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Eco-Innovation in the Chemical Manufacturing Firms: Insights for Policy Response

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Abstract: *Designing effective policies to promote a firm's eco-innovation activities require policy makers to have significant knowledge on current industrial practices and activities. This paper investigates the state of eco-innovation activities, namely process, product and organisational eco-innovation in the chemical industry and further unveils common characteristics of firms that eco-innovate. Data was collected from interviews and surveys of 97 chemical firms. The results suggest that a large percentage of firms are involved in process technology and organisational eco-innovation and most of the innovation are adoptions rather than creations. Likewise, a higher percentage of foreign firms are eco-innovative. Export destination seems to play no role in improving the likelihood of firms to eco-innovate. The evidence suggests that local environmental policies are instrumental in encouraging eco-innovation. Policy implications are further discussed.*

Keywords: Chemical industry, eco-innovation, environmental policy, sustainable manufacturing
JEL classification: L23, L65, O30

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1. Introduction

Sustainability became a hot topic when it became clear the industrial revolution had adverse effects on the socio-ecological environment. Environmental policies and firm practices designed to cope with the growing environmental problems received increasing attention from scholars of different disciplines and fields (Guoyou, Saixing, Chiming, Haitao, & Hailiang, 2013; Dangelico, 2016). Eco-innovation was offered as a solution to major environmental problems (Triguero, Moreno-Mondéjar, & Davia,

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2013). Besides protecting the environment, eco-innovation provides a new impetus for green economic growth. Increasing resource scarcity coupled with extreme environmental problems entails a green growth model to achieve the state of green utopia. With regards to growth model, Schumpeter (1934) have long emphasised the importance of innovation for growth. Therefore, eco-innovation is a valuable component to reconfigure the existing innovation system within the growth model for an economy to embrace green growth characteristics. Eco-innovation boosted economic growth has led to the creation of new industries and jobs (Machiba, 2010). Firms are taking advantage of this transformation by adding value to their business and creating their own niche to remain competitive (Lozano, 2013). Additionally, with eco-innovation, firms are also able to offset costs induced by environmental regulations to protect the environment. Scholars have acknowledged the need for firms to eco-innovate in order to protect the environment and to foster green growth, arguing that market forces alone are not sufficient for firms to trigger eco-innovation. Additionally, environmental policies provide the required pressure and incentives for firms to eco-innovate (Dechezlepretre, Glachant, Hascic, Johnstone, & Meniere, 2011; Johnstone, Haščič, Poirier, Hemar, & Michel, 2012; Johnstone, Haščič, & Popp, 2009; Kneller & Manderson, 2012). In 1997, under Kyoto Protocol, the signatories were recommended to implement environmental policies to solve their environmental problems, as it was regarded highly efficient.

Nevertheless, formulating and designing policies to encourage eco-innovation requires an in-depth understanding of the state of eco-innovation in the industry including the characteristics of firms that eco-innovate. In addition, given that countries around the world are pursuing green growth via industrial policies, information becomes crucial for better policy options. The argument for government failure put forward by the market proponents is based on lack of information and political risks on the part of government to make proper interventions. Nevertheless, Rodrik (2014) argues that these policies can be improved through the design of institutional frameworks that counter informational and political risk. Responding to the above arguments and by considering Malaysia’s more than 40 years of experience implementing environmental policies, this study aims to investigate the state of eco-innovation in Malaysia particularly in the chemical industry. This study provides insights into ways to reduce some of the informational risk at least from the eco-innovation perspective which will be useful for policymakers. It provides an understanding of eco-innovation and proposes ways to ensure current policies are more efficient. In doing so, we attempt to answer the following research questions: a) what is the state of eco-innovation in the chemical industry? b) how far are those eco-innovations adopted or created by the firms themselves? This will indicate as to how far the chemical industry has embraced eco-innovation concept and practices.

The remainder of the paper is organised as follows: Section 2 presents the concept of eco-innovation while section 3 discusses research methodology and the study framework. Section 4 discusses major findings while section 5 focuses on the discussion and policy implications. The last section concludes the study.

2. Eco-Innovation - A Brief Review

Eco-innovation refers to "the creation or implementation of new, or significantly improved, products (goods and services), processes, marketing methods, organizational structures and institutional arrangements which - with or without intent - lead to environmental improvements compared to relevant alternatives" (Economic Co-operation and Development [OECD], 2009). The United Nation Environmental Program (UNEP) defines eco-innovation as the backbone to achieve the state of 'green utopia'- an ideal state of green economy in which the usage of energy, resources and materials are highly efficient (UNEP, 2008). Eco-innovation has the capability to conserve and regenerate resources by increasing the existing resource efficiency. Schmidheiny (1992) refers to it as "eco-efficiency", minimising the ecological impact of firms' manufacturing activities through the production of economically valuable products and services that meet the market demand by employing fewer resources. Therefore, eco-innovation has a huge potential to increase eco-efficiency (Machiba, 2010) and to reverse the damages to the socio-ecological system. Literature review shows the different types of eco-innovation activities which capture the state of eco-innovation. We consulted with experts and practitioners before undertaking a web survey. Three different types of eco-innovation were considered in this study, namely process, product and organisational eco-innovation. Table 1 provides a detailed description of the three different types of eco-innovation practices.

It is imperative for countries to assess their eco-innovation activities, as the concepts and practices of sustainable manufacturing are evolving overtime. In order to achieve a state of green utopia, economies are required to move away from eco-innovation that merely treats pollution and embrace eco-innovation that synergises industrial ecology. Therefore, determining the overall trend and practices in eco-innovation (i.e., creation, adoption, increasing, decreasing and transition such as from pollution control to lifecycle thinking) are important for policymakers, business managers and other stakeholders. These information is valuable for policymakers to assess their current environmental policies, benchmark their eco-innovation initiatives with the current practices of the firms and identify key eco-innovation drivers. This information is also important to develop a holistic eco-innovation framework for planning better innovation-oriented environmental policies (Kemp & Arundel, 2009). Additionally, it helps forward-moving firms that are adopting new business models to take into account the environmental aspect to remain competitive (OECD, 2009) to strategically allocate their resources and invigorate their existing capabilities. Availability of information on eco-innovation and its environmental benefits bolsters other stakeholders such as investors, research institutes, employees and others to adopt such practices.

Table 1: Types of Eco-innovation (EI)

Description	Source
Process Technology Eco-Innovation	
A new addition or improvements to the production process that totally changes or partially alters the way products are manufactured. This transformation minimises environmental harm during the production process and promotes efficient usage of resources. The change is largely aimed at operational activities. Example of EP: scrubbers, water treatment technologies, green energy technology.	(Cheng, Yang, & Sheu, 2014; Docter, Van Der Horst, & Stokman, 1989; Kemp & Arundel, 2009; Negny, Belaud, Cortes, Roldan, & Ferrer, 2012; Rennings, 2000)
Product Eco-Innovation	
Developing a new product or improving the features of the existing products in terms of technical components and materials. This transformation minimises environmental harm throughout the product lifecycle. Example of EPR: new eco-products, eco-buildings/houses.	(Bernauer, Engel, Kammerer, & Sejas, 2007; Carrillo-Hermosilla, Del Río, & Könnölä, 2010; Kemp & Arundel, 2009)
Organisational Eco-Innovation	
Facilitates and coordinates technical knowledge to eco-innovate as well as transforms the organisational structure and coordinates the entire infrastructure to minimise environmental harm. The focus is largely on organisational management practices. Example of EO: Pollution prevention schemes, EMAS, ISO14001.	(Bernauer et al., 2007; Birkinshaw, Hamel, & Mol, 2008; Cheng et al., 2014; Kemp & Arundel, 2009)

3. Methodology and Framework

3.1 Approach and Method

A mixed method was employed in this study, namely interviews and questionnaire survey, to collect data. Interviews with experts were aimed at capturing important dimensions of eco-innovation. Dimensions of eco-innovations (Kemp & Arundel, 2009) were discussed with three environmental consultants and practitioners in Malaysia to verify their relevance and applicability in the chemical firms in Malaysia. This helped refine the types of eco-innovation that suits the developing countries' perspectives. Secondly, interviews were conducted with four firms to further understand their eco-innovation activities. We used the refined list (see Table 2) to explore the state of eco-innovation using four face-to face semi structured interviews, which was organised with four chemical firms. In addition, the interviews were able to provide in-depth insights on the state of eco-innovation. To preserve the firms' anonymity, they were labelled as A1, A2, A3 and A4. Qualitative data obtained from the interviews were analysed thorough the use of categorisation (Strauss & Corbin, 2008).

To capture and generalise the state of eco-innovation, a web based survey was conducted. We targeted chemical firms located in the state of Selangor given a high concentration of chemical firms there. The survey consists of 12 binary scale items for three types of eco-innovations described in Table 1. Since there is no standard definition for each type of eco-innovation, several studies were reviewed to provide description for each type of eco-innovations as shown in Table 1. For each type of eco-innovation, respondents were required to select 'yes' or 'no' to confirm whether it was introduced or not for the period 2010 - 2015. If the eco-innovation was introduced, then the respondent needs to state whether it was an adoption or creation. Creation refers to newly developed and utilised eco-innovation by firms that replace or complement their existing innovation (Altmann, Rundquist, & Florén, 2011) while adoption refers to the acquisition of eco-innovation that is readily available in the market and customised to suit firm production and process specification (Khanna, Deltas, & Harrington, 2009). It involves modifications and adjustments, known as incremental innovation, made to the technologies or products to mitigate environmental problems. The Web survey questionnaire was emailed to all the 132 chemical firms in Selangor and 97 firms responded accounting for 73% response rate. Follow-up calls were made to ensure a good response rate.

3.2 Framework of Assessment and Techniques of Analysis

The study aims to capture the current state of eco-innovation and the evolution of the eco-innovation practices in the chemical industry.

Figure 1: Framework of assessment on the state of eco-innovation

Types of Eco-Innovation	**Dimensions/Technologies**
Process Technology Eco-Innovation	• Cleaning technology that treat pollution released into the environment: Pollution control technologies for air, water & soil (Scrubbers/dust collection system/waste water treatment) • Cleaner process technologies: New manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives • Waste management technologies/ equipment's (Incinerators/recycling equipment) • Environmental monitoring technologies and instrumentations • Noise and vibration control technologies • Green energy technologies (solar/wind/bioenergy)
Product Eco-Innovation	• Products that will have lower emissions when used • Products that are more energy efficient • New environmentally improved products or services for end users
Organisational Eco-Innovation	• Pollution reduction/prevention schemes that address source reduction, reuse and recycling, and energy consumption: To eliminate wasteful management practices • Formal systems of environmental management involving measurement and reporting. For example, ISO 14001, EMAS and other • Chain management: cooperation between companies to close material loops and to prevent environmental damage across the value chain

Adoption

Creation

Thus, the framework of assessment defines, identifies and measures the types of eco-innovation as well as captures the evolution of the eco-innovation practices. In order to capture the state of eco-innovation, 6 process technologies and 3 product organisational innovation were considered. These innovations are relevant in the context of developing countries. Figure 1 shows the framework of assessment of those dimensions.

Data analysis was conducted by computing the percentage of number of firms undertaking the various types of eco-innovation, including the nature of eco-innovation, undertaken by the firms. We employed chi-square test to examine the effects of ownership and export destination on the types of eco-innovation.

4. Findings

4.1 State of Eco-Innovation

Table 2 shows the state of eco-innovation in the chemical industry. From all the three types of eco-innovation, majority of the firms are involved in eco-innovation. Among them, 69% and 57% of the firms agree that they focus on cleaner technologies. On average, 50% of firms acknowledged introducing process innovation. Nevertheless, these technologies were adopted with incremental modification and were not created by the firms entirely. Nearly, 74-90% of the firms adopted process technologies and only 10-25% of the firms were involved in creating their own technologies. The aforementioned process technology eco-innovations are among the required pollution mitigation technologies under the Malaysia Environmental Quality Act, 1974. The results indicate that over the years, the firms have continuously invested in these mandatory technologies. The firms also highlighted that their investment into this type of innovation were primarily to reduce waste generation and to promote energy efficiency. Furthermore, they are constantly seeking advanced technologies and solutions to replace or improve their existing capacity. For green energy technology, 75.3% of firms indicated that they are still heavily dependent of non-green energy technologies, despite clean energy resource being an important issue for the top management. However, a few firms responded that they are using green energy source from methane and steam, which is generated from their by-product/waste (i.e., IETS/WWTP, H2Richoffgas). Data shows that most of the process technology eco-innovations are adopted. Interviews revealed that adopting these technologies is a better option, as it is cheaper and readily available. Technology creation is also taking place at a small scale but to a large extent, it only complements existing technologies.

"For now, we prefer adoption, its much cheaper and readily available. In-house process innovations do take place and most of these innovation complements the existing technologies that we have."(Respondent A3)

Table 2: State of eco-innocation (IE) in the chemical manufacturing firms

Types	During the five years, 2010-2015, did your enterprise introduce any new or significantly improved of the following:	Yes (%)	No (%)	Adoption (%)	Creation (%)
Process Technology Eco-Innovation (EP)					
	Cleaning technology that treat pollution released into the environment: Pollution control technologies for air, water & soil (Scrubbers/dust collection system/waste water treatment) **(EP1)**	69.07	30.93	74.62	25.37
	Cleaner process technologies: New manufacturing processes that are less polluting and/or more resource efficient than relevant alternatives **(EP2)**	56.70	43.30	78.18	21.81
	Waste management technologies/equipment(Incinerators/recycling equipment) **(EP3)**	52.58	47.42	86.27	13.72
	Environmental monitoring technologies and instrumentations **(EP4)**	55.67	44.33	88.88	11.11
	Noise and vibration control technologies **(EP5)**	41.24	58.76	90.00	10.00
	Green energy technologies (solar/wind/bioenergy) **(EP6)**	24.74	75.26	87.50	12.50
Product Eco-Innovation (EPR)					
	Products that will have lower emissions when used **(EPR1)**	44.33	55.67	53.49	46.51
	Products that are more energy efficient **(EPR2)**	47.42	52.58	54.35	45.65
	New environmentally improved products or services for end users **(EPR3)**	53.61	46.39	57.69	42.31

Table 2: (Continued)

Organisational Eco-Innovation (EO)				
Pollution reduction/prevention schemes that address source reduction, reuse and recycling, and energy consumption: Which eliminates wasteful management practices **(EO1)**	70.10	29.90	58.82	41.18
Formal systems of environmental management involving measurement and reporting. For example, ISO 14001, EMAS and other **(EO2)**	53.61	46.39	71.15	28.85
Chain management: cooperation between companies so as to close material loops and to prevent environmental damage across the value chain **(EO3)**	42.27	57.73	53.66	46.34

Data show that product eco-innovation, compared with process and organisational eco-innovation, accounts for the largest share of a firm's R&D. Stringency of environmental standards imposed on chemical products, both locally and internationally, has been the main reason for investment in product eco-innovation. Furthermore, interviews with firms suggest that there is a huge demand for Malaysian chemical products as they are of high quality and comply with international environmental standards. Thus, to retain their market share and to remain competitive the products should have environmentally friendly features. Taking all these factors into consideration, firms have to constantly upgrade their R&D facilities and search for advanced solutions and materials to improve their products. Additionally, firms have embraced product lifecycle approach to reduce the ecological impact of using their products. Three types of eco-innovation that exhibits three features - emission level, energy efficiency as well as green products - were examined. The results showed that 53.6% of the firms introduced new environmentally improved products, 47.4% and 44.3% of the firms introduced energy efficient and low emission products respectively. Since chemical firms deploy a product life cycle approach, the firms have improved specific aspects of chemical products such as reduced derivatives, design for degradation and others (Anastas & Warner, 1998), which are captured by new environmentally improved products. About 55.8% and 44.8% of all three types of product eco-innovation are through adoption and creation respectively. In comparison to process eco-innovation and organisational eco-innovation, product eco-innovation has a greater level of creation.

> *"Taking into account the stringent environmental standards in overseas and Malaysia and also the huge market for our chemical products, we conduct greater product related R&D. Malaysian chemical products are of good quality and we comply with all the international standards. To protect our market, green chemical products are important." (Respondent A3)*

> *"Our facilities are upgraded to conduct product related research. Over here, we use product life cycle approach... There is tough competition out there, to survive we have to follow the trend." (Respondent A4)*

According to their firms organisational innovation is imperative to increase their environmental performance in the long-term. Environmental management and pollution prevention system assisted the firms in integrating every effort, resources and capabilities to solve their environmental problems. With such a system in place, the firms indicated identification and rectification of environmental issues is more effective and it is easier for the top management to monitor the achievement of their environmental strategies. The results indicated that 70.1% of firms introduced pollution prevention schemes from 2010 to 2015 with minor modifications and 53.6% of firm employed formal environmental management systems during that 5 years. For pollution prevention schemes, even though the adoption (58.8%) is greater than creation (41.2%), a significant number of firms are developing their own pollution prevention schemes. For formal systems of environmental management, however, the results indicated otherwise. Furthermore, firms indicated that adoption of organisational eco-innovation was necessary at the initial stage, as it provided the firms with ideas and 'technical know-how' before the firms independently developed their own organisational eco-innovation.

> *"For us there are carefully administered environmental management schemes and plans, because the business that we are in there is no room for mistakes. These systems integrate every aspect of environment, which automatically makes the execution and monitoring of environmental goals much easier…we adopt the existing ones here and there, but we have our very own structure". (Respondent A4)*

Interestingly, besides pollution reduction/prevention schemes and formal systems of environmental management, firms are seriously venturing into chain management to further reduce their carbon footprint. Firms indicated that they are going to greater lengths from involving their suppliers and vendor to close material loops throughout the supply chain. Firms deemed this was necessary for two reasons. First, there is increasing pressure from their trading partners, as they impose stringent environmental standards on almost every process of chemical manufacturing. Second, to remain competitive, firms need to look at emerging environmental issues, chain management. In the five-year period, 42.3% of firms introduced chain management, 53.7 % through adoption and 46.3% through creation. Notably, as chain management is an emerging issue almost 50% of the firms had created their own mechanisms to tackle this issue.

> *"We have started working on chain management very seriously now. Realization among companies is there, that looking into this area rewards long-term sustainability...procedures and mechanism are there in place to close material loops throughout the supply chain but with new emerging issues and requirements from trading partners more need to be done". (Respondent A1)*

> *"We have our own system, which takes into account every single thing that we do. This system allows us to track problems ...besides internal environmental management we do manage our suppliers, which is a larger requirement under our green bending procedures. Before we accept any vendor we thoroughly audit them first. In fact, we even audit 'Kualiti Alam' (Malaysia's integrated waste management company)". (Respondent A2)*

4.2 Firm's Ownership, Export Destination and Eco-Innovation

We examined some of the firms' characteristics to determine the intensity of eco-innovation activities. In the literature on innovation, ownership matters, especially in developing countries. Likewise, there is a wide spread believe that export destinations matter when it comes to eco-innovation. Firms exporting to destinations that have stringent environmental regulations are likely to be more eco-innovative than those who export elsewhere. Table 3 shows the percentage of firms that have introduced eco-innovation and their nature. A relatively higher percentage of foreign firms (58%) have introduced eco-innovation compared with local firms (47%). Likewise, 53% of the firms exporting to countries with stringent environmental rules and regulations undertake eco-innovation compared with only 48% of those exporting to the countries with lax regulations. However, the difference is marginal – about 5%.

Table 3: State of eco-innovation (EI) by ownership and export destination

	% of firms introducing eco-innovation (2010-2015)	**Adoption** (%)	**Creation** (%)
Ownership			
Domestic	46.99	77.62	22.38
Foreign	58.06	59.26	40.74
Export Destination (Environmental Regulation)			
Stringent	53.48	64.59	35.41
Lax	47.62	79.17	20.83

Note: The figures indicate percentage of firms that introduced eco-innovation for all the three types of eco-innovations (Process E1: EP1–EP6; Product eco-innovation: EPR1–EPR3; Organizational eco-innovation: EO1–EO3) during 2010-2015.Total number of firms = 97 (local owned = 66, foreign owned = 31. Local/foreign ownership is classified based on 51% and above of local/foreign shareholding and vice versa.

We further explore each type of eco-innovation by ownership and export destinations. Table 4 shows the percentage of foreign and local firms undertaking eco-innovation for each type of eco-innovation. It appears that foreign owned firms are more eco-innovative than the local ones (see Table 4) particularly on EP1, EP2 and EPR1. Foreign influence within the firm is an extremely important factor to promote eco-innovation. Additionally, these firms largely introduced process related eco-innovations, which are imperative to reduce environmental harm throughout the production process. Similarly, locally constituted firms – ownership wise - are also introducing process related eco-innovations but these process eco-innovations are basic types of eco-innovations required to mitigate pollution (environmental monitoring, noise and vibration control technologies). Next, considering the nature of eco-innovation from the firm owners' perspective, the results show that both firms, foreign and local, are net adopters. Local firms recorded the highest average percentage of adoption, 77.8%, while it was 60.8% for foreign owned ones (see Table 4). The rate of adoption for both the ownership types is highly concentrated in the process technology and organisational eco-innovation category. Interestingly, foreign firms involve in more creation related product eco-innovation and to some extent organisational eco-innovation. This suggests that local firms should further catch-up in terms of creating their own environmental friendly products to remain competitive in the global market.

We examined the importance of export destination. A firm's export destination was divided into those stringent environmental regulation and those with lax environmental regulation.

Table 4: State of eco-innovation by ownership

	% of Firms Introduced EI				**Local**		**Foreign**	
Types of EI	**Local (%)**	**Foreign (%)**	χ^2	***p*-value**	**Adoption (%)**	**Creation (%)**	**Adoption (%)**	**Creation (%)**
EP1	62.3	85.70	5.103	0.024**	77.78	22.22	66.67	33.33
EP2	49.3	75.0	5.369	0.021**	86.67	13.33	68.18	31.82
EP3	50.7	57.1	0.329	0.566	96.67	3.33	70.59	29.41
EP4	53.6	60.7	0.406	0.524	93.75	6.25	83.33	16.67
EP5	42.0	39.3	0.062	0.804	96.15	3.85	72.73	27.27
EP6	23.2	28.6	0.310	0.578	84.62	15.38	90.00	10.00
EPR1	44.9	75.0	7.243	0.007***	70.37	29.63	41.67	58.33
EPR2	39.1	57.1	2.619	0.106	66.67	33.33	38.89	61.11
EPR3	47.8	46.4	0.016	0.901	65.52	34.48	42.86	57.14
EO1	68.1	75.0	0.450	0.502	66.67	33.33	43.48	56.52
EO2	52.2	57.1	0.198	0.657	71.88	28.13	64.71	35.29
EO3	39.1	50.0	0.964	0.326	56.52	43.48	46.67	53.33
Average	**47.69**	**58.92**			**77.77**	**22.23**	**60.82**	**39.19**

During the interviews, firms were required to provide a list of countries which imposed stringent and lax environmental regulation on their exports.

This list was further refined and calibrated with the environmental regulatory regime index (ERRI) score that ranked countries based on the quality of their environmental regulation system (Esty & Porter, 2001). During the survey, firms were required to list two major export destination of the firms. The country information was then coded '1' for stringent environmental regulation export destination and '0' for lax environmental regulation export destination. In the case of Malaysia, chemical products are the second largest export. The industry faced immense pressure in the area of technological competition related to environmental protection issues and regulations (Faucheux, 2000) such as ISO14001, Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), Environment, Health and Safety (EHS) and Restriction of Hazardous Substances Directive (RoHS). Firms have indicated that it is a mandatory requirement for them to comply with these regulations in order to stay competitive. Table 5 shows a list of countries that imposed stringent environmental regulation on Malaysian exports. According to the ERRI, five out of the six countries that was listed by the firms are among the top 20 countries with stringent environmental regulation. Therefore, Malaysia would have faced significant pressure to eco-innovate when exporting to countries with stringent environmental regulations. Singapore is among the top five destination for Malaysia's chemical products (Ministry of International Trade and Industry [MITI], 2014). About 21%, 14% and 13% of the firms export to Singapore, European Union and Japan respectively (see Table 5) while United States (9.3%), Korea (8.2%) and Australia (7.2%).

Table 5: Export - Countries with stringent environmental regulations

Export destination	Ranking (ERRI)	Percentage of firms
Singapore	3	20.6%
European Union	Average 9.3	14.4%
-*Germany*	7	
-*France*	8	
-*United Kingdom*	13	
Japan	17	13.4%
United States	14	9.3%
Korea	37	8.2%
Australia	16	7.2%

Note: Environmental regulatory regime index (ERRI) ranks countries based on the quality of their environmental regulation system. The index includes regulatory stringency, structure, subsidies and enforcement sub index. To represent European Union, the rank for these largest economy (GDP) was used (7+8+13=9.3). Total firms = 97.
Source: Author and ERRI (Esty & Porter, 2001).

Table 6 shows the percentage of firms eco-innovating based on export destinations. As for export destinations - those exporting to countries with stringent regulations versus those exporting to countries with more lax regulations - the results show that a higher percentage of firms eco-innovative when they export to countries with stringent regulations. On average, 53% of the firms exporting to countries with stringent regulation eco-innovative compared with 48% of those exporting to countries with lax regulations. Nevertheless, statistically, there is no significant evidence that export destination matters except for EP1 and EPR1. This may be due to the fact that the chemical industry - regardless of export destination - to some extent have to be more environmental friendly compared with other types of industry since they are one of the most highly polluting industries. Indeed, local environmental rules and regulations may have played a more important role than export destination. Again, firms are largely adopting eco-innovation regardless of export destinations.

5. Discussion and Policy Implication

Based on our interviews and data analysis, it can be inferred that a large number of firms still depend on end-of-pipe solution. They directly adopt these technologies to comply with environmental requirements set by the authorities to treat pollutants before they pollute the atmosphere. The nature of environmental regulation in Malaysia, which has long emphasised enforcement and monitoring to treat pollution, is the reason for firms to be comfortable with end-of-pipe solutions. However, this effort is definitely not sufficient to promote long-term sustainable manufacturing. Firms have to move away from process EIs that mere treat hazardous chemicals before releasing them to the environment to process eco-innovations that prevent and minimise the usage of such chemicals. The Ministry of Natural Resource and Environment intends to promote the cradle-to-cradle principle among firms (Ismail & Julaidi, 2015). For this to work, initiatives to push firms to adopt more advanced pollution mitigation strategies and process eco-innovations are required. Furthermore, from all the three types of eco-innovation, the commercialisation of process eco-innovations has the highest economic value, as the profit margin is greater. Thus, the adoption of process eco-innovations is greater than creation. Policies that encourage home-grown process eco-innovations are urgently required to harness the benefits if Malaysia does not want left behind in the green technology race. It is interesting to know that firms are introducing green energy technologies (EP6), however, percentage of firms introducing this process technology innovation is still low

Table 6: State of eco-innovation by export destination

	% of Firms Introduced EI				Stringent Regulation		Lax Regulation	
EI	**Stringent (%)**	**Lax (%)**	χ^2	*p*-value	**Adoption (%)**	**Creation (%)**	**Adoption (%)**	**Creation (%)**
EP1	76.36	59.52	3.161	0.075*	73.81	26.19	72.00	28.00
EP2	60.00	52.38	0.563	0.453	75.76	24.24	81.82	18.18
EP3	50.91	54.76	0.142	0.707	78.57	21.43	95.65	4.35
EP4	60.00	50.00	0.965	0.326	87.88	12.12	90.48	9.52
EP5	36.36	47.62	1.245	0.265	80.00	20.00	95.00	5.00
EP6	21.82	28.57	0.583	0.445	91.67	8.33	83.33	16.67
EPR1	63.64	40.48	5.136	0.023**	45.71	54.29	76.47	23.53
EPR2	49.09	38.10	1.167	0.280	40.74	59.26	75.00	25.00
EPR3	50.91	42.86	0.619	0.431	46.43	53.57	72.22	27.78
EO1	74.55	64.29	1.196	0.274	48.78	51.22	77.78	22.22
EO2	54.55	52.38	0.045	0.832	73.33	26.67	68.18	31.82
EO3	43.64	40.48	0.097	0.755	50.00	50.00	58.82	41.18
Average	**53.49**	**47.62**			**66.06**	**33.94**	**78.90**	**21.10**

Note: The figures indicate the percentage of firms that introduced each of the EIs according to export destination.

For the period of 2010-2015, almost 50% of the firms ventured into product eco-innovation which the largest share of R&D allocations compared with process and organisational eco-innovation. Besides improving energy efficiency and lower emission feature of the products, firms are actively changing other specific features (i.e., chemical related) of the products as well. This is entirely due to the product lifecycle approach that firms have currently employed. Firms are also creating their own green products to secure their market share and to explore the wide green product market to remain competitive. The findings suggest that firms are ripping huge benefits by greening their products because Malaysian chemical products are recognised for their quality and compliance with environmental standards. Understanding the reputation that Malaysian chemical products have gained internationally and the chemical industry being the second largest export sector of the country, Malaysia has a comparative advantage by seriously venturing into green chemical products. Issues that require immediate attention by policy makers are patent and institutional support. As there is an influx of green products, the authorities have to increase the sophistication of the patenting system (i.e., specifically for eco-innovations), which is currently lacking. Overwhelming institutional support is vital as firms invest in product eco-innovation R&Ds, which takes into account advanced manufacturing approach such as product lifecycle. Thus, for now, research laboratories and training centres must at least be equipped with facilities that churns research and human resource according to product lifecycle principles and practices.

The findings revealed that the level of organisational eco-innovation that firms have acquired so far has advanced from just treating environmental problems to managing them. Firms are aware that in order to increase their environmental performance a collective organisational involvement is important (Brunnermeier & Cohen, 2003) as well as a strong interplay between each type of eco-innovation, to holistically tackle environmental problems (Cheng et al., 2014). Therefore, firms have adopted a systematic environmental management approach, where firms use organisational eco-innovations to integrate each environmental initiative to improve their environmental performance. This integration allows them to execute their environmental strategies more effectively, as the implementation and monitoring of these strategies becomes much easier. For organisational eco-innovation, there is greater level of creation compared with process eco-innovation. Firms have developed their own unique ways to manage their resources, materials and stakeholders, which either directly or indirectly contributing to their environmental performance. In addition to increasing their eco-efficiency through systematic environmental management organisational eco-innovations, firms are using these organisational eco-innovations to slowly embrace lifecycle thinking approach as make serious efforts to greening their supply chain. The lifecycle thinking approach that firms are embracing is highly related to the cradle-to cradle principles that the Ministry of Natural Resource and Environment Malaysia is planning to promote. Therefore, policies that assist the firms in their transition from organisational eco-innovations that manage their environmental issues to organisational eco-innovations that extend their environmental responsibility by greening their entire supply chain is important. Policies are important to provide firms with proper guidance and knowledge. Malaysia Investment Development Authority and Ministry of International Trade and Industry have a role to play in this regard. Besides promoting investments, these government agencies should involve in supporting and promoting the innovative culture within firms through various mechanisms. Indeed, given that the nature of the chemicals industry in Malaysia exhibit a strong backward and forward linkages within the sector and between other sectors in the economy it is easier to promote the industry to move to the next level with the right policies.

Additionally, data suggest that foreign presence within the local firms has influenced major aspects of a firm's innovative capability through the provision of knowledge and resources via collaborations. Foreign presence has definitely influenced the local firm's behaviour towards the environment and the environmental integration and the level of eco-innovation that firms have achieved so far. A number of studies have shown that a certain degree of foreign ownership within a firm especially in developing countries leads to greater probability for the firm to adopt international certification (i.e., ISO14001) (Fikru, 2014; Prakash & Potoski, 2007). In addition to pressure from international linkages to adopt international certification, the adoption of corporate environmental practices as a result of foreign affiliation will boost company growth. Furthermore, given that technological development in the Malaysian manufacturing sector is largely due to a strong foreign presence (Chandran, Rasiah, & Wad, 2009) it is important to foster a closer partnership between them.

6. Conclusion

It has been proven that eco-innovation has the capability to increase a firm's environmental performance and promote green innovation-led economic growth. Recognising the importance of eco-innovation, Malaysia has embarked on various polices to either directly or indirectly stimulate eco-innovation. However, there is no effective account of the current state of eco-innovations in Malaysia. Scholars have highlighted that the knowledge of the current state of eco-innovation is important mainly for policy makers to gauge the performance of their past environmental policies and to design more robust innovation-oriented environmental policies. This information also assists environmentally committed business managers who plan to adopt green business models. Our results showed that large percentage of chemical firms are involved in process technology and organisational eco-innovation. Most of the innovation are adoptions rather than creations. Likewise, a higher percentage of foreign firms are eco-innovative. Export destination seems to play no role in improving the likelihood of more firms to eco-innovate. Evidence suggests that local environmental policies are instrumental in encouraging eco-innovation. Examining the current state of eco-innovation, it is suggested that the government focuses on innovation-oriented environmental policies that focus on lifecycle thinking manufacturing initiatives especially encouraging firms to advance from eco-innovations that merely treat pollutants to eco-innovation that manages the entire green supply chain. Indeed, to further boost the level of eco-innovation and to promote eco-innovation driven economic growth, policy makers need to identify mechanisms (e.g incentives and other forms of mechanism) to encourage collaboration between the foreign and local firms. This study is not without any limitations. It only reports the percentage of firms undertaking different types of eco-innovation. Likewise, only ownership and export destination were considered when examining characteristics of firms in terms of their eco-innovation. Further research is required to unveil the common drivers of eco-innovation in the chemical industries.

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