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Analyzing the relationship between green innovation and environmental performance in large manufacturing firms

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A B S T R A C T

Extant literature suggests that green intellectual capital (GIC), green human resource management (GHRM), and green innovation (GI) impacts the environmental performance of firms. In this paper, we argue that the relationship between GIC, GHRM, GI and environmental performance is more complex than previously suggested. We propose that neither GIC nor GHRM are directly related to environmental performance. We argue instead that GI mediates the relationships between GIC, GHRM, and environmental performance. Further, we suggest that environmental strategies are directly related to environmental performance, while also moderating the relationship between GI and environmental performance. We tested our proposed model on a sample of 244 large manufacturing firms. The results of a structural equation modeling analysis provide support for most of our hypotheses.

1. Introduction

The natural-resource-based theory of the firm suggests that organizations actively seek to improve and harmonize their relationship with the external natural environment. They can do so by pursuing the three types of distinct yet interrelated environmental strategies of pollution reduction, product stewardship, and sustainable development (Hart, 1995; Hart and Dowell, 2011). Advancing the natural-resource-based theory, this paper approaches green intellectual capital (GIC) (Chen, 2008; Chang & Chun, 2012) as both a tacit resource and dynamic capability that can allow an organization to secure a sustainable competitive advantage. This can be achieved by (1) strengthening the effect of GIC on green innovation (GI); (2) using advanced green human resource management (GRHM) to motivate an organization to develop and leverage its GIC and enhance its GI; (3) absorbing new knowledge developed via GI into GIC; and (4) applying GIC, GI, and GHRM, coupled with proactive environmental strategies, to improve environmental performance.

In her groundbreaking study, Chen (2008a, 2008b) introduced the concept of GIC, describing GIC as the total stock of all kinds of intangible assets, knowledge, capabilities, and relationships associated with environmental protection or green innovation observed at the individual and organizational levels of a company (Chen, 2008b; Chang & Chen, 2012). Importantly, GIC is expected to be positively related to GI and environmental performance in firms (Chen, 2008). Although the definition of GIC (Chen, 2008a, 2008b; Chang & Chen, 2012) suggests that it could be related to GI, this may not be the case if GIC contains abstract stocks of knowledge that are not utilized to continually advance and improve environmental performance.

To reflect the fact that GIC may or may not be related to GI, in this study, we define GIC as the total stock of all intangible assets, knowledge, capabilities, and relationships present on the individual and organizational levels in a firm that are managed with the overriding goal of environmental protection. This implies that GIC can in fact be oriented towards environmental performance, while at the same time failing to spearhead GI. Ideally, GIC should absorb new knowledge developed by GI and contribute to GI so that GIC and GI are continually generating new cycles of knowledge evolution.

GI focuses on improving existing products and processes, making them environmentally friendly (Albort-Morant et al., Cepeda-Carrión, 2016). Selecting greener raw materials, avoiding waste, designing products using eco-design principles, reducing carbon emissions and footprints, and reducing consumption of water, electricity, and other raw materials (Gunasekaran & Spalanzani, 2012; Singh et al., 2020) are some avenues for engineering GI. In addition to GI based on exploitation, organizations may pursue an exploration-based GI that focuses on

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inventing fundamentally new processes and technologies that allow firms to positively impact their environment and engage in sustainable development (Hart, 1995; Hart & Dowell, 2012). Overall, we propose that GI and GIC form a dialectical relationship and can mutually influence and strengthen one another.

A recent study established that GIC is positively related to all aspects of sustainable performance including economic, social, and environmental performance (Yusliza et al., 2020). However, not all aspects of sustainable performance are equally related to GIC. For example, social performance that refers to "improvement of stakeholder welfare, community health and safety, employee's health and safety, and reduction of risk on the general public" (Yusliza et al., 2020: 8) has a stronger association with GIC compared to environmental performance's association with it. The diminished impact of GIC on environmental performance referring to a reduction in environmental damage and protection from resource exploitation, and compared to its impact on the economic and social aspects of sustainability (Yusliza et al., 2020) is intriguing and important for scholars and practitioners to understand. This means that the relationship between GIC and environmental protection require further examination.

Research suggests that a firm's environmental strategy ranges from being proactive to reactive (Aragon-Correa et al., 2008; Foisteris et al., 2018). One study suggests that a firm's environmental strategy may mediate the relationship between its corporate social responsibility and environmental performance (Kraus, Rehman, & Garcia, 2020), with the findings indicating that a firm's environmental strategy is an important variable that can influence the effect of GI on its environmental performance.

In recent years, along with GIC (Chen, 2008; Chung & Chen, 2011; Yusoff et al., 2019; Yong et al., 2019; Yusliza et al., 2020), scholarly interest in the subject of green human resource management (GHRM) has grown significantly in the literature. Multiple published reviews on GHRM highlight different aspects of the concept while examining contributions of the research in the area (Renwick, Redman, & Maguire, 2013; Renwick et al., 2016). A recent study has shown that leveraging GHRM may help achieve environmental sustainability (Paille et al., 2020). Furthermore, green relational capital and green human capital reinforce GHRM, although green structural capital lacks a similar impact (Yong et al., 2019). Scholars also argue that green HRM may contribute to higher GI (El Kassar & Signh, 2017). Other research demonstrates that green human capital may not be related to economic sustainability (Yusoff et al., 2019). These inconclusive results regarding the relationship between GIC, GI, GHRM, and environmental performance suggest that the relationships between these fundamental variables need to be revisited.

In this paper, we contribute to and build on prior research (Yong et al., 2019; Yusoff et al., 2019; Kraus et al., 2020) to argue that neither GIC nor GHRM directly impact environmental performance. We argue instead that GIC and GHRM indirectly affect environmental performance through GI as we demonstrate that GI mediates the relationship between GIC and GHRM and environmental performance. Further, we argue that environmental strategy is related to and moderates the effect of GI on a firm's environmental performance. Overall, the goal of this study is to reexamine the complex relationships between GIC, GI, GHRM, environmental strategies, and environmental performance. We assess our proposed model using a sample of 254 Malaysian firms, with the structural equation modeling results providing support for most of its hypotheses.

2. Hypotheses development

2.1. Theoretical background

The natural-resource-based theory suggests that organizations may use various environmental strategies such as pollution reduction, product stewardship, and sustainable development to create a competitive advantage (Hart, 1995; Hart and Dowell, 2011). Advancing this theory, we propose that GIC can be regarded as both a tacit organizational resource as well as a continually advancing dynamic capability. From this perspective, organizations strengthening the effect of GIC on GI, and ultimately on their environmental performance may achieve an advantage that competitors are unable to replicate. Furthermore, organizations can continually upgrade their competitive advantage by absorbing the knowledge generated via GI into their GIC while applying GIC to enhance GI. This includes both exploitative GI focused on improving existing products and technologies to reduce their negative environmental impact, along with exploratory GI focused on creating new products and technologies that could potentially reverse and heal damage to the environment.

2.2. Green intellectual capital, environmental performance, and green innovation

Research has established that all the main types of GIC (i.e. green human capital, green relational capital, and green structural capital) are positively related to a firm's competitive advantage (Chen, 2008b). However, scholars suggest that different components of GIC can have a varying degree of impact (from stronger to weaker) on economic sustainability (Yusoff et al., 2019). Further, some of them (e.g. green relational capital) may have no impact on economic sustainability at all (Yusoff et al., 2019). In contrast, some studies examining the impact of GIC as a whole (as opposed to looking into the impact of its individual components) have established that GIC is positively related to the economic, environmental, and social performance of business organizations (Yusliza et al., 2020). Studies have additionally suggested that GIC and GI are interrelated (Chen, 2008b), implying that GIC may lead to GI, whereas GI may further enhance GIC. We therefore propose the following:

H1. GIC is positively associated with environmental performance.

H2. GIC is positively associated with GI.

2.3. Green human resource management, green innovation, and environmental performance

GHRM has been developing over the last thirty years. Job seekers often prefer environmentally-conscious organizations (Gully, Phillips, Castellano, Han, & Kim, 2013), meaning that organizations seeking to attract and recruit the best talent offer positions emphasizing environmental protection and improvement (Ones & Dilchert, 2013, Renwick et al., 2016). Here, both the recruitment and selection processes in organizations reflect the increasing influence of GHRM (Renwick et al., 2016). In addition, as the need for environmental protection grows, GHRM is increasingly influencing environmental training, management, and leadership development in organizations (Renwick et al., 2016).

Studies have established that environmental training as part of GHRM is positively related to organizations' environmental performance (Singh et al., 2020). Furthermore, GHRM and individual environmental performance have been shown to be positively related (Paille et al., 2020). Therefore, GHRM can influence individual employees' awareness of environmental protection and improvement. By turning the attention of individual employees and organizational units to environmental amelioration, GHRM is likely to influence the outcomes of individual and organizational efforts directed at reducing the negative impact of an organization on the environment, increasing its positive impact on environmental healing and recovery. We propose:

H3. GHRM is positively associated with environmental performance.

H4. GHRM is positively associated with GI.

2.4. Green innovation and environmental performance

GI is positively related to a firm's overall performance (Qui et al., 2020; Kraus et al., 2020; Mahto et al., 2020). Firms can use it to improve

their productivity and recover the rising costs of raw materials (Chen, 2008 a;b). GI encompasses (1) exploitative GI, which focuses on improving but not radically transforming the existing products and processes, making them more environmentally friendly, and (2) exploratory GI, focused on introducing new products and processes. Due to GI, new products and processes may radically transform the existing methods of operations, significantly reducing their negative impact on the environment. In addition, exploratory GI may lead to the creation of novel products and processes that can contribute to environmental cleaning, healing, and recovery.

Research has shown that a firm's environmental strategy and specific proactive strategies focusing on developing eco-friendly technologies can improve their financial outcomes (Walker et al., 2014; Fousteris et al., 2018). On the other hand, an inefficient managerial culture could make environmental strategy reactive rather than proactive, potentially increasing the risk of potential disasters and damaging reputation as a result (Zhang, Wang, & Zhao, 2019). The natural-resource-based theory regards pollution prevention, product stewardship, and sustainable development as key environmental strategies that lead firms towards competitive advantages (Hart, 1995; Hart and Dowell, 2011). A recent study has demonstrated the effect of environmental strategies on environmental performance in general, as well as the key role of environmental strategies mediating the impact of CSR on environmental performance (Kraus et al., 2020).

Since GI in an organization can be strengthened via a proactive environmental strategy, and conversely weakened by a reactive environmental strategy, we hypothesize that environmental strategies could perhaps moderate the relationship between GI and environmental performance. Thus:

H5. GI is positively associated with environmental performance.

H6. Environmental strategies moderate the relationship between GI and environmental performance.

H7. Environmental strategies are positively associated with environmental performance.

2.5. Green innovation as a mediator

Depending on its interaction with GI, GIC may or may not have a positive relationship with environmental performance. Although some studies have shown that GIC is related to social, economic, and environmental performance (Yusliza et al., 2020), other studies have not established this (Lerro et al., 2014). This can be explained by GIC perhaps not being effectively used by organizations, rendering the relationship between GIC and environmental performance insignificant. It is only when GIC enhances GI (and GI, in turn, generates advancements in knowledge that can be absorbed into GIC) that GIC would be likely to have a positive effect on environmental performance. Therefore, GI may serve as a mediator between GIC and economic performance. Similarly, GHRM may or may not be positively related to economic performance. And although studies have established that GHRM and environmental performance can be positively related (Paille et al., 2020), GHRM may not always have a positive effect on environmental performance. For example, employees may be environmentally friendly, but still lack the skills needed to generate improved products and processes and reduce harmful environmental effects while generating restorative environmental ones. This indicates that GI could typically mediate the relationship between GHRM and environmental performance. Thus:

H8. GI mediates the relationship between GIC and environmental performance.

H9. GI mediates the relationship between GHRM and environmental performance.

3. Methodology

3.1. Population and sampling

The Federation of Malaysia Manufacturer Directory (2015) lists 661 manufacturing firms as large organizations. The manufacturing sector is known for being a major source of air pollution, waste, water pollution, a clear contributor to climate change, and over-consumer of natural resources. As such, these large manufacturing companies represent an appropriate population for our research on GIC, GI, GHRM, and environmental strategies.

In this study, we utilized the data collected from the above companies. The study construct measures used in the study have been validated in prior research (Khan et al., 2019; Kraus et al., 2020; Rehman et al., 2019b). We utilized a simple random sampling technique for data collection (Sekaran and Bougie, 2016). Six individuals (three with extensive industry experience, and three academics) performed a pre-test to establish the validity of the constructs used in this study, confirming their validity. The survey questionnaire measured GIC, GHRM, GI, environmental strategy, and environmental performance. The unit of analysis was an organization.

We distributed 550 questionnaires to managers at each company. In several organizations, the managers did not respond to our invitation to take part in the survey. We provided reminders, and visited these organizations two weeks later. This achieved a total of 247 questionnaires that were returned, with three of them having missing values. We analyzed 244 questionnaires in total. In our sample, 113 (46.31%) organizations had 201 to 500 workers with between five to ten HR staffers (82 or 33.60%). 153 (62.70%) organizations were 20 years of age or older. The response rate in our study was 44.36%. The managers' enthusiasm about the subject matter, something of great importance to large manufacturing organizations, was in our opinion the reason for the survey's high response rate.

3.2. Questionnaire development

Green intellectual capital was measured using 22 items adapted from a variety of prior studies. For instance, green human capital was measured using five items, nine items measured green structural capital, and green relational capital was measured via four items following Chen (2008 a, b). In addition, green social capital was measured via four items adapted from Delgado-Verde et al. (2014). *Green human resource practices* were measured by using 15 items from Jabbour (2011). The analysis and description of job positions was measured with three items, recruitment was measured with two items, selection was measured with two items, training was measured with three items, rewards were measured with two items, and performance assessment was measured with three items. *Green innovation* was measured with eight items. Green product innovation was measured with four items, and green process innovation was measured with four items (Chen et al., 2006). *Environmental strategy* was measured with three items adapted from Banerjee et al. (2003). Finally, *Environmental performance* was measured using a five-item scale adapted from Laosirihongthong et al. (2013).

3.3. Common method bias (CMB)

All the exogenous and endogenous variables were collected at the same time from the same respondent, meaning the common method bias (CMB) could potentially be present in the dataset (Kraus et al., 2020; Mahto and Khanin, 2015). We used Herman's single-factor method to compute the CMB value recommended by Podsakoff and Organ (1986). According to Herman's single-factor method, the total variance value must be below 50%. The total variance in the study was 46.29%, ruling out the possibility of significant CMB issues with the data that could impact the relationship between variables.

3.4. Statistical analysis and results

We used structural equation modeling (SEM) for testing the proposed hypotheses. SmartPLS 3.2.8 was applied to conduct statistical analysis. PLS-SEM is widely used in research on innovation (Manley et al., 2020). The partial least square PLS-SEM is an appropriate method for examining both simple and complex frameworks (Hair et al., 2014).

We conducted four tests to validate the reflective variables, two tests regarding reliability, and two tests of validity. Individual scale reliability measures should be at least 0.50 (Hair et al., 2014). The lowest factor loading value was 0.619, while the highest value was 0.966. Thus, individual item reliability was not an issue, as all factor loadings were higher than the minimal value.

The internal consistency reliability is the second criterion of a measurement model used to compute CR value. As suggested by Hair et al. (2014), the CR value should be higher than 0.60. Furthermore, for exploratory research, a CR value greater than 0.95 is considered problematic. A CR value ranging between 0.70 to 0.90 and within 0.60 to 0.70 would be regarded as satisfactory. The data analysis showed no issue with CR. The AVE value should furthermore be more than 0.50 (Hair et al., 2014). Our study therefore met this criterion.

We computed the discriminant validity using the Heterotrait-Monotraitratio (HTMT) of correlation (Henseler et al., 2015). The standardized value was 0.85 for conceptually different constructs and 0.90 for conceptually similar ones (Henseler et al., 2015). Variance inflation factor (VIF) value was used to identify the multicollinearity issues. VIF value should be below five, showing that multicollinearity is not an issue (Hair et al., 2014). Table 1 shows that both the discriminant validity and multicollinearity criteria were met in this study.

4. Results

The structural model included several tests such as estimating path coefficients and their significance by running bootstrapping. The bootstrapping had 2000 subsamples. Table 2 demonstrates that neither GIC (β=0.031, $p = 0.124$, t-value=1.679) nor HRM (β=0.021, $p = 0.156$, t-value=1.504) were related to environmental performance. Hence, H_1 and H_3 were not supported. However, GIC (β=0.523, $p = 0.000$, t-value=12.044) and GHRM (β=0.342, $p = 0.006$, t-value=3.522) were positively associated with GI, supporting both H_2 and H_4 as a result.

We also established that GI was related to environmental performance (β=0.277, $p = 0.000$, t-value=5.278), thus supporting H_5. For moderation effect analysis, we found that environmental strategy significantly moderates the relationship between GI and environmental performance as (β=0.104, $p = 0.031$, t-value=2.509). Hence, H_6 was supported as well.Fig. 2 illustrates our finding that environmental strategy significantly strengthens the relationship between GI and environmental performance. The environmental strategy also is significantly related to environmental performance (β=0.496, $p = 0.000$, t-value=8.587), supporting H_7.

Variance accounted for (VAF) was used to determine the mediating effect of GI between GIC, GHRM, and environmental performance. As a guideline, VAF value greater than 80%, in a range of 20% to 80%, and below 20% is considered full mediation, partial mediation, and no mediation, respectively. Table 3 reports the mediating effect of 82.37% and 81.85%, respectively. This demonstrates that full mediation effects are observed in both cases. Thus, H_8 and H_9 are both supported.

Table. 1
Discriminant validity (HTMT) at Second Order.

Variables	VIF	ENPR	ES	GHRP	GI	GIC
Environmental Performance	—					
Environmental Strategy	1.094	0.836				
Green Human Resource Management	2.944	0.613	0.343			
Green Innovation	3.073	0.687	0.338	0.810		
Green Intellectual Capital	3.416	0.599	0.300	0.824	0.849	

4.1. Predictive relevance and effect size

As a guideline, Q^2 values of 0.35 (high), 0.15 (medium), and 0.02 (small) have predictive relevance (Cohen et al., 2013). Environmental performance (Q2=−0.209) and GI (Q2=0.288) fall in the medium range of predictive relevance.

According to Götz et al. (2010), f^2 demonstrates whether exogenous variables have a significant impact on the endogenous variable. Cohen (1988) stated that f^2 is comprised of various categories of smaller (f^2=0.02), medium (f^2=0.15), and higher effects (f^2=0.35). Table 4 shows that environmental strategy has a higher effect on environmental performance, whereas GI has a smaller effect on environmental performance. Neither GHRM nor GIC are related to environmental performance, although GHRM has a small effect on GI, and GIC has a medium effect on GI.

5. Discussion and conclusion

The natural-resource-based theory suggests that companies need to use pollution reduction strategies, product stewardship, and sustainable development to achieve a competitive advantage (Hart, 1995; Hart and Dowell, 2011). Advancing this perspective, we examined the role of proactive environmental strategies in helping a company enhance its environmental performance. Prior research has established that corporate social responsibility has no direct effect on environmental performance, but is positively correlated with environmental strategies that in turn are directly related to environmental performance (Krauss et al., 2020). Furthermore, scholars have shown that a proactive environmental strategy enhances operational performance (Dai et al., 2017) and that the relationship between a proactive environmental strategy and environmental performance can be mediated and moderated by several variables (Zhang et al., 2019). Building on this prior research on the role of proactive environmental strategies that may encompass pollution reduction, product stewardship, and sustainable development (Hart, 1995; Hart and Dowell, 2011), we establish in this paper that a proactive environmental strategy may positively affect environmental performance while mediating the relationship between GI and environmental performance.

We additionally demonstrate that neither the GIC nor GHRM are directly related to environmental performance. We interpret this finding in light of the proposed reinterpretation of the relationship between GIC and GI. Although many definitions of GIC suggest that GI can be part of GIC (Chen, 2008a, b; Chuang & Chen, 2012), we propose that GIC may not always contribute to GI, just as GI may not always contribute to GIC. For example, GIC may be too abstract and lack a practical orientation, whereas GI may not contribute to the growing GIC of an organization. Similarly, GHRM, for all its importance, may not be directly related to environmental performance. HR staffers may have the best intentions while at the same time lacking the knowledge and skills to achieve a positive environmental impact. Nevertheless, an organization actively involved in GI is likely to achieve a robust environmental effect. This is why GI, as shown in this paper, can moderate the effect of GIC and GHRM on environmental performance.

5.1. Theoretical implications

This paper contributes to developing the theory about environmental strategies with GIC, GHRM, and GI. Overall, it is essential to understand that GIC and GI form a dialectical relationship. GIC can only grow when an organization is actively involved in GI. This helps to update and continually increase GIC. As new knowledge generated via GI is absorbed into GIC, an organization can make its GIC more practically oriented and effective. Continually enriched GIC may lead to newer and newer

Table. 2
Hypotheses Results.

Hypotheses	Hypotheses Paths	β value	T-values	P-values	BCI LL	BCIUL	Results
H_1	GIC–>ENPR	0.031	1.679	0.124	−0.001	0.133	Rejected
H_2	GIC–>GI	0.523	12.044	0.000	0.508	0.687	Accepted
H_3	GHRM–>ENPR	0.021	1.504	0.156	−0.023	0.178	Rejected
H_4	GHRM–>GI	0.342	3.522	0.006	0.164	0.300	Accepted
H_5	GI–>ENPR	0.277	5.278	0.000	0.258	0.422	Accepted
H_6	ES*GI –>ENPR	0.104	2.509	0.031	0.016	0.136	Moderated
H_7	ES–>ENPR	0.496	8.587	0.000	0.387	0.554	Accepted
H_8	GIC–>GI–>ENPR	0.175	4.831	0.001	0.162	0.258	Full Mediation
H_9	GHRP–>GI–>ENPR	0.094	3.149	0.010	0.045	0.101	Full Mediation

Note: GIC= Green intellectual capital; GHRM=Green human resources management; ENPR=Environmental performance; GI=Green innovation; ES=Environmental strategy.

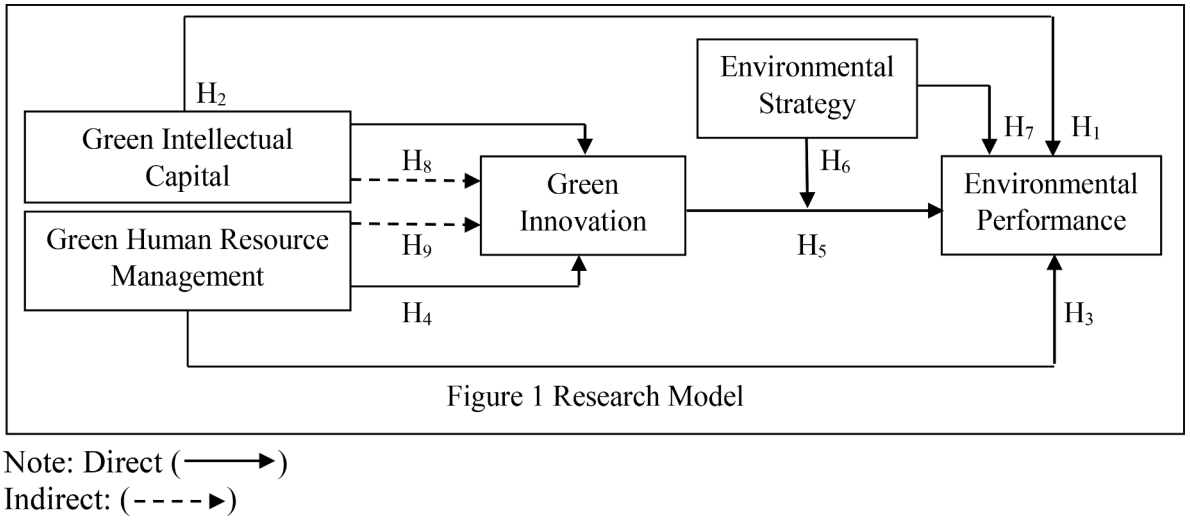

Fig.. 1. presents the research model developed in this study.

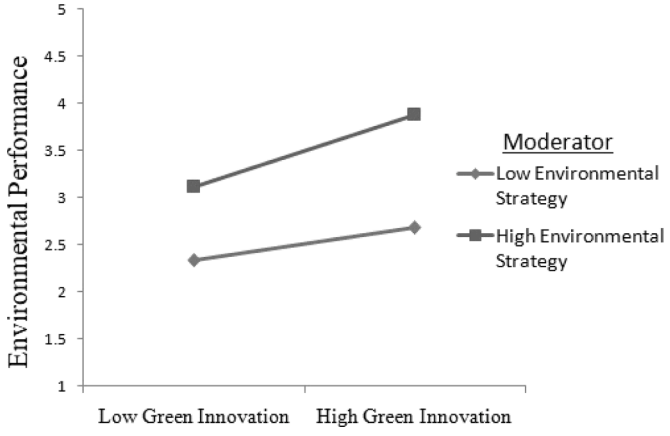

Fig.. 2. Environmental strategies as moderators.

cycles of GI, enhancing GI's contributions as a result. Ultimately, this incessant interaction between GIC and GI may have a strong impact on environmental performance. Similarly, GHRM is dialectically related to GI. It is through successful GI that GHRM can increase its effect on environmental performance.

5.2. Managerial implications

Organizations need to make a strong effort to continually reactivate and enrich their GIC. Only when the GIC of a company leads to successful GI can an organization achieve a competitive advantage. In this sense, GIC represents a tacit resource and dynamic capability continually evolving in interaction with GI. Managers should not stop at merely conducting exploitative GI that leads to the improvement of existing products and processes to make them more environmentally friendly.

Table. 4
The Effect Size of a Model.

	Green Innovation	Environmental Performance
Environmental Strategy	—	0.517
Green Human Resource Management	0.136	0.014
Green Innovation	—	0.057
Green Intellectual Capital	0.319	0.001

Table. 3
VAF of the Mediating Construct for Environmental Performance.

IndependentVariable	Dependent Variable	Mediating Variable	Indirect Effect	Total Effect	VAF (%)
GIC	ENPR	GI	0.144	0.175	82.37%
GHRM	ENPR	GI	0.094	0.115	81.85%

They should also spearhead an exploratory GI that could perhaps reverse negative environmental impacts, and positively impact the environment in the future.

5.3. Limitations and future research

We conducted this study based on a dataset collected in Malaysia. Similar studies set in other countries may arrive at different conclusions regarding the relationship between GIC, GHRM, GI, environmental strategies, and environmental performance. In addition, we did not differentiate in this study between exploitative and exploratory GI. It is conceivable that exploitative GI and exploratory GI may be related to environmental performance in their own particular ways. Furthermore, these GI types may differ in how they play their mediating roles. Future research could therefore further differentiate between different GI types. It will also be important to conduct an advanced analysis of companies' environmental strategies and their efficacy.

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