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The link between eco-innovation and business performance: a Taiwanese industry context

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ABSTRACT

In practice, there are various types of eco-innovation. While each type of innovation has its own attributes, determinants, and contribution to business performance, it is not effective to implement eco-innovation programs without a holistic view. This study draws from the resource-based view theory to investigate inter-relationships among three types of eco-innovation (process, product, organizational) and their relative impact on business performance. Using structural equation modeling with 121 samples collected from Taiwan Environmental Management Association, we find that eco-organizational innovation has the strongest effect on business performance. Additionally, eco-process and eco-product innovations partially mediate the effects of eco-organizational innovation, and eco-product innovation mediates eco-process innovations' effects on business performance. Business performance is directly and indirectly affected by eco-organizational, eco-process, and eco-product innovations. The findings suggest that, in order to develop effective eco-innovation programs, managers must understand the interdependence and co-evolutionary relationships between different types of eco-innovation. Overall, this study extends the discussion of innovation to the area of environmental innovation or eco-innovation.

1. Introduction

Many organizations have advocated innovation programs pertaining to environmental management to effectively reduce waste and improve the utilization of scarce resources (Carrillo-Hermosilla et al., 2010). Kemp and Pearson (2008, p. 7) referred to those innovative programs in relation to environmental management as *eco-innovation*, which is defined as "The production, assimilation or exploitation of a product, production process, service or management or business methods that is novel to the organization (developing or adopting it) and which results, throughout its life cycle, in a reduction of environmental risk, pollution and other negative impacts of resources used (including energy use) compared to relevant alternatives." With the ever increasing pressure from the government and marketplace regarding manufacturing sustainability, developing an effective eco-innovation program and making it an integrative part of a firm's management programs is important (Carrillo-Hermosilla et al., 2010; Dangelico and Pujari, 2010).

In practice, there are various types of eco-innovation (OECD and Eurostat, 2005, p. 16), including product innovations, process innovations, organizational innovations and marketing innovations. While each type of innovation has its own attributes, determinants, and contribution to environmental performance (Christensen, 2011; Damanpour et al., 2009), researchers have cautioned that it is not effective to implement innovation programs separately without a systemic view (Damanpour et al., 2009; Chou et al., 2012; Xing et al., 2013). Nonetheless, previous studies have mostly focused on the development and performance of individual eco-innovation programs (e.g., Pujari, 2006; Anttonen et al., 2013), such as product service innovation (Maxwell et al., 2006), service innovation (Chou et al., 2012; Xing et al., 2013), technological innovation (Moore and Ausley, 2004; Tseng et al., 2013), and infrastructure and policy innovation (Rehfeld et al., 2007; Shin et al., 2008).

Developing eco-innovation without a holistic view could be counter-productive. For instance, several researchers addressed eco-innovation issues from a purely technological perspective (e.g., Dangelico and Pujari, 2010; Weinberger et al., 2012). Socio-technical system theory argues that implementing innovations

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should be coupled with proper social and managerial systems in order to optimize business performance (Cummings and Srivastva, 1977). In addition, an organization must be able to adjust and fine-tune its structure and internal activities to support technological aspects of eco-innovation (Lam, 2005). Brunnermeier and Cohen (2003) and Horbach (2008) also pointed out that an effective eco-innovation program should not be the sole responsibility of the R&D unit. Instead, an organization must take a holistic approach to developing and supporting its eco-innovation programs. Accordingly, knowing how different types of eco-innovation complement each other is critical for firms to effectively implement their entire innovation programs.

Responding to the call from the literature, this study intends to offer a holistic view of eco-innovation programs by investigating the inter-relationships among different types of eco-innovation and their impact on business performance. Specifically, this study examines the relative effects and inter-relationship effects of three types of eco-innovation (eco-process, eco-product, eco-organizational). The following section reviews relevant literature on different types of eco-innovation to develop research hypotheses, followed by a discussion of research methodology, including samples and measurements. The statistical results and discussion are presented and, finally, managerial implications and suggestions for future research are provided.

2. Eco-innovation types

The literature defines the boundary of eco-innovation into external and internal eco-innovation. The external boundary of eco-innovation includes all external activities of the organization for green and sustainable activities, including suppliers (Lee and Kim, 2011), regulators (del Río et al., 2010), and market demand (Lin et al., 2013). The internal boundary of eco-innovation activities is related to practices for effectively and efficiently managing eco-innovation processes within organizations, including organizational management (Eiadat et al., 2008), production process (Dangelico and Pontrandolfo, 2010), and new product development (Lin et al., 2013). For the purpose of this study, we focus on the internal boundary of eco-innovation.

Furthermore, researchers have addressed eco-innovation from different perspectives, including government policy (Veugelers, 2012), stakeholders (e.g., customers, suppliers) Klewitz et al., 2012), organizational strategies (Boons and Lüdeke-Freund, 2012), organizational leadership (Chen and Chang, 2012), organizational culture (Porter-O'Grady and Malloch, 2010), and the characteristics of the eco-innovation itself (Lin et al., 2013). With a focus on the internal boundary of eco-innovation, this study investigates the effects of eco-innovation from the organizational strategic perspective.

An extensive literature review was conducted to ensure inclusion of all relevant aspects of the internal boundary of eco-innovation. For example, Kemp and Arundel (1998) argued that eco-innovations include technical, organizational, and marketing innovations. del Río et al. (2010) classified eco-innovation types into process/product innovation, mature/immature innovation, and radical/incremental innovation. Horbach (2008) and Triguero et al. (2013) studied three types of eco-innovation: eco-process, eco-product, and eco-organizational innovations. The Oslo Manual, developed by the OECD (2005), identified four distinct types of eco-innovation: product innovation, process innovation, organizational innovation, and marketing innovation. Overall, for examining internal innovation, the literature seems to suggest a focus on eco-process, eco-product, and eco-organizational innovation activities (Horbach, 2008; Triguero et al., 2013). This classification was later confirmed by a field study consists of interviews with 24 managers who has more than fifteen years of work experience in environmental innovation management. The interviewees shared their experience and offered suggestions regarding the types of eco-innovation activities involved inside of organizations. (More details of the interviews will be described in the research methods section.) This field study revealed that eco-innovation implementation should cover every major aspect of the organization, including activities arising from the setting up of the different forms of organization and management in different functions of the organization, activities related to the change or improvement of the manufacturing process function, as well as activities that contribute to the improvement to existing products or the development of new products.

In conclusion, synthesizing insights from the literature and the fieldwork, three key eco-innovation types (eco-process, eco-product, and eco-organizational innovations) were identified for further study. While those three eco-innovation programs have been studied separately, their inter-relationships have never been properly examined in a holistic manner (Hallstedt et al., 2013; Lozano, 2013). The remainder of this section defines activities related to these three forms of eco-innovations.

An eco-process innovation stands for new elements introduced into an organization's production system for producing eco-products (Negny et al., 2012). In general, eco-process innovation refers to the improvement of existing production processes or the addition of new processes to reduce environmental impact. Rennings (2000) suggested that innovation can be additive solutions (e.g., smokestack scrubbers) or be integrated into the production processes through substitution of inputs, optimization of production, and reclamation of outputs. As a result, eco-process innovation modifies the organization's operation processes and systems, decreases unit costs of production, produces new or significantly improved eco-products, and reduces environmental impacts (Negny et al., 2012).

In contrast, an eco-product innovation is the introduction of new or significantly improved products (regarding their characteristics), such as improvements in technical components and materials (Pujari, 2006). Eco-product innovation is usually inspired by advanced eco technologies, shortening product life cycles, and increasing competition (Carrillo-Hermosilla et al., 2010). The environmental impact of eco-product innovations stems from their use (e.g., fuel consumption and CO_2 emissions of cars) and disposal (e.g., heavy metals in batteries) rather than their production. According to Pujari et al. (2004), product life cycle analysis involves all aspects of a product, from its creation and use, to its disposal. This concept can be applied to eco-product innovations. For instance, electricity produced from wind power is an example of the use of creation. The compact fluorescent bulb is another example of energy saving through the use of a product, while a chlorofluorocarbon-free air conditioner is considered green primarily due to its reduced disposal impact. In short, eco-product innovations aim at reducing environmental impacts during an eco-product's entire life cycle (Christensen, 2011).

Finally, according to Birkinshaw et al. (2008), an eco-organizational innovation refers to upgrading the organization's management processes through a new and eco method in business practices. Eco-organizational innovations thus can improve business performance by supporting necessary changes, reducing administrative and transaction costs, improving workplace satisfaction, or reducing costs of supplies (Cruz et al., 2006). Eco-organizational innovation generally does not reduce environmental impacts directly, but facilitates the implementation of eco-process and eco-product innovations (Murphy and Gouldson, 2000). Kemp and Arundel (1998) summarized that eco-organizational innovations include eco-training programs, eco-product design programs, eco-learning techniques, or the creation of management teams to deal with eco issues. Thus, eco-organizational innovations are related to administrative efforts toward renewing organizational routines, procedures, mechanisms, or systems to produce eco-innovations in the end (Cruz et al., 2006).

In summary, eco-process innovations are directly related to operations activities, while eco-organizational innovations are indirectly related to the organization's basic work activities and infrastructure, and eventually affect the entire management systems. In addition, eco-product innovations can be viewed as creating new products aimed at satisfying market needs, while eco-process innovations are concerned with introducing new techniques into production operations. While the relationship between three types of eco-innovation might have been discussed individually, to our knowledge, there are no studies that specifically examine the formation of different types of eco-innovation as a whole. The next section discusses such relationships and the relative impact each eco-innovation type has on business performance. Accordingly, a research model with several hypotheses is developed.

3. Theoretical development

Resource-Based View (RBV) provides a good theoretical basis to discuss the contribution of resources and capabilities to performance in each of the aforementioned three types of eco-innovation. Specifically, these theories shed light on the relations among internal resources, capabilities and performance, which constitutes the basis for discussing eco-innovation in a holistic view.

The principal idea of the RBV and Natural RBV is that the competitive advantage of a firm lies in its heterogeneous resources, which are valuable, inimitable, and non-substitutable (Barney, 1991). In order to use such assets, a firm has to develop and accumulate them over time (Markard and Worch, 2010). However, the RBV has been criticized for not being able to explain how resources are deployed to achieve competitive advantage (DeSarbo et al., 2005). Teece et al. (1997) proposed the concept of Dynamic Capabilities that emphasizes appropriating, adapting, integrating, and reconfiguring internal and external organizational competence to match the requirements of changing environments. Therefore, competence is seen as the basis of competitiveness, and it enables a firm to innovate new products, to offer new values to customers, and thus to develop a sustained competitive advantage (van Kleef and Roome, 2007).

Built on the concept of RBV, Hart (1995, 2005) developed Natural RBV by including the constraints and opportunities of the natural environment. According to Natural RBV, environmental practices require the accumulation of resources and the management of capabilities within the firm. Thus, Hart (1995) developed a concept of green capabilities, while Sharma and Vredenburg (1998), Hart (2005), and Hart and Dowell (2011) further elaborated and empirically corroborated this concept to highlight the links among environmental strategies, capabilities development, and competitive advantage.

Accordingly, eco-process innovation, eco-product innovation, and eco-organizational innovation can be viewed as distinctive green capabilities developed with various resources including administrative support, organizational activities and structure, green infrastructure, eco technologies, and so on. The accumulation of those resources toward green activities develops unique green capabilities in the form of the three types of eco-innovation, which should in turn contribute to competitive advantage and business performance.

Fig. 1 displays the basic model that displays the theoretical relationships among three types of eco-innovation on business performance.

First, previous studies implied that an organizational innovation leading to administrative and structural renewal is a facilitator for the other types of innovation (Damanpour et al., 2009). In practice, through organizational renewal in the form of structural improvements, eco-organizational innovation can create better intra-organizational coordination and cooperation mechanisms toward effective environmental management. Namely, eco-organizational innovations are able to contribute to a fitting environment conducive with the development of eco-product and eco-process innovations. For instance, Staropoli (1998) verified the importance of organizational innovation in enhancing technological innovations in the pharmaceutical industry. Germain (1996) found that organizational innovations might be significant predictors of process innovations in the logistics sector. More recently, Armbruster et al. (2008) indicated that organizational innovations lead to product innovations. Walker (2008) asserted that organizational and product innovations were found to be inter-related. Borrowing from the general innovation literature, we propose that the same relationships exist in the context of eco-innovation. Namely, eco-organizational innovations can contribute to the formation of eco-process and eco-product innovations.

H1: The greater the firm's eco-organizational innovation, the greater its eco-process innovation.
H2: The greater the firm's eco-organizational innovation, the greater its eco-product innovation.

While the literature does not offer explicit empirical results for the relationship between eco-process innovation and eco-product innovation, previous general innovation studies lend theoretical support for their relationship. For example, Klepper (1996) argued that product innovation must precede process innovation for better effect. On the other hand, Damanpour and Aravind (2006) and Adner and Levinthal (2001) both indicated that product and process innovations are complementary to each other and that firms that pursue both simultaneously would produce better performance. Finally, Ettlie and Reza (1992) suggested that various process innovation activities such as installing new equipment, redefining task specifications, and upgrading information flow, could facilitate new product development. Oke (2007) also found that an effectively new manufacturing process (e.g., a decrease in the unit costs of production) was necessary to facilitate product innovation. Many recent studies (e.g., Bigliardi and Dormio, 2009; Raymond and St-Pierre, 2010; Maine et al., 2012) seem to support the notion that process innovation often equips existing production processes with advanced techniques which, in turn, improves the capability of adding new product features to meet the market needs. In short, the improvement of eco-process innovations is a

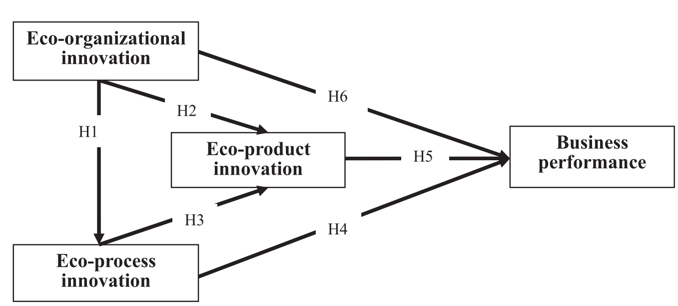

Fig. 1. The research model. (H: Hypothesis).

driving force for eco-product innovations. Therefore, the following hypothesis is proposed.

H3: The greater the firm's eco-process innovation, the greater its eco-product innovation.

Many studies on the innovation–performance relationship suggested successful innovations improve business performance. For example, Baer and Frese (2003) examined the effects of process innovation, and Li and Atuahene-Gima (2001) confirmed the benefits of product innovation. The contribution of environmental management (including all three types of eco-innovation) on business performance has also been recognized since Porter and Van der Linde's seminal work (1995). Several publications clearly confirmed the links between pro-active environmental strategy (including innovation) and business performance, as well as the generation of organizational capabilities through environmental practices (see, for example, Christmann, 2000; Klassen and Whybark, 1999; Marcus and Geffen, 1998). All of them supported positive associations between process/product innovations and business performance. Accordingly, we propose that business performance (measured by ROI, market share, profitability, and sales) can be enhanced by eco-process innovation and eco-product innovation.

H4: The greater the firm's eco-process innovation, the greater its business performance.
H5: The greater the firm's eco-product innovation, the greater its business performance.

Previous studies also advocated the contribution of both regular organizational and eco-organizational innovations (e.g., innovative design, speed, or flexibility) to a firm's business performance (e.g., Armbruster et al., 2008; Klassen and Whybark, 1999). Strategic theories suggest that organizations that adopt an innovation (e.g., capabilities, resources, technologies, or knowledge of the innovation) would subsequently create a unique mechanism that protects profit margins, thus enabling the organization to gain great benefits (Teece et al., 1997). Lin and Chen (2007) specifically associated organizational innovation with improved business performance. Accordingly, the following hypothesis is proposed.

H6: The greater the firm's eco-organizational innovation, the greater its business performance.

Overall, these research hypotheses allow the study to closely examine both the direct effects and indirect effects of eco-process and eco-organizational innovations. Specifically, eco-process, eco-product and eco-organizational innovations directly improve business performance respectively (H4, H5 and H6). Moreover, eco-organizational innovation indirectly affects business performance via the mediators, eco-process innovation (H1) and eco-product innovation (H2), and eco-product innovation also mediates the relationship between eco-process innovation and business performance (H3). Namely through eco-product innovation, eco-process innovation and eco-organizational innovation could indirectly enhance firms' business performance. Eco-product innovation allows a firm to incorporate its organizational innovative activities into developing new goods or services. Similarly, those activities also facilitate eco-process innovation to enhance business performance. Consequently, the total effects of eco-organizational innovation and eco-process innovation on business performance are likely to include their direct effects as well as indirect effects through eco-product innovation. Previous research has demonstrated other types of capabilities as mediators, such as marketing capabilities or operations capabilities, within the capability–performance relationship (e.g., Murray et al., 2011; Yu et al., 2013). To our best knowledge, no studies have investigated the inter-relationships among the three forms of eco-innovation.

4. Research methods

The survey method is used in this study to provide an overview of the existing eco-innovation practices and effectiveness in Taiwan. This section presents the development and validation of eco-innovation measurement. A discussion of data collection and sample used for statistical analysis is also presented.

4.1. Measurement development

While previous studies have identified and validated the scales of innovation variables (e.g., Damanpour et al., 2009), none of the scales was specifically developed for eco-innovation. To ensure the validity of the study, we decided to develop new scales for eco-innovation, following suggestions of Churchill (1979).

Based on field studies and the relevant literature (e.g., Rennings and Zwick, 2002; Murphy and Gouldson, 2000; Kemp and Arundel, 1998), the domain of eco-innovation was created and an initial list of items was generated. The field studies were conducted in Taiwan, including 24 in-depth interviews with managers and one focus group. All the interview participants were managers with more than fifteen years of work experience in environmental innovation management. The computer manufacturers in Taiwan rely heavily on exporting to Europe and the U.S., and they have to regularly engage in various eco-innovation programs to meet strict international environmental regulations (e.g., WEEE) (Tung and Wan, 2013; Yang and Sheu, 2011). As a result, Taiwanese manufacturers seem to offer an appropriate case for the study of eco-innovation issues.

As suggested by Eisenhardt (1989) and Yin (2009), an interview protocol was developed and subsequently pretested by two academics specializing in marketing research. Next, each interviewee received a file with a brief introduction, the purpose of this study, a guarantee of confidentiality, and a request for an interview. During the interviews, notes were taken and the proceedings of each interview were tape recorded. If necessary, follow-up interviews were conducted to clarify issues or explore for more details. On average, each interview took 54 min. Finally, the authors and two other academics used the software NVivo 8 (NVivo, 2008) to code interviewees' open-ended responses electronically and then to organize them into theoretical themes, meaningful phrases, cross-tabulated items, and initial sets of scale items.

To ensure a comprehensive list of eco-innovation items was generated, we also conducted one focus group discussion with 12 participants. Following the same procedure as that used for the interviews, the focus group discussions were video-recorded, transcribed and then analyzed using NVivo 8 computer software. Six of the 12 participants were academics specializing in eco-innovation research and six were senior managers with a minimum of 15 years of work experience related to eco-innovation. All participants were screened to confirm their willingness to participate and their familiarity with our study. The focus group was conducted in a conference room at a convention center and it lasted 88 min. As a result, 20 items were generated, including five items measuring the eco-process construct, eight items measuring the eco-product construct, and seven items measuring the eco-organizational construct.

Business performance was measured using four items developed by Im and Workman (2004). All the items were self-reported by asking respondents to rate their market and financial performance (ROI, sales, profit, and market share) compared with that of their major competitors. The use of subjective performance measures is a well-accepted approach (Atuahene-Gima and Ko, 2001; Im and Workman, 2004).

All items were subsequently evaluated by two university professors who specialized in innovation research and four senior managers with extensive experience developing eco-innovation to ensure content and face validity. Suggestions for additional measures were also requested. As a result, all items remained on the list, while a few of the items were revised to improve their specificity and precision (e.g., "radically improve" was replaced with "innovatively update"). For those items adapted from previous studies (e.g., business performance) and written in English, a double-translation method was used to translate them into Chinese. Specifically, the authors initially translated the items into Chinese; another two academics then translated the Chinese version back into English; and finally, this translation work was checked by the third academic to ensure conceptual equivalence. The initial instrument contained 24 items that were measured on a 7-point Likert scale (1 = strongly disagree; 7 = strongly agree).

Once the initial set of items was ready, a pilot-test was performed to ensure its reliability and validity. Performing a pilot-test is an important step in the scale development process, because it can remove invalid items (Anderson and Gerbing, 1991). The pilot-test used a convenience sample of 53 senior managers with experience in eco-innovation activities. Of the respondents, 72% were from IT manufacturing, 54% of were product managers, 65% were male, the average number of years working was 18.4 years, and all were between the ages of 38 and 62. They were asked to complete a questionnaire to indicate any ambiguity or difficulty **in responding to the questions** and to offer any suggestions they thought appropriate. At this stage, some wordings were refined but all 24 items were retained.

4.2. Sample and data collection

Samples were collected from Taiwan Environmental Management Association (www.ema.org.tw), a renowned trade association with more than 20,000 members. During the sample screening, emails were sent to identify those who had extensive experience in eco-innovation. Similar to the previous innovation studies (e.g., Atuahene-Gima and Ko, 2001), senior managers responsible for eco-innovation development were selected. Based on these criteria, each member was requested to provide the name of a senior manager involved in eco-innovation development. To this end, these procedures produced a sample of 611 firms.

Using Dillman's (2000) design method for mail surveys, 611 copies of the questionnaire were mailed, along with preaddressed postage-paid envelopes and a cover letter explaining the purpose of the study, expressing appreciation for participating, and assuring the confidentiality of the shared information. The questionnaire included three sections: (1) the covering page with contact information, (2) a series of items on eco-process innovation, eco-product innovation, eco-organizational innovation, and business performance, and (3) demographics. After a follow up contact by mail, telephone, or fax, 121 usable questionnaires were collected, resulting in a response rate of 19.8%. Of the participants, 58% were male, the average number of working years was 14.2, and their ages ranged between 36 and 55 years. The samples covered four industries and were classified under the three-digit level of Taiwan's Standard Industry Classification (SIC), including Manufacture of Communication Equipment (SIC: 272, 29%), Manufacture of Computers and Peripheral Equipment (SIC: 271, 32%), Manufacture of Integrated Circuits (SIC: 261, 34.5%), and others (4.5%). More than 70% of the sample consists of large firms with over 3000 employees and 68.9% have been established over 15 years.

4.3. Non-response bias and common method bias

To assess the possibility that those participants who responded were systematically different from those who chose not to participate, an assessment for non-response bias was performed (Armstrong and Overton, 1977). A comparison of the means of all items was conducted by one-way ANOVA using SPSS 19. All mean pair comparisons exhibit insignificant differences at .05, suggesting no non-response bias occurs.

Since the measures for the independent and dependent variables are collected from the same respondents in the same way, there is a potential for common method bias (Podsakoff et al., 2003). If common method variance exists, a Confirmatory Factor Analysis containing all constructs should produce a single method factor (Podsakoff and Organ, 1986). The goodness-of-fit indices (χ^2/d.f. = 27.8, RMSEA = .33, CFI = .42, NFI = .31, PNFI = .37) indicate a poor fit for the single factor model. In addition, Harman's one-factor test is also used, where all variables are simultaneously entered into an exploratory factor analysis through principal components without rotation. According to the results, no single factor emerges that could account for the majority of the covariance in the measures. Overall, both tests suggest no common method bias occurs.

5. Statistical results

This section examines the psychometric properties of measurement, including reliability, and convergent and discriminant validity. Structural equation modeling (SEM) analysis was applied to test research hypotheses with firm size and firm age as control variables. For firm size, we used the logarithm of the number of employees. Firm age is defined as the number of years the firm has been in operation. The results of SEM analysis regarding the direct, indirect, and total effects of three types of eco-innovation on business performance are also presented.

5.1. Psychometric properties

To purify the sample, we conducted Exploratory Factor Analysis to identify dimensionality of eco-innovation, and then assessed reliability and item-to-total correlations (see Table 1).

Five factors were extracted, accounting for 78.3% of the variance in the construct with the first factor explaining 22.8%. Three items in the fifth factor were temporarily regarded as outliers. The tests for reliability and item-to-total correlations were then conducted and a factor was accepted if the Cronbach's alpha value was greater than .7 (Nunnally, 1978). Items were deleted if they negatively correlated to other items within a scale or had a correlation value below .1. The results show that, without the three outliers, all factors have Cronbach's alpha values from .86 to .93. Previous researchers have suggested that unusual patterns of scores can cause a threat to validity/reliability of a scale and disproportionately influence the results (Tabachnick and Fidell, 2006). Three outliers identified were discarded for their low correlation value, below .1, and negative correlations with other items. As a result, 21 items were retained for the subsequent tests (see Appendix for the complete list of measurement items).

We further evaluated measurement properties by running Confirmatory Factor Analysis. Following the suggestions from Hult et al. (2004), we divided the items into four related groups. Each item was set to load only on its respective latent construct, and the latent constructs were allowed to be correlated. The results indicate that the measurement model of eco-process innovation (χ^2/d.f. = 1.94, RMSEA = .07, CFI = .91, NNFI = .92, PNFI = .81), eco-product innovation (χ^2/d.f. = 2.34, RMSEA = .10, CFI = .92, NNFI = .93, PNFI = .84), and eco-organizational innovation fit the

Table 1
The results of exploratory factor analysis.

Scale item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
	Eco-organizational innovation	Eco-product innovation	Eco-process innovation	Business performance	Outliers
1	**.809****	.393	.284	.242	−.024
2	.082	−.015	−.158	.295	**.692****
3	**.747****	.393	.262	.343	−.071
4	**.622***	.387	.287	.244	−.118
5	**.728****	.352	.216	.174	.074
6	**.698****	.280	.169	.290	−.126
7	**.822****	.226	.251	.258	−.042
8	−.293	−.159	**.765****	.150	.082
9	−.347	−.149	**.734****	.135	.098
10	−.329	−.174	**.798****	.152	.140
11	−.340	−.180	**.819****	.002	.086
12	.197	.123	−.102	.015	**.868****
13	−.361	**.664****	−.039	−.074	.064
14	−.339	**.695***	−.009	−.051	.021
15	−.409	**.605****	.096	−.010	.121
16	−.397	**.727****	−.029	−.009	−.008
17	.203	.046	−.060	−.017	**.750****
18	−.414	**.749****	.035	.072	−.126
19	−.251	**.601****	.022	.117	−.061
20	−.370	**.717***	−.028	.098	.062
21	.040	.253	.173	**.762****	.249
22	−.002	.328	.151	**.567****	.269
23	.004	.392	.091	**.575****	.206
24	.036	.392	.195	**.679****	.301

**$p < .01$; *$p < .05$.

data satisfactorily (χ^2/d.f. = 1.32, RMSEA = .05, CFI = .92, NNFI = .95, PNFI = .76). Business performance measures are also represented satisfactorily (χ^2/d.f. = 1.46, RMSEA = .05, CFI = .94, NNFI = .97, PNFI = .87). The factor loading of indicators is significant ($p < .01$) and well above the recommended levels (Joreskog and Sorbom, 1993).

We proceeded to examine construct convergent and discriminant validity. Composite reliability is an indicator of shared variance among the set of observed variables used as indicators of a latent construct (Fornell and Larcker, 1981). As shown in the Appendix, the composite reliabilities of all constructs exceed the usual .60 benchmark (Bagozzi and Yi, 1988). The results provide the necessary evidence that all the constructs exhibit convergent validity.

Discriminant validity was reviewed by comparing the average variance extracted (AVE) with the variance each factor shared with the other factors in the model (Fornell and Larcker, 1981). The results in Table 2 suggest that all the diagonal elements representing the square root of the AVE are greater than the highest shared variance (the off-diagonal correlations).

In addition to Fornell and Larcker's procedure, we also examined discriminant validity, using an alternative approach that Anderson and Gerbing (1988) recommended. The chi-square values for the unconstrained models, which allowed each pair of constructs to covary freely, were always significantly lower than those of the constrained models, which constrained the estimated correlation of each pair of estimated constructs to one. In this study, the value of the unconstrained model is significantly lower than that of the constrained model in all cases (for example, for the pair of constructs, eco-process and eco-product, the unconstrained model had a chi-square of 45.4 and the constrained model had a chi-square of 152.8. The chi-square difference is significant at $p < .001$). Since the criteria for both approaches are satisfied, an inference error of multicollinearity is unlikely. Accordingly, the measurement model fits the data satisfactorily and exhibits unidimensionality, convergent, and discriminant validity.

Table 2
The correlation matrix.

Factors	1	2	3	4	5	6
1 Eco-process innovation	.69					
2 Eco-product innovation	.28**	.72				
3 Eco-organizational innovation	.30**	.31**	.73			
4 Business performance	.20**	.18*	.35**	.67		
5 Firm size	.18*	.17*	.06	.19*	N/A	
6 Firm age	.23**	.26**	.28**	.35**	.08	N/A

**$p < .01$; *$p < .05$.

5.2. SEM analysis

SEM was applied because it accounts for measurement error and corrects for attenuation, thereby overcoming many of the problems associated with regression models (Jaccard and Wan, 1996). As such, following Ping (1995), this study uses SEM with maximum likelihood estimation to test the hypotheses. The SEM results (χ^2/d.f. = 1.89, RMSEA = .03, CFI = .95, NNFI = .93, PNFI = .84) conform to the acceptable standards, demonstrating an acceptable level of model fit for our research model. Turning to individual research hypotheses, eco-organizational innovation is positively and significantly related to both eco-process and eco-product innovations ($\beta = .59$, $p < .01$; $\beta = .46$, $p < .01$), supporting H1 and H2. Eco-process innovation is significantly related to eco-product innovation ($\beta = .41$, $p < .01$) and H3 is supported. Finally, eco-process, eco-product, and eco-organizational innovations are positively and significantly related to business performance ($\beta = .42$, $p < .01$; $\beta = .36$; $p < .01$; $\beta = .51$, $p < .01$). Thus, H4, H5, and H6 are supported. In summary, all the arrows in Fig. 1 are significant ($p < .01$), confirming our hypotheses regarding the relationships among three different eco-innovation types and business performance.

5.3. Mediation effects

The direct effects of eco-organizational and eco-process innovations on eco-performance are expected and consistent with the extant innovation literature (e.g., Damanpour et al., 2009). However, their indirect effects were never properly examined. Using Baron and Kenny (1986)'s approach, we examined the mediating effects of eco-organizational and eco-process innovations in greater details. Three competing models were tested: full mediating, partial mediating, and no mediating. The hypothesized (partial mediating) model was used as the basis for comparing with the nested model. The significance level of the changes in chi-square results between three models reflects the effects of the added paths. If chi-square difference tests show that the competing models do not improve the fit significantly, at the .05 level, then the partial mediating model will be supported (Baron and Kenny, 1986).

The SEM results in Table 3 reveal that the partial mediating model has better fit than the "full mediating" model, and the full mediating model is better than the "no mediating" model. This finding suggests that the partial mediating models most accurately represent the data and should be used to illustrate the relationships among all eco-innovation types. Namely, eco-product innovation mediates the performance of eco-organization and eco-process innovations. Eco-process innovation, which is found to be significantly associated with performance, influences business performance through eco-product innovation. In addition, eco-organization innovation has direct and indirect (through eco-product innovation) effects on business performance.

5.4. Indirect and total effects

The proposed model accounted for 54% of the variance in business performance. According to the path coefficients, eco-

Table 3
Fit indices for the mediating effect.

	χ^2/d.f.	RMSEA	CFI	NNFI	PNFI
Eco-organizational innovation, Eco-process innovation, and Business Performance					
Partial mediating	1.39	.06	.94	.94	.84
Full mediating	3.79	.08	.83	.89	.68
Non-mediating	6.41	.17	.81	.69	.53
χ^2 test results: Partial vs. Full ($\Delta\chi^2 = 74.56$), $p<.001$; Full vs. No ($\Delta\chi^2 = 115.14$), $p < .001$					
Eco-organizational innovation, Eco-product innovation, and Business Performance					
Partial mediating	1.48	.05	.90	.91	.81
Full mediating	2.10	.07	.92	.90	.88
Non-mediating	7.01	.13	.71	.73	.42
χ^2 test results: Partial vs. Full ($\Delta\chi^2 = 15.75$), $p<.01$; Full vs. No ($\Delta\chi^2 = 113.57$), $p<.001$					
Eco-process innovation, Eco-product innovation, and Business Performance					
Partial mediating	1.79	.07	.92	.93	.80
Full mediating	4.97	.10	.90	.89	.72
Non-mediating	5.56	.21	.73	.79	.50
χ^2 test results: Partial vs. Full ($\Delta\chi^2 = 64.37$), $p<.001$; Full vs. No ($\Delta\chi^2 = 10.01$), $p<.01$					

organizational innovation exhibits the strongest direct effect on business performance. Eco-process innovation, despite showing a slightly weaker direct effect than eco-organizational innovation on business performance, exhibits a stronger total effect on business performance than that of eco-product innovation. The total effect of eco-organizational and eco-process innovations on business performance is $\beta = .36$ and $\beta = .43$, respectively. The direct, indirect, and total effects of eco-organizational, eco-process, and eco-product innovations on business performance are summarized in Table 4.

6. Discussion

Examining all three types of eco-innovation and reviewing their inter-relationship offers a holistic view of eco-innovation programs that previous studies fail to do. The analysis of direct and indirect effects of individual eco-innovation types also provides valuable guidelines for developing well-aligned eco-innovation programs.

First, the results on Table 3 delineate the inter-relationship between eco-organizational, eco-process, and eco-product innovation. While eco-process innovation mediates the effect of eco-product innovation, both types of innovation act as bridges between eco-organizational innovation and business performance. It is important to recognize the mediating effect of organizational and process innovation, as previous studies are likely to under-estimate the impact of organizational innovation by focusing only on its direct effect. The statistical findings in Table 4 further indicate that, among all three eco-innovation types, eco-organizational innovation has the strongest effect ($\beta = .77$) on business performance due to its direct ($\beta = .51$) and especially indirect effects ($\beta = .26$) via eco-process and eco-product innovations. In addition, it has stronger positive direct ($\beta = .46$) and indirect ($\beta = .22$) impacts on eco-product innovation than that of eco-process innovation ($\beta = .41$). These results extend the organizational literature and stress that eco-organizational innovation indeed plays a fundamental role in enhancing eco-process and eco-product innovative activities.

The findings in Tables 3 and 4 also lend additional support for a causal relationship between eco-process and eco-product innovations. Namely, process innovation activities could effectively facilitate new product development. Additionally, including organizational innovation in this discussion would provide managers with a holistic view of eco-innovation management. Our results imply that firms should first engage in eco-organizational innovation, develop necessary infrastructure, and obtain eco knowledge in order to be ready for improving their manufacturing processes and existing eco-products. Along with eco-organizational innovation, eco-process innovation develops competence (e.g., innovative tools, devices, and knowledge) in upgrading required manufacturing processes for new eco-product development, which, as a result, leads to introduction of new eco-products to the marketplace.

Treating organizational innovation as the fundamental of developing eco-innovation programs seems to be consistent with the industry practice. For instance, when developing its eco-innovation programs, Asus, a renowned IT manufacturer in Taiwan, first engaged in extensive organizational innovation activities by distributing new eco-knowledge within the firm and building a management team to guide further process and product innovations (Asus Annual Report, 2008). Consequently, the company was able to develop innovation capability and continuously deliver impressive sales growth. This example clearly illustrates how organizational innovation can provide organizations with continual organizational learning, which leads to more effective eco-innovation and better business performance. Overall, this study lends additional evidence to organizational innovation literature that indicates technical innovation is directly related to organizational innovation activities (Damanpour et al., 2009).

Another interesting finding is the differential business performance between eco-process and eco-product innovations. Without considering eco-process innovation's mediating effect, one would have concluded that both eco-process and eco-product innovations have similar influence on business performance. Nonetheless, based on total effect, eco-product innovation clearly has less influence on business performance ($\beta = .36$) compared to that of eco-process innovation ($\beta = .67$). One possible interpretation is that new eco-products are a necessary result of eco-innovation. Fig. 2 summarizes the results of the mediating effects.

Table 4
The direct, indirect, and total effects of eco-innovation.

	Direct effect			Indirect effect			Total effect		
	Proc	Prod	BP	Proc	Prod	BP	Proc	Prod	BP
Proc	N/A	.41	.42	N/A	N/A	.25	N/A	.41	.67
Prod	N/A	N/A	.36	N/A	N/A	N/A	N/A	N/A	.36
Org	.59	.46	.51	N/A	.22	.26	.59	.68	.77
R^2	N/A	N/A	N/A	N/A	N/A	N/A	.48	.50	.54

Org: eco-organizational innovation; **Proc**: eco-process innovation; **Prod**: eco-product innovation; **BP**: business performance.

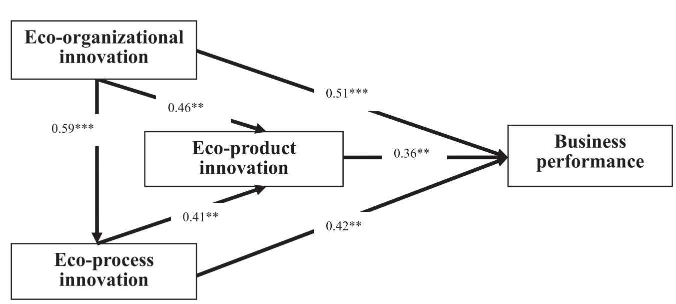

Fig. 2. Model testing results. ***$p < .001$; **$p < .01$.

7. Conclusions

Drawing from the extant innovation literature and the field studies, we constructed a research model that demonstrates the relative importance of each type of eco-innovation, and the nature of the interdependency between them. While previous studies suggested possible relationship between organizational innovation and product/process innovation, there is never a definite conclusion as to how eco-organizational innovation can contribute to the formation of eco-product or eco-process innovations. Our statistical results suggest that eco-process and eco-product innovations partially mediate the effects of eco-organizational innovation, and eco-product innovation mediates eco-process innovations' effects on business performance. Business performance is directly and indirectly affected by eco-organizational, eco-process, and eco-product innovations.

Several research contributions are noteworthy. First, the importance of systematically implementing various aspects (e.g., technological, sustainable, social, organizational, etc.) of innovation programs has been previously suggested. However, the current eco-innovation research does not offer a holistic view of eco-innovation (Hallstedt et al., 2013; Lozano, 2013). As indicated by Jayal et al. (2010), to achieve green and sustainable manufacturing requires a holistic view spanning product, manufacturing processes, and managerial systems across multiple product life cycles. As such, a major contribution of this study to the eco-innovation literature is to employ the RBV theory to frame a conceptual model that links organizational resources (three types of eco-innovation) and business performance, and therefore, provide a holistic view in explaining the inter-relationship among eco-process, eco-product, and eco-organizational innovations. Consequently, a holistic view of the eco-innovation program provides a valuable, inimitable, and non-substitutable resource that should enable a firm to develop the competence leading to better business performance.

Second, the relationships among the three eco-innovation components and their effects on business performance suggest that all components could be performed in a distinct role but also be performed in a systemic manner. In particular, the eco-process innovation literature typically focused on cost reduction or operating system adjustment but failed to recognize the need for discussing how process innovation facilitates eco-product innovation or mediates eco-organizational innovation. Moreover, our findings add to the eco-innovation literature by uncovering the underlying innovation development process of which eco-organizational innovation is the fundamental for building eco-process and eco-product innovations. Evidently, without a systemic view of all three types of eco-innovation simultaneously, managers would not be able to realize effective eco-innovation programs.

Finally, previous studies related to organizational innovation have focused primarily on the technological aspect and neglected change in the social system. This study enriches the organizational innovation literature by arguing that a simultaneous adoption of technological (e.g., eco-produce and eco-process) and administrative (e.g., eco-organizational) innovation is important to firms.

Our findings also offer several managerial implications. First, eco-organizational restructuring brings about managerial and structural renewal and facilitates creating eco-manufacturing processes. In practice, managers must rebuild their eco-infrastructure to motivate and reward eco-organizational members, devise strategy and structure of tasks and units, and modify the organization's management processes (e.g., new management accounting methods, or an enterprise resource planning system).

Second, management must fully understand the relative benefits and limitations of each eco-innovation type, in order to improve business performance. Eco-organizational and eco-process innovations are able to help firms directly in achieving better business performance, compared with eco-product innovation. However, both eco-organizational and eco-process innovations can achieve better business performance due to their influences on eco-product innovation. Therefore, when adopting eco-innovation, management needs to rely on, invest in and implement all three types of eco-innovation, with an initial emphasis on eco-organizational innovation.

Third, the results of this study could offer policy makers guidelines regarding developing effective environmental regulations to enforce the development of effective eco-innovation programs in industry. The lack of resources would hinder the development of environmental management. The literature has suggested proper environmental regulation could force or encourage the industry to make eco-decisions that lead to better resource efficiency and higher environmental productivity (Porter and van der Linde, 1995; Brio and Junquera, 2003; Yang and Sheu, 2011). Our findings indicate that a successful eco-innovation program requires a systemic approach. In particular, administrative support programs must be in place to enhance the technological aspects of eco-innovation. Administrative activities generally do not reduce environmental impacts directly, and managers are inclined to place more emphases on technological aspects of innovation (Brio and Junquera, 2003). Evidently, without necessary procedures and administrative support, resource investment in eco-product and eco-process innovations would not be as effective, considering the indirect effects of eco-organizational innovation. Therefore, policy makers should set regulations or offer incentives to prompt companies to design and implement eco-innovation programs in a more effective sequence.

In short, this study confirms the inter-relationships and contributions of three eco-innovation types. The synergetic mechanism identified in this study should assist managers in gaining an integral understanding of the concept of eco-innovation and its implementation for improving business performance.

This study has several limitations that should be considered in the interpretation and implication of its findings. First, while business performance was measured by several subjective indicators, a true effect of eco-innovation on performance can be evaluated more effectively through collecting a diversity of viewpoints (e.g., objective data) to potentially overcome such biases. Second, the relationship between eco-innovation and business performance may be moderated by factors including innovation attributes (e.g. relative advantage) and managers' characteristics (e.g. entrepreneurship orientation). Moderating effects were not examined here and would need to be explored in the future. Third, this study only examined three types of eco-innovation. Other types of innovation (e.g., marketing innovation, technological innovation) should be included in the future studies. Finally, the findings may be peculiar to Taiwanese firms. Pohlmann et al. (2005, p. 3) found that innovation activities are closely related to "social behavior of a specific culture setting." The applicability of our findings to other countries should be considered with caution. The replication of this research in other countries is necessary to ensure global generalizability of the findings. Similarly, we have grounded our arguments on concepts and models, from innovation literature, which have mainly been developed in the context of manufacturing organizations. Additional tests of our theoretical argument across other business organizations (e.g., service) and with other measures of performance should add to the conclusiveness of our findings. Finally, this study examined how the increased competence resulting from a holistic view of eco-innovation programs improves business performance. Future studies should also review the eco-innovation – environmental performance – business performance connection.

Appendix. Eco-innovation Measurement

Eco-innovation measurement items	Factor loading	*t*-value
Eco-process innovation ($\alpha = .87$, CR = .90)		
Rate your firm relative to your major competitors over the last three years on the extent to which…		
Our firm often innovatively updates manufacturing processes to protect against contaminations.	.82	8.97
Our firm often innovatively updates manufacturing processes to meet standards of environmental law.	.85	13.58
Our firm often uses innovative technologies in manufacturing processes to save energy.	.80	8.53
Our firm often innovatively updates manufacturing equipment in manufacturing processes to save energy.	.86	11.22
Eco-product innovation ($\alpha = .90$, CR = .95)		
Rate your firm relative to your major competitors over the last three years on the extent to which…		
Our firm often places emphasis on developing new eco-products through new technologies to simplify their package.	.90	13.58
Our firm often places emphasis on developing new eco-products through new technologies to simplify their construction.	.84	11.13
Our firm often places emphasis on developing new eco-products through new technologies to easily recycle their components.	.80	9.27
Our firm often places emphasis on developing new eco-products through new technologies to easily decompose their materials.	.89	10.88
Our firm often places emphasis on developing new eco-products through new technologies to use natural materials.	.86	12.01
Our firm often places emphasis on developing new eco-products through new technologies to reduce damage from waste as much as possible.	.81	10.88
Our firm often places emphasis on developing new eco-products through new technologies to use as little energy as possible.	.82	10.94
Eco-organizational innovation ($\alpha = .93$, CR = .94)		
Rate your firm relative to your major competitors over the last three years on the extent to which…		
Our firm's management often uses novel management systems to manage eco-innovation.	.82	9.62
Our firm's management often collects information on eco-innovation trends.	.90	12.29
Our firm's management often actively engages in eco-innovation activities.	.83	11.13
Our firm's management often communicates eco-innovation information with employees.	.87	10.78
Our firm's management often invests a high ratio of R&D in eco-innovation.	.84	10.22
Our firm's management often communicates experiences among various departments involved in eco-innovation.	.86	10.61

(*continued*)

Eco-innovation measurement items	Factor loading	*t*-value
Eco-process innovation ($\alpha = .87$, CR = .90)		
Business performance ($\alpha = .86$, CR = .89)		
Relative to competing eco-innovation firms' business performance during the last three years, our firm's business performance is very successful in terms of		
Return on investment	.82	10.22
Profits	.81	8.97
Market share	.84	11.64
Sales	.80	9.67

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