.[2,3]

Income difference is driving force for international fragmentation of production process[4]. Multinational corporations can exploit factor endowment difference in each country by fragmenting capital-intensive part of production to capital abundant country on one hand and labour-intensive part of production to labour-abundant countries on the other hand. For large automobile production countries, however, agglomeration effect as in Krugman and Venables (1995) and Venables (1996) for upstream firms (component suppliers) by locating near downstream firms (another component suppliers or automobile makers) can be too strong to offset the benefit of exploiting factor endowment difference. We found income difference effect on VIIT is non-linear via size of automobile production. Income difference effect is positive only for small size of automobile production countries.

This paper has close relevance to two strands of existing studies. The first strand of studies relates recent increase in VIIT in Asia to increased component trade in the region. Fragmentation of production among East Asian countries is widely supported by empirical evidence. Ando (2006) concluded that vertical international production became an essential part of each economy in East Asia. By finding that a larger income gap increases the components trade among East Asian countries, Kimura et al. (2007) conclude that the trade in components among East Asian countries is more a case of vertical trade driven by the fragmentation of machinery production. Our study contributes to the literature by providing similar evidence in Europe. The other strand of studies focuses on intra-industry trade in the automobile industry. Montout et al. (2002) consider the determinants of IIT for the automobile sector and automobile components in NAFTA. Turkcan and Ates (2009) also examined automobile components for the U.S. A contribution of our study in this strand is that we introduce, for the first time in literature, automobile production variable to address the issue of agglomeration versus fragmentation.

This study analyzes the determinants of VIIT between Portugal and 25 countries (21 countries of the European Union 27 (EU-27), 3 of the BRIC countries (Brazil, China, India)

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[1] Jones and Kierzkowski (1990, 2000, 2001) were the first researchers to use the concept of fragmentation in the international trade theory.

[2] VIIT may capture two way trades with different prices, simply reflecting the quality differentials, (see Falvey, 1981, Falvey and Kierzkowski 1987, and Shaked and Sutton, 1984). Interpreting VIIT as evidece of fragmentation may lead to upward biase if two-way trade for quality is large. We, however, believe that this kind of biase is limited for the parts and compnents products than for final consumer products.

[3] Wakasugi (2007) constructed an index of vertical intra-industry trade to measure the fragmentation of production. The author used a gravity model and analyzed the impact of VIIT in East Asia, NAFTA, and the European Union. The author concluded that fragmentation increased with intra-industry trade.

[4] In the literature, differences in income per capita are often interpreted as differneces in captial-labor endowment ratios. See Helpman and Krugman (1985) and Clark (2006).

and USA) in the automobile parts and components industry[5]. The paper uses an unbalanced panel for the period 1995-2006. The regression coefficients are estimated using OLS with time dummies and probit models.

2. Econometric Model

Elaborating on the intra-industry trade (IIT) index originally suggested by Grubel and Lloyd (1975), Kol and Rayment (1989) and Greenaway and Milner (1994) propose that the exchange of intermediate goods be divided into horizontal IIT and vertical IIT. Kol and Rayment (1989) suggest the unit values of exports and imports of intermediate goods to separate total IIT into its horizontal and vertical components. If the difference in unit values of export and import is larger than the cutoff level, this intra-industry trade is classified as vertical. We assume the difference in unit values represents the difference in quality (Falvey and Kierzkowski, 1987) or different stage of production process (Jones and Keirzkowski, 1990). On the other hand, intra-industry trade with similar unit values of exports and imports is classified as horizontal IIT. In this paper we use the traditional cutoff level of 15 percent[6].

$$VIIT_{it} = \frac{(X_{it} + M_{it}) - |X_{it} - M_{it}|}{(X_{it} + M_{it})} \qquad \text{If } \frac{P_{it}^X}{P_{it}^M} < 0.85 \text{ or } \frac{P_{it}^X}{P_{it}^M} > 1.15 \qquad (1)$$

where X_{it} and M_{it} are export and import to partner country i at time t and where P_{it}^X and P_{it}^M are unit price of exports and imports. When $\frac{P_{it}^X}{P_{it}^M} < 0.85$ or > 1.15, we have lower price (or quality) export or higher price (or quality) export.

Closely reviewing the VIIT literature, the following four hypotheses are consistently supported by both theoretical and empirical studies.

Hypothesis 1: There is a positive relationship between differences in income per-capita and VIIT.
Hypothesis 2: VIIT occurs more frequently among countries that are <u>dissimilar</u> in terms of factor endowments.
Hypothesis 3: The larger economic dimension (average size of two countries) increases VIIT.
Hypothesis 4: VIIT increases when partners are geographically close.

Regarding hypothesis 1, the model of Falvey and Kierzkowski (1987) suggest a positive effect of income difference on VIIT model and Kimura et al. (2007) and Wakasugi (2007) found a positive relationship between income difference and VIIT for parts and components trade while Egger and Egger (2005) found a negative relationship for EU processing trade. Hypothesis 2 has theoretical support in the model of multinational firms in Helpman and Krugman (1985, Chapter 13, p.247-p.259) and fragmentation framework of Jones et al. (2002). As a proxy for difference in factor endowments, Zhang et al. (2005) use the absolute difference in electric power consumption in examining VIIT for China. Regarding hypothesis 3, Jones and Kierzkowski (2004) and Grossman and Helpman (2005) suggest a positive correlation between economic size and VIIT. Turkcan (2005) found a positive correlation for Turkish VIIT. Hypothesis 4 is supported in Badinger and Breuss

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[5] Russia and the remaining five EU countries (Bulgaria, Cyprus, Estonia, Lithuania, and Latvia) were excluded due to the unavailability of data. In addition, note that Belgium and Luxembourg are treated as one combined economy.
[6] For robustness check, we also use the cutoff level of zero percent. However, the qualitative result does not change. We owe this point to the associate editor of this journal, Rick Bond.

(2008) and Clark (2006). They found a negative relationship between distance and VIIT.

In addition to these standard hypotheses, this study further investigates the following three hypotheses.

Hypothesis 5: The culture similarity promotes VIIT.
Hypothesis 6: The economic integration increases VIIT.
Hypothesis 7: A larger automobile (assembly) production promotes higher VIIT.

For hypothesis 5, we include BRAZIL as a dummy variable and we expect the effect of this variable on VIIT to be positive. This variable captures similarity in the culture and language between Portugal and Brazil. Portugal and Brazil have cooperation agreements with excellent diplomatic and historical relations. Chemsripong et al. (2005) applied similar approach for Thailand and APEC countries. For hypothesis 6, we introduce an EU dummy variable which takes one for EU member countries. The economic integration increases VIIT by easing the use of international fragmentation of production process among different income level of economies within the block. For hypothesis 7, we introduce the sum of automobile production (in terms of units) in two countries. These hypotheses can be tested with estimators from the following regression equation:

$$\ln \frac{VIIT_{it}}{1 - VIIT_{it}} = \alpha + \beta_1 \ln DGDP_{it} + \beta_2 \ln EP_{it} + \beta_3 \ln DIM_{it} + \beta_4 \ln DIST_{it}$$
$$+ \gamma_1 BRAZIL_i + \gamma_2 EU_{it} + \gamma_3 \ln AUTO_{it} + \lambda_t + \varepsilon_{it} \tag{2}$$

where $VIIT_{it}$ is the Portuguese VIIT index. Following the empirical work of Hummels and Levinsohn (1995), we apply a logistic transformation to VIIT, because VIIT is an index varying between zero and one. DGDP is the absolute difference in per-capita GDP (PPP, in current international dollars) between Portugal and the trading partner. EP is the absolute difference in electric power consumption (Kwh per capita) between Portugal and its partners[7]. DIM is the average GDP of the two trading partners. DIST is the geographical distance between the Portugal and partner country. EU is a dummy variable that equals 1 if trade partner is a member country of EU in the year and 0 otherwise. BRAZIL is dummy variable for VIIT with Brazil. AUTO is the number of automobile production. All explanatory variables are in the natural logarithm form except dummies; λ_t is a fixed time dummy; ε_{it} is a random disturbance. We decided against using the fixed-effects estimator, as some relevant variables do not vary along time.

3. Empirical Results

Automobile component VIIT index between Portugal and 21 European countries, Brazil, India, China and the US for the period between 1995 and 2005 are constructed from in *INE*, the Portuguese National Institute of Statistics. Automobile production data are taken from the *World Automobile Statistics*, Fourin. Other explanatory variables, electric power

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[7] EP (the absolute difference in electric power consumption per capita) is used in this study to represent the difference in capital endowments (Jones et al. 2002) for hypothesis 2 while DGDP (the absolute difference in GDP per capita) for hypothesis 1 represents the difference in income levels which in turn leads to the difference in demand for quality (Falvey and Kierzkowski, 1987). These hypotheses are based on the different models; however, we need to be careful when interpreting empirical results because these variables can be interpreted to represent the other hypotheses (see footnote 4) In addition the variance inflation factor indicates no multicollinearity between EP and DGDP.

consumption, GDP, GDP per capita, and geographical distance are taken from *World Development Indicators* (2008), the World Bank.

Table I: The determinants of vertical intra-industry trade

	(1)OLS	(2)OLS	(3)OLS	(4)OLS	(5)OLS	(6)Probit
ln DGDP	0.15	0.15	-0.01	-0.13	6.80 **	5.60 **
	(0.13)	(0.14)	(0.12)	(0.15)	(2.91)	(2.26)
ln EP	0.79 ***	0.74 ***	0.63 ***	0.49 **	0.64 ***	0.21 **
	(0.20)	(0.20)	(0.19)	(0.20)	(0.18)	(0.10)
ln DIM	-0.05	-0.06	0.00	-0.03	0.01	-0.01
	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.04)
ln DIST	-1.29 ***	-1.13 ***	-1.05 ***	-0.61 *	-0.72 **	0.29
	(0.21)	(0.33)	(0.22)	(0.35)	(0.30)	(0.21)
BRAZIL	0.94					
	(0.96)					
EU		0.07				
		(0.49)				
ln AUTO			0.58 ***	0.66 ***	5.37 **	4.12 ***
			(0.12)	(0.13)	(2.09)	(1.60)
EU * ln DGDP				0.09		
				(0.06)		
ln AUTO * ln DGDP					-0.52 **	-0.43 **
					(0.22)	(0.17)
constant	3.96 **	3.13	-3.51	-6.34 **	-69.12**	-56.67 ***
	(1.73)	(2.31)	(2.35)	(3.12)	(28.96)	(21.52)
Adj R²	0.13	0.12	0.19	0.19	0.20	
Nob	193	193	193	193	193	250

Note: Dependent variable for specification (1) through (5) is logistic transformation of automobile components VIIT. For specification (6), dependent varaible is without transformation. Estimates for time dummies are suppressed. (Heteroskedastic-consistent for OLS) standard errors are in brackets. ***, **, and * indicate significance of coefficients at 1, 5, and 10 percent, respectively.

From specification (1) to (3) in Table I we present OLS estimator with time dummies. Regarding the traditional four hypothesis, signs of two estimated coefficients are consistent with expected signs: electric power consumption (EP) and the geographical distance (DIST). We expect the difference in electric power consumption per capita, to reflect the difference in endowments between Portugal and its trade partners, following the approach by Hummels and Levinshon (1995) and Zhan et al. (2005). The geographical distance is also consistent with the literature (Badinger and Breuss, 2008 and Clark, 2006). Our results validate the hypothesis 2 and 4.

Regarding the hypothesis for the effect of cultural dimension on VIIT, empirical results does not support that VIIT between countries with similar cultural background, namely Portugal and BRAZIL, is higher than VIIT for other pairs. Empirical results do not support that the economic integration via joint EU membership for Portugal and other EU countries promote higher VIIT. The larger sum of automobile production in a pair of countries has a positive effect on VIIT with statistical significance.

As a further investigation for hypothesis 1, we explore a possible non-linear relationship between difference in income level and VIIT. We introduce interaction terms with EU dummy and automobile production variable. In equation (3) we introduce these interaction terms along traditional four variables and automobile production variable.

$$\ln\frac{VIIT_{it}}{1-VIIT_{it}} = \alpha + \beta_1 \ln DGDP_{it} + \beta_2 \ln EP_{it} + \beta_3 \ln DIM_{it} + \beta_4 \ln DIST_{it}$$
$$+ \gamma_3 \ln AUTO_{it} \qquad (3)$$
$$+ \delta_1 (EU_{it} \times \ln DGDP_{it}) + \delta_2 (\ln AUTO_{it} \times \ln DGDP_{it}) + \lambda_t + \varepsilon_{it}$$

In specification (4) neither ln DGDP by itself nor its interaction term with EU dummy is statistically significant. In specification (5), on the other hand, the estimated coefficients for ln DGDP by itself and its interaction term with automobile production are statistically significant. The result is quite interesting. The indirect effect, δ_2, of automobile production through interaction with difference in income levels is negative on VIIT while direct effect, γ_3, of automobile production on VIIT is positive.

With regard to total effect of income difference on VIIT, we can calculate criteria for positive total effect by equation (4)[8]. By calculating the threshold value for automobile production from equation (4), we obtained 33% of observations fall into the boundary in which the total effect of income difference is positive.

$$\frac{\partial \ln\left(VIIT_{it}\Big/1-VIIT_{it}\right)}{\partial \ln DGDP_{it}} = \beta_1 + \delta_2 \ln AUTO_{it} > 0 \Leftrightarrow AUTO_{it} < e^{-\frac{\beta_1}{\delta_2}} \qquad (4)$$

For automobile parts and components industry, income difference becomes more important between countries with smaller scale of automobile production since δ_2 is negative. For a country with very large automobile production, agglomeration effect via vertical linkage as in Krugman and Venables (1995) and Venables (1996) in home country is too strong to offset the advantage of exploiting income difference in foreign countries. This agglomeration effect may deter international fragmentation of component production.

As a robustness check, we estimate specification (5) using probit model. For probit model, we should note that dependent variable need not be transformed in logistic form[9]. Probit estimator confirms the qualitative result of OLS estimators for the total effect of income difference although coefficients for other variables become statistically insignificant. In order to address the question of the sensitivity of our results to differences in the cutoffs for measurement of VIIT, we estimated equation (3) for the specification (1) through (5) with total IIT. Please note for total IIT that the cutoff level is zero percent while we use conventional level of 15 percent in the paper. The result is very similar with Table 1. The only noteworthy changes appear in specification (4) in which distance becomes (marginally) statistically insignificant and interaction term between *EU* and ln *DGDP* becomes statistically significant. It is noteworthy to mention that there are only 17 observations (out of 210 observations) which are categorized as non-VIIT. This is consistent with our intuition that intra-industry trade of automobile components is vertical in nature.

4. Conclusions

In this paper, we have analyzed the link between fragmentation and vertical intra-industry trade in the automobile components sector. In the case of Portugal, there is evidence of the growing importance of fragmentation of production in the automobile sector. With

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[8] The reversal of inequality sign is necessary in the second equation because our estimated δ_2 is negative.

[9] We needed to drop zero value of VIIT for logistic transformation. Our sample increases for probit estimation since we can include oservations with zero value of VIIT.

regard to VIIT, our paper finds positive effect of difference in electric power consumption and negative effect of distance.

Income difference, representing factor endowments difference, is driving force for international fragmentation of production process. Multinational corporations can exploit factor endowment difference in each country by fragmenting capital-intensive part of production to capital abundant country and labour-intensive part of production to labour-abundant countries. For large automobile production countries, however, agglomeration effect for upstream firms by locating near downstream firms can be too strong to offset the benefit of exploiting factor endowment difference. We found income difference effect on VIIT is non-linear via size of automobile production. Income difference effect is positive only for small size of automobile production countries.

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