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The Effect of EU Environmental Regulation on International Trade: Restriction of Hazardous Substances as a Trade Barrier

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Abstract

In 2003 the Restriction of Hazardous Substances (RoHS) was established in the EU, which limited the trade of machinery, electrical and electronic equipment that have at least one of the substances considered hazardous under RoHS directive. Since countries trading with the EU must comply with this new regulation, it is expected a decrease in value of imports to the EU. In this paper, it is followed the procedures used in Heckman (1979), as well as the extended procedure suggested by Helpman, Melitz, and Rubinstein (2008) to ascertain the effects on the persistence of trade and values of trade.

Keywords: the RoHS directive, harmonized standards, gravity model, intensive and extensive margin, sample selection and firm heterogeneity

JEL classification: F13, F18, Q56

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1. Introduction

As import tariffs and other trade policies are reduced or eliminated, according to negotiations within the WTO and the increase in FTAs, the importance of other policies are playing a fundamental role in international trade, such as non-tariff barriers to trade. In addition, pro-environmental policies unintentionally change the structure of trade and hinder international trade. In 2003, the EU established restrictions on the use of hazardous substances, this restriction is known as the RoHS directive. This directive restricts the sale of machinery, electrical and electronic equipment that contain hazardous substances detailed in RoHS, for both foreign and EU countries. Since all imports must comply with this regulation, a decrease in the value of imports from foreign countries to EU countries is expected. In this study, I attempt to confirm the effect of the RoHS directive on trade in the EU.

In empirical research, the gravity model is widely used to analyze international trade flows. Moreover, many researchers consider including zero trade flows to obtain unbiased estimates. In this study, I employed a sample selection model and the extended procedure suggested by Helpman, Melitz, and Rubinstein (2008, the HMR model), to address the effect on "trade persistence" and "trade value".

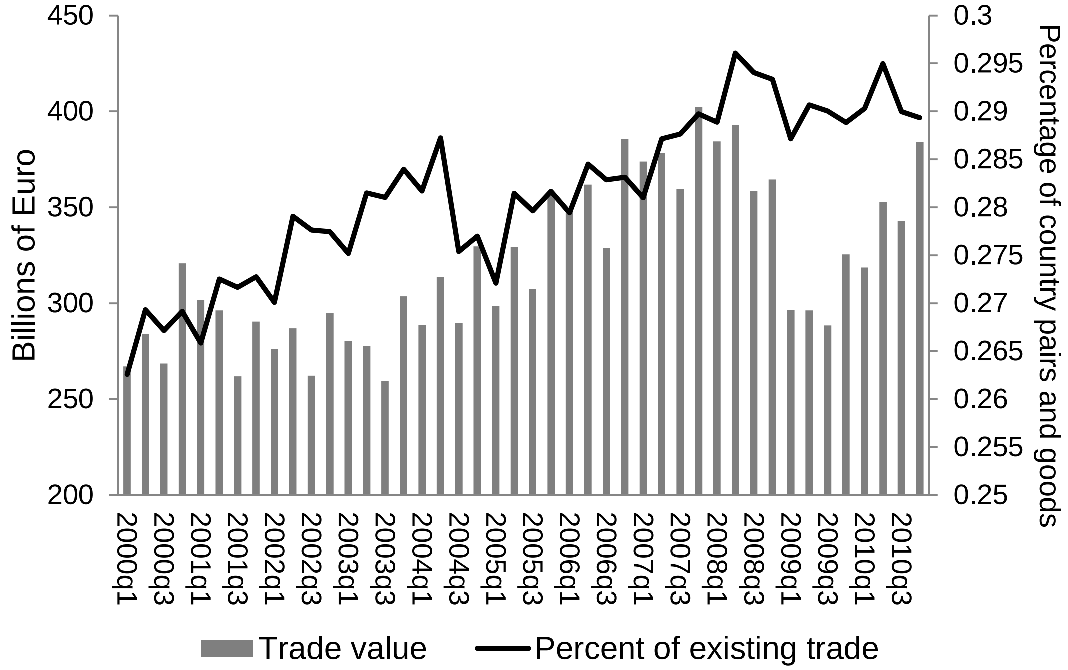
The rest of this paper is organized as follows. Section 2 describes the trade flows of machinery, electrical and electronic equipment as well as environmental regulation in the EU, and it reviews some previous studies of environmental standards. Section 3 describes the gravity model for international trade and considers the observation of zero trade flows. Section 4 describes the estimation procedures of this analysis and dataset. Section 5 presents and discusses the estimation results. Section 6 summarizes the empirical results of this study.

2. Components of Trade, Policy, and Previous Studies

2.1. Trade Flows and Environmental Regulation in the EU

Figure 1 plots the imports of machinery, electrical and electronic equipment in the EU. The bars represent the aggregate trade value of these goods, while the solid line indicates the percent of country pairs and goods that are actually trade. It is easy to notice that the value increased from 2004 to 2007, before the global recession in 2008. Conversely, a fraction of the existing trade of machinery, electrical and electronic

Figure 1. EU imports of machinery, electrical and electronic equipment



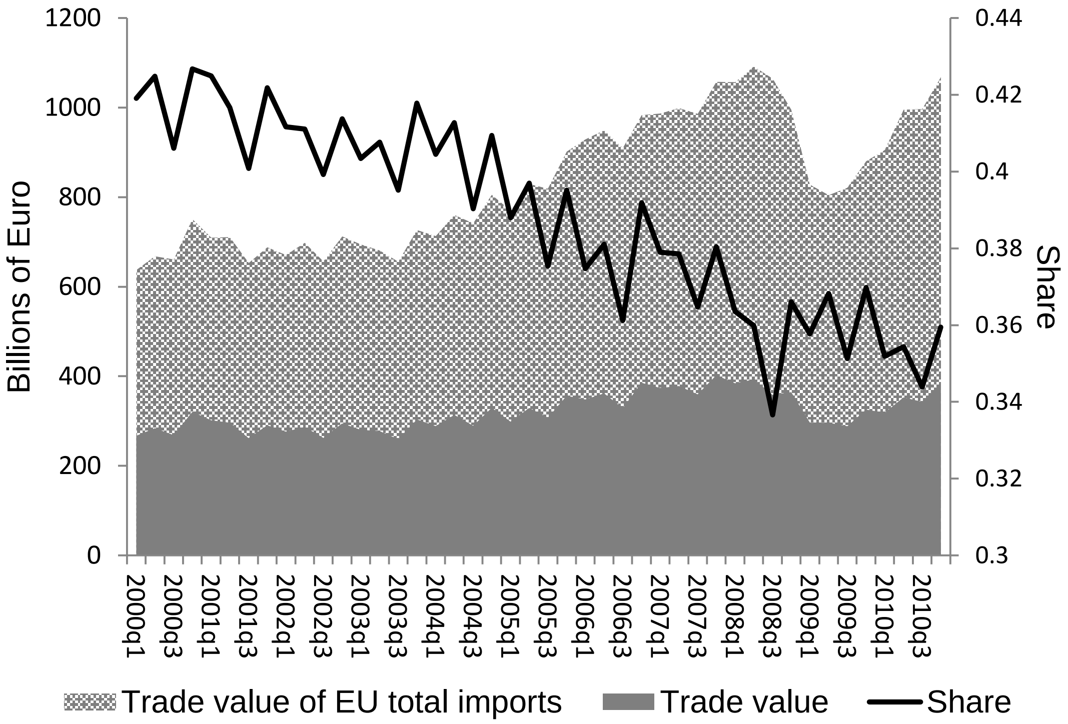
Note: Constructed from data on HS84-HS92 commodities imported into EU27 countries from 199 export countries.

equipment rose until 2003 and then dropped sharply in 2004. As it is patent from the Figure 1, the trade value and the fraction of existing trade do not exhibit the same behavior. Policies including environmental regulations have different impacts on these two measurements; thus each of them should be analyzed separately. Moreover, a fraction of existing trade is lower than 0.3 after 2000. Therefore, in an empirical analysis, the zero trade flows that dominate a large fraction of the country pairs and goods should be considered.

In figure 2, it is shown the total trade value of machinery, electrical and electronic equipment imports as well as the share of these goods in total import. As it is possible to notice, the EU total import value increases as does the values of machinery, electrical and electronic equipment, but at a sharper rate. This is reflected in the decrease in the share of these goods.

The decline in the fraction of existing trade after 2004 and the share of machinery, electrical and electronic equipment are thought to be aftereffects of strengthening the environmental regulations in the EU. In recent years, the EU has attached great importance to environmental problems, in particular, waste reduction.

Figure 2. Share of machinery, electrical and electronic equipment in the EU



Note: Constructed from data on EU27 import countries and 199 export countries

As an example, the collection and recycling of container and packaging waste were defined and made into law in each country. Similarly, recycling vehicle waste is also mandated by the End-of-Life Vehicles (ELV) directive. The strictest regulation is the RoHS directive, which restricts the sale of goods that contain hazardous substances in the EU.[1] This directive also requires that waste (the recycling of all disposals such as,) from machinery, electrical and electronic equipment must be recycled. This directive is also valid for goods imported into the EU; in other words, exports from foreign countries to the EU may face environmental regulations as trade barriers. The RoHS directive was established on February 13, 2003, and enforcement began on July 1st, 2006. The deceleration of the increasing trade of machinery, electrical and electronic equipment relative to total imports and enforcement of this policy ware observed to occur simultaneously. While there are many other causes, it is possible that the RoHS directive hindered the import of machinery, electrical and electronic equipment in the EU.

[1] Specifically, lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyl, and polybrominated biphenyl ether are subjects.

2.2. Previous Studies on Standards and Regulations

There has been considerable research on the relationship between standards and regulations, including the environmental regulation and international trade. In such research, an important aspect is whether the focused standards and regulations are harmonized among trading partners. Theoretical predictions suggest that if the standard harmonizes exporter and importer, then the policy would promote international trade. Conversely, if the standard is country-specific, it would reduce international trade. Some of the researches attempting to confirm this theoretical prediction are Moenius (2004), which found that the country-specific standards inhibit international trade in the non-manufacturing sector but promote it in the manufacturing sector: Fontagne et al. (2005), which found mixed evidence across industries: Swann et al. (1996), which was focused on the impact of standards on trade performance in the UK. They found that, although internationally equivalent (harmonized) standards promote international trade, idiosyncratic UK standards promote exports but interrupt imports.

These previous research intensely focused on the collective effect of standards and regulation. Although some related studies exist, there is no research that addresses the detailed effects of a specific policy, in particular, the effect of the RoHS directive on international trade in the EU. Thus, this study contributes a confirmation of the detailed effect of a specific policy.

3. The Gravity Model and Zero Trade Flows

In this analysis, I employ the gravity model suggested by Tinbergen (1969), which is an empirical specification used to explain trade flows and FDI flows. In the basic model, the dependent variable is the bilateral trade flow, and independent variables are the economic scales of each country and the distance between exporter and importer. The gravity model has the advantage that the estimation results tend to have a high goodness-of-fit. However, this model is criticized for its lack of theoretical background. Thus, Anderson and van Wincoop (2003) suggested the modified gravity equation, obtained from the monopolistic competition model of Dixit and Stigliz (1977).

With respect to international trade flows, much recent research attempts to consider many trade observations that contain zero trade values. For example, Disdier, Fontagne, and Mimouni (2008) estimated the gravity equation with log(1 + trade) as the dependent variable.[2] Instead of adjusting the trade flow, Eaton and Tamura (2004) recommended adopting the Tobit model. Silva and Tenreyro (2006, 2010, 2011) suggested Poisson Pseudo Maximum Likelihood estimator for estimating the gravity equation. This method is used to obtain consistent estimates in the log-linear form and can consider the zero values of a dependent variable to assume a Poisson distribution.

In this study, as already noted in figures 1 and 2, I employ the sample selection model and the extended procedure suggested by HMR.

3.1. Sample Selection

The sample selection model has two types of estimation methods: the maximum likelihood method and the OLS method with an inverse Mills ratio used by Heckman (1979). The gravity model with a two-step estimation procedure measures a different effect during each stage. The effect on persistence of trade is measured in the first stage estimation, and the effect on values of trade is measured in the second stage estimation. The former corresponds to an extensive margin of trade, and the latter an intensive margin. For example, Czubala, Shepherd, and Wilson (2009) use this procedure to measure the impact of harmonized standards on African exports.

3.2. Correction of Sample Selection and Firm Heterogeneity

The two-stage sample selection model can estimate the impact of every variable on the trade flow. However, HMR observes that firms vary in productivity and that if the firm heterogeneity correlates with the decision making of the firm's export behavior, it is not sufficient to correct only the sample selection bias. Moreover, they suggest the appropriate estimation procedure for that case. I employ not only the sample selection model but also their procedure to estimate the gravity model with an environmental regulation as a trade barrier.

The first stage estimation equation of the HMR procedure is same as the first one of sample selection. However, in the second stage estimation, the consistent estimator is obtained by adding firm heterogeneity correction terms and a sample

[2] See also Kellenberg (2009). He regressed the Heckscher-Ohlin model with log(1 + trade).

selection correction term. The firm heterogeneity correction term is a monotonic function of the predicted value of first stage probit. HMR found no noticeable changes when expanding beyond a cubic polynomial. Therefore, I use the cubic polynomial form in the predicted value of first stage probit instead of the firm heterogeneity correction term.

To estimate the effect of the environmental regulation, specifically the RoHS directive, on the presence of trade and trade value, I apply the standard Heckman's correction and the HMR correction for sample selection and firm heterogeneity to estimate the gravity model.

4. Estimation Procedures and Data

As described above, I employ two estimation methods, Heckman's sample selection model and HMR's sample selection and firm heterogeneity correction model. Both methods require the same first stage probit selection equation:

$$\begin{aligned} \rho_{ijk} &= \Pr\left(T_{ijk} = 1 | \text{observed variables}\right) \\ &= \Phi\left(\alpha_0 + \alpha_{EX} + \alpha_{IM} + \alpha_{HS} + \alpha_{QT} + \mathbf{x}'_{ijk}\boldsymbol{\alpha} + \mathbf{x}'_{2ijk}\boldsymbol{\alpha_2}\right) \end{aligned} \quad (1)$$

where ρ_{ijk} is the probability that country j exports goods k to country i, conditional on the observed variables, and where the indicator variable T_{ijk} is equal to 1 when country j exports goods k to country i and 0 otherwise. This equation includes the fixed effects of exporter, importer, goods, and quarterly time: α_{EX}, α_{IM}, α_{HS} and α_{QT} respectively. The variables $\mathbf{x}$ and $\mathbf{x_2}$ are the vector of explanatory variables; note that $\mathbf{x_2}$ is only included in the first stage probit. The parameters $\boldsymbol{\alpha}$ and $\boldsymbol{\alpha_2}$ are vectors of coefficient of explanatory variables. The estimated results from equation (1) imply an extensive margin of each variable.

The second stage regression equation using Heckman's (1979) estimator, the Heckit estimator, is as follows:

$$m_{ijk} = \beta_0 + \beta_{EX} + \beta_{IM} + \beta_{HS} + \beta_{QT} + \mathbf{x}'_{ijk}\boldsymbol{\beta} + \beta_\lambda\hat{\lambda} + \varepsilon_{ijk} \quad (2)$$

where m_{ijk} is the log of import value. The parameters β_{EX}, β_{IM}, β_{HS} and β_{QT} are the fixed effects of exporter, importer, goods, and quarterly time, respectively. The parameter λ is the inverse Mills ratio from the first stage probit, and β_λ is its parameter. The error term ε_{ijk} is i.i.d. satisfying $\mathrm{E}(\varepsilon_{ijk}|T_{ijk}=1)=0$.

Alternatively, the HMR estimator is as follows:

$$m_{ijk} = \beta_0 + \beta_{EX} + \beta_{IM} + \beta_{HS} + \beta_{QT} + \mathbf{x}'_{ijk}\boldsymbol{\beta} + \delta_1 \hat{\bar{z}}^*_{ijk} + \delta_2 \left(\hat{\bar{z}}^*_{ijk}\right)^2 + \delta_3 \left(\hat{\bar{z}}^*_{ijk}\right)^3 + \beta_\eta \hat{\eta}^*_{ijk} + e_{ij} \quad (3)$$

where the variable $\hat{\eta}^*_{ijk} = \phi(\hat{z}^*_{ijk})/\Phi(\hat{z}^*_{ijk})$ is the inverse Mills ratio calculated using $\hat{z}^*_{ijk} \equiv \Phi^{-1}(\hat{\rho}_{ijk})$, and β_η is the parameter of the inverse Mills ratio. $\hat{\bar{z}}^*_{ijk}$, $\left(\hat{\bar{z}}^*_{ijk}\right)^2$ and $\left(\hat{\bar{z}}^*_{ijk}\right)^3$ are the firm heterogeneity correction terms in cubic polynomial form in $\hat{\bar{z}}^*_{ijk} \equiv \hat{z}^*_{ijk} + \hat{\eta}^*_{ijk}$. The The error term e_{ijk} is i.i.d. satisfying $\mathrm{E}(e_{ijk}|T_{ijk}=1)=0$.[3] The estimated results of equations (2) and (3) show an intensive margin.

Because the RoHS directive covers a subset of goods traded in the EU market, this study considers only the imports of EU countries and the manufacturing industries HS 2-digit commodities, 84-85 (machinery and electrical), 86-89(transportation) and 90-92(miscellaneous related to machinery excluding arms). Furthermore, the estimation periods from the first quarter of 2000 to the fourth quarter of 2010 are used to compare the before and after of this policy. Because of the data availability, I use 19 countries as importers and 54 countries as the exporters, including all countries of the EU.[4]

The dataset used in this study includes bilateral trade values, the basic variables of the gravity equation, other control variables, and information about the RoHS directive. The bilateral trade value is obtained from Eurostat. Real GDP is obtained from International Financial Statistics. The distance between exporter and importer, common language, common border, colonial relationship and landlocked status are obtained from CEPII. For estimation, the bilateral trade value, GDP, and distance data are used in logarithmic form. The common language dummy variable is equal to 1 if both the exporter and importer countries use a common language and 0 otherwise. The common border dummy variable is equal to 1 if the exporter and importer have a common border and 0 otherwise. The colonial relationship dummy variable is equal to 1 if the exporter and importer have a previous colonial relationship and 0 otherwise. The landlocked dummy variable is equal to 1 if both the exporter and importer lack a coastline or direct sea access and 0 otherwise.

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[3] For more details on how this estimation equation was obtained, see Appendix II.
[4] For more details concerning the considered countries, see Appendix I.

Table 1. Descriptive Statistics

Variable	Unit	Obs.	Mean	Std. Dev.	Min	Max
trade	million in Euro	406296	32.548	170.837	0.000	5720.330
ln(trade)		276092	-0.479	3.849	-13.8155	8.652
T_{ijk}		406296	0.680	0.467	0	1
GDPexp	million in Euro	361791	416262.200	1592002.000	360.009	13096258.514
ln(GDPexp)		361791	10.893	1.808	5.886	16.388
GDPimp	million in Euro	381024	148969.000	171530.200	4161.994	607043.900
ln(GDPimp)		381024	11.235	1.202	8.334	13.316
distance	km	406296	5827.042	4563.115	141.446	19537.120
ln(distance)		406296	8.210	1.085	4.952	9.880
EU dummy		406296	0.256	0.436	0	1
common language		406296	0.055	0.227	0	1
common border		406296	0.049	0.215	0	1
colonial relationship		406296	0.076	0.265	0	1
landlock		406296	0.012	0.108	0	1
cost		406296	0.146	0.353	0	1
proc&days		406296	0.171	0.376	0	1
RoHS dummy		406296	0.227	0.419	0	1
RoHS transition period		406296	0.177	0.381	0	1

Both methods are identified by the first stage probit selection equation (1), where it is learnt that. These variables affect fixed trade costs but do not affect variable trade costs. I use a country-level data on the regulation costs of firm entry, collected by Djankov et al. (2002) according to the procedure in HMR. Specifically, I use the number of days, the number of legal procedures, and the relative cost of an entrepreneur to begin operation as a percentage of GDP per capital. In a manner similar to that of HMR, I use these data to construct two indicator variables for a high fixed cost, consisting of country pairs in which both the importing and exporting countries have entry regulation measures above the cross-country median. One of the regulation cost variables is constructed from the sum of the number of days and procedures, and the other variable is constructed from sum of the relative costs.

The RoHS directive is represented as an indicator variable. According to the policy schedule, the RoHS dummy variable is equal to 1 when it correspond to HS84, 85, 90, 91, or 92, which include the target goods of the RoHS directive in the third quarter of 2006 and after, and 0 otherwise.[5] In addition, I construct an indicator variable

[5] The goods represented by each code are as follows:
HS84: Nuclear reactors, boilers, machinery and mechanical appliances, and computers
HS85: Electrical machinery, equipment and parts, telecommunications equipment, sound recorders, and television recorders
HS90: Optical, photographic, cinematographic, measuring, cheking, precision and medical or surgical

to represent the transition period between the establishment and the enforcement of the regulation to examine the firm behavior in these periods. The RoHS transition period dummy variable is equal to 1 when the goods are targets of the RoHS directive from the first quarter of 2003 to the second quarter of 2006 and 0 otherwise.

Additionally, I use an EU dummy variable that is equal to 1 if both the exporter and importer countries are members of the EU and 0 otherwise. The descriptive statistics used in this study are shown in Table 1.

5. Estimation Results

5.1. Baseline Results

Table 2 shows the baseline estimated results. As a benchmark, it is shown separately the estimation results of equation (1) without entering for the identification variables and the basic gravity model using OLS. In the first stage probit, all variables are significant at a 1% level. As we can imagine, the distance between exporter and importer has a negative effect on the probability of persistence of trade, whereas a common language, common border, colonial relationship, and whether the country is landlocked have positive effects. If both countries become members of the EU, the bilateral trade between these countries disappears. The RoHS dummy variable has a negative effect, implying that the probability of persistence of trade of machinery, electrical and electronic equipment decline in response to the RoHS directive. Estimation of the traditional gravity equation using OLS uses data on country pairs that trade in at least one direction for each good. Note that the OLS estimator does not contain zero trade values and is econometrically problematic. The GDPs of the exporter and importer have a positive effect and are statistically significant. Distance, common language, common border, colonial relationship, and landlocked status have the same effect in direction as in the first stage probit. Unlike the results of the first stage, the coefficient of joining the EU is positive and statistically significant. In addition, the RoHS dummy variable is significantly negative in the first stage. These results of the benchmark estimation show that the RoHS directive decreases the fraction of existing the trade and trade values of the intended goods.

Next, the Heckit estimator of the second stage estimation, equation (2), is shown

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instruments and accessories
HS91: Clocks, watches, and parts
HS92: Musical instruments, parts, and accessories

Table 2. Baseline results

	Probit	1st stage	OLS	2nd stage	
				Heckit	HMR
RoHS	-0.00632***	-0.00634***	-0.0684***	-0.0836***	-0.0912***
	(0.00216)	(0.00216)	(0.0185)	(0.0184)	(0.0210)
GDPexp	-0.00746***	-0.00740***	0.0568*	0.0493*	0.0400
	(0.00280)	(0.00280)	(0.0297)	(0.0292)	(0.0314)
GDPimp	-0.0196***	-0.0196***	0.664***	0.659***	0.629***
	(0.00569)	(0.00569)	(0.0505)	(0.0503)	(0.0593)
distance	-0.0852***	-0.0851***	-0.855***	-0.907***	-0.986***
	(0.00227)	(0.00226)	(0.0143)	(0.0144)	(0.143)
EU dummy	-0.0119***	-0.0120***	0.373***	0.337***	0.353***
	(0.00271)	(0.00271)	(0.0188)	(0.0188)	(0.0267)
common language	0.0284***	0.0292***	0.358***	0.362***	0.402***
	(0.00271)	(0.00271)	(0.0223)	(0.0225)	(0.0602)
common border	0.0650***	0.0651***	0.244***	0.224***	0.523***
	(0.00218)	(0.00217)	(0.0203)	(0.0206)	(0.173)
colonial relationship	0.0388***	0.0386***	0.510***	0.581***	0.609***
	(0.00202)	(0.00203)	(0.0203)	(0.0203)	(0.0825)
landlock	0.0402***	0.0396***	0.194***	0.277***	0.174*
	(0.00483)	(0.00490)	(0.0428)	(0.0422)	(0.0952)
cost		-0.00866***			
		(0.00245)			
proc&days		0.00198			
		(0.00221)			
inverse mills ratio				0.966***	
				(0.0223)	
$\hat{\eta}^*$					3.048***
					(0.250)
$\hat{z}^*$					2.932***
					(0.259)
$(\hat{z}^*)^2$					-0.641***
					(0.0107)
$(\hat{z}^*)^3$					0.0371***
					(0.000795)
constant			0.00166	0.537	4.711
			(0.836)	(0.829)	(3.799)
Obs.	339,039	339,039	239,322	239,322	239,322
R-squared	0.581	0.581	0.735	0.738	0.750

Note: The marginal effect of sample means and pseudo R^2 reported for probit and first stage. The robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

in Table 2. For the two-step sample selection procedure, two fixed cost variables are added in the first stage probit. Only relative cost has a significant effect at 1%, implying that a fixed entry cost decreases the probability of persistence of trade. Based on these first stage results, the second stage result using the Heckit estimator is obtained with the inverse Mills ratio. The coefficient of the inverse Mills ratio is statistically significant at a 1% level, implying that the Heckit estimator is better than the OLS because a correlation exists between the error terms in the first and second stage. The RoHS dummy variable continues to have a significantly negative effect, but the magnitude of the estimated parameter is approximately 1.22 times that of the OLS.

Alternatively, the HMR estimator is obtained using the same first stage estimated results. The correction term for the sample selection, $\hat{\eta}^*_{ijk}$, and firm heterogeneity correction terms $\hat{z}^*_{ijk}$, $\left(\hat{z}^*_{ijk}\right)^2$ and $\left(\hat{z}^*_{ijk}\right)^3$ are statistically significant at a 1% level, implying that both firm heterogeneity and sample selection require correction. The coefficient of the RoHS dummy variable is -0.0912, and statistically significant. This value is larger than the results using the OLS and Heckit estimator and is approximately 1.33 times that of the OLS.

These results show that the RoHS directive decreases the fraction of existing trade and the trade values of intended goods. Additionally, in an appropriate approach, the magnitude of the extensive margin caused by the RoHS directive is 0.6%, and that of the intensive margin is 0.0912%.

5.2. Intraregional trade in the EU versus import from outside the EU

Next, to consider the effect of whether the same regulation exists for both the exporter and importer, I split the sample used in the estimation. One subsample includes only EU countries as exporter (i.e., intraregional trade in the EU), and the other subsample includes only imports from outside the EU.

In EU intraregional trade, the effect of the RoHS dummy variable in the first stage probit is significantly negative, as it is in the baseline results. However, the coefficients of RoHS using the Heckit estimator and the HMR estimator are significantly positive at a 1% level. According to the significance of each correction term, the result of the HMR estimator, 0.143, is more appropriate and larger than that of the Heckit estimator (approximately 1.82 times). However, even after using both methods for estimating the coefficients of RoHS dummy variable, an importer from

Table 3. Estimated results using subsample

	Intraregional trade in EU			Import from outside of EU		
	1st stage	2nd stage		1st stage	2nd stage	
		Heckit	HMR		Heckit	HMR
RoHS	-0.000219**	0.0785***	0.143***	-0.0107**	-0.216***	-0.338***
	(9.85e-05)	(0.0223)	(0.0221)	(0.00510)	(0.0271)	(0.0325)
GDPexp	-0.000269	0.111	0.165**	-0.0122*	-0.131***	-0.260***
	(0.000218)	(0.0690)	(0.0681)	(0.00638)	(0.0347)	(0.0402)
GDPimp	-0.000231	0.638***	0.682***	-0.0505***	0.553***	-0.00436
	(0.000217)	(0.0634)	(0.0623)	(0.0140)	(0.0715)	(0.112)
distance	-0.00214***	-1.112***	-0.578***	-0.185***	-1.307***	-3.279***
	(0.000321)	(0.0156)	(0.0266)	(0.00723)	(0.0353)	(0.323)
EU dummy	-0.000211***	0.510***	0.570***			
	(6.87e-05)	(0.0210)	(0.0207)			
common language	-0.000823*	0.116***	0.232***	0.0786***	0.292***	1.246***
	(0.000421)	(0.0290)	(0.0288)	(0.00682)	(0.0319)	(0.148)
common border	0.000829***	0.0573***	-0.219***	0.190***	0.618***	4.152***
	(0.000137)	(0.0214)	(0.0234)	(0.0103)	(0.0596)	(0.506)
colonial relationship	0.000730***	0.370***	0.0414	0.0838***	0.590***	1.570***
	(0.000119)	(0.0252)	(0.0285)	(0.00591)	(0.0306)	(0.162)
landlock	2.14e-05	-0.0900*	-0.118**	0.111***	0.334***	1.665***
	(0.000198)	(0.0469)	(0.0460)	(0.0148)	(0.0749)	(0.242)
cost	-0.000176			-0.00653		
	(0.000117)			(0.00566)		
proc&days	0.000496***			-0.0127**		
	(9.03e-05)			(0.00556)		
inverse mills ratio		-0.491***			1.467***	
		(0.0388)			(0.0275)	
$\hat{\eta}^*$			0.647***			6.742***
			(0.0670)			(0.537)
$\hat{z}^*$			2.248***			0.609
			(0.0766)			(0.540)
$(\hat{z}^*)^2$			-0.254***			-0.925***
			(0.0134)			(0.0184)
$(\hat{z}^*)^3$			0.0114***			0.0598***
			(0.000887)			(0.00147)
constant		-0.523	-9.336***		-8.695***	31.50***
		(1.115)	(1.129)		(0.743)	(4.896)
Obs.	118,728	105,040	105,040	220,311	134,282	134,282
R-squared	0.541	0.797	0.805	0.564	0.694	0.707

Note: The marginal effect of sample means and pseudo R^2 reported for the first stage. The robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

outside the EU faces a significantly negative effect at a 1% level, as in the baseline results. Although one of the correction terms, $\hat{z}^*_{ijk}$, is not significant, the HMR estimator is more appropriate than the Heckit estimator; the estimate value is -0.338.

These results imply that the intensive effects of the RoHS directive are different between intraregional trade in the EU and for imports from outside the EU. In the intraregional, all EU countries conform to the same RoHS directive, and exporting firms in EU countries must pay the additional cost induced by the RoHS directive, but at the same time it is possible to avoid the additional cost of compliance for an importer country. Conversely, exporting firms outside the EU must pay the additional cost for compliance in the EU. Thus, this increased cost of production caused by the RoHS directive can potentially cause firms to exit the exporting market regardless of harmonization. However, an exporter regulated by harmonized standards has an advantage over an exporter regulated by non-harmonized standards and can increase the export value.

5.3. Effect during Transitional Period

I also consider the transition periods between the establishment of the restrictive policy and its enforcement. In these periods, some firms attempt to adapt their products to the forward new regulations, in spite of not being regulated at that time. These firms may incur into additional costs associated with both identifying alternative inputs as substitutes for restricted materials and purchasing such inputs, which are expected to be more expensive than restricted materials. Thus, the probability and value of trade can potentially decrease due to the restrictive policy.

In Table 3, the estimation with the RoHS transition period dummy variable is repeated using the full sample with the result that the RoHS directive has a negative and significant effect on the extensive and intensive margins, with all correction terms are significant at a 1% level. The results using HMR estimator remain more appropriate than those of the Heckit estimator. The transition period dummy variable considered in this section also has a significantly negative effect on the probability of the persistence of trade and trade values. Using the same subsample as in section 5.2, the RoHS dummy variable differs little from the results in section 5.2 in sign and magnitude. However, in EU intraregional trade, the transition period dummy variable has a significantly negative effect with the Heckit estimator but an insignificantly negative effect with the HMR estimator. Although we cannot reject the possibility of no effect, the RoHS directive

Table 3. The effect during the transition period

	Full sample			Intraregional trade in EU			Import from outside of EU		
	1st stage	2nd stage		1st stage	2nd stage		1st stage	2nd stage	
		Heckit	HMR		Heckit	HMR		Heckit	HMR
RoHS	-0.0125***	-0.149***	-0.168***	-0.000371***	0.0370	0.135***	-0.0241***	-0.314***	-0.588***
	(0.00276)	(0.0229)	(0.0305)	(0.000136)	(0.0277)	(0.0275)	(0.00642)	(0.0340)	(0.0534)
trans RoHS	-0.0106***	-0.116***	-0.135***	-0.000246*	-0.0747***	-0.0149	-0.0234***	-0.170***	-0.434***
	(0.00284)	(0.0242)	(0.0293)	(0.000131)	(0.0289)	(0.0286)	(0.00662)	(0.0359)	(0.0533)
inverse mills ratio		1.060***			-0.418***			1.523***	
		(0.0258)			(0.0449)			(0.0318)	
$\hat{\eta}^*$			3.047***			0.649***			6.758***
			(0.250)			(0.0670)			(0.538)
$\hat{z}^*$			2.931***			2.251***			0.592
			(0.260)			(0.0766)			(0.541)
$(\hat{z}^*)^2$			-0.641***			-0.255***			-0.925***
			(0.0107)			(0.0134)			(0.0184)
$(\hat{z}^*)^3$			0.0371***			0.0114***			0.0599***
			(0.000795)			(0.000887)			(0.00147)
Obs.	339,039	239,322	239,322	118,728	105,040	105,040	220,311	134,282	134,282
R-squared	0.581	0.738	0.750	0.541	0.797	0.805	0.564	0.694	0.707

Note: The marginal effect of sample means and pseudo R^2 reported for the first stage. The robust standard errors are in parentheses. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

would likely decrease the trade value in the transition period.

These results imply that the exporting firms paid an additional cost for compliance before the RoHS directive was first enforced. After this, the exporter regulated harmonized standards had the potential to increase trade values. However, it is observed that the RoHS directive has the potential of decreasing trade value because of two important points. First, exporters may seek alternative inputs; and second, they may purchase more expensive materials during the transition period, prior to the regulation enforcement.

6. Conclusion

This study estimates the effect of the RoHS directive that restricts the sale of machinery, electrical and electronic equipment that contain hazardous substances. In empirical research, the gravity model is widely used to analyze international trade flows. In this study, it is employed the sample selection model and the extended procedure suggested by HMR in order to consider the effect on persistence of trade and values of trade. Estimated results show that the RoHS directive decreases the fraction of existing trade and trade values of intended goods in the EU. However, to distinguish between intraregional trade in the EU and imports from outside the EU, I find that the RoHS directive as a harmonized standard promotes intraregional trade. Additionally, this policy has the potential to decrease trade value during the transition period of regulation. The RoHS directive is inadvertently a protective policy, that is, a trade barrier to exporting to the EU market from outside the EU. In EU countries, the probability of existing trade decreases but trade value increases because of the harmonized standard. This effect represents the potential of specialized and divisional production.

References

Anderson, J. E. and E. van Wincoop (2003) "Gravity with Gravitas: A Solution to the Border Puzzle," *American Economic Review* 93, pp.170-192.

Czubala, W., B. Shepherd, and J. S. Wilson (2009) "Help of Hindrance? The Impact of Harmonised Standards on African Exports," *Journal of African Economics* 18, pp.711-744.

Disdier, A. C., L. Fontagne, and M. Mimouni (2008) "The Impact of Regulations on Agricultural Trade: Evidence from the SPS and TBT Agreements," *American Journal of Agricultural Economics* 90, pp.336-350.

Dixit and Stiglitz (1977) "Monopolistic Competition and Optimum Product Diversity," *American Economic Review* 67, pp.297-308.

Djankov, S., R. La Porta, F. Lopez-de-Silanes, and Andrei Shleifer (2002) "The Regulation of Entry," *Quarterly Journal of Economics* 117, pp.1-37.

Fontagne, L., M. Mimouni, and J-M. Pasteels (2005) "Estimating the Impact of Environmental SPS and TBT on International Trade," *Integration and Trade Journal* 22, pp.7-37.

Heckman, J. J. (1979) "Sample Selection Bias as a Specification Error," *Econometrica* 47, pp.153-161.

Helpman, E., M. J. Melitz, and Y. Rubinstein (2008) "Estimating Trade Flows: Trading partners and Trading Volumes," *Quarterly Journal of Economics* 123, pp.441-487.

Kellenberg, D. (2009) "An Empirical Investigation of the Pollution Haven Effect with Strategic Environment and Trade Policy," *Journal of International Economics* 78, pp.242-255.

Melitz, M. J. (2003) "The Impact of Trade on Intra-industry Reallocations and Aggregate Industry Productivity," *Econometrica* 71, pp.1695-1725.

Moenius, J. (2004) "Information Versus Product Adaptation: The Role of Standards in Trade," *International Business and Markets Research Center Working Paper*, Northwestern University.

Silva, J. M. C. S. and S. Tenreyro (2006) "The Log of Gravity," *Review of Economics and Statistics* 88, pp.641-658.

Silva, J. M. C. S. and S. Tenreyro (2010) "On the Existence of the Maximum Likelihood Estimates in Poisson Regression," *Economics Letters* 107, pp.310-312.

Silva, J. M. C. S. and S. Tenreyro (2011) "Further Simulation Evidence on the

Performance of the Poisson Pseudo-Maximum Likelihood Estimator," *Economics Letters* 112, pp.220-222.
Swann, P., P. Temple, and M. Shurmer (1996) "Standards and Trade Performance: the UK Experience," *Economic Journal* 106, pp.1297-1313.
Tinbergen, J. (1962) *Shaping the World Economy*, New York: Twentieth Century Fund.

Appendix I

List of countries is shown in Table A1.

Table A1. Countries in the dataset

Exporter		Importer
Argentina	Ireland	Austria
Australia	Israel	Belgium
Austria	Italy	Bulgaria
Belgium	Jamaica	Czech Republic
Bolivia	Japan	Denmark
Brazil	Jordan	Finland
Bulgaria	Korea, Rep.	France
Cambodia	Malaysia	Germany
Canada	Mexico	Greece
Chile	Morocco	Hungary
China	Netherlands	Ireland
Colombia	New Zealand	Italy
Costa Rica	Norway	Netherlands
Czech Republic	Peru	Poland
Denmark	Philippines	Potrugal
Ecuador	Poland	Romania
Egypt	Potrugal	Spain
El Salvador	Romania	Sweden
Finland	Singapore	United Kingdom
France	Spain	
Germany	Sweden	
Greece	Switzerland	
Guatemala	Thailand	
Hong Kong SAR, China	Tunisia	
Hungary	Turkey	
India	United Kingdom	
Indonesia	United States	
Iran, Islamic Rep.		

Appendix II

I explain the theoretical model of Helpman, Melitz, and Rubinstein (2008) to obtain the estimation equation.

Consider that country j's consumer has constant elasticity of substitution (CES) preference for differentiated varieties of product. Under budget constraint, standard demand function is obtained; depend on a given price index and income. Firm in country j produces one unit of output with a cost-minimizing combination of inputs that cost $c_j a$, where c_j reflect differences across countries in factor prices and this is country specific, whereas a is firm specific amount of inputs, reflecting productivity differences across firms in the same country. The inverse of a represents the firm's productivity level. HMR assume that a cumulative distribution function $G(a)$ with support $[a_L, a_H]$ describes the distribution of a across firms, where $a_H > a_L > 0$, based on Melitz (2003).[6] This distribution function is the same across all countries. Country j's producer have two additional cost to seek to sell its product in country i: a fixed cost of entering the market in country i, which equals to $c_j f_{ij}$, and a transport cost. As is customary, they adopt the "iceberg" specification that τ_{ij} units of a product have to be shipped for one unit to arrive. A cost of entry is needed only if firm try to go into foreign market, i.e. $f_{jj} = 0$ for all j. And, assume that there is no transport cost in home country, i.e. $\tau_{jj} = 1$ for all j.

There is monopolistic competition in final products. Every producer set price of product with profit maximization. Using demand function and profit maximizing price, the operating profit of firm in country j selling to country i is depend on the firm's productivity level as following:

$$\pi_{ij}(a) = (1-\alpha)\left(\frac{\tau_{ij} c_j a}{\alpha P_i}\right)^{1-\varepsilon} Y_i - c_j f_{ij} \qquad (A.1)$$

where P_i is price index, Y_i is the income of country i. α is the parameter that determine the elasticity of substitution across product, which is $\varepsilon = 1/(1-\alpha)$. The operating profits are positive for sales in the domestic market because $f_{jj} = 0$. Therefore all producer, N_j, sell in country j. On the other hand, sales in foreign country are profitable only if $a \le a_{ij}$, where a_{ij} is defined by $\pi_{ij}(a_{ij}) = 0$, or:

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[6] HMR assume that firm's productivity $1/a$ is Patero distributed, truncated to the support $[a_L, a_H]$. Then, they assume $G(a) = (a^k - a_L^k)/(a_H^k - a_L^k), k > (\varepsilon - 1)$, and so suggest nonlinear estimates but I do not adopt this.

$$(1-\alpha)\left(\frac{\tau_{ij}c_j a_{ij}}{\alpha P_i}\right)^{1-\varepsilon} Y_i = c_j f_{ij} \qquad (A.2)$$

Using the demand function and pricing equation, the value of country i's imports from j is obtained as following:

$$M_{ij} = \left(\frac{c_j\tau_{ij}}{\alpha P_i}\right)^{1-\varepsilon} Y_i N_j V_{ij} \qquad (A.3)$$

where

$$V_{ij} = \begin{cases} \int_{a_L}^{a_{ij}} a^{1-\varepsilon} dG(a) & \text{for} \quad a_{ij} \geq a_L \\ 0 & \text{otherwise} \end{cases} \qquad (A.4)$$

This bilateral trade value is equals zero when $a_{ij} \leq a_L$, because $V_{ij} = 0$. If $a_{ij} > a_L$, V_{ij} is increasing in a_{ij}. Therefore, V_{ij} is depend on the cutoff value of a_{ij}, which is implicitly defined by zero profit condition (A.2). Let define a related latent variables Z_{ij} as follow:

$$Z_{ij} \equiv \frac{(1-\alpha)\left(P_i \frac{\alpha}{c_j\tau_{ij}}\right)^{\varepsilon-1} Y_i a_L^{1-\varepsilon}}{c_j f_{ij}} \qquad (A.5)$$

This is the ratio of variable export profits for the most productive firm to the fixed export costs for exports from j to i. If Z_{ij} becomes equal to 1, there is no exporting firm by zero profit condition (A.2). If Z_{ij} becomes greater than 1, the gap between a_L and a_{ij} is increasing in Z_{ij}. In fact, more firms export to foreign market. Positive exports are observed if and only if $Z_{ij} > 1$. In this case, V_{ij} is monotonic function of Z_{ij}. Moreover, the value of Z_{ij} affects the export value M_{ij}.

For obtaining parameterized estimation equation, I specify some variables. τ_{ij} captures variable trade costs that affect the volume of firm-level exports. Assume that these costs are stochastic due to i.i.d. unmeasured trade friction u_{ij}, which are country-pair specific. In particular, let $\tau_{ij}^{\varepsilon-1} \equiv D_{ij}^{\gamma} e^{-u_{ij}}$, where D_{ij} represents the distance between i and j, and $u_{ij} \sim N(0, \sigma_u^2)$. In addition, let $f_{ij} \equiv \exp(\phi_{EX,j} +$

$\phi_{IM,i} + \kappa\phi_{ij} - \nu_{ij})$, where $\nu_{ij} \sim N(0, \sigma_\nu^2)$. The export value from j to i and latent variable can be expressed in log-linear form as follows:

$$m_{ij} = \beta_0 + \lambda_j + \chi_i - \gamma d_{ij} + v_{ij} + u_{ij} \tag{A.6}$$

where $\lambda_j = -(\varepsilon - 1)\ln c_j + n_j$ is a fixed effect of the exporting country and $\chi_i = (\varepsilon - 1)p_i + y_i$ is a fixed effect of the importing country, and:

$$z_{ij} = \gamma_0 + \zeta_j + \xi_i - \gamma d_{ij} - \kappa\phi_{ij} + \eta_{ij} \tag{A.7}$$

where $\zeta_j = -\varepsilon \ln c_j - \phi_{EX,j}$ is a fixed effect of the exporting country and $\xi_i = (\varepsilon - 1)p_i + y_i - \phi_{IM,i}$ is a fixed effect of the importing country.

Now, since V_{ij} is function of Z_{ij}, assume $v_{ij} \equiv v(z_{ij})$ that is arbitrary increasing function of z_{ij}. Although z_{ij} is unobserved, we can observe the presence of trade flows. Therefore $z_{ij} > 0$ when j exports to i, and $z_{ij} = 0$ when does it not. Define the indicator variable T_{ij} to equal when country j exports to i, and 0 otherwise. Let ρ_{ij} be the probability that j exports to i, conditional on the observed variables. I divide (A.7) by the standard deviation σ_η, $\sigma_\eta^2 \equiv \sigma_u^2 + \sigma_\nu^2$, and specify the Probit equation to estimate the equation (A.7) as following:[7]

$$\begin{aligned} \rho_{ij} &= \Pr(T_{ij} = 1 | \text{observed variables}) \\ &= \Phi(\gamma_0^* + \zeta_j^* + \xi_i^* - \gamma^* d_{ij} - \kappa^*\phi_{ij}) \end{aligned} \tag{A.8}$$

where Φ is the cumulative distribution function of the standard normal distribution, and every stared parameter represents the original coefficient divided by σ_η. Using predicted probability of exports from j to i, $\hat{\rho}_{ij}$, let $\hat{z}_{ij}^* = \Phi^{-1}(\hat{\rho}_{ij})$ be the predicted value of the latent variable $z_{ij}^* \equiv z_{ij}/\sigma_\eta$.

Consistent estimation of (A.7) requires controls for both the endogenous number of exporters, v_{ij}, as well as the sample selection. Using $\hat{z}_{ij}^*$, the inverse Mills ratio $\hat{\eta}_{ij}^* = \phi(\hat{z}_{ij}^*)/\Phi(\hat{z}_{ij}^*)$ is obtained to correct the sample selection bias. For firm heterogeneity, assume that $v(z_{ij})$ is approximately a polynomial in $\hat{\bar{z}}_{ij}^* = \hat{z}_{ij}^* + \hat{\eta}_{ij}^*$. HMR found no noticeable changes from expanding $v(\hat{\bar{z}}_{ij}^*)$ beyond a cubic polynomial. Therefore, I use cubic polynomial form in $\hat{\bar{z}}_{ij}^*$ in place of v_{ij}. Using these correction terms, estimation equation for value of imports is as follow:

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[7] HMR employs dividing the equation (A.7) to avoid imposing $\sigma_\eta^2 \equiv \sigma_u^2 + \sigma_\nu^2 = 1$.

$$m_{ij} = \beta_0 + \lambda_j + \chi_i - \gamma d_{ij} + \beta_\eta \hat{\eta}^*_{ij} + \delta_1 \hat{\bar{z}}^*_{ij} + \delta_2 \left(\hat{\bar{z}}^*_{ij}\right)^2 + \delta_3 \left(\hat{\bar{z}}^*_{ij}\right)^3 + e_{ij} \quad \text{(A.9)}$$

where $\beta_\eta \equiv \mathrm{corr}(u_{ij}, \eta_{ij})(\sigma_u / \sigma_\eta)$ is parameter of inverse Mills ratio, δ is parameter of the term to correct the firm heterogeneity and e_{ij} is an i.i.d. error term. I expand the dimension of these estimation equations by the addition of the variety of goods, index k, but this keeps unchanged the structure of the model in essentials.