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Impact on Asian Firms of Product-related Environmental Regulations through Global Supply Chains: A Study of Firms in Malaysia

Etsuyo Michida^{*}, Yasushi Ueki^{**} and Kaoru Nabeshima^{***}

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This paper sheds light on the important role played by global supply chains in the adaptation to product-related environmental regulations imposed by importing countries, with a focus on chemicals management. By utilizing a unique data collected in Penang, Malaysia, we depict the supply chain structures and how differences among firms in participation to global supply chain link to differences in chemical management. We found that firms belonging to a supply chain are in a better position to comply with these regulations because information and requirements are transmitted through global supply chains. In contrast, those firms that are neither exporters nor a part of a global supply chain lack the knowledge and information channels relevant to chemical management in a product.

Keywords: global supply chain, FDI, product-related environmental regulation, REACH, RoHS

JEL classification: F18, O14

* Associate Senior Research Fellow, IDE **, Economist, Economic Research Institute for ASEAN and East Asia (ERIA) *** Chief Senior Researcher, IDE,
Corresponding author: Etsuyo Michida (Etsuyo_Michida@ide.go.jp)

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INSTITUTE OF DEVELOPING ECONOMIES (IDE), JETRO
3-2-2, WAKABA, MIHAMA-KU, CHIBA-SHI
CHIBA 261-8545, JAPAN

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Abstract

This paper sheds light on the important role played by global supply chains in the adaptation to product-related environmental regulations imposed by importing countries, with a focus on chemicals management. By utilizing a unique data collected in Penang, Malaysia, we depict the supply chain structures and how differences among firms in participation to global supply chains link to differences in chemical management. We found that firms belonging to a supply chain are in a better position to comply with these regulations because information and requirements are transmitted through global supply chains. In contrast, those firms that are neither exporters nor a part of a global supply chain lack the knowledge and information channels relevant to chemical management in a product.

I. Introduction

In recent years, many countries have adopted green growth strategies to achieve sustainable growth, leading to an increase in environmental and health-related regulations for products, known as product-related environmental regulations (PRERs).¹ This imposition of PRERs by importing countries has raised concern among exporting countries. If exported products do not satisfy the regulatory requirements, these products cannot be placed in the regulated markets, and firms might also face technical barriers to trade. Since recent PRERs tend to be more demanding than those in the past, and as their numbers increase in many markets, the related challenges facing manufacturers in developing countries seem to be mounting.

The concerns are especially relevant to countries in East and Southeast Asia, which has been a center of global manufacturing for decades and in which many parts and component suppliers to global assemblers are located.² Although Asian developing countries have accumulated manufacturing capability by integration into global production networks,³ the capacity of firms to deal with technical regulations still seems to be limited. The main reason is that PRERs have been implemented mainly in countries overseas, especially in the European Union (EU), and the concepts are relatively new to many Asian countries.

Increasing concerns about the chemical contents of products, mainly in the EU, has led to a number of initiatives to limit or at least provide sufficient information on chemicals contained in a product. Chemicals are used for a variety of industrial purposes including as main ingredients of plastic, synthetic

¹ See Michida (2014) for examples of PRERs. Malaysia also has a number of PRERs, mainly in response to introduction of these in developed countries (Chen et al. 2014).

² See, for instance, Hiratsuka and Uchida (2010).

³ See, for instance, Kuroiwa and Toh (2008) on the experience of Indonesia, Malaysia, and Thailand, and Kuroiwa (2009) on the strategies adopted by Cambodia, Laos, Myanmar, and Vietnam.

fiber, synthetic rubber, dye, and fertilizer and so on. However, certain chemicals are known to cause a broad range of health effects as well as adverse effects on the environment. In response, regulatory bodies and private groups have collaborated to introduce appropriate management of chemicals. Examples of such technical regulations are the EU Directive on Restriction of the use of certain Hazardous Substances in electrical equipment (RoHS) and the Registration Evaluation Authorisation and Restriction of Chemicals (REACH) regulation. Once chemicals contained in a final product are regulated, materials, parts, and components composing the final product may need to be redesigned, monitored, tested, and approved to meet the stipulated chemical thresholds. As parts and components suppliers for a given product may be located in several countries, the effort to comply with such regulations needs to be coordinated throughout the supply chain. The RoHS is aimed only at the electronics industry and covers the use of only six chemicals, but the coverage of REACH is much broader in terms both of chemicals in questions and industries affected. REACH requires registration of chemical compounds contained in products as well as reduction or elimination of the use of chemicals listed in the Substances of Very High Concern (SVHC) list. Not all firms and industries have prepared themselves to comply with PRERs. Rather, some firms have handled and adapted to PRERs well, but others have faced challenges. There are differences in adaptation capacity among industries as well. While industries such as electrical and electronics and automotives, which have been exposed to global competition for a long time, have been successful in coping with their related PRERs, other industries have not been as familiar with PRERs and have only recently started adapting. Moreover, even within the same industry in the same country, differences among firms in progress of adaptation are observed. The situation of the Malaysian electrical and electronics industry illustrated in UNCTAD (2006, 126–127), for example, suggests that firms attached to global supply chains (GSCs) have managed the introduction of the EU RoHS well, while products of firms that are more isolated from GSCs may be limited to less regulated markets, such as their domestic markets.

This paper attempts to show how the move toward complying with PRERs has impacted participation in GSCs that are extensions of multinational companies and also supply goods and services to multiple markets. Previous studies have not emphasized the role of supply chains, so the main focus of this paper is to examine how participating in supply chains changes the manner of complying with PRERs. A related focus is how the structure of supply chains themselves could be affected by compliance with PRERs, as suppliers and destination markets may undergo changes to meet requirements.

In this paper, GSC firms are defined as those firms attached to supply chains⁴ that target multiple external markets and that procure from multiple countries.

II. Literature Review

While there are as yet few studies that have examined PRERs, there is extensive research on the impact of

⁴ Kokubu (2013) classifies supply chain management into three categories with regard to environmental issues: compliance with regulations, voluntary actions, and both.

technical barriers to trade (TBT), and more broadly of non-tariff measures (NTMs) on trade. The issue of non-tariff measures is gaining importance partly because of the success of the World Trade Organization's General Agreement on Tariffs and Trades in reducing tariff rates and restricting governments on substitutes for tariffs and other trade restricting measures. TBTs are an important subset of NTMs, and PRERs falls within TBTs.⁵ There have been a number of attempts to quantify the impact of NTMs, many of which rely on estimating equivalent *ad valorem* tariffs. For instance, Kee, Nicita, and Olarreaga (2009)⁶ estimate that the total impact of NTMs is double that of the impact from tariffs.

To analyze the effect of TBTs⁷ on trade, one can think of the introduction of new regulations on products as an increase in the fixed cost of exporting. If this is the case, then only more productive firms can service a market, reducing the number of entrants into that market (Helpman, Melitz and Yeaple 2004; Melitz 2003). This will lead to higher prices (for all firms) and higher prices and profits for domestic firms compared with when TBTs did not exist. However, at the same time it is possible that demand for imported goods will increase if the TBT related to product quality because conforming products now meet new regulations and may be considered to be more desirable goods. Therefore, the impact on trade is ambiguous; which effect dominates is an empirical issue. No studies of TBTs as a fixed cost of exporting have examined the issue of PRERs from environmental or supply chain perspectives. The perspective from the supply chain is needed because production of manufactured goods is organized around supply chains and we expect that belonging to a supply chain will have an effect similar to lowering of fixed costs of exporting, making the impact of PRERs smaller for those firms already belonging to a supply chain.

There is a body of literature focusing on the impact of various product-related environmental standards on firms in developing countries⁸. Chaturvedi and Nagpal (2003) have reported their concern over food and textile standards as well as eco-labeling in the context of Indian industries in various sectors. Sankar (2007) focuses on the Indian leather industry and examines the impact through supply chains. Some studies specifically look into the impacts of EU regulations such as Angerer et al. (2008) who examine the impacts of PRERs on firms located in the EU, and Tong, Shi, and Zhou (2012) who examine the diffusion of lead-free soldering in China because of regulations in major export markets, such as the EU, the United

⁵ Not all TBTs are trade distorting or undesirable. TBTs do have genuine public policy motivations to solve particular market failures domestically (such as environmental, health, safety-related issues) (WTO 2012).

⁶ There are several different approaches. The price gap approach compares prices before and after imports, but data for this kind of analysis are hard to find. The direct method uses gravity equations and attributes the difference between an estimate with NTM and without NTM as the effect of NTM. The indirect method also uses gravity equations and attributes the difference between the actual and predicted price as the impact of NTM (Chen and Novy 2012; Ferrantino 2012).

⁷ We discuss TBT here, but the discussion on SPSs is quite similar. A metastudy by Li and Beghin (2012) finds that for agriculture trade, TBTs and SPSs have negative impacts more often than not.

⁸ The impact of product-related environmental standards has some common features with the impact of food safety standards on imported products. For example, see IDE-JETRO and UNIDO (2013). For the linkages between multinational firms and firms in developing countries, see Jeppesen and Hansen (2004)

States (US), and Japan. Only a handful of studies examine the impacts of EU regulations on developing countries. Among previous studies, Rock, Angel, and Lim (2006) examined the role of lead firms in spreading better environmental management throughout their subsidiary networks through a case study of Motorola in Penang, Malaysia. Michida and Nabeshima (2012) gauged the impact of PRERs imposed by the EU through interviews with firms in Vietnam belonging to supply chains. They reaffirmed that supply chains that are tightly controlled seem to have little problem complying with PRERs while small and medium enterprises (SMEs) exporting on their own or attempting to join supply chains are struggling to adapt. Ramungul, Michida, and Nabeshima (2013) have examined Thai cases of such impacts.

Most existing research uses the case study approach, and we found no research that uses a large sample to examine this issue quantitatively. Moreover, many studies focus on PRER impacts on only firms or industries in developing countries without any consideration given to supply chains. However, in recent decades more products that are exported to external markets, whether or not they are tightly regulated, are manufactured neither in a single country nor by a single firm but, rather, are manufactured through globally extended supply chains and production networks. In Asia, liberalization of trade and investment in the region has enabled manufacturing firms to procure parts and components from different countries according to comparative advantage, and such activities have led to formation of extensive supply chain networks in the region. On one hand, the impact of PRERs seems to be significant in general; the longer a supply chain is, the more complex it becomes to manage. Therefore PRERs, which may call for significantly more monitoring and screening along the supply chain, could adversely affect existing and future production networks. On the other hand, properly managed global supply chains could be an effective measure to comply with PRERs. Based on experiences of the Malaysian electrical and electronics sector, it was found that multinational corporations (MNCs) and their suppliers have been less affected because technical information and support have been provided to member firms through supply chains (UNCTAD 2006, 125–127).

III. Global Supply Chains and Firms in Penang, Malaysia

Figure 1 shows a simple conceptual diagram of a supply chain. In this chapter, a GSC is defined as a supply chain supplying multiple markets overseas, in which procurement is done from multiple companies in multiple countries. Previous studies have looked at case studies or focused on a specific industry such as electrical and electronics to assess the impacts stemming from PRERs. These leave us with little to conclude about the extent to which PRERs (especially those concerning chemicals) affect the manufacturing sector as a whole, mainly because of insufficient data. That is, we do not always know which industrial subsectors are affected by a given PRER because an individual regulation on a final good could affect a wide range of industrial subsectors located in different countries through global supply chain linkages. Moreover, the magnitude and distribution of the impact and firms' preparedness to comply

can vary across industries and across countries, so to grasp the situation it is necessary to examine the impact in a comparative manner. Using the accumulated data from case studies, this paper attempts to examine how those cases represent the general economy-wide situation.

With this objective, we conducted firm surveys in Vietnam in 2011 and in Malaysia in 2012. This paper presents the results from the Malaysia survey. One of the research aims is to assess whether PRERs influence the structure of supply chains in a way that would have an important bearing for industrial development in developing countries.

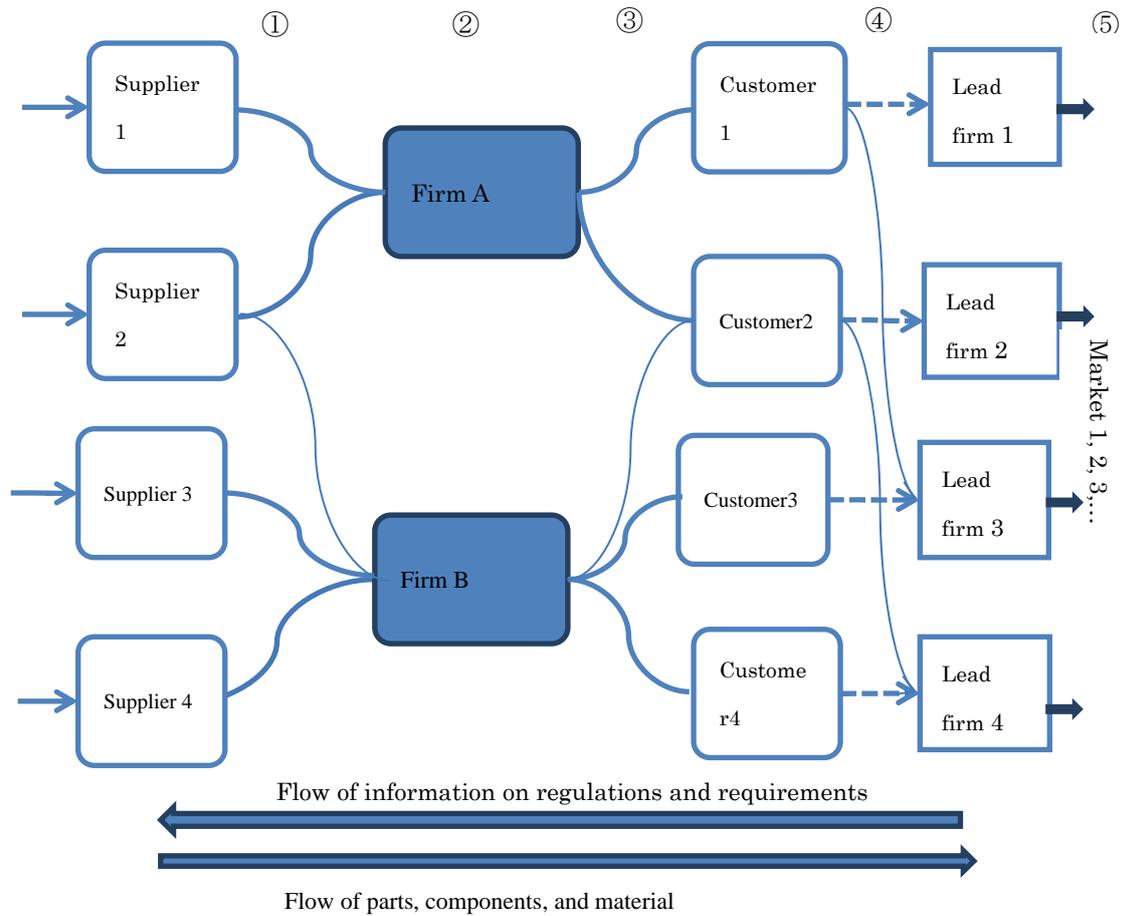
Technical regulations are often translated into private standards and requirements set by customers. We therefore address the impact of both voluntary private standards and mandatory technical regulations.

In our firm survey in Malaysia, we set the following two main research questions.

Question 1: What are the differences between GSC firms and non-GSC firms in terms of their knowledge and sophistication about chemical management?

Question 2: Do firms belonging to a GSC manage PRERs better than non-GSC firms in general? If so, what are the reasons for the difference?

Our *a priori* expectation is that firms belonging to GSCs (this also includes MNCs) manage PRERs better than non-GSC firms. In the following sections, we examine in detail the characteristics of firms in our sample.



- ① Relationship with suppliers
- ② Adoption process within a firm
- ③ Relationship with customers
- ④ Relationship with a lead firm
- ⑤ Market selection

Figure 1: Concept of supply chain

IV. General Information about the Sample

We collected data from firms in Penang, Malaysia from 2012 to 2013.⁹ Penang is the third largest state of Malaysia, after Selangor and Johor. It is a developed area and had the highest GDP per capita in Malaysia in 2010. A major industrial zone developed over the decades hosts a conglomeration of manufacturing industries that make a major contribution to the state and national economy (PE Research 2012).

⁹ Data were collected under a IDE-JETRO research project, “Impact of product-related environmental regulations on international trade and technological spillovers through supply chains in Asia.”

Our questionnaire was comprised of four sections: 1) basic information 2) input procurement and certification 3) chemical management 4) exporter status. Surveyed firms were sampled from firms recorded in the 2011 Penang Industrial Census. which includes data on 2,116 firms (1,898 manufacturing firms and 218 service firms). Beginning in November 2012, we contacted 732 firms by distributing questionnaires followed up by telephone calls. We received replies from 374 firms for a response rate of approximately 51%.¹⁰ Table 1 compares our collected sample with the Penang Industrial Census.

Table 1: Penang Industrial Survey 2011 and PRER survey

	Number of companies		
	Our sample	Penang Industrial Census	% sampled
Food products	34	201	20%
Beverages	6		
Textiles	8	68	26%
Wearing apparel	10		
Wood and products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	5	56	23%
Paper and paper products	10	86	12%
Printing and reproduction of recorded media	11		
Coke and refined petroleum products	1	110	17%
Chemicals and chemical products	18		
Basic pharmaceutical products and pharmaceutical preparations	3	30	10%
Rubber and plastics products	50	191	26%
Other non-metallic mineral products	1	28	4%
Basic metals	41	110	37%
Fabricated metal products, except machinery and equipment	60	355	17%
Computer, electronic and optical products	34	216	28%
Electrical equipment	15		
Machinery and equipment	23	261	9%
Motor vehicles, trailers and semi-trailers	3	32	28%
Other transport equipment	6		
Furniture	8		
Other manufacturing	23	154	15%
Repair and installation of machinery and equipment	1		
Wholesale trade, except motor vehicles and motor cycles	3		
Retail trade, except of motor vehicles and motor cycles			
Number of firms (N)	374	1,898	20%

¹⁰ The authors thank the local government, 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 the firms that kindly responded to our survey questionnaires.

Manufacturing Related Services:	
Logistics	58
Multimedia/ICT	23
Other Manufacturing Related Services	137
Sub-total	218
Total	2,116

Table 2 shows the distribution of firms' equity structure and employment size. 268 (72.6%) of the respondent firms are purely domestic firms and 69 (18.7%) of the respondent firms are wholly owned subsidiaries of multinational corporations (MNCs). There is a positive correlation between foreign equity share and employment size. In our sample, the largest number of parent countries of foreign subsidiaries and joint ventures are from Japan (29 companies), followed by Taiwan (22 companies), other ASEAN (20 companies), the US (17 companies), the EU (7 companies), and South Korea (2 companies).

Table 2: Firms' equity structure and employment size

Equity structure/ Employment	0-4 Micro		5-74 Small		75-200 Medium		over 201 Large		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
100% local	9	100	155	81.2	73	67.6	31	50.8	268	72.6
Joint venture	0	0	16	8.4	11	10.2	5	8.2	32	8.7
100% foreign	0	0	20	10.5	24	22.2	25	41	69	18.7
Total	9	100	191	100	108	100	61	100	369	100

In our sample, 69.4% of the firms are direct exporters. Table 3 shows the relation between the equity structure of firms and being an exporter. While 89.9% of foreign direct investment (FDI) firms are exporters, the share is lower for locally owned firms, of which only 63.5% are exporters. Nonetheless, domestic firms in Penang are engaging in export activities much more often than domestic firms in other countries.

Table 3: Firm equity structure and exporters

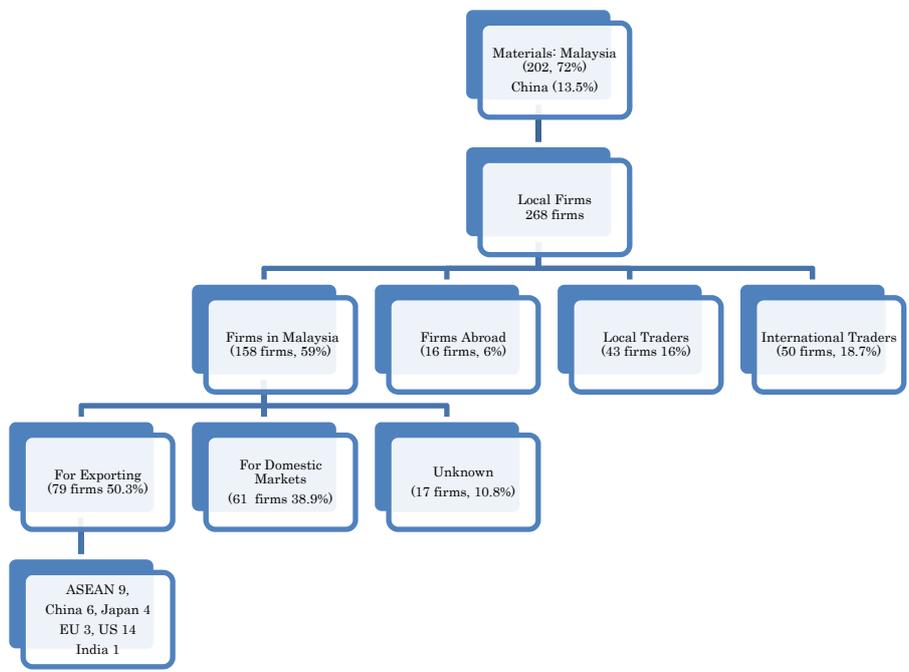
Direct exporter	Local firm		Joint Venture		FDI Firm		Total	
	No.	Col %	No.	Col %	No.	Col %	No.	Col %
Not exporting	103	36.5	3	16.7	7	10.1	113	30.6
Exporting	179	63.5	15	83.3	62	89.9	256	69.4
Total	282	100	18	100	69	100	369	100

V. Supply Chain Structure in Penang

To examine what kind of supply chains are established among FDI firms and local firms and to examine the function of supply chains, we attempted to characterize supply chain structures for domestic markets

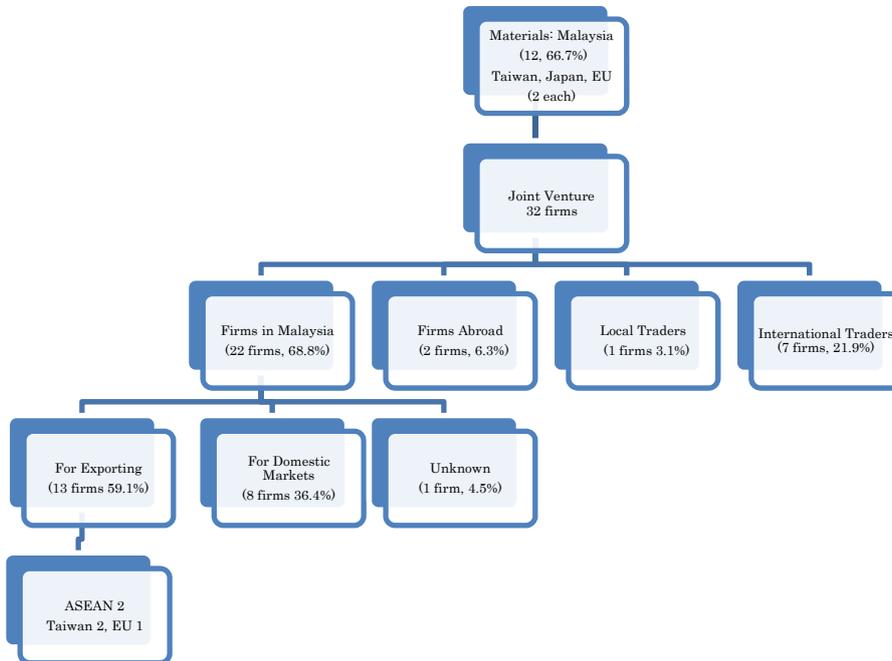
and for international markets. We asked the firms to categorize their customers into four groups: domestic manufacturing companies, foreign manufacturing companies, local trading companies, and international trading companies. We then asked about their suppliers, their customers and their lead firm, and the final destination markets. This information does not allow us to reconstruct the whole supply chain from sourcing to consumers, nor does it capture all customers and suppliers. However, it is helpful in identifying important relationships among major suppliers and customers and also the roles of a lead firm that might be only remotely connected to the local firm.

shows the supply chain structure of firms in the sample separately for local, joint venture, and FDI firms. It is clear from these figures that the destination markets for all three categories of firms are overseas markets once we take into account both direct and indirect exports. In the case of local firms, 59% of their customers are firms located in Malaysia, but through these firms about half of the products are finally exported. A rough estimate of export shares (including direct and indirect exports) can be calculated as the sum of shares of indirect exporters, international traders, and foreign firms and sales to domestic firms of products that are exported. By this calculation, 54% of the local firms, 68.8% of joint ventures firms, and 78% of FDI firms are connected to export markets.¹¹ FDI firms tend to have companies in foreign countries as customers. Among FDI firms, 22% directly export to firms abroad, while only 6% of local firms do so. Local firms tend to rely on international buyers for exports or to indirectly export their products by providing intermediate products to other firms for further processing before being exported.

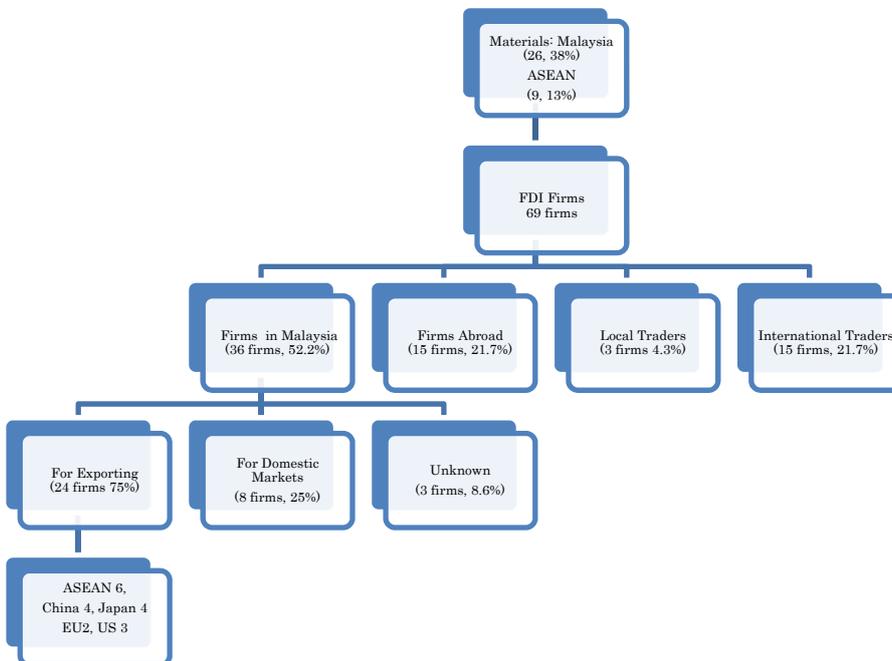


¹¹ Given that we do not have data on the destination markets for local traders, we assume that these are destined for the domestic market.

(1) Supply chains of local firms



(2) Supply chains of joint ventures



(3) Supply chains of foreign-owned firms

Figure 2: Supply chain structures

Table 4 shows the largest customers of domestic, foreign, and joint venture firms. It shows that 52.3% of

local firms sell their products to local customers such as local traders and other local (manufacturing) firms in Malaysia, while 62% of FDI firms supply directly to international customers such as international trading companies and firms in foreign countries. It is important to note that although the share of customers differs among local firms and FDI firms, both types of firms deal with all types of customers. Supply chains are interwoven among firms, both local and abroad, by domestic and international traders, and these chains are interdependent on one another. This implies that supply chain management is necessary for both local and FDI firms to be successful exporters.

Table 4: Largest customers

	Local firms		Joint Venture		FDI firms	
	No.	Share %	No.	Share %	No.	Share %
Local traders	97	26.6	4	16.7	8	10.1
Firms in Malaysia	94	25.8	7	29.2	11	13.9
Malaysia total	191	52.3	11	45.8	19	24.1
International traders	39	10.7	1	4.2	15	19.0
Firms abroad	41	11.2	5	20.8	34	13.9
International total	80	21.9	6	25.0	49	62.0

Note: Multiple responses were allowed so that the total number of firms is larger than the number of firms in the sample.

When we asked firms directly whether their company is connected to a global supply chain, 51.5% of firms answered positively. The share is higher for joint venture and FDI firms, as shown in Table 5. This also confirms that many local firms as well as multinational firms are participants in global supply chains. The FDI firms that do not belong to a GSC may be those which sell goods overseas to only a single market.

Table 5: Participation in GSC: Does your firm participate in global supply chains?

	Local firms		Joint venture		FDI firms		Total	
	No.	%	No.	%	No.	%	No.	%
GSC participant	127	46.4	13	72.2	46	66.7	186	51.5
GSC non-participant	113	41.2	4	22.2	17	24.6	134	37.1
Status unknown	34	12.4	1	5.6	6	8.7	41	11.4
Total	274	100.0	18	100.0	69	100.0	361	100.0

Note: In the questionnaire, we describe global supply chain as production chains with contributing multinational firms or with lead firms selling to multiple markets.

Regarding lead firms, 44 companies answered that their lead firms produce computers, 30 companies

produce electrical and electronics products, followed by machinery (18 companies) and rubber, plastic and fabricated metals (11 companies for each category). Table 6 shows the industries of lead firms of the firm surveyed. Not only are the lead firm industries very diverse, but their supply chains can span various industries.

Table 6: Lead firms' industries and their suppliers' industries

Lead firm industry	Supplier firm industry	No. of supplier firm industries
Food	Food, beverage, printing	3
Beverage	Beverage	1
Textiles	Textiles	1
Apparel	Apparel	1
Wood	Wood	1
Paper	Paper	1
Chemicals	Chemicals	1
Pharmaceutical	Pharmaceutical, rubber, fabricated metals, chemicals	4
Rubber/Plastic	Rubber, wholesale	2
Non-metallic mineral	Computer	1
Basic metals	Basic metals	1
Fabricated metal	Fabricated metal, machinery,	2
Computer	Computer, electrical product, machinery, basic metal, non-metal, rubber, chemicals	7
Electrical	Paper, rubber, basic metal, fabricated metal, computer, electrical	6
Machinery	Fabricated metal, machinery, wholesale, chemicals	4
Motor	Motor, machinery, electrical, basic metal, rubber	5
Other transport	Other transport, paper	2
Furniture	Furniture, basic metal, wood	3

Note: Other manufacturing sectors and trade sectors are excluded from the table.

VI. Measures Taken to Control Chemical Substances in Products

As Figure 3 shows, 225 firms answered they have taken measures about chemical substances in products. There is wide variation by industry in the propensity to take these measures. While all firms in the textile, pharmaceutical, and automotive sectors in the sample have taken some measures, less than half of wood and apparel companies have yet done so. This shows heterogeneity in chemical management in products across industries.

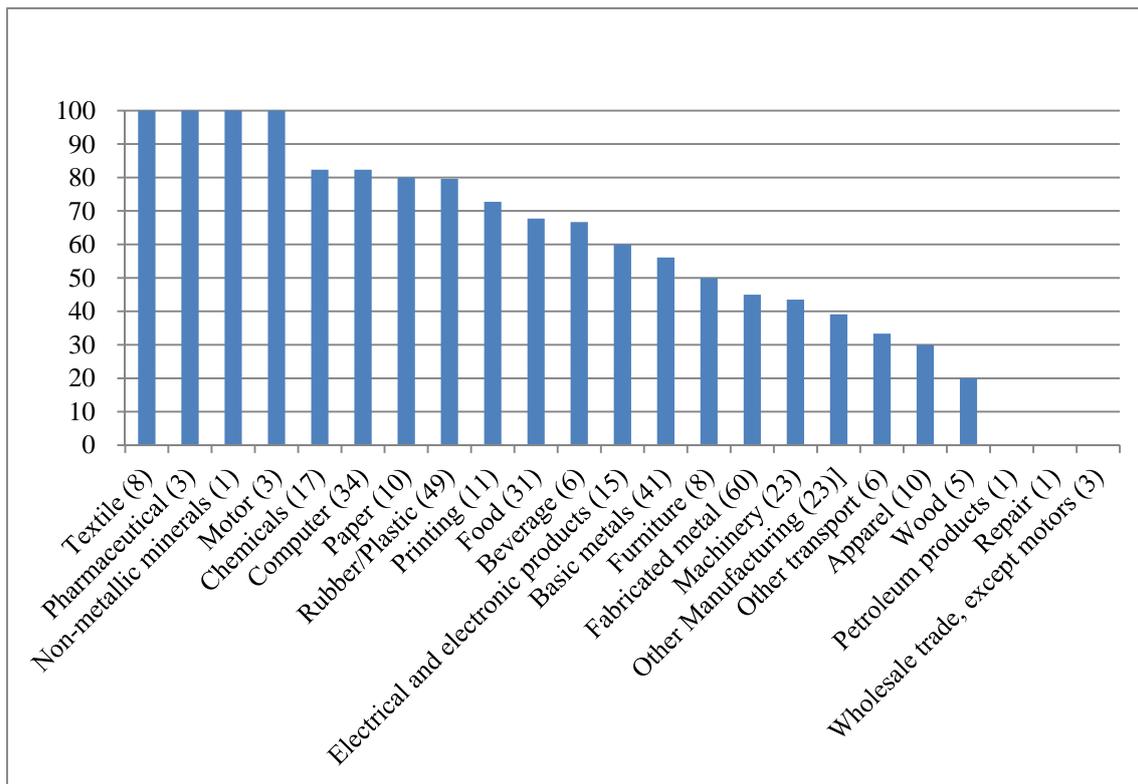


Figure 3: Proportion of companies that have taken measures

Similar to the variation in adaptation among industries, there are marked differences in their efforts among firms with different ownership types. More than three-quarters of foreign firms (78.3%) have taken some measures already, compared to 65.6% for joint ventures and 55.8% for local firms (see Table 7).

Table 7: Firms' equity structure and firms that have taken measures

	Measures taken		No measures taken		Total	
	No.	%	No.	%		
Local	149	55.8	118	44.2	267	100
Joint venture	21	65.6	11	34.4	323	100
Foreign	54	78.3	15	21.7	69	100
Total	224	60.9	144	39.1	368	

VII. Management of Chemicals in Products, within and outside Global Supply Chains

Because eco-minded countries, especially European and other developed countries, have introduced various voluntary and mandatory standards and regulations on chemical substances in products, it is expected that firms exporting to those countries would be more likely to be aware of the requirements for controlling and monitoring chemical substances in products. In practice, firms in a global supply chain can access information on PRERs imposed in a foreign market through several channels. Firms exporting directly to foreign markets have direct access to the information. Even if suppliers of intermediate goods in a supply chain do not ship their products directly to buyers in the foreign country, they export indirectly through their downstream buyers, who export the products incorporated in intermediate goods. In the case of such indirect exports, the suppliers can obtain information on PRERs from their buyers. Even if the suppliers do not know the details of a PRER, they can conform to the regulations simply by meeting technical specifications set by their downstream buyers. This indirect channel for transmitting PRER information would seem to be especially important for locally owned firms in developing countries and SMEs that lack resources and capabilities to search for information, understand technical requirements, create technical solutions, and make necessary investments to implement the proper measures.

These observations indicate that direct exporters in developing countries bring information on PRERs imposed by export markets to a global supply chain that includes indirect exporting suppliers. The indirect exporters would be able to obtain the information on regulations from their downstream partners. This transmission mechanism would be especially crucial for a “captive” global value chain, where suppliers are dependent on information and technical guidance from a dominant lead firm (Gereffi, Humphrey and Sturgeon 2005). Also, the information transmitted through the supply chain facilitates collaboration to meet PRERs among all the parties in the global supply chain. When the indirect exporting suppliers are more innovative, the lead firm can collaborate with their suppliers in a more interactive manner and take more advantage of the knowhow the upstream suppliers can provide. When the lead firm has transactions with global suppliers in the supply chain, the lead firm will be able to obtain technical information and assistance appropriate to comply with PRERs. In other words, the transmission of PRER information and the transfer of PRER-conforming management practices are partially determined by the governance structure of supply chains.

Lead firms tend to have globally recognized brands and reputations, and so are sensitive to risks to client

trust. They take advantage of their own capacities to develop international production and sales networks, invent state-of-the-art technologies and exert pressure on other parties in the supply chain. They export their products to countries where consumers pay more for safe products, so their business practices already incorporate management of PRERs. Consequently, lead firms are more likely to acquire and maintain up-to-date and accurate information on PRERs introduced in their markets. They use the information to optimize the internal management of chemical substances in their products, but their dominant position in GSCs also forces their suppliers to use the information they provide to meet the regulations faster and more efficiently than suppliers outside the supply chain. Such information sharing along the supply chain is beneficial for both the lead firm and its suppliers.

In contrast to lead firms within a GSC, non-lead exporting firms outside a supply chain will have more heterogeneous characteristics. Vertically integrated firms are often competitive in international markets as global branding firms, while non-lead exporters may have limited technical and managerial capabilities and export only irregularly or to buyers in less-developed countries where consumers might prioritize price over product safety. If non-lead firms outside a GSC are vertically integrated, they will have limited opportunities to utilize information available from their upstream suppliers compared with GSC firms. Therefore, it can be expected that lead (exporting) firms are more likely to respond to PRERs earlier and more effectively than non-lead exporting firms in GSCs, even though the latter would be more capable of satisfying the requirements than non-exporting firms outside GSCs.

To summarize, firms can be categorized into four broad types of internationalization on the criteria of export status and participation in a GSC: (1) exporting GSC firms who are exporters; (2) exporting non-GSC firms who are exporters; (3) non-exporting (or indirect exporting) GSC firms who are not direct exporters; and (4) non-exporting non-GSC firms who are not direct exporters. We postulate that measures for complying with regulations on chemical substances in products imposed in foreign markets is more likely to be undertaken by (1) exporting GSC firms than exporting non-GSC firms, and (2) exporting non-GSC firms than non-exporting non-GSC firms. The *a priori* difference between exporting non-GSC firms and non-exporting GSC firms is ambiguous, so this is an empirical issue.

To investigate these conjectures empirically, the variable for GSC participant firms defined in section 5 and the variable for exporters are combined to categorize the respondent firms in the survey into the four types described above. In this section, GSC firms are restricted to those that recognize an industrial category for their lead firm. As a result, the empirical investigation in this section includes 355 observations, of which 146 are exporting GSC firms (41.1% of the 355), 28 are non-exporting GSC firms (7.9%), 102 are exporting non-GSC firms (28.7%), and 79 are non-exporting non-GSC firms (22.3%).

Table 8: Firms by type of internationalization

	No.	%
GSC	174	49.0
Export	146	41.1
No export	28	7.9
Non-GSC	181	51.0
Export	102	28.7
No export	79	22.3
Total	355	100

Participation in GSC and adoption of PRER compliance measures for chemical substances

Table 9 shows that 220 of the 355 firms (62.0%) have taken or been asked to take PRER compliance measures for chemical substances. Among firms that have taken or been asked to take measures, 216 of the 220 firms have taken measures while only four firms have not taken any measures although they were asked to do so. When we look at the data on exports and participation in GSC, the difference among these firms shows clearly. Of the exporting GSC firms, 77.4% have introduced a measure. Among exporting non-GSC firms, 63.7% have done so, and among non-exporting GSC firms, 53.6% have done so. Only 34.2% of the firms that neither export nor participate in a GSC have taken or been asked to take measures about chemical substances. These figures indicate that internationalization significantly increases the likelihood that firms will take PRER compliance measures for chemical substances. As hypothesized, irrespective of participation in global supply chains, exporting firms are the most likely type to be encouraged or forced to adopt measures to monitor or control chemical substances in their products. Indirect exporters in a GSC are more likely to introduce such measures compared to domestic-oriented firms outside of GSCs.

Table 9: Firms taken or been asked to take PRER compliance measures for chemical substances

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Taken or asked	113	77.4	15	53.6	65	63.7	27	34.2	220	62.0
Taken	111	76.0	15	53.6	64	62.7	26	32.9	216	60.8
Asked	2	1.4	0	0.0	1	1.0	1	1.3	4	1.1
Neither	33	22.6	13	46.4	37	36.3	52	65.8	135	38.0
Total	146	100	28	100	102	100	79	100	355	100

Table 10 indicates that firms are not necessarily proactive toward the adoption of chemical substance management, even though 60.8% of the 355 firms have taken necessary measures. Among the 220 firms that have taken or been asked to take measures, only 8.6% of the firms (19 of 220) did so on their own initiative. The table also indicates that strong incentives originated in supply chains. Of the 220 firms that

took or were asked to take measures, about 73.2% and 35.5% were required or recommended to do so by their buyers and suppliers, respectively. Public organizations, such as standards authorities and industrial associations, play only a marginal role as initiator of requests for PRER compliance. By the level of internationalization, about 80% of the firms participating in GSCs regardless of their exporting status were motivated to adopt measures by their buyers. In contrast, only 11% of the sampled firms not participating in GSCs regardless of their exporting status used their own initiative to introduce measures. Although more than 30% of the 220 firms (irrespective of participation in GSCs) were recommended to take actions by suppliers, non-exporting firms outside GSCs were more likely to be dependent on information from suppliers.

Table 10: Who required/recommended that you take measures about chemical substances?

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Self-initiative	8	7.1	1	6.7	7	10.8	3	11.1	19	8.6
Buyers	89	78.8	12	80.0	44	67.7	16	59.3	161	73.2
Suppliers	38	33.6	5	33.3	24	36.9	11	40.7	78	35.5
Competent authorities	7	6.2	0	0.0	4	6.2	0	0.0	11	5.0
Industrial associations	7	6.2	1	6.7	4	6.2	2	7.4	14	6.4
Others	11	9.7	1	6.7	11	16.9	4	14.8	27	12.3
Total	113	100	15	100	65	100	27	100	220	100

Awareness of regulations and standards on management of chemical substances

The observations from Table 9 and Table 10 can be summarized as follows. More than 60% of the firms in Penang have already taken measures for chemical substances in products. Only a few firms that were asked to take measures have not done so. But most firms are not proactive in meeting the related regulations or standards. In particular, firms participating in global supply chains are most likely to have been encouraged by their downstream buyers in the chains to do so. Their upstream suppliers also play a key role in enhancing their buyers' awareness of the need for PRER compliance measures for their products.

These observations leave open the question of whether participants in GSCs actually absorb all the details of requirements for chemical ingredients in products. Table 11 shows that about 78% of exporting firms and 66.7% of non-exporting firms that took or were asked to take measures know which regulations or requirements demand a range of measures, regardless of whether they take part in GSCs. In other words, about 21% of the exporters and 33.3% of the domestic-oriented firms outside global supply chains have taken or been asked to take measures without any specific information on chemical-related regulations or private requirements.

Table 11: Do firms know which chemical regulations and private requirements require measures?

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Know	89	78.8	10	66.7	51	78.5	18	66.7	168	76.4
Do not know	24	21.2	5	33.3	14	21.5	9	33.3	52	23.6
Total	113	100	15	100	65	100	27	100	220	100

Table 12 provides a similar observation to that from Table 11. There is a significant difference in the knowledge of the Globally Harmonized System of Classification and Labelling of Chemicals (GHS)¹² between exporting and non-exporting GSC firms that already took or were asked to take measures. Some 33.6% of the former know about it, while only 13.3% of the latter have information on this system. Among non-exporting GSC firms, there is no significant difference in the awareness of GHS between those that did and did not adopt measures necessary for satisfying public or private requirements for chemical management. Such figures imply that indirectly exporting firms within GSC might not collect information on chemical-related regulations independently. It is possible that awareness of such requirements would have only a weak influence on non-exporting GSC firms' decisions to invest in meeting regulations. On the other hand, the percentage is significantly different between exporting GSC firms who have taken or been asked to take necessary measures (33.6%) and those who have not (12.1%). Therefore it would seem that directly exporting GSC firms are self-motivated to collect information on PRERs when they decide to take necessary measures.

An additional inference from Table 12 is the apparent high pressure to establish better chemical management on directly exporting GSC firms from export markets. In contrast to the results seen in Table 11, we see a significant difference in the recognition of GHS between exporting GSC and non-GSC firms: only 16.9% of the latter group is aware of GHS versus 33.6% of the former group.

¹² GHS categorizes chemicals by types of hazard and proposes harmonized labels and safety data sheets.

Table 12: Do firms know about GHS?

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Have taken/asked										
Know	38	33.6	2	13.3	11	16.9	3	11.1	54	24.5
Do not know	75	66.4	13	86.7	54	83.1	24	88.9	166	75.5
Subtotal	113	100	15	100	65	100	27	100	220	100
Have not taken										
Know	4	12.1	2	15.4	2	5.4	0	0.0	8	5.9
Do not know	29	87.9	11	84.6	35	94.6	52	100.0	127	94.1
Subtotal	33	100	13	100	37	100	52	100	135	100
All observations										
Know	42	28.8	4	14.3	13	12.7	3	3.8	62	17.5
Do not know	104	71.2	24	85.7	89	87.3	76	96.2	293	82.5
Total	146	100	28	100	102	100	79	100	355	100

Table 11 and Table 12 indicate that exporting firms are more likely to have opportunities and incentives to obtain information on chemical-related regulations and private standards imposed by their export markets, which are mainly in developed countries. This direct access to information on the requirements allows them to take necessary measures. They also provide their suppliers, who export indirectly through them, with the information in enough detail to take necessary action. Therefore, non-exporting firms that participate in GSCs are more likely to have taken or been asked to take measures than non-exporting firms outside GSCs, as shown in Table 11.

Behind the higher propensity of GSC firms to address chemical requirements may be the role of GSCs as a conduit for information on public and private requirements for chemical substances management. Table 13 shows that 57.1% of the indirectly exporting firms in GSCs were requested or recommended by their buyers to use certain inputs, versus only 36.7% for non-exporting firms outside GSCs. Without knowing the details of a country's requirements, indirect exporters within GSCs could comply with chemical regulations or standards from their buyers' export markets just by conforming to specifications set by their buyers.

Table 13: Do buyers specify or recommend inputs?

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Specified/recommended	114	78.1	16	57.1	64	62.7	29	36.7	223	62.8
None	32	21.9	12	42.9	38	37.3	50	63.3	132	37.2
Total	146	100	28	100	102	100	79	100	355	100

Approach to meeting regulations and standards on chemical substances in products

Even if firms have access to information on regulations and standards on chemical substances in products, it does not mean that they can comply. Firms need to take necessary actions against problems in fulfilling their requirements. Table 14 summarizes actions taken by firms to meet chemical-related regulations or standards. Among the actions listed in the table, “send products for testing,” “change production process,” and “change inputs” were the most common for all types of firms. Firms that participate in GSCs tend to change production processes rather than change inputs, whereas non-GSC firms tend to change inputs. One characteristic of non-exporting firms outside GSCs is the importance of investments in new production facilities. All of these actions, except testing of products, are related to improvements in production processes.

Table 14: Important actions taken for meeting chemical regulations

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Change production process	40	35.4	5	33.3	16	24.6	5	18.5	66	30.0
Invest in new production facility	17	15.0	2	13.3	6	9.2	5	18.5	30	13.6
Invest in testing facility	15	13.3	0	0.0	7	10.8	3	11.1	25	11.4
Send products for testing	51	45.1	7	46.7	28	43.1	13	48.1	99	45.0
Change inputs	35	31.0	4	26.7	18	27.7	7	25.9	64	29.1
Change product design	14	12.4	2	13.3	5	7.7	4	14.8	25	11.4
Obtain certification	14	12.4	0	0.0	12	18.5	4	14.8	30	13.6
Utilize private consulting service	10	8.8	2	13.3	3	4.6	3	11.1	18	8.2
Utilize external tech. assistance	9	8.0	0	0.0	4	6.2	0	0.0	13	5.9
Increase technical workers	7	6.2	1	6.7	2	3.1	1	3.7	11	5.0
Increase R&D investment	11	9.7	1	6.7	6	9.2	0	0.0	18	8.2
Others	24	21.2	6	40.0	18	27.7	8	29.6	56	25.5
Obs. (multiple answered allowed)	113	100	15	100	65	100	27	100	220	100

Table 14 shows the various measures that firms have already taken. If they lacked necessary resources, they could have gotten assistance from external entities such as their buyers, suppliers, and public institutions, or else they would not have been able to fulfill the requirements. Table 15 provides data on actions with or without some sort of support from external institutions.

As seen in Table 14, irrespective of participation in GSC or exportation, firms receive support mainly from suppliers, buyers, and government agencies. In particular, about half of all firms used assistance from their suppliers except for exporting GSC firms, which relied more on assistance from their buyers. Firms not participating in GSCs, especially non-exporting firms, make more use of assistance from government institutions. Non-exporting GSC firms are more dependent on their own human resources.

Table 15: Important organizations that helped in satisfying regulations on chemical substances

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Government/Government agencies	34	30.1	2	13.3	21	32.3	11	42.3	68	31.1
Universities/public research institutes	4	3.5	0	0.0	4	6.2	2	7.7	10	4.6
Industrial associations	10	8.8	1	6.7	4	6.2	2	7.7	17	7.8
Internal human resource	23	20.4	3	20.0	9	13.8	3	11.5	38	17.4
External Consultants	22	19.5	2	13.3	16	24.6	2	7.7	42	19.2
Buyers' assistance	54	47.8	5	33.3	17	26.2	6	23.1	82	37.4
Suppliers' assistance	49	43.4	8	53.3	33	50.8	13	50.0	103	47.0
International cooperation	3	2.7	1	6.7	2	3.1	2	7.7	8	3.7
Others	22	19.5	1	6.7	11	16.9	2	7.7	36	16.4
Obs. (multiple answered allowed)	113	100	15	100	65	100	26	100	219	100

Assistance from buyers and suppliers in a GSC can enable non-exporting firms in the chain to meet regulations or standards in a short period. Table 16 shows that 86.7% of the non-exporting GSC firms took less than one year to meet regulations. Although non-GSC firms that do not export also use assistance from their buyers and suppliers, 22.2% of them took more than five years to meet regulations. The greater time needed for appropriate chemical management by non-exporting non-GSC firms than by non-exporting GSC firms could be due to differences in buyers' requirements.

An additional finding shown in Table 16 is that 31.0% of the exporting GSC firms still took one to three years to meet regulations, even though they would generally have been more capable of chemical management than non-exporting GSC firms. As shown in Table 17, about 46% of the exporting GSC firms started taking or were asked to take necessary measures for the first time before 2000, while non-exporting GSC firms did so in the period of 2001–2007, when European countries started introducing strict regulations on chemical substances in products. The time period when firms started taking action may have had an effect on the amount of time firms required to meet regulations.

Table 16: How long did it take to meet regulations?

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
Less than 1 year	65	57.5	13	86.7	41	63.1	13	48.1	132	60.0
1–3 year	35	31.0	0	0.0	15	23.1	5	18.5	55	25.0
3–5 years	6	5.3	0	0.0	1	1.5	3	11.1	10	4.5
More than 5 years	7	6.2	2	13.3	8	12.3	6	22.2	23	10.5
Total	113	100	15	100	65	100	27	100	220	100

Table 17: First year in which measures were taken/asked to be taken

	GSC				Non-GSC				Total	
	Export		No export		Export		No export		No.	%
	No.	%	No.	%	No.	%	No.	%		
2010–2012	10	8.8	2	13.3	9	13.8	2	7.4	23	10.5
2008–2009	13	11.5	2	13.3	8	12.3	5	18.5	28	12.7
2006–2007	15	13.3	3	20.0	9	13.8	4	14.8	31	14.1
2001–2005	23	20.4	4	26.7	9	13.8	7	25.9	43	19.5
1995–2000	18	15.9	2	13.3	14	21.5	3	11.1	37	16.8
Before 1995	34	30.1	2	13.3	16	24.6	6	22.2	58	26.4
Total	113	100	15	100	65	100	27	100	220	100

Summary

The tables presented in this section present an overview of the awareness and response by firms in Penang to increasing requirements for managing chemicals in products so as to comply with PRERs. Almost all of the firms asked to take necessary measures on chemical substances in products accommodated requests from their buyers. Internationalization and participation in global supply chain both seem to influence whether firms take the necessary measures. Not only direct exporters but also firms exporting indirectly through global supply chains are more likely to do so than firms that neither export nor participate in a global supply chain.

For firms in Penang, their downstream buyers play the most important role in making them aware of the necessity for satisfying regulations related to chemical substances in products. Exporting firms can have more opportunity and incentive to secure direct access to information on chemical requirements, allowing them to take the necessary measures quickly. Especially when they need inputs or processes to produce goods free from harmful chemicals, they can also transfer to their suppliers (who are indirect exporters through themselves) related information with enough details to take necessary action at their facilities. There are also information flows from suppliers to buyers. Suppliers can provide their buyers with information on chemical substances they use, and whether their inputs and process comply with the regulations. Therefore, non-exporting firms that are part of a GSC are more likely to have taken or been asked to take measures than non-exporting firms that are not in a GSC. Their upstream suppliers also provide them with information on regulations obtainable from their other buyers, and may require or recommend to their buyers the measures necessary to maintain sales of their products. In this manner, interactions between buyers and suppliers as well as competitive pressures among suppliers within a supply chain may motivate firms to take compliance measures. Only a small proportion of the firms take measures on chemical substances on their own initiative.

Such observations illustrate roughly how information and measures about regulations diffuse into firms in Penang, but do not uncover the depth of firms' understanding of PRERs and similar regulations. In fact, the research data suggest strongly that firms that take compliance measures do not necessarily absorb all

the details of requirements for chemical substances in products. However, detailed information on regulations is not always critical. Firms can comply with chemical regulations or standards imposed in their buyers' export markets without knowing the full details of requirements by conforming to specifications set by the buyers. Buyer–supplier relationships within a GSC also facilitate the assimilation of effective solutions in the form of technical specifications.

Lack of a sufficient number of observations for non-exporting GSC firms is a limitation on the conclusions that can be drawn from this section. The small number makes it difficult to statistically verify differences between non-exporting GSC and non-GSC firms. Statistical regression analysis should be performed to examine the findings from this section.

VIII. Conclusion

As more countries pursue sustainable growth strategies, product-related environmental regulations will only increase in the future. This is not limited to developed countries since some developing countries are introducing similar measures (see Michida 2014). This means that firms exporting to regulated markets need to constantly gather and act on information so that their products meet the required safety and quality standards. What kind of impacts would this have on exports and industrialization in developing countries? We think that the increase in the number of PRERs may have detrimental effects on exporting firms in developing countries, especially if these firms are not already part of a global supply chain. While the lack of data on this issue has prevented researchers from assessing the exact magnitude of the potential problems, we can use the survey conducted in Penang to shed light on some of the evidence on this issue.

From the survey, it is apparent that most firms that have taken necessary actions for compliance in chemical management are direct exporters and those that are a part of global supply chains. For direct exporters, knowing the regulations and standards of the importing countries is a crucial component of their capacity to service the intended market. It is interesting that those firms that are not direct exporters but supply necessary materials to direct exporters also have taken actions. They are a part of the global supply chain, and for a final product to meet the PRERs, all of its inputs must also meet the requirements. Hence, the information and the requirements are transmitted through the supply chain. In contrast, those firms that are neither an exporter nor a part of supply chain lack the knowledge and information channels regarding the need for better compliance in chemical management of products. Therefore a smaller portion of them have taken necessary measures to comply. This means that the entry barrier to join a production network is becoming higher. To stimulate industrialization and export activities, governments need to pay attention to firms that are not direct exporters and are not a part of a GSC. Our survey shows clearly that such firms lack the necessary information sources for these kinds of regulations. Improvements in dissemination of this information, along with provision of necessary technical assistance may improve the likelihood of firms joining a GSC in the future. This kind of assistance should be also

provided to indirect exporters who are a part of a supply chain. While many of these firms have taken necessary measures to comply with the regulations, often under the guidance from their lead firm, they tend to lack fundamental understanding of why such regulations are introduced and why they need to comply. At present, many of these firms are reactive to the introduction of new regulations, rather than proactive. Even though they are able to keep their current business relationships within the supply chain, future improvements in their capacities will be needed for them to move up the supply chain. Otherwise, these firms will be captive players in a supply chain, forever depending on the lead firms (main buyers, from their point of view). These actions may be best performed by public laboratories, which often provide the necessary testing services to comply with these regulations for firms. In collaboration with industrial associations, public laboratories can be a source of knowledge and information channels for non-exporting non-GSC firms.

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