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The Role of Public-Private Partnerships in Cleaner Production Programs: Enhancing Environmental Performance in Malaysia's Manufacturing Sector

(Peranan Perkongsian Awam-Swasta dalam Program Pengeluaran Bersih: Meningkatkan Prestasi Alam Sekitar dalam Sektor Pembuatan di Malaysia)

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ABSTRACT

This study aims to analyze the factors influencing the quality of Public-Private Partnerships (PPP) and their impact on environmental performance among factories participating in the Cleaner Production program. We employ the theory of cooperation to determine how seven attributes affect the quality of PPP and environmental performance within 148 manufacturing firms involved in the Cleaner Production (CP) program organized by the Department of Environment Malaysia (DOE). The study findings revealed that partnership quality in the Cleaner Production program has been positively and significantly influenced by information sharing, communication quality, top management support and skills. In addition, the quality of the partnership has a significant positive impact on the reduction of raw material, energy savings and waste management costs. Recently, much research has focused on PPPs on mega-project, especially economics infrastructure and social infrastructure. This study adapts the theoretical framework of PPP in a pollution reduction project that has received little attention. PPPs enhance partnership quality by offering firms shared resources, incentives, and expertise, helping achieve environmental goals. These initiatives promote voluntary actions beyond compliance, like reducing raw material use, boosting energy efficiency, and cutting waste management costs, fostering proactive efforts for sustainable practices.

Keywords: Public-private partnership; partnership quality; cleaner production; environmental performance; manufacturing sector; Malaysia

ABSTRAK

Kajian ini bertujuan untuk menganalisis faktor-faktor yang mempengaruhi kualiti Perkongsian Awam-Swasta (PPP) dan kesannya terhadap prestasi alam sekitar bagi kilang-kilang yang menyertai program pengeluaran bersih. Kami menggunakan teori kerjasama untuk menentukan bagaimana tujuh atribut mempengaruhi kualiti PPP dan prestasi alam sekitar bagi 148 firma pembuatan yang terlibat dalam program Pengeluaran Bersih (CP) anjuran Jabatan Alam Sekitar Malaysia (JAS). Dapatan kajian mendapati kualiti perkongsian dalam program Pengeluaran Bersih dipengaruhi secara positif dan signifikan oleh perkongsian maklumat, kualiti komunikasi, sokongan pengurusan atasan dan kemahiran. Selain itu, kualiti perkongsian memberi kesan positif secara signifikan terhadap pengurangan penggunaan bahan mentah, penjimatan tenaga dan kos pengurusan sisa. Kebelakangan ini, banyak penyelidikan yang menumpukan pada PPP pada projek mega, terutamanya infrastruktur ekonomi dan infrastruktur sosial. Kajian ini mengadaptasi kerangka teori PPP dalam projek pengurangan pencemaran yang kurang mendapat perhatian. PPP meningkatkan kualiti kerjasama dengan menyediakan akses kepada sumber bersama, insentif, dan kepakaran, membantu syarikat mencapai matlamat alam sekitar. Inisiatif ini menggalakkan tindakan sukarela melebihi pematuhan, seperti mengurangkan penggunaan bahan mentah, meningkatkan kecekapan tenaga, dan mengurangkan kos pengurusan sisa, mendorong usaha mampan secara proaktif.

Kata Kunci: Perkongsian awam-swasta; kualiti perkongsian; pengeluaran bersih; pengurusan alam sekitar.

JEL: Q5, Q52, Q53, L2, L50

INTRODUCTION

Recently, a significant amount of research on Public-Private Partnerships (PPP) has concentrated on large-scale infrastructure projects, especially those involving economic and social infrastructure (Aladağ & Işik 2022; Mayer & Yusuf 2022; Navalersuph & Charoenngam 2021; Nyanyofio et al. 2022; Li et al. 2021; Shambaugh & Joshi 2021; Ogunbayo et al. 2021; Opara et al. 2022; Shevchuk et al. 2021). Economic infrastructure comprises physical systems and facilities, among them roads, ports, energy supply, and telecommunications. These facilitate economic activities. In contrast, social infrastructure encompasses facilities and services that promote social development and welfare, namely educational institutions, health facilities, housing, and water supply systems. Initiatives like these frequently arise to respond to the democratic deficit through liberalization, privatization, and globalization, which have steered the provision of public services towards models of collaborative governance.

Contrastingly, PPPs in the environmental field are interpreted and run under dissimilar principles. Instead of concentrating purely on infrastructure projects that are highly expensive, these PPPs serve as governance mechanisms to improve the environment. Hodge and Greve (2005) describe environmental PPPs as involving cooperative institutional arrangements that exhibit qualities of joint production and risk-sharing between entities in the public and private sectors. These arrangements signify a shift aimed at co-regulation, blending established laws with voluntary tools to tackle environmental issues (McAllister 2012). The tools used to regulate the environment have largely been highly legislative and used sanctions for enforcement (Nawawi & Ahmat 2018). There is now a move towards promoting co-responsibility, with institutions engaging in consultative agreements or voluntary programs to address environmental concerns by taking specific actions. PPPs have grown from just focusing on infrastructure to now include environmental governance, emphasizing co-production, shared duties, and collaborative decision-making in the effort to overcome challenges to the ecology (Hodge & Greve 2005; McAllister 2012).

Over the past two decades, public-private partnerships (PPPs) in environmental governance has shown mixed results, which has led to a deeper investigation of their effectiveness, especially concerning their supposed function in pollution control and prevention (Bhan 2013; McAllister 2012). What this indicates is a broader shift in environmental policy, moving from strict, top-down regulations, which are often punitive, to more adaptive, participative, and incentive-driven approaches. For example, the Common-Sense Initiative (CSI) in the U.S. did not meet its objectives due to excessive intervention by enforcement authorities in decision making (Bhan 2013). Therefore, the built-in flexibility offered by public-private partnerships often helps provide opportunities for companies to develop innovative ways to achieve set targets and at the same time improve environmental quality and competitiveness (Åm & Heiberg 2014). Mandell et al. (2020) said that "Private players are usually better prepared than government departments to negotiate, manage and renegotiate PPP contracts because they are focused from the very beginning on project output and outcomes, while government departments are usually still trying to move away from the traditional focus on the production of services (concerned with inputs and processes) to the PPP focus on the real result of the projects (output quantity and quality)." Appropriately, it's important to focus on aspects of partnership phenomenon and to observe actor perspectives on the partnerships, framing them as possible strategic instruments for achieving goals and problem solving at firm level (Van Huijstee et al. 2007).

The PPP approach in environmental management practiced in developed countries has shown success, but there are also programs that have failed (Orts & Deketelaere 2001). Literature studies on factors that drive PPP success generally place the role of public and private institutions in improving performance through joint agreements (Bhan 2013; Freeman 1997; McAllister 2012). The success of a program in a PPP context is determined by the quality of the partnership itself. This is because the quality of the partnership reflects the compatibility of the relationship between the two parties and the continuity of the relationship from the perspective of the industry (Ates 2013). Lee and Kim (1998) stated that previous literature studies did not clearly disentangle the elements that can influence the quality of partnership from the factors that influence it. Most studies look at these elements separately such as trust elements (Klijn et al. 2010; Marana et al. 2017; Marana et al. 2020), commitment (Marana et al. 2017; Marana et al. 2020), information (Brogt et al. 2015; Adam 2016). This element is also usually focused on in studies that look at the form of a partnership between buyers and sellers for private internal contracts (Cunningham & James 2017; Ee E. et al. 2013; Ee. O. et al. 2013; Espino-Rodríguez & Ramírez-Fierro 2018; Kim et al. 2013; Parker & Russell 2004; Reynaers 2014; Wei et al. 2018; Wibisono et al. 2019; Yang et al. 2019).

Public-Private Partnerships (PPPs) have been extensively studied in infrastructure development, but their role in environmental governance—especially in voluntary initiatives like Cleaner Production (CP)—is less explored. Most previous research focused on the structural or contractual elements of PPPs, or on less well-known factors like trust, commitment, or information sharing. However, there is a gap in comprehensive studies that examine how these factors on the whole impact partnership quality, particularly from the industry's viewpoint in the environmental sector. Additionally, most existing literature is based on the relationship between buyers and suppliers in private settings, which may not fully capture the unique aspects and issues faced by environmental PPPs. These partnerships will succeed or fail depending not just on institutional design but also on relationship qualities like mutual trust, shared commitment, and ability to communicate effectively.

This research attempts to address these gaps by exploring the determining factors of partnership quality inherent in the Cleaner Production program and evaluating the way this quality impacts environmental performance, focusing on pollution reduction in the manufacturing industry. Through the application of a firm-level viewpoint, the study adds to the ongoing discussion on collaborative environmental governance and offers practicable insights for decision-makers aiming to create PPP structures that are more effective. The research is conclusively important as it provides a more in-depth comprehension

of environmental PPPs' relationship dynamics, which is a crucial aspect to achieve viable industrial progress and meet wider environmental objectives.

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The application of PPP in environmental management provides several benefits including: i) government intervention through the provision of incentives will increase the industry's participation in voluntary programs (Freeman 1997), ii) reducing the burden of the enforcement authorities as a result of the commitment shown by the industry in achieving the objectives of the program (McAllister 2012). However, the success of this PPP depends a lot on the level of cooperation, clear objectives, industry involvement, flexibility, and the impact of transaction costs.

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LITERATURE REVIEW

QUALITY OF PUBLIC PRIVATE PARTNERSHIPS

According to Lee and Kim (1999) and Lahiri and Kedia (2009), the quality of partnership is defined as the extent to which the partnership results can meet the expectations of the parties involved. There are several scholars who present their argument that the quality of partnership is an important key to success in the formation of contractual bonds (Levina & Ross 2003; Lee & Kim 1999). Gebizlioglu (2016) explained that the quality of partnership is not a reflection of the success factor of a bond but is a characteristic of the success factor. In fact, Lahiri and Kedia (2009) and Raman et al. (2013) classified the quality of partnership as a valuable and exclusive form of relationship that leads to an increase in the ability and success of a firm. This is because the relationship formed depends on the principle of joint action and interdependence based on elements of trust, commitment, and understanding between the parties in an effort to improve performance (Lahiri & Kedia 2009; Lee & Kim 1999).

According to Liu (2020), a high level of partnership quality can give an indication of the reliability status for the parties involved. Not only that, it can also promote more programs in the form of development and also ensure that the cooperative relationship built can be maintained and easily obtain the support of new parties. A good level of partnership is explained through complete resources, capabilities, exchange of expertise and knowledge and reduces the firm's transaction costs According to Lee and Kim (1999) and Lahiri and Kedia (2009), the quality of partnership is defined as the extent to which the partnership results can meet the expectations of the parties involved. There are several scholars who present their argument that the quality of partnership is an important key to success in the formation of contractual bonds (Levina & Ross 2003; Lee & Kim 1999). Gebizlioglu (2016) explained that the quality of partnership is not a reflection of the success factor of a bond but is a characteristic of the success factor. In fact, Lahiri and Kedia (2009) and Raman et al. (2013) classified the quality of partnership as a valuable and exclusive form of relationship that leads to an increase in the ability and success of a firm. This is because the relationship formed depends on the principle of joint action and interdependence based on elements of trust, commitment, and understanding between the parties in an effort to improve performance (Lahiri & Kedia 2009; Lee & Kim 1999).

According to Liu (2020), a high level of partnership quality can give an indication of the reliability status for the parties involved. Not only that, it can also promote more programs in the form of development and also ensure that the cooperative relationship built can be maintained and easily obtain the support of new parties. A good level of partnership is explained through complete resources, capabilities, exchange of expertise and knowledge and reduces the firm's transaction costs (Dyer & Singh 1998). Addition, Liu (2020) found that partnership can improve coordination and complementary activities in the effort to obtain resources.

If the conditions regarding quality are not specified in the contract, the quality of public services will most likely be negatively affected by private interests alone (Hart 2003). Studies by Chakrabarty et al. (2016), Hsieh and Hiang (2004), and Grover et al. (1996) explained that service quality can be achieved based on the measurement of the partnership quality construct. Lee and Kim (1999) stated that the quality of partnership is built on the three elements of i) trust: the expectation to avoid being opportunistic even if the opportunity exists without any guarantee or refers to the psychological level with the intention to accept deviations with good faith towards other individuals; ii) sharing of risks and benefits: related to the level of smoothness of collaborative relationships involving benefits and risks between stakeholders; and iii) commitment: the desire to maintain relationships that are valued and considered important.

FACTORS AFFECTING THE QUALITY OF PUBLIC PRIVATE PARTNERSHIPS

Based on the theoretical framework presented by Lee and Kim (1999), there are seven factors that affect the quality of partnership in collaborative relationships among firms, including information sharing, coordination, leadership, communication quality, experience, skill and management support. First, information sharing is the access or availability of information communicated among the parties involved; it is influenced by the attitude, characterization and tendency of individuals to obtain information (Bao & Bouthillier 2013; Dawes 1996). Tong and Crosno (2015) explained that the information needs to be controlled according to the time period so that the information delivered is more beneficial to each party. The direction of information sharing depends on the openness between the parties involved according to certain circumstances. Information sharing enhances transparency and trust, enabling smoother collaboration and decision making, and connects positively with partnership quality. Second, the coordination element is defined by Liu and Cross (2016) as an action process to coordinate resources and information from various task areas. This action is an effort to obtain adaptation and compatibility between partners to achieve mutually determined goals (Gulati et al. 2012). Coordination contributes to

partnership quality by aligning roles and responsibilities, reducing ambiguity, and minimizing potential conflicts during implementation. This element plays an important role in reducing conflict and uncertainty in partnerships (Gardet & Mothe 2012).

The quality of partnership requires top management support, which is defined as awareness of the organizational environment in an effort to achieve goals without any problems (Tawalare & Laishram 2018). Management support signals top-level commitment and facilitates access to strategic resources. When leaders back the collaboration, it increases legitimacy and ensures smoother decision-making processes. Next, experience is one of the important factors that can demonstrate successful partnership and is positively connected with participants' capacity to manage the interface between their own organizations and external actors, among other outcomes (Meerkerk & Edelenbos 2014). A possible reason for this is that businesses with experience from many PPP can navigate and connect with the public partners more readily (Munksgaard et al. 2017).

In addition, skills are one of the most important factors for improving partnership quality. Most significantly, business represents technical skills and inventive abilities, while government and business comprise complimentary partners for mutual progress (Dittmer et al. 2009; Meglio 2013). According to Provan and Kenis (2008), private or professional abilities must be relevant to the partnership's main objective. As the goal of PPP in the context of Cleaner Production is to develop and implement new options in this context—specifically constituting technical know-how, professional knowledge, abilities and innovation training—these skills are particularly important (Brogaard 2017; Munksgaard et al. 2017). "Know-how" is the practical expertise, skills, and experience required to effectively complete a task. It encompasses more than just theory because what it really means is being able to apply that knowledge in real-life settings.

In a similar spirit, quality communication in partnerships is crucial. Communication that is unambiguous and regular instils partners' confidence in each other and minimizes misinterpretations. To accomplish the planned goals, partners must effectively communicate with one another. In reality, this results in better information for the parties, which should boost each party's confidence in the partnership and willingness to successfully sustain it (Lee & Kim 1999; Lee et al. 2008). Communication quality and information sharing are intertwined, but they are distinct concepts. Information sharing involves the actual content and freely available data transmitted among partners (Bao & Bouthillier 2013), while communication quality is concerned with the manner of interactions and how frequent and clear they are because they influence perceptions and relationships (Lee & Kim 1999). Communication that maintains a high quality ensures that the information shared is correct, time appropriate, and context appropriate.

The final factor is leadership that deals with how public or private leadership of the PPP affects creative results by assisting in the removal or mitigation of barriers and facilitating learning (Steijn et al. 2011; Hartley et al. 2013). Mei et al. (2013) and Nissen et al. (2014) demonstrate the need for strong public leadership in PPP in order to promote and create opportunities for strong connections and knowledge sharing, particularly in PPP with numerous partners, no prior history of collaboration, and therefore low initial trust.

PUBLIC-PRIVATE PARTNERSHIP PROGRAM ON ENVIRONMENTAL MANAGEMENT IN MALAYSIA

The implementation of Cleaner Production using the PPP concept was first applied in Malaysia starting in 1989, through the collaboration of Danish Cooperation for Environment and Development (DANCED), the Standards and Industrial Research Institute of Malaysia (SIRIM) and the Department of Environment Malaysia *(*DOE). The aim is to promote clean technology in the manufacturing sector in Malaysia. This project focuses on three main sectors namely food, electroplating and textiles and has successfully audited 40 industries where 90% of them are small and medium enterprises (SMEs) and the rest multinational industries. This project has successfully achieved its objectives with various cost savings achievements, increased productivity in addition to increasing the companies' profits (Cleaner Production Audit Report 2019).

In 2003, a DOE collaboration with consultants from Universiti Teknologi Malaysia (UTM) documented the Clean Production Action Plan for Malaysia. This framework is used as a guide to reduce water, air and waste intensity by the industrial sector. Based on records from the DOE annual report (2009–2019), a total of 220 premises were selected to entire CP process and used as a benchmark for other premises. There are several documentations of achievements published by the DOE for premises that participated in the demonstration program organized by the department (see Table 1).

TABLE 1. Cleaner production performance in Malaysia

Opsyen	Benefits after the program	Opsyen
MM Vitaoils Sdn. Bhd (2009-2010)	1. Crystallizer Bypass Pipe Installation 2. Increase the Pipe Diameter 3.Pneumatic Control Valve Installation 4. Use of Semi-Automatic Sealing Machine	Electricity savings of RM3893/month and labor cost RM18000/year
Dagang Batikraf (2010-2011)	1.16 types of options for arrays and premises security equipment 2. Installation of batik effluent treatment system	Improve the work environment. Decrease in energy intensity and waste water.
Jabi Rice Mill Sdn. Bhd (2014-2016)	1. Supply of personal protective equipment to employees 2. Installation of transparent roof or wall layers 3. Build a temporary storage place as well as a new channel 4. Supply of high-tech equipment	Electricity savings 12,824kWh/month (93%) CO2 reduction 8.6 tons/month
PPNJ Poultry and Meat Sdn Bhd	1. Conversion of fluorescent lamps to LED lamps 2. Installation of variable speed drive 3. Installation of thermal insulation on hot water tank	Electricity savings of RM120000/year by CO2 reduction 8.6 tons/month 221.94 tons/year

**Source: DOE annual report (2009 - 2019)*

Undeniably, most of the premises involved in this demonstration project obtained benefits in the form of cost savings in addition to a reduction in the use of energy and water, and waste intensity. Overall, the effect of CP implementation can be seen based on the immediate impact.

ENVIRONMENTAL PERFORMANCE AND PUBLIC-PRIVATE PARTNERSHIP PROGRAM

Environmental programs that use the PPP approach aim to achieve a level of pollution reduction and long-term effects on environmental policy. According to Lober (1996), environmental performance is a firm's commitment to preserve and protect natural resources throughout the production process. The components of environmental performance include pollution reduction, resource saving, waste reduction, energy conservation, and reporting potential risk between the parties (Epstein & Roy 1998).

There are various measurements of PPP performance levels that are used among researchers, such as the achievement of project progress over time, budget and efficiency achievement. For contract-based PPPs, target achievement refers to elements that have been set in the contract itself. The study of the behavior of firms in PPP such as by Warsen et al. (2018), uses the perception of five dimensions which is the achievement of the effectiveness of the solution, support, key features of the solution, robustness of the solution for the future and cost effectiveness.

For the Cleaner Production program organized by the DOE Malaysia, the achievement of program results is clearly stated in the Cleaner Production Blueprint for Malaysia (2007) which is to reduce the use of raw materials and environmental pollution, energy saving, increased productivity and reduction of waste management costs.

THEORETICAL FRAMEWORK

The Theory of Cooperation acts as the underpinning of this research. This theory highlights mutual goals, interdependence, and trust as key elements to ensure the success of a collaboration (Deutsch 1949; Axelrod 1984). In Public-Private Partnerships (PPPs), this theory suggests that cooperation is more than just a formal agreement; it is a relational process built on mutual understanding, trust, and ongoing shared benefits. The seven characteristics discussed in the following paragraphs act as mechanisms for operationalizing and sustaining cooperation in PPP contexts.

According to previous studies, the theoretical framework adapted from Lee and Kim (1999) is used to explain elements that influence partnership quality in the CP program. Figure 1 illustrates the seven main factors that influence partnership quality: Information Sharing (IFM), Coordination (COR), Leadership (LDR), Communication Quality (QCM), Experience (EXP), Management Support (MS), and Skill (SKL). These factors, derived from established literature, are crucial to building public-private partnerships that are robust and effective in environmental initiatives.

Aligned with CP program objectives, the framework contains five indicators of environmental performance: raw material reduction (RM), waste reduction (WSTE), energy savings (ENG), waste management cost reduction (CW), and productivity improvement (PR). These benchmarks, based on the Cleaner Production Blueprint for Malaysia (2007), reflect the desired outcomes of CP practical implementation.

This framework offers a structured model of the contribution of varied organizational and relationship factors to partnership quality and the way such partnerships can enhance environmental performance. The framework acts as a basis for empirical analysis and aids in comprehending PPPs' role in advancing sustainability goals in the Malaysian manufacturing industry.

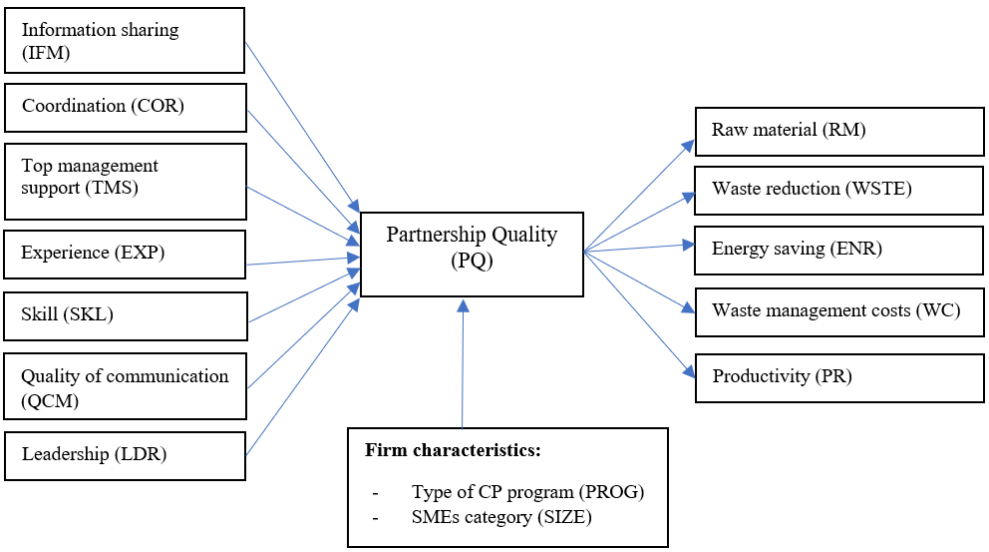

FIGURE 1. Theoretical framework

METHODOLOGY

DATA SOURCE AND COLLECTIONS

The primary source of the research data is a structured questionnaire distributed to 220 manufacturing industry premises involved in the CP program organized by the Department of Environment (DOE). A census approach with a 30% sample baseline was used, employing 66 respondents as the population sample. This approach is based on the work by Neuman (2003), who states that a 30% sample is suitable for populations below 1,000. The threshold 30% is also considered sufficient for exploratory surveys aiming to capture diversity within a defined population (Krejcie & Morgan 1970; Hill 1998). Because of the target population's relative homogeneity and the logistic barriers, this threshold makes sure that the representation is enough for statistical analysis while remaining practical.

This study was supported by a research grant from the Ministry of Higher Education Malaysia and was closely monitored by Universiti Malaysia Terengganu. Ethical permission was secured from the university's research ethics committee. Participants were informed of the study's objectives, and participation was voluntary. Informed consent was obtained, and strict measures ensured participant anonymity and confidentiality throughout the research.

Before the full survey, a pilot survey with 10 manufacturing firms involved in the Cleaner Production program tested the questionnaire's clarity, relevance, and reliability. Respondent feedback was used to refine a few of the items' wording and structure. The pilot also enabled preliminary reliability testing using Cronbach's alpha for internal consistency prior to its distribution to respondents. The questionnaire was sent to the 220 companies at the end of 2022, after the COVID-19 pandemic, during a period of stable business operations when data collection was feasible either on-site or remotely. Data collection finished by June 2022. Although collected in 2022, the data remains relevant for policy deliberations due to the consistent environmental and industrial policy framework regarding Cleaner Production programs in Malaysia.

VARIABLE AND MEASUREMENT

This study focuses on i) the factors influencing the Partnership Quality (PQ) based on self-assessment by top management, and ii) the effect of PQ and control variables on five environmental performance indicators of the firm. The factory manager should express his perception of the cooperative relationship with the environmental department throughout the implementation of the Cleaner Production program. The five-point Likert scale is used, i.e. "1 = strongly disagree" to "5 = strongly agree". As an example, for the coordination factor, the factory manager needs to state his level of agreement with three statements: i) We and the DOE are able to solve most of our problems through mutual discussion; ii) We know and support what is required by the DOE at all necessary times, and iii) We are able to have a coordination system in solving problems that arise with the DOE. All questions to develop the dependent variable and seven independent variables were adapted based on Lee and Kim (1999) and Bhan (2013). Two variables of factory characteristics that were identified as influencing the quality of partnership, namely firm size and program type, were also included in the model. The model for partnership quality is as follows;

$$PQ = b_0 + b_1 SKL_i + b_2 EXP_i + b_3 LDR_i + b_4 COR_i + b_5 QCM_i + b_6 IFM_i + b_7 \text{TMS}_i + b_8 SIZE_i + b_9 PROG + \varepsilon_i \quad (1)$$

Where:

PQ	= Partnership Quality (average score)
SKL	= Skill (average score)
EXP	= Experience (average score)
LDR	= Leadership (average score)
COR	= Coordination (average score)
QCM	= Quality of communication (average score)
IFM	= Information sharing (average score)
TMS	= Top management support (average score)
SIZE	= Firm size ('0' = small and medium enterprise: '1' = others)
PROG	= Type of program ('0' = Audit program: '1' = Demonstration project)

The size of the firm refers to the type of enterprise whether it has the status of SME or non-SME. The literature review found that large-sized firms (non-SMEs) have the ability to implement cleaner production, and this study expects the quality of partnership for non-SME premises to be significantly high. In order to analyze the effect of PPP quality on environmental performance, there are five separate OLS models:

$$RM = b_0 + b_1 PQ_i + b_2 SIZE_i + b_3 PROG_i + \varepsilon_i \quad \text{..... (2)}$$

$$WSTE = b_0 + b_1 PQ_i + b_2 SIZE_i + b_3 PROG_i + \varepsilon_i \quad \text{..... (3)}$$

$$ENR = b_0 + b_1PQ_i + b_2SIZE_i + b_3PROG_i + \varepsilon_i \quad \text{..... (4)}$$

$$CW = b_0 + b_1PQ_i + b_2SIZE_i + b_3PROG_i + \varepsilon_i \quad \text{..... (5)}$$

$$PR = b_0 + b_1PQ_i + b_2SIZE_i + b_3PROG_i + \varepsilon_i \quad \text{..... (6)}$$

Where;

RM	= reduction in the use of raw materials (%)
WSTE	= waste reduction (%)
ENR	= Energy saving (%)
CW	= Reduction of waste management costs (%)
PR	= Productivity (%)

METHOD AND DATA ANALYSIS

Based on the theoretical framework (Figure 1), the research hypothesis examines the factors that influence the quality of the partnership (Equation 1). Multiple regression analysis is used to do this and attention should be paid to the existence of multicollinearity problems due to high bias when it comes to behavioral studies. According to Daoud (2017), multicollinearity can be resolved by combining the highly correlated variables through principal component analysis, or omitting a variable from the analysis that is highly associated with other variable(s). Based on the literature review, there is a specific factor that is the most dominant in influencing the quality of the partnership and this places all the potential factors influencing the quality of the partnership. Since this study is an exploratory analysis, regression analysis uses a stepwise procedure where one method is appropriate special case of hierarchical regression in which statistical algorithms determine what predictors end up in the model (Chen et al. 2016). The ordinary least squares (OLS) stepwise selection assists in screening for those explanatory variables that appear to significantly impact quality of partnership. Control variables are included in the first stage of the stepwise regression to isolate the variable's effect on the partnership quality variable. Statistical analyses in this study were all done with IBM SPSS Statistics version 29.0.

RESULTS

Table 2 shows the response rate of 220 firms after the census process ended. Of the 220 premises that followed the CP program organized by the DOE, a total of 148 factories (67.27%) cooperated in completing the questionnaire. About 25.9% of factories refused and another 5.9% could not be contacted or traced.

TABLE 2. Response rate

	Number of response (%)			
Number of firm (%)	The factory is not operating	The factory could not be contacted	The factory refused	The factory that completed the questionnaire
220 (100%)	2 (0.9)	13 (5.91)	57 (25.91)	148 (67.27)

Source: N/A

According to Cummings et al. (2001), there is no prevalence set by previous researchers in determining the accepted value for the response rate. However, most researchers agree that the acceptable response rate received is in the range of 30 to 70% (De Vaus, 2002). Therefore, the sample size in this study can represent the industrial population that follows the Cleaner Production program in Malaysia.

INDUSTRIAL PROFILING

Table 3 summarizes the data distribution based on the firm's criteria such as position of respondent, number of employees, annual sales and type of industry. The unit of analysis in the study requires respondents who are responsible for environmental management. The results show that 43.2% hold the position of manager followed by other positions (32.4%) consisting of quality control officers, environmental executives and executives.

More than a third of firms have between 5 and 74 employees and over 200 employees. In terms of annual sales, 33.78% of firms have sales values of less than RM300,000 and 29.73% of premises have sales values of between RM15 million and up to RM50 million. According to SME Corporation (2023), small and medium enterprises (SME) in the manufacturing sector refer to firms with several full-time employees not exceeding 200 or annual sales not exceeding RM50 million. The cross-tabulation analysis found that 54.1% of the respondents in this study have SME status. Out of 148 cooperatives, 32.4% are in the food and beverage industry, followed by the metal finish and electroplating industry (16.2%).

TABLE 3. Profile of industries participating in the cleaner production program

No.	Firm characteristics	Frequency	Percentage
1	Position of respondent:		
	Manager	64	43.24
	Assistant manager	16	10.81
	Environmental Health and Safety Manager	20	13.51
	Others	48	32.43
2	Number of employees:		
	Less than 5	4	2.70
	5 – 74	52	35.14
	75 – 200	40	27.02
	More than 200	52	35.14
3	Annual sales:		
	Less than RM300,000	50	33.78
	RM300,000 to < RM 15 million	24	16.22
	RM15 million to RM 50 million	44	29.73
	More than RM 50 million	30	20.27
4	Type of Industry:		
	Food and beverage	48	32.43
	Metal finish and electroplating	24	16.22
	Textile	16	10.81
	cement	16	10.81
	Metal fabrication	12	8.11
	Pulp and paper	4	2.70
	Chemical	4	2.70
	Others	24	16.22

Source: N/A

RELIABILITY TEST

Alpha reliability coefficients for all explanatory variables and response variables are listed in Table 4. Of all seven factors that affect partnership quality, communication quality and management support seem to be the most internally consistent (α = 0.923) based on Fraenkel and Wallen's (1996) opinion by setting the value of α between 0.70–0.99, while the errors scale has the lowest alpha values (α = 0.708).

TABLE 4. Alpha reliability coefficients of partnership quality and determinant

Variables	No. Of Item	Internally consistent (α)	
		Pilot test (n=10)	Full survey (n=148)
Response variable			
Partnership Quality	8	0.841	0.847
Explanatory variables			
Skill	3	0.835	0.846
Experience	3	0.852	0.726
Leadership	4	0.756	0.742
Coordination	3	0.791	0.834
Communication	4	0.915	0.923
Information sharing	3	0.830	0.834
Management support	2	0.899	0.923

Source: N/A

CORRELATION AND REGRESSION ANALYSIS

The two main goals of this inferential analysis are, i) to identify the relationship between the partnership quality and its determinants, and ii) to analyze the factors that affect the quality of partnership. The measurement of all variables uses the 5-point likert scale. Table 5 summarizes the Pearson coefficient between variables.

TABLE 5. Analysis correlation of factors affecting the partnership quality

	PQ	SKL	EXP	LDR	COR	QCM	IFM	TMS
PQ	1							
SKL	.603***	1						
EXP	.797***	.602***	1					
LDR	.652***	.576***	.690***	1				
COR	.820***	.545***	.807***	.634***	1			
QCM	.810***	.588***	.831***	.588***	.809***	1		
IFM	.854***	.446***	.734***	.600***	.759***	.697***	1	
TMS	.605***	.448***	.540***	.733***	.743***	.488***	.484***	1

Note: *significant at 0.10
** significant at 0.05
*** significant at 0.01

Source: N/A

A Pearson correlation coefficient was computed to assess the relationship between the partnership quality and its determinants. There is a strong and positive correlation between partnership quality and all its determinants, especially

information sharing (r = 0.854), coordination (r = 0.820) and communication quality (r = 0.810). The results of the analysis also found a strong and significant positive relationship between the explanatory variables. This may be a multicollinearity problem for the regression model. According to Daoud (2017), multicollinearity can be resolved by excluding variables from the analysis that are highly related to other variables. This study uses a stepwise procedure which is a method that uses the appropriate hierarchical regression; a statistical algorithm determines the predictors that end up in the model (Chen et al. 2016).

Table 6 is the regression results using the stepwise procedure, with four models formed from this analysis. The highest R^2 value of 0.859 was found in model 4, meaning it explains 85.9% of the variation in the dependent variable. This indicates that model 4 offers the best fit for the study's data compared to the others. According to Lewis-Beck and Skalaban (1990), models with higher R^2 and adjusted R^2 values are considered to offer a better fit to the data.

TABLE 6. Model summary for stepwise analysis

Model	R	R^2	Adjusted R^2	Error
1	0.849	0.721	0.719	0.326
2	0.902	0.814	0.811	0.267
3	0.920	0.846	0.842	0.244
4	0.927	0.859	0.855	0.234

Source: N/A

Table 7 shows the regression results of model 4 from the stepwise procedure. Based on the results, variables of IFM, QCM, TMS and SKL were significant at the 0.01 significance level and related as positive with PQ. What this indicates is that for each one-unit increase in information sharing, partnership quality is raised by 0.478 units, assuming other variables remain constant. This significant effect suggests that enhancing internal data-sharing mechanisms can meaningfully impact partnership quality. Similarly, increases in communication (β = 0.227), top management support (β = 0.130), and skills (β = 0.107) have a moderate contribution to partnership quality. Furthermore, the SKL variable is also significant at the 0.01 significance level and is positively related to partnership quality. This means that skills in the form of technical know-how, professional knowledge, abilities and innovation training positively affect the quality of the partnership.

TABLE 7. Results of regression analysis for partnership quality

Variable	PQ	
	β	VIF
Constant	0.308	
	(0.138)	
IFM	0.478***	1.999
	(0.041)	
QCM	0.227***	2.522
	(0.041)	
TMS	0.130***	1.422
	(0.028)	
SKL	0.107***	1.614
	(0.029)	
n	148	
R^2	0.859	
Adj. R^2	0.855	
F Statistic	217.144 (0.000***)	

Note: *significant at 0.10
** significant at 0.05
*** significant at 0.01
Source: N/A

The second objective is to analyze the influence of quality public-private partnership on environmental performance in the manufacturing industry in Malaysia. Table 8 shows that PQ has a significant positive relationship with all five environmental performance variables of at least 0.05.

TABLE 8. The correlation between partnership quality and environmetal performance

	RM	WSTE	ENR	CW	PR
PQ	.612***	.320**	.538***	.371**.	426**

Note: *significant at 0.10
** significant at 0.05
*** significant at 0.01
Source: N/A

Table 9 shows the regression results for Equation (2) to Equation (6). All models were found to have no multicollinearity problem with a VIF (variance inflation factor) value of less than 5. The F-test also shows that explanatory variables can influence environmental performance significantly. Overall, the partnership quality (PQ) variable is seen to have a significant effect on the environmental performance in Equations (2), (4) and (6). Equation model (2) shows the partnership quality (PQ) to be significantly positively influencing the reduction of raw material consumption (RM) at a 0.01 significance level. A one-unit increase in partnership quality is associated with an 18.5% improvement in raw material savings. This is a large practical impact, reinforcing that collaborative partnerships significantly support cleaner production efforts.

Equation model (4) shows that the PQ is significantly and positively affecting the reduction of energy consumption (ENR) at a 0.01 significance level. PQ has a significant positive impact on energy reduction, at 23.68%, indicating

substantial cost savings for companies' operations. Additionally, the PROG variable has a significant and positive influence on energy consumption reduction (ENR) at a 0.01 significance level. This implies those firms in the demonstration category achieve a drop of about 20.43% more in energy consumption compared to firms in the audit category, with other variables unchanging. Firms in the demonstration group, selected by the Department of Environment (DOE), are given technical and financial support to carry out Cleaner Production practices effectively, while audit category firms only receive a report with recommendations.

Similarly, in Equation (5), partnership quality (PQ) significantly minimizes waste management costs (WC) at a 1% significance level. What this means is a one-unit increase in PQ results in a 12.8% more reduction in these costs, with other factors remaining unchanged. This result underscores the value of robust public-private partnerships in enhancing environmental management cost-efficiency. However, the PROG variable has a significant and negative impact on WC at 5%, indicating that audit firms achieve a 12.2% greater reduction in costs compared with demonstration firms, when controlling for other variables. This could be because audit category firms focus more on immediate cost-saving strategies, prioritizing short-term financial gains through efficient waste management, whereas demonstration firms may pursue more comprehensive, long-term, and more expensive improvements with the assistance of the DOE.

The PROG variable in Equation model (3), positively and significantly affects waste reduction (WSTE) at a 1% significance level, meaning demonstration firms achieve a bigger reduction of 8.6% in waste than audit firms, with other factors held unchanged. This illustrates the practical benefits of participating in the demonstration program for waste reduction.

In Equation model (6) though, the PROG variable negatively predicts productivity (PR), suggesting that audit firms have higher productivity than demonstration category firms. This might be because demonstration firms, while engaged in broader initiatives, may at the same time temporarily redirect resources from production, impacting short-term production numbers. As a contrast, audit firms, receiving only assessment reports, may have better efficiencies in operations by focusing solely on productivity. In addition, non-SME firms show a 9.9% better productivity than SMEs, which is expected since larger firms usually have greater resources, more advanced technology, and higher capacity for production efficiency.

TABLE 9. Results of regression analysis for environmental performance

	RM (eq. 2)		WSTE (eq. 3)		ENR (eq. 4)		WC (eq. 5)		PR (eq. 6)	
	β	VIF	β	VIF	β	VIF	β	VIF	β	VIF
Constant	-36.375		38.474		-69.631		-9.401		-51.335	
	(25.22)		(12.215)		(18.036)		(21.741)		(22.001)	
PQ	18.509***	2.281	-0.842	1.424	23.684***	1.416	12.845***	1.160	21.031	1.026
	(5.438)		(3.008)		(4.525)		(4.743)		(4.974)	
PROG	-7.152	2.396	8.563***	1.212	20.431***	1.411	-12.183***	1.188	-2.834***	1.160
	(8.866)		(3.308)		(6.005)		(4.996)		(5.520)	
SIZE	4.240	1.107	16.350***	1.503	7.957	1.687	5.199	1.033	9.926*	1.185
	(5.121)		(3.684)		(6.5567)		(4.939)		(5.579)	
n	68		92		68		96		96	
R^2	.391		.217		.398		.207		.207	
Adj. R^2	.362		.190		.370		.181		.181	
F-Stac.	13.690		8.110		14.113		7.998		8.717	
(P-value)	(.000)***		(.000)***		(.000)***		(.000)***		(.000)***	

Note: *significant at 0.10
** significant at 0.05
*** significant at 0.01
Source: N/A

DISCUSSION

This study explores the factors affecting partnership quality (PQ) in PPPs and the influence exerted on the manufacturing industry's environmental performance. The results indicate that communication, information sharing, top management support, and technical expertise significantly influence PQ. Shared understanding and trust are fostered by effective communication, aligning with Ee et al. (2013) and Galanaki and Papalexandris (2005), who highlighted the importance of open dialogue in meeting shared objectives. Information sharing positively impacts PQ by enabling firms to adapt environmental goals and coordinate efforts, as espoused by Calza et al. (2017).

Top management support is critical as it facilitates internal alignment for collaboration, supports training and change management, and demonstrates commitment to sustainability (Henderson 1990). Additionally, having technical expertise in green technologies allows firms to effectively navigate complex environmental requirements (Hoffman 2017). This result underscores the importance of continuous learning and adaptability for green partnerships and their success. PQ's positive impact on environmental performance is evident in raw material use reductions, energy consumption decline, and lower waste management costs, suggesting that high-quality partnerships enhance the implementation of Cleaner Production practices, as found by Xie et al. (2020), Tang and Zhou (2021) and Zhang et al. (2020). It must be noted that demonstration-based PPP programs provided higher benefits than audit-based programs, highlighting the higher marginal impact of technical and financial support mechanisms on sustainability results.

The second objective examined how PQ affects environmental performance, focusing on three vital indicators: reducing raw material usage, energy use, and waste management costs. Higher partnership quality was significantly linked to a greater reduction in raw material usage, supporting the idea that strategic partnerships facilitate input optimization

through innovation sharing, improvement in processes, and strategies for joint procurement (Xie et al. 2020). Regarding energy use, PQ positively influences energy-saving initiatives, with collaborative partnerships enabling firms to adopt technologies that are most cost efficient, share best practices, and co-develop approaches to reduce energy intensity (Tang & Zhou 2021), leading to cost reductions and lower emissions of carbon.

In waste management, firms with higher PQ achieve greater cost reductions through joint recycling initiatives, resource recovery, and consolidated waste treatment infrastructure. This result aligns with the work by Liu and Chen (2021) and Zhang et al. (2020), who emphasized the benefits of collaborative waste reduction on firm economics and environment. Additionally, firms in demonstration programs—offering technical assistance and financial support—consistently achieved better environmental outcomes compared to those receiving only audit reports, indicating that resource-backed collaboration is more effective than solely information-based interventions.

CONCLUSION

This study enhances the understanding of how public-private partnerships (PPPs) improve environmental performance in the manufacturing industry by exploring the determinants and influences of partnership quality (PQ). The results highlight that the key underpinnings of PQ are effective communication, information sharing, top management support, and technical expertise. Such results emphasize the importance of both relational (i.e., trust and commitment) and structural (i.e., managerial and technical capabilities) elements in fostering partnerships that are successful and have impact.

Significantly, the study shows that high-quality partnerships result in major benefits to the environment, such as lower use of raw materials, reduced energy consumption, and highly efficient waste management. These results place PQ as a strategic enabler for adopting Cleaner Production practices as well as an operational variable. Firms in demonstration-based PPPs, which provide technical and financial support, achieved better environmental performance than those in audit-only programs, highlighting the value of comprehensive collaborations.

Theoretically, this study expands the existing body of work on PPPs by removing the focus from frameworks at the macro level to partnership dynamics at the micro level. It illustrates how experiences and internal capabilities at firm level combine with external partnerships to influence sustainability results. This perspective enriches the resource-based view by demonstrating that developing internal competencies (e.g., top management support, technical expertise) enhances outside collaborations. It also contributes to institutional theory by showing how firms internalize expectations through high-quality partnerships at the organization level, aligning practices with broader environmental goals.

In conclusion, the study challenges the traditional compliance-focused view of PPPs by presenting them as dynamic, capability-enhancing mechanisms that drive solid and practical environmental improvements. This reconceptualization opens new research avenues on optimizing PPP design and implementation for both aspects of economy and ecology.

LIMITATIONS AND SUGGESTIONS FOR FUTURE RESEARCH

Notwithstanding its practical benefits, the study possesses several limitations. First, the analysis relies on cross-sectional data collected after the pandemic of COVID-19 (in 2022), limiting its ability to draw causal conclusions or observe changes over time. Further studies in the future should contemplate applying longitudinal designs to investigate how partnership quality and environmental performance develop over a period of several years.

Second, the study focused only on Malaysian manufacturing companies. The dynamics and institutional support structures may differ based on sector and country. Studies in the future could consider conducting comparative analyses between sectors (for example, food processing, electronics) or carry out benchmarking of different countries to gain an understanding of each country's policies affect PPPs' effectiveness. Third, while this study captures perceptions of partnership quality at company level, it precludes the public agency (i.e., DOE) and its perspective. Future studies might adopt an approach that is dyadic or consider the multitude of stakeholders, taking in input from governmental agencies, non-governmental agencies, and other relevant stakeholders for a more comprehensive assessment.

Lastly, upcoming studies should investigate Cleaner Production implementation in terms of its maturity, including the depth and breadth of environmental practices in companies' operational and strategic processes. Finding this data can help policymakers tailor interventions according to firms' levels of readiness and capability.

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