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IDE DISCUSSION PAPER No. 455

Estimating the effect of chemical safety standards on firm performance in Malaysia and Vietnam

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March 2014

Abstract

This paper uses firm-level data to examine the impact of chemical safety regulations imposed by importing countries such as RoHS and REACH on the production costs and export performance of firms in Malaysia and Vietnam. We find that in addition to the initial setup costs for compliance, EU RoHS and REACH implementation causes firms to incur additional variable production costs by requiring additional labor and capital expenditures of around 12% of the variable costs, respectively. We also find that compliance with RoHS and REACH significantly increases the probability of export. Furthermore, we find that compliance with EU RoHS and REACH helps firms to penetrate into a greater variety of countries. Also, we find that multinational enterprises and firms participating in global value chains generally exhibit better export performance and their costs rise less steeply.

Keywords: trade, RoHS, REACH cost function, market access, Malaysia Vietnam

JEL classification: F14, L15, O53

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1. Introduction

Various countries adopt technical regulations, including safety and performance requirements, to ensure consumer safety and product quality. At the same time, these regulations can constitute barriers to trade by imposing compliance costs on firms. There has been a great deal of study focusing on the effect of regulations on producer performance in export and production in the agricultural sectors. The majority of these studies have found that the safety requirements tend to reduce exports, particularly those from developing countries (see, for example, Otsuki et al. (2001)). Research on the effect of technical regulations on manufacturing exports, however, has been limited. Chen et al. (2008) examined the effect of quality, safety standards, and labeling requirements on the export performance of the manufacturing firms of 16 developing countries using firm-level survey data. Using the same dataset, Maskus et al. (2013) investigated the effects of technical regulations on variable costs. The results of these studies generally imply that technical regulations can increase exports even as they impose additional variable cost on firms. While the dataset used in these studies covers a global set of developing countries, it does not cover East Asian countries. In addition, the number of samples for individual countries is not large enough to conduct detailed analysis of a single country.

Our study attempts to examine the effect of technical regulations on the performance of manufacturing firms in Malaysia and Vietnam with respect to both export and production by using a new survey dataset. This study focuses on two sets of technical regulations targeting consumer and environmental safety in the EU: the Restriction of Hazardous Substances (RoHS) Directive and the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). The EU RoHS Directive (Directive of the European Parliament and the Council on restriction of the use of certain hazardous substances in electrical and electronic equipment) was implemented in 2006[1]. This directive restricts the amount of hazardous substances allowed in electronic and electrical (E&E) equipment. The EU REACH Regulations (Regulation of the European Parliament and

[1] The regulated substances are lead, mercury, cadmium, polybrominated biphenyls, and polybrominated diphenyl ethers.

Council concerning Registration, Evaluation, Authorisation and Restriction of Chemicals) was implemented in 2007 and regulates the use in products of chemical substances that cause serious concern for consumer health and the environment. Under REACH, if a product contains chemicals classified as SVHCs (Substances of Very High Concern) in excess of 0.1% by weight, firms are required to notify the European regulatory body, the European Chemicals Agency, for authorization.

Once the chemicals contained in a final product are regulated, the materials, parts and components composing the final product need to be redesigned, monitored, tested and proved to meet the stipulated chemical thresholds. Because parts and components suppliers are often located across borders, supply chain/value chain/production network management takes place across firms, industries, and countries. To make the adaptation even more complex, the impact of product-related environmental regulations that regulate chemicals are spread over various industries. Industries affected by REACH and RoHS include not only the chemical industry, but also the textiles, garment, wood products, plastic, rubber, machinery, and E&E industries, among others. Potentially affected industries are often located in developing countries, with those aiming at exporting to EU markets most affected.

Malaysia and Vietnam are rapidly industrializing countries in East Asia, and manufacturing exports have become an increasingly important engine of export-led growth for these countries. At the same time, these countries have faced increasing pressure from importing countries, and in particular from developed countries, to meet safety and quality requirements. Although RoHS and REACH are only EU requirements, meeting those requirements may also signal superior safety and quality. Compliance with these standards may therefore help a firm to enter non-EU markets. Our study addresses the effect of these regulations on the export performance and cost effectiveness of firms to provide a complete picture of the effects. Although production costs may increase, exports may do so as well. The empirical results will then allow us to determine whether these requirements have a positive or negative net effect on firms by assessing which effect is dominant.

For export analysis, we employ a probit model to examine the effect of RoHS and REACH on firm entry into the export market. We also employ an ordered probit model to examine the standards' effects on the number of export markets. We also analyze their effect on average exports per market for firms. In the production analysis, we evaluate an increase in variable costs due to RoHS and REACH compliance by using an estimation of a translog cost function.

The remaining part of this paper is organized as follows. Section 2 describes the backgrounds of Malaysia and Vietnam in terms of export performance and technical regulations. Section 3 explains the empirical approaches used in our analyses. Section 4 presents and interprets the results of these analyses. Section 5 concludes the paper.

2. Background

2.1 Export performance of Malaysia and Vietnam

Exports of goods from Malaysia and Vietnam have grown rapidly during the past two decades, as shown in Figures 1 and 2. Malaysia has been a World Trade Organization (WTO) member since 1995, and Vietnam joined the WTO in 2007. Although Malaysia is a larger exporter than Vietnam, exports from both countries have been increasing rapidly. This is especially true for manufactured goods, where growth has been relatively higher than that of exports of agricultural products. Figure 2 clearly shows the positive impact of WTO membership on Vietnam's exports. Both figures illustrate the recovery from the financial crisis and continued increase in exports. Our data show that 70% and 74% of sampled firms in Malaysia and Vietnam, respectively, exported their products.

Vu et al. (2014) found rapid growth in the number of both domestic firms and multinational enterprises in Vietnam since 2000. Increased foreign direct investment and export has led to greater pressure on firms in Malaysia and Vietnam to comply with safety and quality regulations. After the introduction of the RoHS Directive, an increasing number of countries have implemented their own RoHS standards. Vietnam introduced its version of RoHS in September 2011. Malaysia also has a long history of regulation of hazardous chemicals. This implies that firms in Malaysia and Vietnam are quite aware of the importance of regulations on hazardous chemicals. Among respondent firms in Malaysian and Vietnam, 81% and 88%, respectively, had achieved compliance with RoHS by 2011; additionally, 70% (in Malaysia) and 87% (in Vietnam) had achieved compliance with REACH by 2011.

2.2 Related literature

Producers in developing countries face capacity constraints when complying with food safety and quality standards, typically in developed countries. Its significance is yet to be clear since firm-level quantitative studies on technical regulations are very limited, and even more so when it comes to developing countries.

On the other hand, country-level empirical studies that examine the effect of technical regulations on trade are relatively abundant, predominantly in the food and agricultural sectors. Otsuki et al. (2001a) showed that EU's aflatoxin standards discouraged African groundnut exports to the EU using a gravity model. A majority of studies of this kind have found negative effects of food safety standards (see, for example, Otsuki et al. (2001a), Wilson et al. (2003), Chen et al. (2008), Drogué and DeMaria (2012), and Winchester et al. (2012)). Honda (2012) is one of the few studies focusing on the manufacturing sector. He applied a gravity model to examine the effect of EU's RoHS on exports to the EU market from EU and non-EU countries. He found that RoHS promoted intra-EU trade, but destructed exports from non-EU countries. Unlike the other country-level studies, Xiong and Beghin (2013) tried to isolate the positive demand-enhancing effect of food safety standards from the negative trade-cost effect using a more sophisticated gravity model.

In contrast, there are a relatively smaller number of firm-level studies. Wilson and Otsuki (2004) tried to describe the benefits and difficulties that technical regulations bring to firms in developing countries using the World Bank's Technical Barriers to Trade (TBT) Survey Database. They showed that approximately 70 percent of the surveyed firms in various industries in 17 developing countries claimed that the costs of testing and certification are likely to prevent them from exporting to major developed country markets. At the same time, approximately 80 percent of the surveyed firms claimed that assurance of product quality and safety is important for expanding their exports. Firms try to comply with the technical regulations in a variety of ways – by expanding their plant or equipment, re-designing products, and hiring labor for production and testing.

Using the above mentioned database, Maskus et al. (2013) and Chen et al. (2008) developed methodological techniques to analyze the effect of technical requisitions using firm-level data. Using a translog cost function, Maskus et al. (2013) estimated whether the presence of technical regulations can increase firms' recurring variable production cost in addition to the initial setup costs. Chen et al. (2008) estimated firm-level export functions of intensive and extensive margins. They identified the factors that increase the amount of exports in firm's total sales (intensive margin), and the number of export markets and products that are exported (extensive margin). Compliance with quality standards was found to increase the export amount, as well as the number of export markets and products exported. On the contrary, standard certification procedures are found to reduce the number of export markets and products exported.

Ragasa et al. (2011) also supports the cost augmenting effect of technical regulations. They found that the US hazard analysis and critical control points (HACCP) standard incurred significant additional production cost to the firms in the seafood industry in the Philippines. There are several studies supporting the demand-enhancing effect of compliance with technical regulations. Maertens and Swinnen (2008) pointed out that developed countries' stringent food safety standards do not always discourage developing country firms. Maertens and Swinnen (2009), and Maertens et al. (2011) demonstrated through a case study of Senegal's fresh and processed fruit and vegetables, that compliance with food safety standards in developed countries can increase developing country exports to developed countries which appreciate high-quality products. Maertens et al. (2011) also pointed out the importance of the role of multinational enterprises in improving product quality and safety as leaders in the supply chain of food products. Fontagné et al. (2013) examined the effect of SPS standards on firm's probability to export (extensive margin), value of exports (intensive margin) and export prices using firm-level data for French agricultural and manufacturing firms.

3. Empirical strategy

3.1. Estimating the effect of RoHS and REACH on production costs

Compliance with technical regulations entails various costs to firms. Maskus et al. (2013) distinguished between initial setup costs and running costs of complying with technical regulations. Although firms can be asked directly about their initial setup costs, they often cannot give an exact amount, especially if many years have passed since they first complied with the regulations. The additional running costs associated with regulations affect the persistence and amount of exports because these costs reduce profit margins. We therefore follow the approach of Maskus et al. (2013) to cost function estimation and use a translog cost function, which is flexible and can incorporate non-price variables such as factors for technical regulations.

Assume a short-run cost function

$$C = C(w, y; s, z)\,, \qquad (1)$$

where w is a vector of factor prices, y is output, s indicates the stringency of the foreign standard, and z is a vector of other variables affecting firm-level costs. The firm minimizes variable costs wx, where x is the vector of variable inputs. The cost function is assumed to have some standard properties: non-decreasing in w and y, concave in w, and homogeneous of degree one with respect to w. This general cost function has a variable for technical regulations, s, as an argument because different technical regulations should affect the choice of inputs for producing a given output level. Maskus et al. (2013) used initial setup costs for technical regulations as a measure of the stringency of technical regulations, but we use a dummy variable indicating compliance with RoHS or REACH because of a lack of data about setup costs associated with these regulations.

We assume that the cost function is weakly separable from the aggregator for material inputs and other inputs (separability). The separability assumption is necessary because we do not have data on the prices of materials and other inputs. We therefore specify equation (1) as the cost of producing net output, or value added, introducing only labor and capital as variable inputs, obtaining weak separability in this instance. This implies that the choice of relative labor and capital inputs is independent of material and intermediate input prices.[2] As a result, the cost function that reflects this technology is rewritten as

$$C(w, y; s, z) = (C^1(y, w^1; s, z), C^2(y, w^2; s, z)), \tag{2}$$

where $w^1 = \{w_L, w_K\}$ and w^2 is the vector of prices for variable inputs other than labor and capital. These subcomponents of the overall cost function are assumed to be homogeneous of degree one in w^1 and w^2, as appropriate, to be consistent with the linear homogeneity of C in w. Separating the cost function allows us to ensure that the elasticity of cost (value added) with respect to our technical regulation variables derived from the first component (C^1) is unaffected by the presence of the second component (C^2). This cost elasticity can be written as[3]

$$\sigma_s \equiv \frac{\partial C^1}{\partial s}\frac{s}{C^1} = \partial \ln C^1 / \partial \ln s. \tag{3}$$

Our specification of a short-run variable cost is a translog function. This translog function allows a flexible second-order approximation to a cost structure depending on output, input prices, and other factors, including technical regulations. We also instrument the binary variable for technical regulations due to its possible endogeneity (a firm with

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[2] In our specific case, the separability condition is expressed as
$\frac{\partial}{\partial w_j}\left(\frac{\partial C(w, y; s, z)/\partial w_L}{\partial C(w, y; s, z)/\partial w_K}\right) = 0$, $j \neq L, K$ or $\frac{\partial}{\partial w_j}\left(\frac{\partial L(w, y; s, z)}{\partial K(w, y; s, z)}\right) = 0$, $j \neq L, K$.

[3] When the technical regulation variables are of a binary type, we will have $\sigma_s \equiv C^1(y, w^1; 1, z) - C^1(y, w^1; 0, z)$.

greater efficiency or lower costs is more likely to export, and is thus more likely to be subject to foreign technical regulations). This allows us to treat that variable as continuous because the predicted value from the first-stage regression is used instead of binary values. The specification of costs for firm *i* is as follows.

$$
\begin{aligned}
\ln \tilde{C}_i &= \beta_0 + \beta_y \ln y_i + \beta_L \ln w_{Li} + \beta_K \ln w_{Ki} + \frac{1}{2}\beta_{LL}(\ln w_{Li})^2 + \frac{1}{2}\beta_{KK}(\ln w_{Ki})^2 \\
&+ \frac{1}{2}\beta_{yy}(\ln y_i)^2 + \beta_{LK} \ln w_{Li} \ln w_{Ki} + \beta_{Ly} \ln w_{Li} \ln y_i + \beta_{Ky} \ln w_{Ki} \ln y_i + \beta_s s_i \\
&+ \beta_{Ls} s_i \ln w_{Li} + \beta_{Ks} s_i \ln w_{Ki} + \beta_{ys} s_i \ln y_i + \frac{1}{2}\beta_{ss} s_i^2 \\
&+ \sum_{n=1}^{N} \beta_{zn} z_n + \sum_{c=1}^{C} \beta_{zc} z_c + \varepsilon_i
\end{aligned}
\tag{4}
$$

where $\tilde{C}$ denotes value added (cost of labor and capital, referred to as production costs hereafter), w_L denotes the wage rate, w_K denotes the unit price of capital, y denotes sales as a measure of output, and s denotes the firm-specific measure of technical regulations. The variables z_n and z_c denote industry-specific and country-specific factors, respectively, that affect firm costs. We use industry and country dummies to control for these effects.

This translog cost function is estimated jointly with an equation for the share of labor cost in production costs:

$$S_{Li} = \beta_L + \beta_{LL} \ln w_{Li} + \beta_{LK} \ln w_{Ki} + \beta_{Ly} \ln y_i + \beta_{Ls} s_i + \mu_i \,. \tag{5}$$

We eliminate the capital-share equation from the estimation because it is fully determined by the constraints below.

Note that in writing these equations we have imposed the required symmetry in cross-variable coefficients. Furthermore, the linear homogeneity condition imposes the following constraints:

$$
\begin{aligned}
&\beta_L + \beta_K = 1 \\
&\beta_{KK} + \beta_{LK} = 0 \\
&\beta_{LL} + \beta_{LK} = 0 \\
&\beta_{Ly} + \beta_{Ky} = 0 \\
&\beta_{Ls} + \beta_{Ks} = 0
\end{aligned} \tag{6}
$$

Equations (4) and (5) are estimated jointly in an iterative three-stage least squares procedure (I3SLS), subject to the constraints in the system of equations (6). In addition to consistency and asymptotic efficiency, the I3SLS procedure guarantees identical translog cost parameters irrespective of which share equation is dropped (Berndt and Wood, 1975). The parameters for the dropped equation can be recovered by using the symmetry condition and the conditions in the system of equations (6).

From equation (4), we can calculate the direct elasticity of production costs with respect to foreign standards as $\sigma_s^d = \beta_s + \beta_{ss} \ln s_i$, which varies with the level of technical regulations. We are also interested in the impact of the standards on factor demands. The coefficient β_{Ls} in the system of equations (6) measures the bias toward labor use (impact on labor share) from an increase in foreign technical regulations ($\varphi_{Ls} \equiv \partial S_L / \partial \ln s = \beta_{Ls}$), and the bias toward capital use, ($\varphi_{Ks} \equiv \partial S_K / \partial \ln s = \beta_{Ks}$). The need to meet these technical regulations could effectively generate an overall increase in costs, along with a bias in factor use toward either labor or capital.

In addition to the direct elasticity of cost, we can calculate the total elasticity of cost with respect to a change in the stringency of technical regulations while accounting for impacts on factor use, as

$$
\sigma_S \equiv \partial \ln \tilde{C} / \partial \ln s = \beta_s + \beta_{ss} \ln s_i + \beta_{Ls} \ln w_{Li} + \beta_{Ks} \ln w_{Ki} + \beta_{ys} \ln y_i . \tag{7}
$$

This elasticity will vary with different observations on factor prices and output. Likewise, we can calculate the total elasticity of scale as

$$\sigma_y \equiv \partial \ln \tilde{C} / \partial \ln y = \beta_y + \beta_{yy} \ln y_i + \beta_{Ly} \ln w_{Li} + \beta_{Ky} \ln w_{Ki} + \beta_{ys} \ln s_i \,. \qquad (8)$$

Finally, the Allen partial elasticities of substitution between inputs i and j (σ_{ij}) are

$$\sigma_{ii} = \frac{\beta_{ii} + S_i^{\;2} - S_i}{S_i}, \; i = L \text{ or } K$$

$$\sigma_{ij} = \frac{\beta_{ij} + S_i S_j}{S_i S_j}, \qquad i = L,\, j = K \,.$$

3.2. Estimation of the effect of RoHS and REACH on export performance

We now move to the estimation approach for the effect of technical regulations on various measures of export performance of firms, namely the firm’s entry into export markets, the number of export markets, and export amount.

We begin by considering the firm’s entry into export markets. A binary variable is given the value one when the firm exports to at least one foreign country and zero otherwise. A probit model is used to estimate the effect of technical regulations, *s*, along with other regressors. We then focus on the number of export markets as a measure of export diversification (we refer to this as the extensive margin in keeping with the literature). This model allows us to examine whether meeting RoHS or REACH will offer opportunities for the firm to export to a greater variety of export markets. An ordered probit model is used for this estimation because we deal with an ordered dependent variable. We focus on the amount of a firm’s exports as a measure of the magnitude of exports instead of entry or count of markets to capture the intensity of exports (we refer to this as the intensive margin). Since the ordered probit estimation addresses market diversification, a complementary measure of export intensity would be the average export amount per market instead of the total export amount. The total amount reflects both the extensive and intensive margins. It is also common in the literature to estimate the intensive margin model using the Heckman sample selection model with taking the sample selection into account. This sample selection is represented by the above probit model corresponding to the extensive margin, as is typical.

4. Data

4.1. Survey in Malaysia

The data for Malaysia was collected in Penang, Malaysia from 2012 to 2013[4]. Penang was chosen because of the large agglomeration of industries, with many of the targeted firms located in the area. The project was also endorsed by the government of Penang, as the state government recognized the importance of the issue. The actual survey was conducted by PE Research of Malaysia.

Our questionnaire comprised four sections: 1) basic information, 2) input procurement and certificates, 3) chemical management, and 4) export status. Surveyed firms were sampled from those firms recorded in the Penang Industrial Census of 2011, which collected data on 2,116 firms, of which 1,898 were manufacturers and 218 were service firms. Beginning in November, 2012, we contacted 732 of these firms by distributing questionnaire sheets and following up with phone calls. We received replies from 374 firms, giving us a response rate of approximately 51%[5]. Among the manufacturing industries 346 were chosen, and 23 firms were chosen from the service sectors. We targeted those sectors for which the management of chemicals contained in products was likely to be necessary. The share of small and medium enterprises, here defined as fewer than 200 employees, was 83.4%, or 308 of the chosen firms. Among the chosen firms, 72.6% (268) were 100% locally owned, and 18.7% (69) firms were 100%

[4] The data were collected under the IDE-JETRO research project “Impact of product-related environmental regulations on international trade and technological spillovers through supply chain in Asia”.

[5] The authors wish to thank the local governments, Invest Penang and Penang industrial associations, Federation of Malaysian manufacturers (FMM) in the Northern Region and the association of companies in the free zones (FREPENCA) for endorsing our research project and also those firms who kindly filled out our form.

foreign-owned firms; the remaining 32 firms were joint ventures between local and foreign owners.

4.2. Survey in Vietnam

The data for Vietnam were collected from the entire country in 2011 to 2012. In Vietnam the survey was implemented by the Vietnamese Chamber of Commerce and Industry. The population consists of firms in operation according to the General Department of Taxation. Target firms include both those in manufacturing and those in commerce sectors where the management of chemicals in products is an issue. Of the 15,358 firms in the population, survey forms were sent to 11,978 firms across all provinces. A response rate of 8.8% (1055 firms) was obtained. Domestic firms account for 67.4% of respondents (710 firms), foreign direct investment (FDI) firms account for 31.8% of respondents (335 firms), and state-owned enterprises account for 0.9% of respondents (9 firms). Among respondents, 57.6% were small and medium enterprises, here those with fewer than 300 employees.

4.3 Descriptive statistics

The survey focuses on a variety of industries in Malaysia and Vietnam. The industries studied and the count of firms can be found in Table 1. Table 2 shows the descriptive statistics of the variables used in the cost and export analyses. First, we will describe the variables used in the cost analysis. The average value added cost and sales are greater in Vietnam than in Malaysia, but the standard deviations of these variables are smaller in Malaysia. This implies that firms are more diverse in terms of the size of operation in Vietnam. In Malaysia, we find that the wage rate and unit price of capital are higher. We define global value chains as the networks of firms that procure inputs from various countries and sell the products globally, such as automotive products, electronics, and garments. Firms were asked whether they supplied their main products to global supply chains. In Malaysia, more firms were integrated into global value chains. The number of firms complying with RoHS and REACH is also far greater in Malaysia. The survey also asked firms if they were able to meet EU RoHS and REACH standards along with other regulations and requirements.[6]

We next describe the variables used in the export analysis that were not used in the cost analysis. The fraction of firms exporting to any foreign country is quite close between Malaysia (69%) and Vietnam (62%). However, the fraction of firms exporting to EU countries is greater in Vietnam (34%) than in Malaysia (25%). The average export amount per market in Malaysia is twice that in Vietnam. The number of years since the firm was established is greater in Malaysia, perhaps reflecting the earlier economic growth and industrialization of Malaysia. The number of employees follows the same tendency as cost and sales: Malaysia has a greater average size and a smaller variation. The fraction of multinational enterprises is greater in Vietnam. The number of years since the firm's main product was first produced is used for the exclusion restriction in the Heckman sample selection model.

5. Results

5.1. Cost function estimation

The cost function was run jointly with the labor share equation under alternative specifications. Instrumental variables were used for RoHS and REACH to mitigate the effects of endogeneity. These variables include dummies for export, being a multinational enterprise, and being in a global value chain. The parameter estimates with respect to translog models are presented in Table 3. For the sake of comparison, we also show the parameters estimated by the Cobb–Douglas functional form. Robust standard errors are reported in parentheses. The "translog I" model follows a specification without interaction terms with RoHS (or REACH); the "translog II" follows the full translog specification. All equations include industry and country fixed effects. The fit of each model is good with adjusted R-squared coefficients of 0.8 or greater. We examine local concavity in input prices and positivity of input shares for the translog model according to procedures

[6] We assume that non-response implies non-compliance so as to conserve a loss of samples due to missing data.

described by Berndt and Wood (1975). Our fully specified translog cost functions were found to satisfy these conditions.

The results of the Cobb–Douglas model estimation show that the coefficients for RoHS and REACH are both statistically insignificant. However, the Cobb-Douglas specification may be too simple to represent the underlying technology. In the translog models (translog I and translog II), the coefficients for the (linear) RoHS and REACH variables are positive and significant in both specifications. This indicates that the direct effect of RoHS and REACH is significant and indicates increased variable production cost. The coefficients for the quadratic RoHS and REACH are not significant. According to the translog I model, cost increases due to RoHS and REACH are 12.5% and 12.7% of total (labor and capital) costs, respectively.

When we take the indirect costs of technical regulations into account in translog II model according to equation (5), the cost increases due to RoHS and REACH are 11.5% and 12.0%, respectively, although the effect of REACH is not significant (see Table 5). The effects of RoHS and REACH may not be particularly large, but the result suggests that the payoffs for compliance in terms of increased price and improved access to foreign markets should be greater than around 12%.

When we consider that our estimate concerns only labor and capital costs, we find that additional cost variables may be necessary. These could include cost of raw materials, intermediate inputs and other costs. Firms have also already incurred the initial setup costs for compliance with these regulations. We therefore see that the costs associated with RoHS and REACH compliance appear to be nontrivial.

The effect of participating in a global value chain seems to reduce firm’s variable costs because the coefficients for the global value chains dummy are negative and significant in both RoHS and REACH cases. Firms can therefore expect some cost-saving effect from participating in global value chains, although there may be some correlation between firm efficiency and tendency to participate in the global value chains.

Finally, we examine robustness of the results of the cost function estimation using the sub-sample which belongs to the industries facing RoHS or REACH regulations. The industries facing RoHS and REACH are indicated in Table 1. The results are presented in Table 4. The significance levels and magnitudes of the estimated parameters are largely unchanged from the full-sample results in Table 3. The direct effect of RoHS and REACH compliance in terms of cost increase is 12% as is the case of the full-sample estimation in both translog I and II models. The indirect effect calculated from translog II model is also around the same order although the results are not presented. Thus, the full-sample results are considered to be reasonably robust.

5.2. Export estimation

In the export analysis, we focused on the firm's entry to export markets, the number of export markets, and the export amount. The results for RoHS and REACH are presented in Tables 6 and 7, respectively. The first and second columns of these tables show the results of the probit regression used to examine whether compliance with RoHS and REACH improves the firm's ability to access, respectively, foreign markets generally and the EU market specifically. The results indicate that RoHS does not increase the probability of entering foreign markets in general, but that it does increase the probability of entering the EU markets. In the case of REACH, it increases probability to enter both export markets in general and the EU market.

The third column of these tables shows the results of the ordered probit estimation. We find that compliance with RoHS and REACH significantly increases the number of export markets. We can therefore conclude that compliance with RoHS and REACH helps firms to access a greater variety of countries. Thus, compliance with RoHS and REACH seems to signal safety and quality of the products of the firms and to help the products to be accepted in the other markets. However, one should be cautious about the exception that the effect of compliance with RoHS on the probability to export is not significant. This is perhaps because the effect of compliance with RoHS is not homogeneous across export markets. There may be a group of countries which highly appreciate RoHS compliance, and therefore the firms in our sample were able to export to multiple countries within this group, most likely the EU countries. On the other hand, there may be a considerable number of countries that do not appreciate compliance with EU-specific RoHS very much, resulting in the statistical insignificance of the effect of RoHS compliance on the probability to export.

The fourth and fifth columns of these tables show the results of a Heckman sample selection estimation examining the effect of compliance with RoHS and REACH on the average amount exported per market as a measure of the intensive margin.[7] The results indicate that the average export amount per export market does not significantly increase with compliance with RoHS or REACH. Thus, the major benefit of RoHS and REACH compliance remains to be diversification of export markets instead of an increase of export amount.

Multinational enterprises exhibit a greater probability to export, diversity in export markets and the scale of export according to Tables 6 and 7, confirming our expectation that multinational enterprises tend to possess superior technological knowledge and greater expertise in export procedures than local firms. Also, participation in global value chain are found to increase export probability and diversity in export markets. However, it does not affect the scale of export perhaps because the major role of global value chain is to assist firms to penetrate into markets through quality assurance accomplished by the value chain.

We also examine robustness of the full-sample results of the export analysis using the sub-sample of firms in the industries facing RoHS and REACH as has been done in the cost analysis. The results are largely the same as those of the full-sample estimation.

Overall, compliance with RoHS and REACH provides firms with better access to export markets but the advantage of a compliance with RoHS is likely to be found in accessing the EU market. This may indicate that EU REACH is more universal than EU RoHS. However, this finding seems to contradict our observations that RoHS-type regulations are more widely adopted worldwide than REACH-type regulations. Thus,

[7] It should be noted that the inverse mills ratios are insignificant in both tables, implying that sample selection is not severe enough to cause the biased coefficient estimators.

detailed investigation about dissimilarity of these regulations across countries would be necessary.

6. Conclusions

This paper uses firm-level data to examine the impact of foreign chemical safety regulations such as RoHS and REACH on the production costs and export performance of firms in Malaysia and Vietnam. We find that in addition to the initial setup costs for compliance, EU RoHS and REACH implementation causes firms to incur additional variable production costs by requiring additional labor and capital expenditures of around 12% of the variable costs, respectively. We also find that compliance with RoHS and REACH significantly increases the probability of export, but that compliance with RoHS only increases the probability of export to the EU. Furthermore, we find that compliance with EU RoHS and REACH helps firms to penetrate into a greater variety of countries. On the other hand, the effect of RoHS and REACH compliance on the average export amount per market is not found. Also, we find that multinational enterprises and firms participating in global value chains generally face less production costs and exhibit better export performance.

In summary, RoHS and REACH cause firms to incur both initial setup costs and additional variable production costs. Compliance with these regulations can, however, reward firms with improved access to a greater number of export markets. The benefits of compliance may therefore exceed the additional costs although a direct comparison is not pursued in this paper due to the difference in the nature of the performance measures. Further investigation that focuses on dissimilarity of RoHS- and REACH-types of chemical safety regulations across countries, in particular, between the EU and non-EU countries would be necessary to make useful prescription for both exporting firms and regulating countries so as to avoid these technical regulations to constitute unnecessary barriers to trade. Effort to harmonise regulations globally may increase economic benefits if they aim to achieve the same public goals and if cross-country dissimilarity of regulations are not significant.

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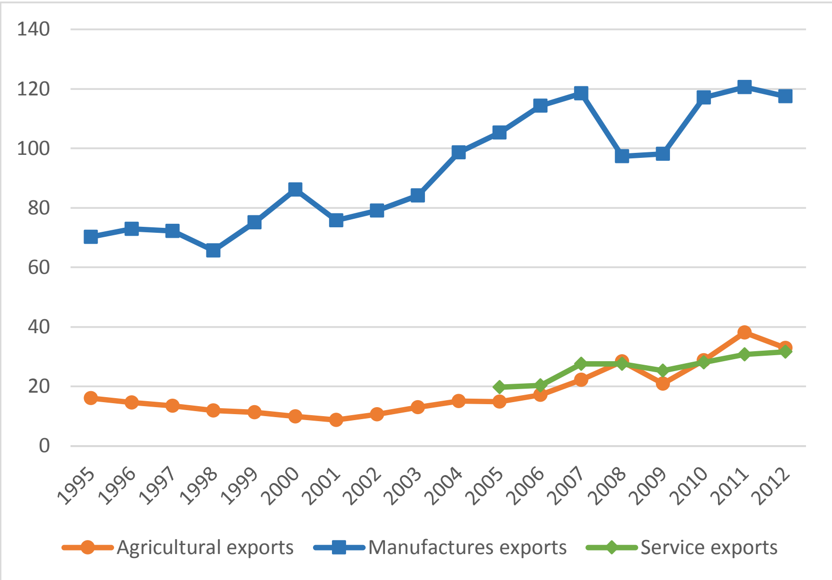
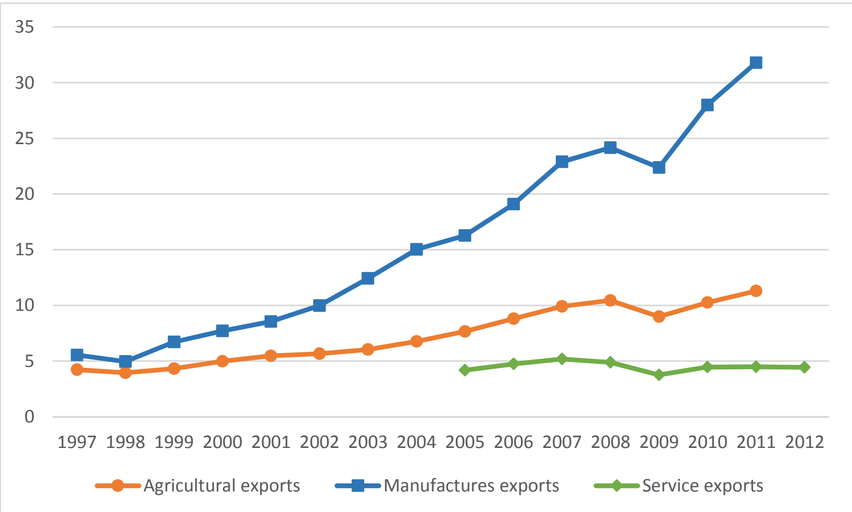
Figure 1. Malaysia's Exports (in billions of USD)



Source: Author's calculations from World Development Indicators data

Figure 2. Vietnam's Exports (in billions of USD)



Source: Author’s calculations from World Development Indicators data

Table 1. Industries included in the analysis

Table 1. Industries included in the analysis

	Number of firms	RoHS	REACH
Food products	51		
Beverages	7		
Textiles	25	x	x
Wearing apparel	113	x	x
Leather and related products	9	x	x
Wood and products of wood and cork, except furniture,	48	x	x
Paper and paper products	9	x	x
Printing and reproduction of recorded media	10	x	x
Coke and refined petroleum products	2	x	x
Chemicals and chemical products	17	x	x
Basic pharmaceutical products and pharmaceutical preparation	2	x	x
Rubber and plastics products	51	x	x
Other non-metallic mineral products	10	x	x
Basic metals	26	x	x
Fabricated metal products, except machinery and equipment	43	x	x
Computer, electronic and optical products	23	x	x
Electrical equipment	17	x	x
Machinery equipment	19	x	x
Motor vehicles, trailers and semi-trailers	5		x
Other transport equipment	6		x
Furniture	21	x	x
Other manufacturing	60	x	x
Wholesale and retail trade, and repair and installation of machinery and equipment including motor vehicles and motor-cycles	11		
Others	50		

Source: Malaysia and Vietnam firm surveys. These counts are for the responses used in the empirical analyses.

Table 2. Descriptive statistics of the variables used in the empirical analysis

	Malaysia			Vietnam		
Variable	Obs.	Mean	Std. Dev.	Obs.	Mean	Std. Dev.
Cost analysis						
Value added cost (million USD)	220	15.9	36.5	391	30.6	50.0
Sales (million USD)	220	23.7	50.0	391	51.2	75.4
Wage rate (USD)	220	7129.4	8180.3	391	3416.6	11558.5
Unit capital price (USD)	220	3.389	5.466	391	1.446	2.639
Participation in global value chain	220	0.518	0.501	391	0.202	0.402
RoHS compliance	220	0.341	0.475	391	0.082	0.274
REACH compliance	220	0.241	0.429	391	0.082	0.274
Export analysis						
Entry to export market	220	0.686	0.465	391	0.619	0.486
Entry to EU market	220	0.250	0.434	391	0.338	0.473
Number of export markets	220	2.700	2.609	391	1.637	2.009
Average export per export market (million USD)	154	53.4	17.0	217	23.8	42.5
Number of years since the firm was established	220	19.568	12.747	358	10.447	9.658
Number of employees	220	151.11	286.0	391	475.96	1063.19
Multinational enterprise	220	0.218	0.414	391	0.281	0.450
Number of years since the main product was first produced	220	16.177	11.706	372	9.312	8.065

Source: The authors' calculations from Malaysia and Vietnam firm survey data.

Table 3. Cost function estimation (full sample)

	(1)	(2)	(3)	(4)	(5)	(6)
	RoHS			REACH		
Variables	Cobb-Douglas	translog I	translog II	Cobb-Douglas	translog I	translog II
Constant	0.403	9.259***	9.106***	0.604***	9.609***	8.908***
	(0.280)	(1.863)	(1.922)	(0.213)	(1.712)	(1.769)
log$y$	0.963***	0.0112	0.0642	0.945***	-0.0439	0.0751
	(0.0242)	(0.248)	(0.257)	(0.0183)	(0.230)	(0.240)
(log$y$)^2		0.0350**	0.0278		0.0412***	0.0309*
		(0.0165)	(0.0171)		(0.0154)	(0.0163)
logw_L	-0.0404***	-0.0345	-0.0939	-0.0411***	-0.0291	-0.0616
	(0.0129)	(0.0591)	(0.0607)	(0.0137)	(0.0587)	(0.0607)
logw_K	0.122***	1.035***	1.094***	0.122***	1.029***	1.062***
	(0.00943)	(0.0591)	(0.0607)	(0.0102)	(0.0587)	(0.0607)
(logw_L)^2		0.0666***	0.0666***		0.0640***	0.0639***
		(0.00254)	(0.00252)		(0.00249)	(0.00249)
(logw_K)^2		0.0666***	0.0666***		0.0640***	0.0639***
		(0.00254)	(0.00252)		(0.00249)	(0.00249)
log$w_L$logw_K		-0.0666***	-0.0666***		-0.0640***	-0.0639***
		(0.00254)	(0.00252)		(0.00249)	(0.00249)
log$w_L$log$y$		-0.0146***	-0.00921**		-0.0133***	-0.0104***
		(0.00355)	(0.00383)		(0.00352)	(0.00381)
log$w_K$log$y$		0.0146***	0.00921**		0.0133***	0.0104***
		(0.00355)	(0.00383)		(0.00352)	(0.00381)
s (= RoHS	-1.024	12.46***	12.33***	-0.371	12.72***	12.34***
or REACH)	(0.823)	(1.801)	(1.868)	(0.594)	(1.102)	(1.165)
s^2			0.214			1.345
			(1.010)			(1.488)
s* logw_L			-0.115***			-0.0725**
			(0.0325)			(0.0362)
s* logw_K			0.115***			0.0725**
			(0.0325)			(0.0362)
s* log$y$			0.0644***			0.0405**
			(0.0183)			(0.0202)
Global value	0.182	-2.177***	-2.190***	0.0664	-2.214***	-2.257***
chain	(0.150)	(0.331)	(0.332)	(0.111)	(0.212)	(0.215)
Malaysia		-1.997***	-2.000***		-1.197***	-1.202***
dummy		(0.248)	(0.249)		(0.119)	(0.119)
Observations	600	600	600	600	600	600
R-squared	0.962	0.801	0.800	0.961	0.825	0.825

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 4. Cost function estimation (sub-sample: firms subject to RoHS/REACH)

	(1)	(2)	(3)	(4)	(5)	(6)
		RoHS			REACH	
Variables	Cobb-Douglas	translog I	translog II	Cobb-Douglas	translog I	translog II
Constant	0.491	7.631***	7.274***	0.743***	7.799***	6.619***
	(0.300)	(2.021)	(2.113)	(0.231)	(1.849)	(1.922)
log$y$	0.965***	0.237	0.325	0.938***	0.190	0.389
	(0.0253)	(0.268)	(0.283)	(0.0189)	(0.247)	(0.261)
(log$y$)^2		0.0218	0.0111		0.0259	0.00903
		(0.0177)	(0.0189)		(0.0165)	(0.0177)
logw_L	-0.0525***	0.0118	-0.0714	-0.0515***	0.0148	-0.0367
	(0.0134)	(0.0674)	(0.0683)	(0.0142)	(0.0661)	(0.0679)
logw_K	0.111***	0.988***	1.071***	0.113***	0.985***	1.037***
	(0.00971)	(0.0674)	(0.0683)	(0.0104)	(0.0661)	(0.0679)
(logw_L)^2		0.0638***	0.0641***		0.0614***	0.0614***
		(0.00271)	(0.00267)		(0.00265)	(0.00264)
(logw_K)^2		0.0638***	0.0641***		0.0614***	0.0614***
		(0.00271)	(0.00267)		(0.00265)	(0.00264)
log$w_L$logw_K		-0.0638***	-0.0641***		-0.0614***	-0.0614***
		(0.00271)	(0.00267)		(0.00265)	(0.00264)
log$w_L$log$y$		-0.0156***	-0.00821*		-0.0144***	-0.00970**
		(0.00405)	(0.00431)		(0.00396)	(0.00425)
log$w_K$log$y$		0.0156***	0.00821*		0.0144***	0.00970**
		(0.00405)	(0.00431)		(0.00396)	(0.00425)
s (= RoHS	-1.061	11.63***	11.39***	-0.0584	12.82***	12.22***
or REACH)	(0.850)	(1.928)	(2.041)	(0.610)	(1.176)	(1.257)
s^2			0.295			1.504
			(1.192)			(1.612)
s* logw_L			-0.150***			-0.109***
			(0.0343)			(0.0381)
s* logw_K			0.150***			0.109***
			(0.0343)			(0.0381)
s* log$y$			0.0792***			0.0619***
			(0.0190)			(0.0212)
Global value	0.222	-2.021***	-2.023***	0.0432	-2.213***	-2.249***
chain	(0.155)	(0.353)	(0.356)	(0.114)	(0.227)	(0.229)
Malaysia		-1.981***	-1.977***		-1.315***	-1.316***
dummy		(0.265)	(0.267)		(0.131)	(0.132)
Observations	483	483	483	492	492	492
R-squared	0.964	0.797	0.794	0.964	0.823	0.824

Robust standard errors are in parentheses *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 5. The effect of RoHS and REACH on the variable cost (in percentage)

RoHS			REACH		
Cobb-Douglas	translog I	translog II	Cobb-Douglas	translog I	translog II
-1.024	12.46***	11.46**	-0.371	12.72***	11.96
(0.823)	(1.801)	(6.20)	(0.594)	(1.102)	(10.42)

These estimates are based on the full sample. Standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1. Those for translog II model are evaluated at the mean values of the variables.

Table 6. Results of export regressions for RoHS (full sample)

	(1)	(2)	(3)	(4)	
	Export entry	Export entry to EU	Number of export markets	Export amount	
Variables	Probit	Probit	Ordered probit	Heckman model	Selection
Constant	-0.793***	-1.414***	4.463***	669,450	-0.326***
	(0.196)	(0.195)	(0.409)	(1.333e+06)	(0.103)
RoHS	0.270	0.413**	0.236*	938,348	0.0827
	(0.192)	(0.174)	(0.134)	(1.360e+06)	(0.173)
Firm age	0.0160**	0.0179***	0.00798*	13,067	0.0568***
	(0.00653)	(0.00575)	(0.00431)	(53,162)	(0.0178)
wage	8.33e-06	5.21e-06	2.38e-06	71.23*	1.32e-05
	(1.13e-05)	(4.72e-06)	(3.00e-06)	(37.75)	(1.12e-05)
employment	0.000393*	0.000227**	0.000228***	527.8	0.000557**
	(0.000230)	(9.99e-05)	(6.45e-05)	(457.4)	(0.000270)
MNE	0.655***	0.104	0.293***	5.102e+06***	0.611***
	(0.173)	(0.147)	(0.109)	(1.745e+06)	(0.156)
Global value	0.627***	0.377***	0.526***	254,245	0.623***
chain	(0.163)	(0.146)	(0.115)	(1.491e+06)	(0.150)
Malaysia dummy	-0.0597	-0.553***	0.452***	5.512e+06	-0.0171
	(0.178)	(0.169)	(0.129)	(3.519e+06)	(0.154)
Years of					-0.0505***
production					(0.0185)
Inverse mills				-1.235e+07	
ratio				(9.644e+06)	
Log pseudolikelihood	-280.742	-292.153	-952.556	-6,772.11	
Observations	542	547	569		574

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 7. Results of export regressions for REACH (full sample)

Variables	(1) Export entry Probit	(2) Export entry to EU Probit	(3) Number of export markets Ordered probit	(4) Export amount Heckman model	Selection
Constant	-0.796***	-1.399***	4.502***	558,959	-0.331***
	(0.197)	(0.196)	(0.424)	(1.494e+06)	(0.104)
REACH	0.657***	0.449**	0.462***	2.297e+06	0.411**
	(0.209)	(0.181)	(0.128)	(1.408e+06)	(0.195)
Firm age	0.0150**	0.0166***	0.00671	7,677	0.0569***
	(0.00668)	(0.00581)	(0.00434)	(51,291)	(0.0178)
wage	8.99e-06	5.91e-06	2.86e-06	74.81**	1.38e-05
	(1.15e-05)	(4.74e-06)	(2.90e-06)	(37.45)	(1.13e-05)
employment	0.000394*	0.000242**	0.000233***	570.0	0.000557**
	(0.000231)	(9.82e-05)	(6.29e-05)	(447.5)	(0.000274)
MNE	0.670***	0.112	0.295***	5.183e+06***	0.590***
	(0.175)	(0.147)	(0.110)	(1.759e+06)	(0.157)
Global value	0.574***	0.369**	0.487***	83,780	0.582***
chain	(0.161)	(0.145)	(0.112)	(1.471e+06)	(0.149)
Malaysia dummy	-0.0543	-0.514***	0.465***	5.511e+06	-0.0385
	(0.180)	(0.169)	(0.129)	(3.508e+06)	(0.154)
Years of					-0.0514***
production					(0.0185)
Inverse mills				-1.023e+07	
ratio				(1.117e+07)	
Log pseudolikelihood	-276.997	-291.911	-948.575	-6,768.89	
Observations	542	547	569		574

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 8. Results of export regressions for RoHS (sub-sample: firms subject to RoHS)

Variables	(1) Export entry Probit	(2) Export entry to EU Probit	(3) Number of export markets Ordered probit	(4) Export amount Heckman model	Selection
Constant	-0.367	-0.675	4.159***	-1.125e+06	-0.310**
	(0.517)	(0.472)	(0.536)	(3.617e+06)	(0.123)
RoHS	0.244	0.385**	0.253*	396,558	0.0769
	(0.200)	(0.183)	(0.137)	(1.557e+06)	(0.186)
Firm age	0.0204***	0.0214***	0.0131***	16,096	0.0689***
	(0.00720)	(0.00623)	(0.00476)	(62,172)	(0.0176)
wage	5.46e-06	-3.78e-06	-3.84e-06	201.2	8.06e-06
	(1.29e-05)	(8.76e-06)	(7.24e-06)	(142.4)	(1.29e-05)
employment	0.000348	0.000176**	0.000202***	635.2	0.000496*
	(0.000234)	(8.74e-05)	(6.42e-05)	(492.1)	(0.000272)
MNE	0.583***	0.0983	0.251**	5.433e+06***	0.542***
	(0.185)	(0.156)	(0.119)	(1.982e+06)	(0.169)
Global value	0.689***	0.345**	0.535***	282,412	0.737***
chain	(0.170)	(0.152)	(0.121)	(1.659e+06)	(0.161)
Malaysia dummy	-0.113	-0.432**	0.384**	6.989e+06	-0.174
	(0.203)	(0.195)	(0.153)	(4.601e+06)	(0.177)
Years of					-0.0583***
production					(0.0187)
Inverse mills				-7.868e+6	
ratio				(1.258e+7)	
Industry dummies	yes	yes	yes	yes	
Log pseudolikelihood	-227.214	-245.821	-782.976	-5,597.47	
Observations	440	443	459		459

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 9. Results of export regressions for REACH (sub-sample: firms subject to REACH)

Variables	(1) Export entry Probit	(2) Export entry to EU Probit	(3) Number of export markets Ordered probit	(4) Export amount Heckman model	Selection
Constant	-0.249	-0.791*	4.305***	-1.942e+06	-0.328***
	(0.497)	(0.409)	(0.509)	(3.785e+06)	(0.121)
REACH	0.603***	0.417**	0.422***	2.258e+06	0.370*
	(0.222)	(0.192)	(0.131)	(1.605e+06)	(0.207)
Firm age	0.0189***	0.0188***	0.0106**	2,872	0.0654***
	(0.00727)	(0.00628)	(0.00477)	(60,848)	(0.0164)
wage	5.38e-06	-1.26e-06	-2.05e-06	209.6	6.83e-06
	(1.23e-05)	(8.69e-06)	(6.99e-06)	(136.3)	(1.17e-05)
employment	0.000334	0.000195**	0.000208***	696.5	0.000471*
	(0.000222)	(8.67e-05)	(6.19e-05)	(483.0)	(0.000261)
MNE	0.597***	0.0875	0.242**	5.330e+06***	0.545***
	(0.185)	(0.155)	(0.119)	(1.978e+06)	(0.168)
Global value	0.654***	0.358**	0.529***	41,501	0.697***
chain	(0.166)	(0.151)	(0.117)	(1.695e+06)	(0.159)
Malaysia dummy	-0.0723	-0.392**	0.408***	6.797e+06	-0.162
	(0.201)	(0.193)	(0.152)	(4.568e+06)	(0.175)
Years of					-0.0554***
production					-0.328***
Inverse mills				-6.785e+06	
ratio				(1.441e+07)	
Log pseudolikelihood	-232.092	-248.865	-796.689	-5,672.84	
Observations	450	449	468		468

Robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1