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Extended producer responsibility in developing economies: Assessment of promoting factors through retail electronic firms for sustainable e-waste management

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Abstract

The adoption of the extended producers' responsibility (EPR) principle as a mitigation strategy for e-waste management has gained impetus over the past few years. However, e-waste management in developing economies through retail electronic firms' or producer responsibility organization is still inceptive. This study identified and analysed promoting factors of EPR principle adoption through retail electronic firms in the Ghanaian electronic industry. Through extant literature and stakeholders' perspectives, 15 factors were identified as strategic and operational promoting factors, which were evaluated by experts. Subsequently, the grey Decision-Making Trial and Evaluation Laboratory technique was used to analyse the data obtained. The outcome of the study suggests that operational factors have more influence than strategic factors to determine the adoption of the EPR principle. In addition, most of the important operational factors tend to be enabled by both push and pull measures by supply chain stakeholders. In the short term, adopting an advanced deposit recycling refund scheme tends to be the most effective elementary operational factor, which can push retailers to adopt the EPR principle. The significant pull elementary factors that need short-term attention include the opening up and creation of new market opportunities for e-companies as well as resilient and effective resources management. The study findings suggest that Ghana's present policy framework is limited for the adoption of the EPR principle by retail electronic firms. The study contributes to identifying promoting factors for adoption of the EPR principle from the perspectives of both the external and internal stakeholders in the electronic industry with emphasis on push and pull strategy.

Keywords

Extended producer responsibility, retail electronic firms, stakeholders perspective, e-waste management, Delphi method, grey-DEMATEL

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Introduction

The rapid urban development, expansion of industrial activities, the advancement of information and communication technologies, and the human desire for new electrical and electronic products have increased the volumes of electrical and electronic waste (e-waste) generation globally. The industrial revolution and unabated introduction of new electrical and equipment in the last three decades by the electronic industries have heightened the discourse on effective management systems of e-waste, owning to the mass production of obsolete products (Bhatia and Srivastava, 2018; Chandra, 2020). The unceasing generation of e-waste in developed economies has become a major threat to the environment, human health and socio-economic activities (de Souza et al., 2016). One of the prime reasons for this threat is the lack of proper recycling technology for processing the massive volumes of e-waste generated annually (Li et al., 2015; Sasaki, 2020).

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The global statistics on e-wastes indicated that e-waste generation reached an unprecedented record of 53.6 million metric tonnes in 2019. The sharp upsurge of 21% was attributed to the consumers' quest for new electronic products and the advancement of information technology in the developing economies. In 2019, an estimated 53.6 million tonnes of e-waste were generated, which is about 7.3 kg per person (Forti et al., 2020; Tiseo, 2021). Out of 53.6 million tonnes of e-waste generated, 13.1 million tonnes were generated in the USA, Asia produced 24.9 million tonnes, 12 million tonnes were generated by the European Union (EU), African countries generated 2.9 million tonnes and Oceania produced 0.7 million tonnes (Ghimire and Ariya, 2020; Islam et al., 2020). According to the Tiseo (2021), Asia produces a substantial amount of e-waste than other regions; thus, on average, Asia generates 5.6 kg per person. However, in contrast, the volume of e-waste generated per capita in Europe and the Americas is considerably higher, at 16.2 and 13.3 kg, respectively. Existing studies have projected that the global e-waste generation by 2030 is estimated to be around 74.7 million tonnes (Dhir et al., 2021; Rautela et al., 2021; Shaikh et al., 2020). It is noteworthy to indicate that only 20% of e-waste generated worldwide is managed through formal practices, whereas the remaining 80% are managed using conventional techniques (Awasthi et al., 2018; Gollakota et al., 2020).

The millions of e-wastes generated globally have fuelled the discussion among scholars, practitioners, policymakers and governments about effective e-waste recycling and management to curb the ever-growing poor e-waste management menace (Gollakota et al., 2020). Currently, many developed countries have initiated and implemented several laws and policies based on the EU directive, Basel convention and extended producer responsibility (EPR) principle to control and manage e-wastes (Mohammadi et al., 2021). According to the EPR principle, original electronic manufacturers must assume responsibility or take back their electronic products at the end-of-life (EoL) span for recycling and management (Lindhqvist, 2000). The original producers of electronic products assume total responsibility for e-waste collection, transportation, remanufacturing, treatment and disposal. This practice by producers has been hugely and successfully implemented in many developed countries such as Germany, Denmark, Australia, Japan and Canada (Li et al., 2015; Rubio et al., 2019). The effectiveness and the success of implementing the EPR principle in the developed countries has been attributed to the availability or the proximity of original producers (Kaya et al., 2020). The availability of producers makes it relatively easier to achieve the adoption of EPR principle for consumers in the developed countries who are able to return their unwanted and obsolete e-waste products for recycling and management. However, in many developing economies, original electronic producers are rare, unavailable and non-existence to access (Kumar et al., 2020). This is because original electronic producers export their finished electronic products to developing economies through retailers for marketing. Therefore, the adoption of the EPR principle for e-waste recycling and management rests greatly on retail electronic firms (Hilton et al., 2019; Tong and Yan, 2013). Nonetheless, there are limited studies that highlight the commitment of retail electronic firms in the adoption of the EPR principle in addressing e-waste in developing economies.

Ghana faces enormous e-waste management challenges that pose a significant impact on the environment, socio-economic activities and public health concerns (Agyei-Mensah and Oteng-Ababio, 2012; Caravanos et al., 2011). Consumers' insatiable desire for new electronic products, including the quest of the government to keep pace with global advancement in information and technology and increase technology to under-serve rural communities has resulted in the surge of e-waste generation (Adanu et al., 2020; Oteng-Ababio, 2010b; Sovacool, 2019). The Ghanaian government recognizes the complexities associated with the unregulated and rudimentary practices for managing e-waste, which causes major threats to the environment and human health. Considering these menace, e-waste management policies called 'Hazardous and Electronic Waste Control and Management Act, 2016 (Act 917)' and legislative instrument (LI 2250) were developed to underpin addressing e-waste management practices challenges (Amoabeng Nti et al., 2020). The policies and legislative instrument creates the legal framework for effective and sustainable management of e-waste. Notwithstanding, the introduction of the policies and legislative instrument effective e-waste management in Ghana continues to be a major concern to decision-makers (Chen et al., 2020; Quaye et al., 2019). The volume of locally generated and imported e-waste in Ghana has increased informal e-waste management activities, which the government, stakeholders and industry actors are grappling to address (Adanu et al., 2020). Hence, in general, sustainable e-waste management has become increasingly important and gained substantial attention in the electronic industry; however, the role of retail electronic firms for the adoption of EPR principle is under explored in existing literature.

With the increasing number of retail electronic firms in Ghana, including *Sollatek Electronics, Somotex Ghana Limited, Nasco electronics* and *Hisense*, the adoption of the EPR principle as a strategy for sustainable e-waste is still nascent. The lack of EPR principle adoption through retail electronic firms has also spurred informal e-waste management practices in places such as the infamous Agbogbloshie e-waste yard (Daso et al., 2016). Poor e-waste recycling and management practices have become a critical challenge that threatens the attainment of Sustainable Development Goals (SDGs), particularly SDG 3 (good health and well-being), SDG 6 (clean water and sanitation) and SDG 11 (sustainable cities and communities) (Arya and Kumar, 2020; van Zanten and van Tulder, 2020). The adoption of the EPR principle via retail electronic firms inure to safe e-waste management that protect the environment and human health (Hilton et al., 2019). Therefore, considering the environmental and health challenges that emanate from informal e-waste, the adoption of the EPR principle through retail electronic firms for e-waste management in Ghana comes in handy. Notwithstanding, environmental and health concerns associated with informal e-waste management, the adoption of the EPR principle provides sustainable employment to several households. Though there are copious research carried out on e-waste management in Ghana

(Agyei-Mensah and Oteng-Ababio, 2012; Feldt et al., 2014; Oteng-Ababio, 2010a; Srigboh et al., 2016; Zhao et al., 2016), there is a gap in literature that concentrate on promoting factors for the adoption of EPR principle by retail electronic firms for sustainable e-waste management. To bridge the above gap and the paucity of studies on EPR principle adoption through retail electronic firms, the present study aims to evaluate promoting factors for the adoption of EPR principle through retail electronic firms in developing economies. Ghana's e-waste context is considered as a potent study due to enormous challenges in addressing informal e-waste management practices. Accordingly, study is guided by the following objectives:

1. To develop a framework to identify promoting factors based on stakeholders' perspectives for the adoption of EPR principle for e-waste management through retail electronic firms in Ghana.
2. To present the interrelationship and sectional diagrams to understand the most influential and elementary promoting factors using grey-Decision Making Trial and Evaluation Laboratory (grey-DEMATEL) approach.
3. To provide practical and theoretical implications of the study for effective decision-making process by policymakers based on pull and push strategy policy technique.

To pursue the defined objectives of the study, Delphi method together with multi-criteria decision-making (MCDM) technique and DEMATEL were employed to explicitly understand promoting factors that will facilitate EPR principle adoption through retail electronic firms. Existing number of studies have employed a hybrid Delphi method and DEMATEL to address numerous complicated issues in science, management, engineering and environment (Bhatia and Srivastava, 2018; Chandra, 2020; Goulart Coelho et al., 2017; Kumar et al., 2017; Mangla et al., 2018; Sharma et al., 2020). In the present study, the Delphi method is applied to ascertain experts' opinion on the identified promoting factors through consensus to select relevant factors among numerous and equally other significant factors, whereas the grey-DEMATEL is employed to analyse the promoting factors into cause–effect groups to determine the causal interrelationship diagram (Karuppiah et al., 2020). However, the conventional DEMATEL technique application is often characterized by uncertainties, ambiguity and incomplete information during the decision-making process (Raj and Sah, 2019; Wang et al., 2017). Hence, in this study, grey theory is integrated to address the uncertainties, vagueness and incomplete information (Chandra, 2020; Deepanraj et al., 2017).

The contribution of this study is threefold: firstly, it identifies promoting factors for EPR principle adoption through retail electronic firms guided by stakeholders' perspectives. Thus, promoting factors that are strongly connected or related to the retail electronic firms are categorized as operational promoting factors, whereas factors that are associated with external stakeholders, such as the government, consumers and non-governmental organizations (NGOs), are considered as strategic promoting factors. The second contribution of the study is the categorization of the promoting factors into pull and push strategy to guide policymakers in formulating punitive and appealing policies for the adoption of EPR principle by retail electronic firms. Thirdly, the study contributes by analysing the causal interrelationship among the identified promoting factors of EPR adoption and their interaction possibilities to facilitate systematic decision-making process by policymakers.

Therefore, the remainder of the study is organized as follows: Section 'Literature review' provides a literature review on EPR, e-waste management and identification of promoting factors for EPR principle adoption. Section 'Research method' explains the methodology employed and data collection in this study. Section 'Study results and sensitivity analysis' presents the study results and sensitivity analysis. Section 'Discussion of results' discusses the results, theoretical and practical implications. The conclusions, limitations and scope of future work are provided in section 'Conclusion and future research'.

Literature review

This section covers previous studies on EPR, e-waste management and promoting factors of EPR principle adoption for e-waste management in developing economies through retail electronic firms. In order to identify the promoting factors from existing studies, a comprehensive literature review was conducted. Keywords such as 'extended producer responsibility' and 'e-waste management', were explored. The database used includes: Google Scholar, Emerald, Web of Science, Springer, Science Direct, Taylor and Francis and Scopus. In addition, the collected studies were examined using abstract and keywords in the article to focus on the EPR principle in developing economies. Furthermore, refining principles were applied to ensure the articles (a) 'articles are written in the English language were only selected' and (b) inclusion of only journal articles that are peer-reviewed and excluding all the conference proceedings. Copious numbers of journals were targeted to select the relevant articles for the study. For example, *Journal for a Sustainable Circular Economy, Journal of Production Economics, Journal of Cleaner Production, Journal of Sustainable Production and Consumption, Journal of Sustainability, Journal of Environmental Science and Pollution Research* and *Journal of Resources, Conservation, and Recycling*.

Extended producer responsibility

The world is transitioning from a linear economy to a circular economy to ensure the judicious utilization of scarce resources, create ecological civilization and socio-economic benefits (Murray et al., 2017). Therefore, diverse ways are been explored to ensure effective and sustainable ways of recycling and managing e-waste (Rotter, 2011). These concerns have attracted a growing interest in the adoption and adoption of the EPR principle to overcome informal e-waste management problems, particularly in the developing economies (Amankwaa, 2013; Ikhlayel, 2018; Islam and Huda, 2019). The EPR principle has gained substantial interest among researchers and practitioners (Kim et al., 2013; Nguyen et al., 2017; Niza et al., 2014; Widmer et al., 2005); however, EPR adoption with focus on the commitment of retail in the developing economies have not received the needed research attention (Ikhlayel, 2018).

The EPR principle is aimed at leveraging resources and shifting the burden of improper disposal of EoL products to safeguard the environment and public health (Hou et al., 2020). The EPR principle was first introduced by Thomas Lindhqvist in 1990 in Sweden, it was intended to encourage manufacturers to resume responsibility for the entire life cycle of consumers' obsolete products for recycling and disposal (Hou et al., 2020; Lindhqvist, 2000). With the intense generation of e-waste products in developed and developing economies, several strategies are being heralded as appropriate means to mitigate and control the ever-growing threat of e-waste (Chandra, 2020). In previous studies, some scholars have carried out numerous theoretical and practical studies premised on deriving measures and perspectives to enhance the adoption and adoption of the EPR principle in the electronic industry. For instance, Ribeiro and Kruglianskas (2020) indicated that the integration of principles of regulatory bodies, government agencies in the decision-making process promote amicable working relationships and collaborations among stakeholders will enhance effective adoptions of EPR policies by producers. They conducted a study of Dutch tyre EPR systems and on how it could be improved and reflect on the systemic approach of integrating the circular economy and EPR principle to properly recycle tyre devoid of environmental and health repercussions. The study highlighted collaboration and multi-stakeholder governance, effective monitoring and continuous improvement of the EPR system as well as improving inclusive social and environmental outcomes beyond EoL electronic products. A study on the adoption of EPR in Colombia revealed that financial, operational responsibility constraints, lack of incentives and tax waivers and collaboration among producers in the product chain are major hurdles obstructing effective adoption EPR practices by manufacturers in Colombia. The study suggests that the effectiveness of the EPR principle adoption in developing economies would require the establishment of comprehensive achievable targets and roadmap, employed interpretive structure modelling (ISM) and analytic network process (ANP) to understand the hierarchical relationship among the promoting factors of EPR practices in the Chinese electronic sector. The study suggested that the EPR-related policies and regulations, the top managerial commitment from industry players and corporate image were the most prominent factors for effective and sustainable adoption of EPR practices in China. From 2001, more than 75% of EPR systems have been implemented globally, after the Organisation for Economic Co-operation and Development (OECD) guidance manual was introduced (Park et al., 2018). In order to ensure effective and smooth adoption of EPR principle, numerous stakeholders inputs are essential, these include: manufacturers, retail firms, local authorities, developmental agencies, NGOs and consumers (Gui et al., 2013; Kunz et al., 2018).

Overview of e-waste management in Ghana

Informal e-waste management has become a lucrative source of livelihood for many unemployed youths in developing economies, especially in Africa and Asia (Loukil and Rouached, 2020). In Ghana, an estimated 200,000 people nationwide are involved in informal e-waste management practices that annually generate US$105–268 million income, especially for unemployed youths (Kwarteng et al., 2020). Nonetheless, informal e-waste management devastates the environment, human health and socio-economic activities (Asante et al., 2012; Prakash et al., 2010). The informal e-waste managing sites in Ghana are considered as the most toxic and unhealthy zones for humans and habitats (Feldt et al., 2014). The application of inappropriate techniques, such as opening burning, the use of hazardous substances and the uncontrolled dumping of e-waste, are common (Chen et al., 2020). Prior studies indicate the use of improper techniques to manage e-waste in Ghana is a major contributor to the spread of disease, water pollution, air pollution and floods due to the chokes of gutters by unwanted e-waste components (Feldt et al., 2014; Kaifie et al., 2020). Ghana's e-waste sector has attracted significant global attention stemming from a documentary by Greenpeace, which highlighted environmental, health and socio-economic effects by informal e-waste management practices (Adanu et al., 2020). Therefore, to address this challenge, the adoption of EPR principle is gaining substantial attraction from scholars, practitioners and stakeholders in the electronics sector.

Concerning EPR principle adoption and adoption, several studies have been carried with varied assessment techniques to derive effective approach to ensure its adoption in developing economies. Gupt and Sahay (2015) combined exploratory factor analysis and comparative analysis to ascertain the most important aspect of EPR in the developed and developing economies with and without informal recycling. The findings of the study identified regulatory provisions, take-back responsibility and financial flow as the most prominent aspects of implementing EPR used a stylized economic model to evaluate the efficiency of European EPR systems. The model reveals that the introduction of static collection targets creates a gap between theory and adoption. The study indicated that static targets lead to inefficient market outcomes and weak incentives for prevention and green product design by producers. Various countries have adopted different models in addressing e-waste management challenges to safeguard the environment, social-economic and health risk of communities (Zheng et al., 2017). Table 1 highlights some of the models been adopted by some countries to ensure effective e-waste management.

Considering the significance of evaluating the efficiency and effectiveness of the adoption of EPR for sustainable e-waste

Table 1. Models adopted by some countries for e-waste management.

Countries	Models of managing e-waste	Explanation
Switzerland	Producer obligation	Based on the principle of EPR. The financing of collection, utilization and disposal is carried out by charging advanced contributions from customers when buying EEE, the so-called advanced recycling fee.
	Collection system	Retailer and municipal collection points offer free drop-off and take-back of like-for-like. PROs have additional collection points as well (e.g. at train stations); Commercial consumers can request for paid pick-up.
	Financing mechanism	Manufacturer and importers pay for collection, treatment, recovery and environmentally sound disposal of WEEE at the point the product is put-on-market.
United Kingdom of Great Britain and Northern Ireland	Collection system	Designated collection facilities and producer compliance schemes set-up collection of WEEE through various channels, including civic amenity sites run by local authorities, retail collection points and direct collection (especially for non-household WEEE).
	Recycling system	An authorized treatment facility is a permitted site carrying out treatment on e-waste. Only operators of AATFs can issue evidence notes for the treatment, recovery or recycling of WEEE that takes place in the UK.
	Financing mechanism	Manufacturer and importers pay for collection, treatment, recovery and environmentally sound disposal of EEE, typically through collective compliance schemes.
	RoHS considerations	Anyone who imports EEE into the UK and places it on the market must be able to show that the EEE complies with the requirements of the RoHS regulations. They must ensure that the manufacturer has a register of non-conforming EEE and product recalls, carried out a conformity assessment procedure, drawn up technical documentation, affixed the CE mark and marked the EEE with the required information.
France	Producer obligation	Registration with the French WEEE Register 'Register DEEE'. Reporting obligations, such as market sales data. Ensuring the collection and environmentally sound treatment and disposal of WEEE, either individually or by joining a collective scheme.
	Recycling system	Producers should provide the EEE product user with recycling information. Producer responsibility organizations remove, sort, decontaminate and recycle collected WEEE.
	Financing mechanism	Manufacturer and importers pay for collection, treatment, recovery and environmentally sound disposal of EEE.
	Standards/audits	Third-party audits contracted by the PROs to audit recyclers and collection points.
	RoHS considerations	Anyone who imports new EEE into the EU and places it on the market must show that the EEE complies with the requirements of the RoHS directive and has the CE mark. The RoHS directive does not independently contain any legal grounds for applying export restrictions on used EEE.
Japan	Producer obligation	Establishment of a recovery and recycling system for used products. Manufacturers obligated to finance the recycling of their own products.
	Collection system	Home Appliance Recycling Law imposes an 'old for new' requirement on retailers, that is, every time a product is sold, the retailer must take back from the consumer either a similar used product or some other product sold in the past. Manufacturers can contract with other organizations, such as the Association for Electric Home Appliances (AEHA), to provide collection services on their behalf. In rural areas, collection is provided by local government or the AEHA if the retailer cannot cover.
China	Legislation	Technical Policy on Pollution Prevention and Control of WEEE (2006; SEPA No. 115). Ordinance on Management of Prevention and Control of Pollution from Electronic and Information Products (China RoHS) (2007; MIIT No. 39).
	Producer obligation	Producers and importers of EEE must pay a fee for the treatment of each unit they produce or import, except exported products. Household appliance producers are responsible for adopting 'green' product design, which is favourable to recycling and reuse.
	Collection system	E-waste is collected by manufacturers, retailers and waste collection enterprises.
	Recycling system	In China, only the manufacturers and certified recyclers are responsible for WEEE recycling. Treatment facilities have to establish an environmental quality monitoring system, an information management system for treated e-waste and a reporting procedure to the local Environmental Protection Agency.
	Monitoring system	Quarterly reporting to province-level environmental authorities by producers and recyclers of quantity and types of e-waste recycled and disposed. The tax and custom authorities are responsible for monitoring and inspection to ensure funds are collected from producers and importers.

(Continued)

Table 1. (Continued)

Countries	Models of managing e-waste	Explanation
Singapore	Collection system	Regulated consumer products are collected by the PRS operator. Regulated non-consumer products are collected by the producers of these items at no extra fee.
	Recycling system	Licensed waste collectors and licensed e-waste recyclers are responsible for disposal of e-waste.
	Financing mechanism	Producers of regulated consumer products pay for e-waste management by financing the PRS. Producers of regulated non-consumer products pay directly for the collection and recycling of the e-waste generated from their products.
Germany	Legislation	The European Directive (2012/19/EU) was transposed into German law by the Act Governing the Sale, Return and Environmentally Sound Disposal of Electrical and Electronic Equipment (Electrical and Electronic Equipment Act – ElektroG).
	Producer obligation	The ElektroG requires manufacturers to: Register electronic products and apply for a WEEE number before market launch; Ensure disassembly friendly production design; Regularly report to the German WEEE authority; Collection and take-back of WEEE; Appointment of an authorized representative for organizations without German subsidiary; Provisioning of a so-called insolvency save guarantee for producers of B2C products.
	Collection system	Public waste management authorities, retailers and producers are responsible. Public waste management authorities shall set up collection points in their districts to which final holders and distributors may return WEEE from private households. Producers are responsible for providing separate containers for each category of WEEE to the collection points.
	Recycling system	Producers must pick up their containers from the municipal collection facilities once they are full and to dispose contents professionally through expert-certified treatment facilities.
	Transboundary movement of used EEE	Export of hazardous/hazardous characteristics WEEE or UEEE is not allowed to countries outside of OECD.
India	Collection system	The producer may opt to implement EPR individually or collectively. Collection of WEEE is the responsibility of the producer and may be carried out, such as through dealer, collection centres, producer responsibility organization, through buy-back arrangement, exchange scheme, deposit refund system, etc., either directly or through any authorized agency.
	Recycling system	Producers and authorized recyclers are responsible for WEEE recycling. Recyclers must be authorized and ensure that the facility and recycling processes are in accordance with the standards or guidelines prescribed by the Central Pollution Control Board (CPCB).
	Financing mechanism	'Producers' (which include dealers, retailer, e-retailer, manufacturers and importers) pay for collection, treatment, recovery and environmentally sound disposal of EEE under EPR.
Australia	Collection system	Households and small businesses can drop-off EoL products at industry-provided collection services for free and may be provided by councils, retailers or other providers.
	Recycling system	Co-regulatory arrangements are responsible for organizing and delivering recycling services on behalf of producers.
	Financing mechanism	Producers pay the co-regulatory arrangement for the ESM of in-scope WEEE. It is a market driven competitive scheme, and the Australian Government is not involved in contracting or fee setting.

RoHS: Restriction of Hazardous Substances; ESM: Environmental Systems Management; WEEE: Waste Electrical and Electronic Equipment; PRS: Personal Response System; PRO: Producers Responsibility Organizations; DEEE: Department of Electrical and Electronics Engineering; CE: Circular Economy; UEEE: Used Electrical and Electronic Equipment; EEE: Electrical and Electronics Equipment.

management, various actors in the supply chain are considered to collaborate and disseminate relevant information that will inure in achieving and adopting EPR principle for e-waste management in the developing economies (Esenduran et al., 2019; Hou et al., 2020). It is imperative to indicate that significant number of electronic producers are not stationed in the developing economies, the availability of technology and sophisticated equipment for recycling obsolete e-waste to facilitate EPR adoption becomes challenging (Niza et al., 2014). An entrusted recycling pattern (third-party) is often introduced in the electronics sector in developing economies in which e-waste is managed by these special enterprises (Shan and Yang, 2020). In these instances, the EPR principle is applied by producers through a third party (from recyclers to producers). Therefore, collaboration among the various industry actors and stakeholders becomes crucial to ensure the signing of an agreement that will enforce the producers to bear the cost and responsibilities of the activities of recyclers in the developing economies (Shan and Yang, 2020).

There are other studies that discuses EPR holistically in the developed countries (Agamuthu and Victor, 2011; Gottberg et al., 2006; Rotter, 2011; Scheijgrond, 2011; Taghipour et al., 2012), but there is a lack of studies that examine promoting factors that will facilitate smooth adoption and adoption of EPR principle for sustainable e-waste management in using Delphi and grey-DEMATEL approach in the Ghanaian context. Furthermore, most identified studies adopted a theoretical and case study approach with none specifically focusing on prioritization of the promoting factors in causal a diagram for strategic decision-making process by policymakers.

Promoting factors for EPR principle adoption

The study identifies promoting factors of EPR principle adoption for e-waste management through retail electronic firms based on stakeholders' perspectives. In the present study, promoting factors associated with government, consumers, NGOs, development agencies and other external actors are considered as strategic promoting factors. In addition, factors related to the producers/retail electronic firms are categorized as operational promoting factors. Thus, after comprehensive literature and thorough consultation with the stakeholders, 15 strategic and operational promoting factors were identified and accepted for the study as highlighted in Table 2.

Research method

In this article, several steps were followed to achieve the objectives of the study. Firstly, the promoting factors for EPR principle adoption by retail electronic firms for e-waste management were identified from an extensive literature review and subsequently approved by a team of 18 evaluators through the Delphi method. Then, grey-DEMATEL technique was employed to determine the causal and effect factors, interdependency relationship as well as to construct causal relationship diagram to give a pictorial understanding of the influential factors to enhance systematic adoption of push and pull measures by policymakers. Figure 1 illustrates the research methodology of the study.

The application of the Delphi method

The Delphi method has been applied in several studies due to its ability to address complicated issues to its simplest form (Fernandez-Brana et al., 2019; Kauko and Palmroos, 2014). The Delphi method is an empirical technique utilized to generate and established experts' candid opinions on a specific subject based on their experience and understanding (Asante et al., 2022; Gardas et al., 2018b; Kauko and Palmroos, 2014; Zeh and Christalle, 2019). In addition, the Delphi method has been applied extensively in several studies to obtain expert opinions until there is a well-grounded and comprehensive consensus on selecting criteria, projects, attributes, solutions and policy directions (Delbecq et al., 1975; Kim et al., 2013). However, it is interesting to note that there is no specific rule that determines the sample size in the application of the Delphi method for a study (Hsu and Sandford, 2007). Hence, in the application of the Delphi method, authors/researchers determine the sampling technique and criteria for the selection of evaluators for a study. Then, the identified attributes or variables are presented to the evaluators for scrutiny, recommendation and approval (Bouzon et al., 2016; Bui et al., 2020; Ocampo et al., 2018). For insistence, Chen et al. (2020) employed six evaluators to evaluate barriers and pathways to the adoption of e-waste formalization management systems in Ghana and used seven evaluators to analyse barriers to municipal solid waste management policy planning in Maputo city, Mozambique; Kim et al. (2013) employed 10 experts' views to assess the priorities of e-waste for recycling in a waste management decision-making tool in Korea. Furthermore, many studies have also employed less than five experts' views for a study (Giunipero et al., 2012; Hsu and Sandford, 2007; Kusi-Sarpong et al., 2016). These indicate that the sample size of evaluators for a Delphi method varies. However, according to Kauko and Palmroos (2014), between 5 and 10 evaluators are considered as an acceptable sample size when evaluators are homogeneous (in the same industry). Therefore, this study employed the Delphi technique to obtain experts' views on the identified promoting factors for EPR principle adoption for e-waste management in Ghana as applied in existing studies (Bux et al., 2020; Mohammadfam et al., 2019). The Delphi method was utilized because it saves time and is cost-effective; it is not limited to geographical location and provides room for evaluators to thoroughly examine the factors and provide relevant solutions (Hsu and Sandford, 2007; Karuppiah et al., 2020).

The grey-DEMATEL

The DEMATEL method is one of the most used MCDM techniques to establish the relationship among criteria into cause–effect groups and prominence aimed at assisting policymakers to avoid discrepancies in the decision-making process (Jeong and

Table 2. Promoting factors of EPR principle based on considered stakeholder perspective.

Code	Promoting factors for EPR principle adoption	Brief description	Categorization	References
F_1	Environmental concerns and pressure from consumers	This occurs when consumers become environmentally conscious due to an improper approach to recycling or management of electronic product. This will influence the adoption of the EPR principle by producers.	Strategic	Johnson and McCarthy (2014); Xiang and Ming (2011)
F_2	Supportive policies and legal frameworks for EPR practices adoption	The enactment and adoption policy and framework towards the adoption of the EPR principle in managing e-waste. The existing policies and regulation will enforce and streamline EPR principle adoption in the electronic industry.	Strategic	Chen et al. (2020); Yadav et al. (2020)
F_3	Subsidies and incentives benefit to consumers	The provision of subsidy and incentives to consumers to return their electronic product will boost the effective adoption of the EPR principle.	Strategic	Rahimifard et al. (2009); Xiang and Ming (2011); Zheng et al. (2017)
F_4	Promotion, support and collaboration with environmentally conscious partners	These entities assist in the area of technology and technical support to e-companies essential for appropriate e-waste management practices.	Strategic	de Oliveira et al. (2018); Mahpour (2018); Zhu and He (2017)
F_5	Open up and create a new market opportunity for the e-companies	The adoption of the EPR principle for e-waste management create and increases e-companies' customers share and profit. This results from consumer's desire to have a collection point for their e-waste equipment.	Operational	Chen (2008); Homrich et al. (2018)
F_6	Effective and systematic approach systems through retail electronic firms	This involves applicable and strategic systems approach to managing e-waste to enhance the enforcement of EPR principle schemes. This will facilitate and lead to the adoption of relevant legislative frameworks for e-waste management.	Operational	Homrich et al. (2018)
F_7	Normative influence from suppliers, customers and associations	Normative influence or pressure arises from vendors, consumers, organizations such as trade unions of businesses, the media, civil society organizations (CSOs) other social institutions. These entities play a crucial role in the adoption EPR principle in the electronic industry.	Operational	Chen et al. (2020); Leclerc and Badami (2020); Zoeteman et al. (2010)
F_8	Adopting advanced deposit recycling refund scheme	The deposit refund scheme is an insensitive plan or approach in which consumers deposit the initial stage of purchasing electronic product from companies. The deposited amount is refunded to the consumer if they return the electronic product for proper management when it becomes obsolete or unwanted.	Operational	Nnorom and Osibanjo (2008); Wath et al. (2010)
F_9	Mimetic influence from industry competitors	Here, leading companies in the electronic industry set an example in the field of implementing EPR practices. The adoption of the EPR principle helps leading companies obtain competitive advantages and a wilder market base.	Operational	Kumar and Dixit (2018); Luo et al. (2015)
F_{10}	Green awareness creation	The majority of consumers are not aware of environmental problems that exude from informal e-waste management practices and the best possible approach to surmount them. Hence, consumers must be well-informed about the environmental challenges and the need to collaborate with stakeholders for EPR principle adoption.	Strategic	Lieder and Rashid, (2016); Su et al. (2013)
F_{11}	Rewards and incentives for greener activities by the government	Rewards and incentives boost companies' morale for practising the EPR principle and ensuring environmental sustainable activities.	Strategic	Rahimifard et al., 2009; Yadav et al. (2020); Zhu and Tian, 2016)
F_{12}	Adopting innovative practices to manage EoL electronic products	The adoption of advanced and quality methods of implementing EPR practices at the various levels in the supply chain will enhance ERP principle adoption.	Operational	Leclerc and Badami (2020)
F_{13}	Resilient and effective resources management	Ensuring the effective and sustainable use of limited resources is required for EPR principle adoption.	Operational	Bodar et al. (2018); Özarslan et al. (2011)
F_{14}	Top management commitment	Top management commitment, involvement and willingness are essential for the EPR principle adoption.	Operational	Saavedra et al., 2018; Yadav et al., 2020
F_{15}	Reverse supply chain practices in the electronic industry	EPR principle adoption will be effective if reverse logistic practices employed, which will indirectly inure to the EPR principle adoption.	Operational	Bouzon et al. (2016); Whicher et al. (2018)

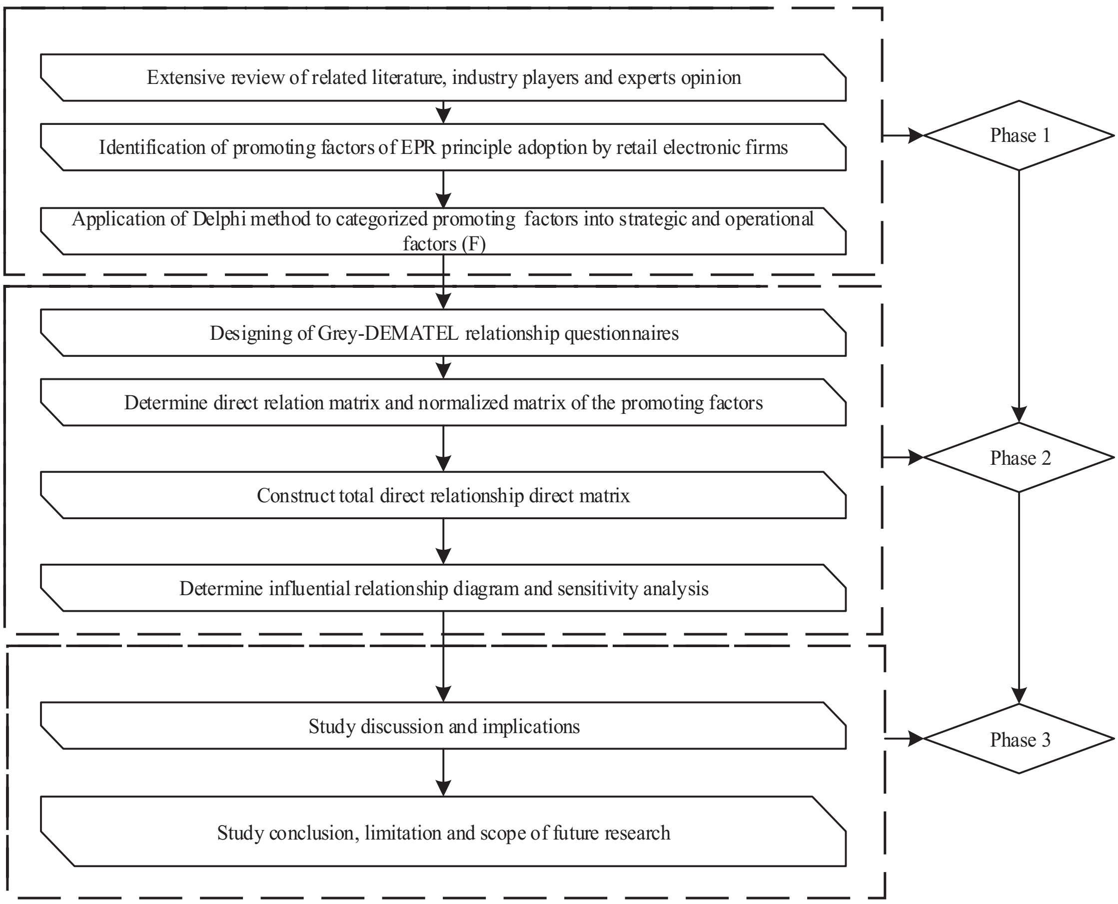

Figure 1. The proposed framework of the study.

Ramírez-Gómez, 2018; Sahu et al., 2018). DEMATEL was developed by the Battelle Memorial Institute of Geneva in 1976 to address intricate issues in various fields (Fontela and Gabus, 1976). DEMATEL technique has been widely applied to address numerous multi-criteria and complex issues across different sectors such as management (Kumar and Dixit, 2018), supply chain (Kusi-Sarpong et al., 2016; Sufiyan et al., 2019), agriculture (Gardas et al., 2018a) and engineering (Xia et al., 2015). As a result, many scholars and researchers discerned on applying DEMATEL technique over other well-known MCDM models such as best–worst method (BWM), ANP, analytical hierarchy process and ISM (Bai and Sarkis, 2013; Beikkhakhian et al., 2015; Bouzon et al., 2016). This is because DEMATEL provides a better relationship diagram among factors by considering the strength of relationship than ISM (Raj and Sah, 2019), it is straightforward and easy to compute (Wang et al., 2017), it provides a wide range of assessment options through linguistic numbers (Bacudio et al., 2016), DEMATEL technique categorizes factors into cause–effect sets, which further helps decision-makers to formulate effective and systematic strategies to address complex issues (Govindan et al., 2015).

The application of conventional DEMATEL is usually associated with inadequacies related to incomplete information, imprecision and subjective evaluation (Bai et al., 2017). Subjective judgements are usually vague and difficult for decision-makers to explain by specific number values (Li et al., 2014). Hence, in this study, grey theory is integrated with DEMATEL to address subjective evaluation, incomplete information and imprecision during the decision-making process (Cui et al., 2019; Govindan et al., 2015). For example, Agyemang et al. (2018) used the grey-DEMATEL technique to evaluate barriers to green supply chain redesign and adoption of related practices in the West Africa cashew industry and also used grey-DEMATEL-modelled enablers of green innovation in manufacturing organizations. Furthermore, analysed critical success factors for adoption of drones in the logistics sector using grey-DEMATEL technique. Many studies have successfully applied this method to address complex issues; however, none has applied this approach in the context of EPR principle adoption for e-waste management in the Ghanaian context. Therefore, the step-by-step application of grey-DEMATEL as indicated in previous studies (Luthra et al., 2017) are as follows:

Step 1: Defining the expert panel and evaluation criteria using grey scales. In the first step, a panel of evaluators is formed to obtain their views on the study objectives through the Delphi technique.

Step 2: Construction of an initial matrix for promoting factors using the linguistic scale as shown in Table 3.

In this step, a five-level pairwise influence comparison scale to construct a direct-relationship matrix is carried out using the grey

Table 3. Linguistic scale and corresponding grey values.

Linguistic assessment	Grey-related values	Influence score
No influence (NO)	(0, 0)	0
Very low influence (VL)	(0, 0.25)	1
Low influence (L)	(0.25, 0.5)	2
High influence (H)	(0.5, 0.75)	3
Very high influence (VH)	(0.75, 1)	4

linguistic scale. Here, we asked each expert to pairwise compare the promoting factors of the EPR principle to obtain the direct matrix of *D* using the scale ranging from 0 to 4. They are 0=no influence (N), 1=very low influence (VL), 2=low influence (L), 3=high influence (H) and 4=very high influence (VH) as shown in Table 3. Since the defined scale in the questionnaire is uncertain, we follow prior studies (Chandra, 2020; Xia et al., 2015).

Step 3: Computation of the grey relation matrix.

Here, we employed Converting Fuzzy data into Crisp Scores (CFCS) (Wu and Lee, 2007) to change the grey numbers into crisp values using equations (1)–(3) as:

$$\otimes\tilde{x}_{ij}^{k} = \left(\underline{\otimes}\tilde{x}_{ij}^{k}, \overline{\otimes}\tilde{x}_{ij}^{k}\right), \tag{1}$$

where $1 \le k \le K; 1 \le i \le n; 1 \le j \le n$, $\underline{\otimes}\tilde{x}_{ij}^{k}$ indicates the lower limit and $\overline{\otimes}\tilde{x}_{ij}^{k}$ represents the upper limit of grey numerical values for respondents *k, i*, and *j*, respectively.

Step 4: Determine the average grey relation matrix *D*.

In this step, the average grey relation matrix *D* is given as: $\left\{\otimes\tilde{x}_{ij}^{k}\right\}$. It is generated from *K*, and the grey relation matrix is shown as,

$$\otimes\tilde{x}_{ij}^{k} = \left(\frac{\xi_k \underline{\otimes}\tilde{x}_{ij}^{k}}{k}, \frac{\xi_k \overline{\otimes}\tilde{x}_{ij}^{k}}{k}\right) \tag{2}$$

$$D = \otimes\tilde{x}_{ij}^{k} \tag{3}$$

Step 5: Determine the crisp relation matrix (*T*).

The crisp values of the grey number $\otimes\tilde{x}_{ij}^{k} = \left(\underline{\otimes}\tilde{x}_{ij}^{k}, \overline{\otimes}\tilde{x}_{ij}^{k}\right)$ can be obtained by using a variation of the CFSC proposed by Opricovic and Tzeng (2003) and Xia et al. (2015). Hence, the following are the steps involved in adopting CFSC to determine the crisp relation matrix.

a. Normalization of the grey values on the lower bound using equations 4 and 5, where *k* is the number of experts.

$$\underline{\otimes}\tilde{x}_{ij}^{k} = \left(\underline{\otimes}x_{ij}^{k} - \min_{j}\underline{\otimes}x_{ij}^{k}\right) \Big/ \Delta_{\min}^{\max} \tag{4}$$

$$\overline{\otimes}\tilde{x}_{ij}^{k} = \left(\overline{\otimes}x_{ij}^{k} - \min_{j}\overline{\otimes}x_{ij}^{k}\right) \Big/ \Delta_{\min}^{\max} \tag{5}$$

In this case,

$$\Delta_{\min}^{\max} = \min_{j}\overline{\otimes}x_{ij}^{k} - \underline{\otimes}x_{ij}^{k} \tag{6}$$

b. Evaluation of total normalized crisp value using equation (7) is given as:

$$y_{ij}^{k} = \left(\frac{\underline{\otimes}\tilde{x}_{ij}^{k}\left(1-\underline{\otimes}\tilde{x}_{ij}^{k}\right)+\left(\overline{\otimes}\tilde{x}_{ij}^{k}\times\overline{\otimes}\tilde{x}_{ij}^{k}\right)}{\left(1-\underline{\otimes}\tilde{x}_{ij}^{k}+\overline{\otimes}\tilde{x}_{ij}^{k}\right)}\right) \tag{7}$$

c. Then, we determine the final crisp values by equation (8) as:

$$z_{ij}^{k} = \left(\min_{j}\underline{\otimes}x_{ij}^{k} + y_{ij}^{k} \cdot \Delta_{\min}^{\max}\right) \quad \text{and} \tag{8}$$

$$T = \left[k_{ij}^{k}\right] \tag{9}$$

Step 6: Computation of the normalized direct crisp relation matrix (*T*).

$$k = \frac{1}{\max\limits_{1 \le i \le n}\sum_{j=1}^{n} z_{ij}^{k}} \quad \text{and} \tag{10}$$

$$X = K \times T \tag{11}$$

where *K* is a normalization factor and *T* is a crisp relation matrix.

Step 7: The total relation matrix (*S*) can be obtained using equation (12):

$$S = X \times (I - X)^{-1}, \tag{12}$$

where *I* represents the identity matrix.

Step 8: Determine the causal influence diagram.

Here, the sum of the rows and the sum of the columns represent as vectors *R* and *C*, by using equations (13)–(15). In this step, $i, j \in \{1,2,\ldots,n\}$ and $i = j$; the horizontal axis $R_i + c_j$ is obtained by adding vector *r* to vector *c*, which reveals the relative importance of each criterion. Similarly, the vertical axis $R_i - C_j$ is made by subtracting vector R_i from the vector C_j, which may divide criteria into cause and effect groups. In general, the value $R_i - c_j$ is positive, then the criterion belongs to the cause group, and it $R_i - c_j$ is negative; then, the criterion belongs to the effect group. Therefore, the causal diagram can be obtained by mapping the data set of $R_i + c_j$ and $R_i - c_j$ values. This provides some insight into making valuable decisions.

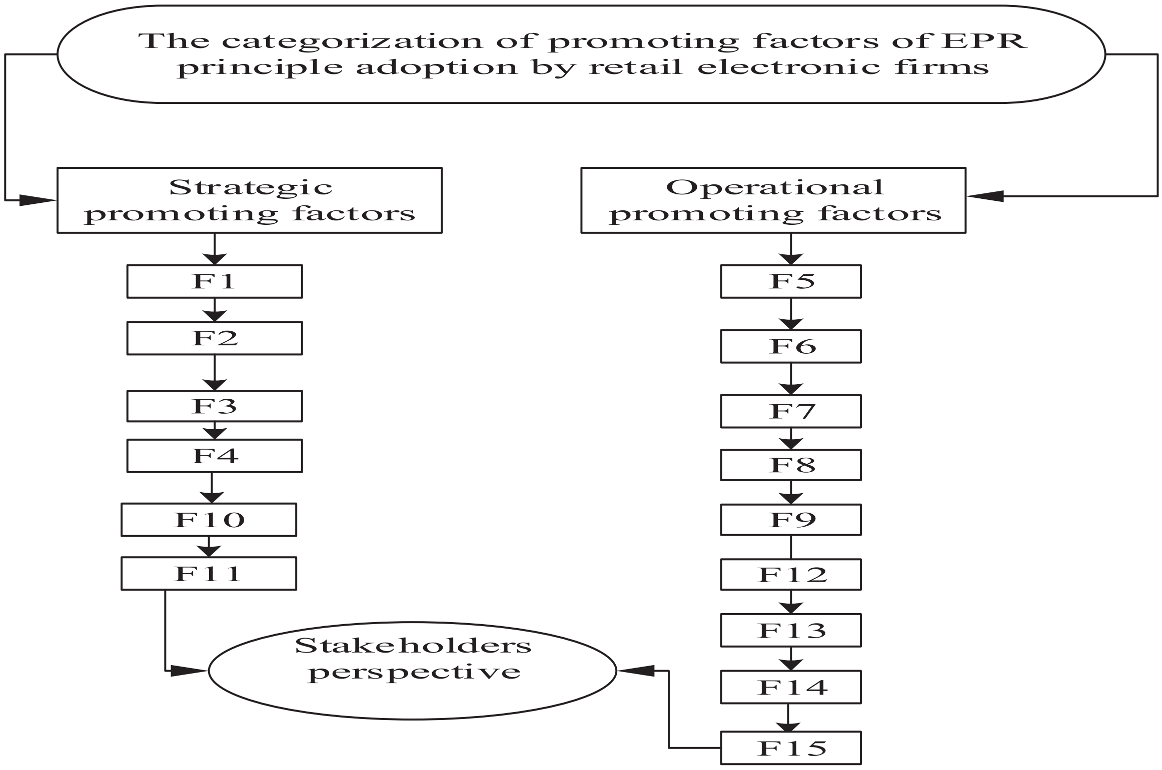

Figure 2. The categorization of promoting factors based on stakeholders' perspectives.

$$S = \left[S_{ij} \right]_{m \times n'} \quad i, j \in \{1, 2, \ldots n\} \tag{13}$$

$$D_i = \left[\sum_{j=1}^{n} S_{ij} \right]_{n\times1} = \left[S_i \right]_{n\times1} = \left[d \right]_{n\times1} \tag{14}$$

$$R_i = \left[\sum_{j=1}^{n} S_{ij} \right]_{n\times1} = \left[S_i \right]_{n\times1} = \left[r \right]_{n\times1'} \tag{15}$$

where D_i and R_i denote the sum of rows and the sum of columns based on the total-influence matrix $S = \left[S_{ij} \right]_{m\times n'}$ respectively.

Data collection and evaluators selection

To achieve the objectives of the study and to analyse the promoting factors of EPR principle adoption for sustainable e-waste management in Ghana, 18 evaluators were purposively selected for the study. They were selected based on their extensive understanding of the study objectives, experience (10 years and above), and their ability to fill and pairwise comparison of the identified promoting factors using a grey-DEAMTEL analytical technique. The reason for selecting 18 evaluators to include is to achieve reliable and consistent study findings (Raj and Sah, 2019). Furthermore, several studies have employed fewer sample sizes such as three, four and five for studies; hence, the selection of eighteen evaluators for the study is permissible (Munny et al., 2019; Sharma et al., 2020). Figure 2 simplifies the categorization of the promoting factors into strategic and operational factors based on stakeholders' perspective for the study. The evaluators were assembled from different industry background, including managers of retail electronic firms, developmental agencies, consumers and government agencies in-charge of the environment. The evaluators were first briefed about the study objectives, methodological approach and how to complete the grey-DEMATEL-structured questionnaires using the linguistic values as shown in Table 3. Subsequently, the identified promoting factors were presented to the evaluators for evaluation and pairwise comparison to construct the initial grey direct relation matrix as shown in Table 4. Then, all the relation matrices by each evaluator were converted into crisp values as shown in Appendices A1–A6. In the present study, 16 of the evaluators were directly interviewed in a face-to-face interaction, whereas two were engaged through Skype due to busy schedules and location. A total of 10 initial grey direct relation matrices were obtained, which were computed and analysed employing the grey-DEMATEL model.

Study results and sensitivity analysis

This section discusses the steps involved in the proposed methodology (grey-DEMATEL) and the sensitivity analysis carried out to check the robustness and the consistency of the study findings. The initial step involved in the grey-DEMATEL application is to construct a direct relation matrix through the data generated

Table 4. Initial direct grey relation matrix of promoting factors by evaluator 1.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	NO	VL	L	H	VH	H	VL	VH	VL	L	L	VH	VH	VH	VH
F_2	VL	NO	VL	VH	VL	VH	VL	H	VH	VH	VL	L	VL	L	VH
F_3	VH	L	NO	L	VL	H	L	VL	VH	L	L	VH	L	L	H
F_4	L	H	VH	NO	L	VL	H	VH	L	VH	L	VL	L	VL	L
F_5	H	VH	VH	VH	NO	L	VL	L	VL	VH	L	L	L	H	VH
F_6	VL	H	VL	H	VH	NO	VH	VH	L	H	VH	H	VL	H	L
F_7	H	VH	H	H	VL	VH	NO	VH	VL	VH	VL	L	VL	L	VH
F_8	H	VL	H	VL	H	L	VL	NO	L	L	L	VH	L	L	VL
F_9	H	H	H	H	H	H	VH	VL	NO	VH	L	VL	L	L	H
F_{10}	VH	H	VL	H	L	VL	H	L	VH	NO	L	L	L	H	H
F_{11}	H	VL	H	VH	VL	H	VL	H	VH	L	NO	H	VL	H	L
F_{12}	VH	VH	VH	H	VL	VL	VH	VH	H	L	VH	NO	VH	L	H
F_{13}	H	VL	VL	VL	H	H	VL	VL	L	H	VH	VH	NO	VH	VH
F_{14}	VL	VH	VL	VL	H	VL	VH	VL	L	H	VH	VH	VH	NO	H
F_{15}	H	VH	VL	H	VH	H	VH	VL	H	VH	VH	VH	VH	VH	NO

Table 5. Direct relation average matrix.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0.000	0.250	0.250	0.275	0.188	0.238	0.238	0.200	0.200	0.188	0.238	0.225	0.200	0.213	0.225
F_2	0.303	0.000	0.250	0.225	0.275	0.300	0.213	0.275	0.263	0.188	0.225	0.213	0.250	0.238	0.250
F_3	0.200	0.288	0.000	0.200	0.200	0.275	0.263	0.350	0.288	0.300	0.175	0.250	0.250	0.250	0.263
F_4	0.293	0.250	0.288	0.000	0.338	0.275	0.213	0.275	0.325	0.238	0.313	0.263	0.288	0.275	0.300
F_5	0.350	0.288	0.250	0.250	0.000	0.250	0.325	0.300	0.238	0.300	0.313	0.275	0.263	0.238	0.275
F_6	0.200	0.288	0.200	0.213	0.263	0.000	0.213	0.263	0.325	0.213	0.275	0.263	0.288	0.338	0.250
F_7	0.225	0.350	0.263	0.175	0.225	0.238	0.000	0.238	0.225	0.288	0.263	0.225	0.263	0.238	0.263
F_8	0.250	0.275	0.300	0.263	0.225	0.238	0.263	0.000	0.200	0.275	0.300	0.263	0.225	0.338	0.300
F_9	0.300	0.298	0.225	0.150	0.200	0.263	0.225	0.263	0.000	0.238	0.325	0.250	0.288	0.313	0.238
F_{10}	0.250	0.275	0.300	0.250	0.213	0.238	0.225	0.275	0.288	0.000	0.250	0.263	0.263	0.238	0.250
F_{11}	0.434	0.300	0.288	0.238	0.250	0.350	0.263	0.238	0.225	0.225	0.000	0.175	0.175	0.263	0.200
F_{12}	0.250	0.225	0.300	0.288	0.263	0.263	0.288	0.213	0.225	0.200	0.250	0.000	0.250	0.238	0.338
F_{13}	0.218	0.313	0.334	0.238	0.275	0.288	0.338	0.238	0.163	0.250	0.263	0.238	0.000	0.275	0.263
F_{14}	0.375	0.238	0.250	0.238	0.313	0.238	0.275	0.313	0.275	0.250	0.188	0.350	0.238	0.000	0.200
F_{15}	0.250	0.263	0.313	0.313	0.275	0.263	0.238	0.300	0.263	0.263	0.288	0.213	0.213	0.300	0.000

from each of the experts. Hence, one direct relation matrix was set up by each of the experts. The initial grey relation matrix for the evaluator 1 is presented in Table 4.

The average grey relation matrix $\overline{\otimes}\tilde{x}_{ij}^{k}$ was computed employing equation (2). Here, to obtain realistic and consistent results, equal weights were assigned to each evaluator. The crisp relation matrix D was determined using equations (3)–(8) as indicated in Table 5. Then, equations (9) and (10) were used to normalize the direct relation matrix as shown in Appendix B. Then, the total relation matrix (S) was calculated using equation (12). The total relation matrix was obtained using equation (11). Then, all the rows R_i and columns c_j of the total relation matrix were added together using equations (13)–(15) to obtain the cause and effect promoting factors of EPR principle adoption for e-waste management. Furthermore, the datasets for $R_i + c_j$ cause and $R_i - c_j$ effect factors are calculated as presented in Table 7. This is to indicate that if the [$R_i - c_j$ value is positive, then the promoting factors are categorized into the causal group, and if the $R_i - c_j$ value is negative, then the promoting factor is considered an effect group indicator. A benchmark value (π) of 0.231 was set to help eliminate insignificant promoting factors as shown in Table 6. The bold figures in Table 6 are the promoting factors that has values above the benchmark value of 0.231. Furthermore, a causal relationship diagram was constructed to explain the degree of influence and interaction of each promoting factor as shown in Figure 3. Furthermore, a sectional causal relationship diagram was determined to give a clear and zonal impact of each of the promoting factor as indicated in Appendix E.

Sensitivity analysis

To avoid any bias and validate the framework and the study findings to underpin effective decision-making, a sensitivity analysis was conducted as indicated in existing studies (Faibil et al., 2021;

Table 6. Total relation matrix for promoting factors.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0.0160	0.1116	0.1058	**0.2822**	0.1405	0.0336	0.1484	**0.3189**	0.0558	**0.3628**	0.0447	0.1584	**0.2660**	0.2161	0.1097
F_2	0.2105	0.1343	0.2917	0.0686	0.1302	0.1419	**0.2403**	0.0868	0.3586	0.1121	0.0894	**0.2433**	0.0743	0.1243	0.0970
F_3	0.1215	0.0125	0.1445	**0.3939**	0.0471	0.3251	0.0849	0.0571	0.0761	0.0495	0.0677	0.1278	0.0778	0.0638	0.1755
F_4	0.2235	0.1145	0.2218	**0.3289**	0.1189	0.2066	0.0872	0.1449	0.2671	0.0558	0.1733	0.3365	0.0473	0.0475	0.1540
F_5	0.2235	0.0438	0.2266	0.1296	0.2089	0.0912	0.0394	**0.2779**	0.0999	**0.3209**	**0.2397**	0.2406	0.1768	0.2104	0.0753
F_6	0.0825	0.0991	0.0568	0.3004	0.1434	0.1330	0.0649	**0.3104**	0.0895	0.0424	0.0410	0.1195	**0.2566**	**0.2575**	0.0487
F_7	0.0544	0.0456	0.0876	0.0435	**0.2321**	0.1348	0.1296	0.0404	0.1694	0.2482	0.1869	**0.2852**	0.0811	0.2010	0.1019
F_8	**0.3022**	0.3766	0.1181	0.1216	0.2288	**0.3839**	0.1632	0.1347	**0.2845**	0.1318	0.1064	**0.4569**	0.0517	0.1437	0.0613
F_9	**0.3836**	0.1607	0.3448	0.0478	**0.2884**	0.1148	0.0604	**0.2704**	0.1220	**0.3345**	0.1529	0.0651	0.1632	0.1730	0.0463
F_{10}	0.0522	0.2017	0.0164	0.0800	**0.3687**	0.2645	**0.3145**	0.0683	0.0129	0.0149	0.2111	0.1400	0.1761	0.1499	0.0834
F_{11}	0.1212	0.1386	**0.3688**	**0.3365**	0.0819	0.0527	0.1744	0.0431	0.1171	0.0558	0.1465	0.0425	0.0594	0.0825	0.0622
F_{12}	0.0491	0.0475	0.0882	0.1844	0.1658	0.1899	0.2229	**0.2635**	0.1502	0.1713	0.1011	0.1232	**0.2347**	**0.2871**	0.0559
F_{13}	0.1034	0.1709	**0.2692**	**0.2808**	0.0165	0.1371	**0.3171**	0.0153	0.0542	0.2327	**0.3876**	**0.2472**	0.2097	0.1931	0.1318
F_{14}	0.1273	**0.2506**	0.0790	0.0696	0.1146	**0.3461**	**0.3007**	0.1033	0.2006	0.0099	0.0451	0.0574	0.0812	0.1066	0.0738
F_{15}	0.0846	0.0429	0.0822	**0.2309**	0.0489	**0.2337**	0.0369	0.0880	**0.3640**	0.1549	**0.2667**	**0.2503**	0.0584	0.0409	0.1252

Benchmark = 0.231.

Table 7. Cause–effect parameters of the promoting factors.

Promoting factors	Rows R_i	Column C_j	$R_i + C_j$	R_i - C_j	Categorization of promoting factors
F_1	2.3705	2.1555	4.5260	0.2150	Cause
F_2	2.4033	1.9509	4.3542	0.4524	Cause
F_3	1.8247	2.5015	4.3262	−0.6768	Effect
F_4	2.5278	2.8987	5.4265	−0.3709	Effect
F_5	2.6045	2.3347	4.9392	0.2698	Cause
F_6	2.0457	2.7889	4.8346	−0.7432	effect
F_7	2.0417	2.3848	4.4265	−0.3431	Effect
F_8	3.0654	2.223	5.2884	0.8424	Cause
F_9	2.7278	2.4219	5.1497	0.3059	Cause
F_{10}	2.1546	2.2975	4.4521	−0.1429	Effect
F_{11}	1.8832	2.2601	4.1433	−0.3769	Effect
F_{12}	2.3348	2.8939	5.2287	−0.5591	Effect
F_{13}	2.7666	2.0143	4.7809	0.7523	Cause
F_{14}	1.9658	2.2974	4.2632	−0.3316	Effect
F_{15}	2.1085	1.402	3.5105	0.7065	Cause

Xia et al., 2015). Sensitivity analysis is a process to test the robustness and consistency of a methodology. Several approaches can be applied to conduct sensitivity analysis such as altering weights assigned to criteria and varying the weights assigned to a particular evaluator to authenticate its effect on the ranking of the criteria/attributes or the system (Jeong and Ramírez-Gómez, 2018; Xia et al., 2015). Therefore, different weights were assigned to evaluators in four different cases as follows: For case A, the weights assigned to the evaluators were 0.15, 0.15 and 0.20, Case B (0. 25, 0.25 and 0.30), Case C (0.35, 0.35 and 0.40) and for Case D (0.45, 0.45 and 0.50), respectively. For each case, the evaluators conducted separate pairwise comparisons, which were later analysed using the grey-DEMATEL technique. Then, we determined the new relationship matrix using the new $R_i + c_j$ and $R_i - c_j$ values and constructed causal sensitivity analysis diagrams to indicate the variations of the factors as shown in Appendices D1–D3. The findings of the sensitivity analysis show insignificant deviations in the rankings of the factors through four different scenarios as promoting factor F_8 (adopting advanced deposit recycling refund scheme) and F_{13} (resilient and effective resources management) were ranked as the first and second causal and strategic promoting factors. Similarly, promoting factor F_{10} (green awareness creation) and F_{14} (top management commitment) were ranked as the first and second effect and operational promoting factors in the system.

Discussion of results

This section discusses the results obtained after analysing the data generated for the study. In the study, an integrated grey-DEMATEL technique was applied to analyse and understand how the promoting factors for EPR principle adoption for e-waste management influence each other in the electronic industry. The grey-DEMATEL technique facilitated in distinguishing among

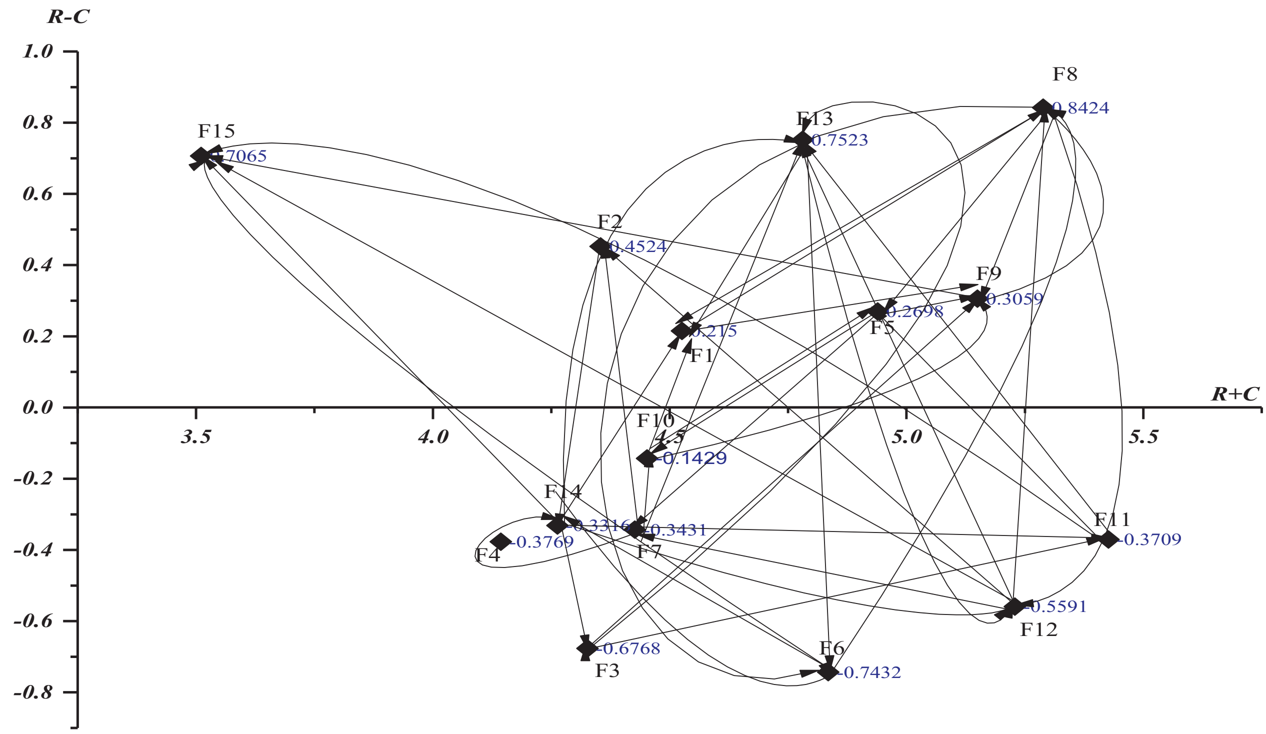

Figure 3. Causal dependency diagram among the promoting factors.

the cause–effect factors and their interdependencies through a causal interrelationship diagram as shown in Figure 3. A benchmark value of 0.231 was derived from the mean total relation matrix to eliminate relatively low-intensity effect factors. All the weights exceeding the benchmark value are in bold font in Table 6. The degree of prominence and the cause–effect values of the operational and strategic factors are indicated in Appendices C1–C2. The factors with the highest prominence values were ranked as follows: F_4 (promotion, support and collaboration with environmentally conscious partners), F_8 (adopting advanced deposit recycling refund scheme), F_{12} (adopting innovative practices to manage EoL electronic products), F_5 (open up and create a new market opportunity for the e-companies) and F_9 (normative influence from suppliers, customers and associations). The outcome indicates that promoting factors for EPR principle adoption is not very much concentrated on a specific stakeholder in the electronic industry. In addition, it shows that many of the factors were spread across both the internal and external stakeholders in the supply chain. Therefore, retail electronic firms need innovative and appropriate policy initiatives from both internal and external stakeholders to enhance effective EPR principle adoption.

The study again ranked and categorized promoting factors into cause–effect based on their values as follows: F_8 (adopting advanced deposit recycling refund scheme), F_{13} (resilient and effective resources management), F_{15} (reverse supply chain practices in the electronic industry), F_2 (supportive policies and legal frameworks EPR principle adoption), F_9 (mimetic influence from industry competitors), F_5 (open up and create a new market opportunity for the e-companies) and F_1 (environmental concerns and pressure from consumers) as shown in Table 7. Furthermore, the promoting factors with high cause–effect values are spread across both internal and external stakeholders in the supply chain, which affirms the significance of pull and push strategy policies to enhance EPR principle adoption for sustainable e-waste management in developing economies. The cause–effect factors were mapped against other factors to certain their degree of interdependencies and interrelationship as shown in Figure 3. The cause–effect factors would play an essential role in the decision-making process; hence, they become decisive factors, addressing elementary cause factors will lead to the elimination of their influence and interdependency on other effect factors.

In the study, F_8 (adopting advanced deposit recycling refund scheme), F_2 (supportive policies and legal frameworks EPR principle adoption) and F_{15} (reverse supply chain practices in the electronic industry) were three operational promoting factors with high net cause–effect values. In addition, these operational factors are related to push strategy; hence, to ensure the adoption of the EPR principle for e-waste management, there is the need for the government to introduce punitive measures to facilitate sustainable e-waste management practices by retail electronic firms. The outcome suggests that to adopt the EPR principle, these operational factors need to be addressed by both policymakers and retail electronic firms in the short term.

The study finding indicated that the most elementary factor is F_8 (adopting advanced deposit recycling refund scheme) had the high net cause–effect and high prominent values. Therefore, the EPR principle can be effectively adopted when consumers make advanced recycling deposits at the retail electronic firms, this will enforce consumers to return their obsolete e-waste products to the retail electronic firms for proper recycling and disposal (Chandra, 2020). It is important to note that the success in implementing the EPR principle for e-waste management in developed countries such as the USA and Japan are attributed to the formulation and adoption of laws and policies for focal electronic firms to implement advanced deposit initiatives (Kannan et al., 2016; Dasgupta et al., 2002). In the study, F_{13} (resilient and effective resources management) is the first ranked strategic promoting factor with high-prominent net cause -effect values but low impact on the promoting factors. According to the evaluators, most retail electronic firms should ensure their resources are effective management, particularly the dynamic capabilities of their firms to equip their workforce with innovative and relevant skills to enhance the adoption of the EPR principle to manage e-waste. However, the resilience of dynamic capabilities is uncommon, among retail electronic firms. Furthermore, F_{13} (resilient and effective resources management) was categorized under the pull strategy policy, which shows that appealing policies that will enhance retail electronic firms to ensure resiliency and effectiveness for resources management to facilitate the adoption of the EPR principle should be formulated. Considering the significance of this factor, it is the only key elementary strategic promoting factor, as such, policymakers must address this factor in the medium-to-long term. The identified highly cause–effect factors for EPR principle adoption in the Ghanaian electronic industry suggest the need for push and pull strategy policies prioritization by policymakers. Therefore, the Act 917 of 2016, which provides legal backing for the establishment of a national e-waste plant to address e-waste management in Ghana (Quaye et al., 2019), can potentially be enhanced, if these cause–effect factors are strategically integrated. For example, under the Act (917), a manufacturer or importer of electronic equipment is required to register with the Environmental Protection Agency of Ghana and pay an electronic waste levy. The levy covers the costs for collection, treatment, recovery and environmentally sound disposal and recycling of e-waste.

In this study, the stakeholders-based identified promoting factors were categorized in pull and push strategy factors that impact retail electronic firms to ensure EPR adoption for sustainable e-waste management systems as shown in Table C3. Thus, the pull strategy factors are appealing policies that stimulate the interest of retail electronic firms for the effective adoption of EPR practices. The pull strategy policies are the more deliberate and proactive approach that will stimulate retail electronic firms to actively participate in the adoption of EPR practices e-waste management. Similarly, with the application pull strategy for e-waste management, retail electronic firms are actively motivated to participate in e-waste management due to the introduction of appealing policies and measures. Therefore, considering the significance of implementing EPR practices by retail electronic firms for e-waste management, the evaluators through the application of the Delphi method prioritized and ranked the pull strategy factors as follows: open up and create a new market opportunity for the e-companies F_5, effective and systematic approach systems through retail electronic firms F_6, rewards and incentives for greener activities by the government F_{11}, resilient and effective resources management F_{13} and top management commitment F_{14} are critical pull strategy factors imperative for EPR principle adoption in the Ghanaian context. On the other hand, push strategy factors are policies or factors that seek to bring on board and attract retail electronic firms to actively get involved in the adoption of the EPR practices. The push strategy factors are punitive policies formulated to guide and encourage the adoption of EPR practices by retail electronic firms.

As result, the evaluators discern on categorizing the push strategy factors for the adoption of EPR practices as following: environmental concerns and pressure from consumers F_1, supportive policies and legal frameworks for EPR practices adoption F_2, subsidies and incentives benefit to consumers F_3, promotion, support and collaboration with environmentally conscious partners F_4, normative influence from suppliers, customers and associations F_7, adopting advanced deposit recycling refund scheme F_8, mimetic influence from industry competitors F_9, green awareness creation F_{10}, adopting innovative practices to manage EoL electronic products F_{12} and reverse supply chain practices in the electronic industry F_{15}. The formulation and adoption of a suitable policy framework are critical for the realization of EPR practices in developing economies; hence, policies could be carrot and stick approach. Therefore, the categorization of the factors into pull and push strategy factors has a significant correlation with the existing policy framework developed by the Ghanaian government to ensure sustainable e-waste management in Ghana.

The existing policy framework for driving the EPR principle in Ghana is anchored by the Act 917. From the perspective of the carrot-and-stick policy approach, the existing policy sheds light on the establishment of e-waste management funds by the government and stakeholders to address informal e-waste management practices (Akon-Yamga et al., 2021). It further requires a manufacturer or importer of electronic equipment to register with the Environmental Protection Agency and pay an electronic waste levy in respect of electronic equipment that is imported into the country or manufactured in the country (Amankwaa et al., 2017). The levy caters for the costs of the collection, treatment, recovery, and environmentally sound disposal and recycling of electronic waste as well as the construction and maintenance of electronic waste recycling or treatment plants, education of the public on the safe disposal of electronic waste and the negative effects of electronic waste offer incentives for collection and disposal of electronic waste. Moreover, a manufacturer, distributor or wholesaler of electronic equipment is required to take back used or discarded electronic equipment manufactured or sold by it for recycling purposes. To facilitate the adoption of these normative provisions, local authorities are obligated to designate points at which electronic waste shall be deposited by importers, manufacturers, wholesalers, distributors, retailers, refurbishers or repairers as per recycling classifications determined by the Environmental Protection Agency. The authorities are also to ensure the compliance of importers, manufacturers, wholesalers, distributors, retailers, refurbishers or repairers of electronic equipment with the procedures for the disposal of electronic waste by delivering collected electronic waste to the designated assembly points.

In terms of management, there is a multi-stakeholder Technical Committee on E-Waste Management coordinated by the Ministry of Environment to synchronize the various initiatives aimed at improving e-waste control and management in Ghana. Despite the progressive nature of the e-waste policy, there remain opportunities for learning in the e-waste management system. According to Akon-Yamga et al. (2021), a business-as-usual approach through implementing policy-based interventions is insufficient as there are questions on coordination, outcomes and the impact that require thorough interrogation centring on the socio-technical systems around e-waste management in Ghana. There is also a shred of emerging evidence (Amankwaa et al., 2017; Sovacool, 2019) that the policymaking processes would follow business as usual in that policies are formulated by 'experts' with a focus on economic factors to the detriment of the marginalized and informal actors in the innovation space. The participation of all relevant actors in decision-making and stimulating bottom-up approaches hold promise in Ghana's e-waste socio-technical system to ensure inclusivity (Daniels and Ting, 2019). To effectively implement regulations and bye-laws in e-waste management and education and awareness creation on e-waste segregation, health and environmental risk factors remain critical.

Theoretical contribution

In the present study, a key theoretical contribution is the identification of factors to promote the adoption of the EPR principle for sustainable e-waste management through retail electronic firms, based on the role and function of both internal and external stakeholders in the electronic industry. For retail electronic firms to adoption of EPR principle as an appropriate e-waste management mitigation instrument for sustainable e-waste management, the roles and views of various key stakeholders in collaboration are essential in the electronic industry. Therefore, the perspectives of these stakeholders with emphasis on push and pull strategy will greatly influence, shape and transform informal e-waste management practices in developing economies. In addition, the study findings show that the framework of the promoting factors to EPR principle implementation through retail electronic firms in the developing economies could be assessed and categorized into push and pull strategy, where punitive and appealing policies could be formulated guide and streamline e-waste management by retail electronic firms. The outcome of the study suggests that successful adoption of the EPR principle through retail electronic firms needs increasing collaboration, joint participation of various parties and strategic support between consumers, government, NGOs and electronic firms. Existing studies have highlighted the significance of push and pull strategy policies as collaboration among the various stakeholders in the adoption of EPR practices (Campbell-Johnston et al., 2020; Diggle and Walker, 2020). Considering resource-based view perspective for EPR adoption, Corsini et al. (2015) highlighted the need for tangible and intangible resource dynamics in retail electronic firms to support the designing of long-term sustainability strategies for e-waste management. Both internal and external stakeholders possess unique tangible and intangible resources, which when harnessed and integrated will aid in achieving resource efficiency that could scale up firms to gain a competitive advantage in the long run. The outcome resonates with a study by Shan and Yang (2020), recent study on promoting the adoption of EPR systems in China. In addition, strategic support from industry actors, government, civil society organizations (CSOs) and NGOs will enhance in formulating policies that bring on board innovative perspectives on effective strategies to implement EPR practices through retail electronic firms.

Managerial implications of the study

The EPR principle originally emerged from the framework of management sciences as a tool for improving resource efficiency and addressing the challenges of effective waste management. Consequently, the EPR policy sought to transfer from local authorities and taxpayers (public budget) to producers and retail electronic firms the burden of taking responsibility for collecting EoL products (Pouikli, 2020). The economic justification underpinning the adoption of sound EPR policy is to have producers internalize treatment and disposal costs so that they have an incentive to design products that last longer and are more easily treated after use. These underscore the significance of the findings of the study in informing the Government, other policymakers, industry actors and focal electronic firm managers about the promoting factors, which can potentially enhance the adoption and adoption of the EPR principle for e-waste management. This will promote environmental sustainability, improve societal well-being and public health, and socio-economic activities for inclusive economic growth in Ghana. This study identifies 15 promoting factors for the adoption of the EPR principle for e-waste management, and grouped them into cause dataset and effect dataset factors.

The outcome of the study as shown in Figure 3 suggests that to implement the EPR principle in Ghana for e-waste management, the following elementary operational factors F_8 (adopting advanced deposit recycling refund scheme), F_{13} (resilient and effective resources management) and F_{15} (reverse supply chain practices in the electronic industry) that also push factors should be addressed through the formulation and adoption of punitive measures by policymakers in the short term. Furthermore, the findings suggest that effective support from the government and stakeholders in collaborating for a push and pull strategy will contribute significantly to the adoption of the EPR principle by retail electronic firms. Furthermore, developmental agencies, CSOs and NGOs should adopt proactive strategies to stimulate the interest of consumers to comply with laws and policies and also desist from informal e-waste management activities. In addition, focal electronic firm managers should focus on developing and investing in green human resource capabilities, innovation, technical and technology in their organizations. By having the necessary resources, the industry can easily and effectively implement the EPR principle in Ghana and other developing economies.

The adoption of the EPR principle requires extensive support and commitment as well as capital intensive, top management should invest much in resources to practice take-back and return policies. Therefore, to ensure sustainable and effective management of e-waste through the EPR principle, these strategic promoting factors may be helpful to key stakeholders in the electronic industry. The approach employed to evaluate the factors into prominence, causal and effect groups will provide decision support and essential guidelines to the Ghanaian government and electronic industry to introduce the EPR principle to manage e-waste. As discussed, sustainable approaches to e-waste management come in different dimensions such as developing strong policies, building capacity and application of efficient technologies to dismantle and recycle e-waste. The EPR policy, for example, ensures that administrative, financial and physical e-waste management responsibilities are shifted from the government to companies producing and selling electronic products (Esenduran et al., 2019). In the case of Ghana, the EPR policy will ensure producers and importers of electronics manage e-waste products (Widmer et al., 2005). As a developing country, shifting the cost of e-waste management to producers and importers will enable the government to focus on building the capacity of the informal sector to collect and recycle e-waste using safe technologies to prevent health and environmental consequences through sustainable e-waste management. This study has highlighted the EPR as a potentially powerful tool for regulating the division of responsibilities for e-waste management among stakeholders and to influence the decision-making of producers.

The outcome of the present study was compared with an existing scholarship to understand the similarity and the behaviour of the identified factors in other jurisdictions and other studies (Esenduran et al., 2019). For instance, in the Indian context, Sharma et al. (2020) identified environmental management system as the most critical and strategic factor for EPR principle adoption whereas this study identifies (deposit and refund scheme) as was identified as the key elementary operational factor for the adoption EPR principle in the Ghanaian electronic industry. In addition, (Kunz et al., 2018), revealed that, the formulation and adoption of EPR-related Laws and Regulations as the most influential factor for EPR adoption in their study findings.

Conclusion and future research

The challenges associated with improper e-waste management in developing economies have attracted significant attention from environmental activists, practitioners, consumers, scholars and stakeholders in the electrical and electronic industry. Due to easy access to original electronic producers, many developed countries have been able to implement the EPR principle as a strategy to enforce original electronic product producers to assume responsibility for taking back electronics at the end of their lifespan.

However, in developing economies, retail electronic firms serve as representatives of electronic producers who are considered to implement the EPR principle. In developing economies such as Ghana, the EPR principle adoption is under-studied in prior studies. +++Presently, the majority of existing studies carried out on e-waste management in Ghana focused on the different facets in the e-waste industry. The EPR principle adoption for e-waste management through retail electronic firms has not garnered the needed attention. Hence, this study endeavours to identify and analyse promoting factors of EPR principle adoption for sustainable e-waste management in Ghana through retail electronic firms grounded on internal and external stakeholders' perspectives with an emphasis on push and pull strategy. The identified promoting factors were categorized into operational and strategic factors. Thus, through literature review and evaluators' view, 15 factors were identified and analysed using the Delphi and grey-DEMATEL method. Delphi was used to evaluate the relevance of the promoting factors identified. Then, the grey-DEMATEL technique was employed to analyse the data obtained and to establish a cause–effect interrelationship diagram of the factors of EPR adoption for tactical decision-making by policymakers.

The results reveal that for successful adoption of EPR by retail electronic firms, 'adopting advanced deposit recycling refund scheme' is the key elementary factor that needs to be addressed by policymakers and other supply chain stakeholders in the electronic industry. Interestingly, 'adopting advanced deposit recycling refund scheme' was identified as a push strategy; thus, the formulation of punitive measures will be critical for the adoption of EPR by retail electronic firms. The study also indicated that for the EPR principle to be adopted and function effectively, there should be stringent laws that control the shipment of electronic products by retail electronic firms. In the study, the promoting factors were categorized in pull and push strategy factors that impact retail electronic firms for the EPR practice adoption for sustainable e-waste management. The pull strategy factors are appealing measures that stimulate the interest of retail electronic firms for effective adoption of EPR practices. The pull strategy factors are the deliberate and proactive approach of alluring retail electronic firms to actively participate in the adoption of EPR practices for managing e-waste. Concerning the application pull strategy, retail electronic firms are actively motivated to be involved in e-waste management due to the introduction of appealing policies and measures.

On the other hand, push strategies are policies or measures that are penalized to encourage, guide and enforce the adoption of EPR practices by retail electronic firms. The push strategies are punitive measures and initiatives formulated to guide the adoption of EPR practices by retail electronic firms, particularly in developing economies. Some key lessons gained from this study include: Ghana can replicate good EPR practices, lessons and initiatives being implemented by developed countries by authorizing retail electronic firms to institute easy and appropriate centres for e-waste collection. In addition, various media platforms should be used effectively to create awareness to educate and strengthen consumers' understanding and knowledge about the significance of EPR practices. In this study, a sensitivity analysis was conducted to check the robustness and the bias of the findings; thus, the outcome of the sensitivity analysis shows no variation in the study findings.

Similar to other studies, this study has some limitations. The study does not explain the impact of each promoting indicator. Future studies could explore this further. The evaluators approved 15 relevant factors in the Ghanaian context that future studies can explore to expand and increase the factors and compare the results. This study also focused primarily on the retail electronic firms, and thus future studies could expand the scope of the study to two or three countries to validate the results. Lastly, this study used the Delphi method and grey-DEMATEL technique to identify and analyse promoting factors. Future research may adopt other decision-making support methods, such as BWM, ISM, fuzzy cognitive map and structural equation modelling, and compare the results.

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Appendix A

Table A1. The background and experience of diverse evaluators considered for the study.

Evaluators	Number considered	Experts/background	Experience
Evaluator 1	1	Government and policy expert	15
Evaluator2	5	General managers of retail electronic firms	15
Evaluator 3	2	Formal WEEE recyclers	14
Evaluator 4	2	Managers of NGO	15
Evaluator 5	2	Heads of developmental agencies	15
Evaluator 6	2	Academic expert	12
Evaluator 7	4	Consumers	15

Table A2. The initial grey relation matrix comparison of the promoting factors by evaluator 1.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0	2	2	2	1	3	2	2	1	1	2	4	3	4	1
F_2	1	0	2	3	1	4	1	3	4	3	1	2	1	3	2
F_3	3	4	0	2	1	2	3	2	2	4	3	2	2	2	2
F_4	2	2	3	0	2	2	2	3	4	4	2	4	3	2	4
F_5	4	2	2	4	0	3	4	3	3	2	4	3	3	3	2
F_6	1	1	4	1	4	0	1	3	4	1	1	2	1	2	3
F_7	2	4	2	3	1	2	0	2	1	2	3	1	4	3	3
F_8	1	3	4	2	2	4	2	0	2	1	4	3	2	4	2
F_9	4	2	1	1	2	2	1	2	0	1	4	1	3	2	3
F_{10}	1	1	3	3	3	3	2	3	2	0	4	4	2	4	3
F_{11}	3	4	3	2	2	4	1	4	2	4	0	1	2	2	1
F_{12}	1	2	2	4	2	2	2	3	3	2	1	0	3	3	4
F_{13}	3	2	4	1	2	3	4	2	1	4	2	2	0	4	4
F_{14}	2	1	2	2	4	1	2	4	3	3	1	4	2	0	2
F_{15}	4	2	1	3	2	3	4	1	3	1	2	1	4	1	0

No influence (NO) = 0, very low influence (VL) = 1, low influence (L) = 2, high influence (H) = 3, very high influence (VH) = 4.

Table A3. The pairwise comparison of the promoting factors by evaluator 2.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0	4	3	4	3	1	2	1	1	2	4	3	4	1	3
F_2	4	0	2	2	4	3	3	4	3	1	2	1	3	2	3
F_3	2	1	0	4	2	3	2	2	4	3	2	2	2	2	4
F_4	2	2	2	0	4	2	3	4	4	2	4	3	2	4	3
F_5	4	3	1	2	0	4	3	3	2	4	3	3	3	2	2
F_6	2	4	3	3	2	0	2	3	4	1	4	2	4	4	1
F_7	3	4	3	1	2	1	0	4	1	3	4	3	1	3	1
F_8	2	2	4	3	2	2	4	0	3	2	2	4	3	4	3
F_9	3	4	4	2	4	3	3	2	0	4	3	3	4	4	2
F_{10}	4	3	4	4	3	3	2	4	3	0	1	2	2	3	2
F_{11}	3	4	3	1	3	4	3	1	2	1	0	1	3	4	3
F_{12}	2	2	4	3	2	2	4	3	2	2	4	0	2	2	4
F_{13}	4	4	4	2	3	4	4	2	4	3	3	2	0	1	4
F_{14}	3	4	3	1	3	2	3	4	3	1	2	2	4	0	2
F_{15}	2	2	4	3	2	4	2	2	4	3	4	2	2	4	0

No influence (NO) = 0, very low influence (VL) = 1, low influence (L) = 2, high influence (H) = 3, very high influence (VH) = 4.

Table A4. The pairwise comparison of the promoting factors by evaluator 3.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0	1	2	2	1	3	3	2	2	2	3	2	1	3	2
F_2	2	0	3	2	2	1	1	2	3	2	2	4	3	1	3
F_3	2	3	0	4	4	3	2	3	3	2	1	3	3	2	1
F_4	2	4	3	0	4	2	1	3	4	2	2	3	4	3	2
F_5	4	3	3	2	0	2	2	1	2	4	3	2	2	3	2
F_6	2	2	1	2	4	0	1	2	3	3	2	3	4	4	2
F_7	2	3	2	3	2	2	0	2	2	1	2	3	2	2	4
F_8	1	2	1	3	1	2	3	0	3	2	3	2	1	4	3
F_9	2	2	2	1	2	2	2	3	0	1	3	1	4	4	3
F_{10}	3	1	2	3	2	1	1	2	2	0	1	2	1	1	2
F_{11}	3	3	4	4	2	2	4	3	2	2	0	3	2	3	2
F_{12}	4	2	2	2	4	3	2	3	2	1	3	0	3	3	3
F_{13}	2	3	3	2	2	1	4	4	2	2	3	2	0	2	2
F_{14}	1	2	1	2	4	2	2	2	4	3	3	3	2	0	1
F_{15}	1	3	2	3	1	2	2	3	2	1	2	3	2	1	0

No influence (NO) = 0, very low influence (VL) = 1, low influence (L) = 2, high influence (H) = 3, very high influence (VH) = 4.

Table A5. The pairwise comparison of the promoting factors by evaluator 4.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0	4	3	2	3	2	4	3	3	2	2	2	2	4	3
F_2	3	0	4	1	4	3	1	2	3	2	1	1	3	4	3
F_3	2	2	0	2	2	4	3	2	3	2	2	2	2	2	4
F_4	2	1	3	0	1	4	2	4	4	4	3	3	3	4	4
F_5	2	2	2	2	0	2	4	3	2	3	3	3	4	3	4
F_6	4	3	1	3	4	0	2	4	4	3	4	4	3	4	3
F_7	3	3	2	1	2	3	0	1	3	2	2	2	2	2	4
F_8	3	4	3	2	2	3	3	0	1	3	4	4	4	4	4

(Continued)

Table A5. (Continued)

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_9	2	2	3	2	1	1	3	4	0	4	2	4	3	4	3
F_{10}	3	4	4	2	2	2	4	2	2	0	3	1	4	2	4
F_{11}	3	2	2	4	3	3	2	1	4	1	0	1	4	2	1
F_{12}	2	1	4	3	3	2	4	1	4	3	2	0	1	2	3
F_{13}	1	4	4	3	4	1	4	3	1	2	3	2	0	3	2
F_{14}	2	1	1	2	2	2	2	4	3	2	1	3	2	0	3
F_{15}	3	2	3	3	4	3	4	4	2	4	3	2	2	2	0

No influence (NO) = 0, very low influence (VL) = 1, low influence (L) = 2, high influence (H) = 3, very high influence (VH) = 4.

Table A6. The pairwise comparison of the promoting factors by evaluator 5.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0	1	3	3	2	2	3	2	1	3	2	1	2	1	3
F_2	3	0	2	4	3	4	2	3	1	2	2	3	2	2	1
F_3	1	2	0	2	3	3	4	2	2	4	1	2	4	3	3
F_4	3	2	2	0	4	2	1	1	2	2	2	4	3	3	2
F_5	2	4	3	4	0	1	3	3	3	3	3	1	4	2	2
F_6	4	3	3	3	2	0	4	4	3	3	1	3	2	3	1
F_7	1	4	2	1	2	3	0	2	4	4	2	2	2	2	2
F_8	3	4	3	2	3	2	1	0	2	4	3	2	4	4	3
F_9	2	3	2	1	3	3	2	2	0	2	3	3	2	3	1
F_{10}	4	4	2	2	1	4	2	4	4	0	2	4	4	3	1
F_{11}	2	2	4	3	3	4	3	4	2	4	0	1	3	2	3
F_{12}	4	1	2	1	2	4	3	2	2	2	3	0	3	2	4
F_{13}	2	3	2	2	3	2	3	2	1	3	2	3	0	2	2
F_{14}	3	2	4	3	3	4	4	2	2	3	3	4	3	0	1
F_{15}	3	4	3	3	4	2	2	4	3	2	3	3	3	4	0

No influence (NO) = 0, very low influence (VL) = 1, low influence (L) = 2, high influence (H) = 3, very high influence (VH) = 4.

Table A7. The pairwise comparison of the promoting factors by evaluator 6.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0	2	2	2	1	2	1	2	2	2	2	1	2	1	2
F_2	4	0	3	3	4	3	2	2	3	1	2	1	3	3	2
F_3	1	4	0	1	2	3	2	1	4	3	2	2	2	2	2
F_4	2	4	3	0	4	4	2	2	4	2	4	3	2	1	4
F_5	4	3	3	2	0	2	4	3	2	4	3	3	2	2	4
F_6	1	4	2	3	2	0	2	1	4	1	4	2	4	3	3
F_7	2	2	4	1	2	2	0	4	1	3	4	3	2	1	2
F_8	4	3	1	3	4	1	3	0	2	4	2	2	1	2	2
F_9	3	3	2	1	2	4	2	4	0	2	4	2	1	4	2
F_{10}	3	4	3	2	2	3	3	1	4	0	3	2	3	1	4
F_{11}	2	2	3	2	1	4	3	2	2	2	0	4	2	3	2
F_{12}	3	4	4	2	2	2	3	2	1	2	3	0	3	2	2
F_{13}	3	2	2	4	3	4	4	2	2	2	2	3	0	4	1
F_{14}	2	1	4	3	3	2	2	4	3	4	1	4	1	0	1
F_{15}	1	4	4	3	4	2	1	2	1	2	2	2	2	4	0

No influence (NO) = 0, very low influence (VL) = 1, low influence (L) = 2, high influence (H) = 3, very high influence (VH) = 4.

Appendix B

Table B1. Normalized direct influence matrix.

Promoting factors	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9	F_{10}	F_{11}	F_{12}	F_{13}	F_{14}	F_{15}
F_1	0.000	0.250	0.250	0.275	0.188	0.238	0.238	0.200	0.200	0.188	0.238	0.225	0.200	0.213	0.225
F_2	0.303	0.000	0.250	0.225	0.275	0.300	0.213	0.275	0.263	0.188	0.225	0.213	0.250	0.238	0.250
F_3	0.200	0.288	0.000	0.200	0.200	0.275	0.263	0.350	0.288	0.300	0.175	0.250	0.250	0.250	0.263
F_4	0.293	0.250	0.288	0.000	0.338	0.275	0.213	0.275	0.325	0.238	0.313	0.263	0.288	0.275	0.300
F_5	0.350	0.288	0.250	0.250	0.000	0.250	0.325	0.300	0.238	0.300	0.313	0.275	0.263	0.238	0.275
F_6	0.200	0.288	0.200	0.213	0.263	0.000	0.213	0.263	0.325	0.213	0.275	0.263	0.288	0.338	0.250
F_7	0.225	0.350	0.263	0.175	0.225	0.238	0.000	0.238	0.225	0.288	0.263	0.225	0.263	0.238	0.263
F_8	0.250	0.275	0.300	0.263	0.225	0.238	0.263	0.000	0.200	0.275	0.300	0.263	0.225	0.338	0.300
F_9	0.300	0.298	0.225	0.150	0.200	0.263	0.225	0.263	0.000	0.238	0.325	0.250	0.288	0.313	0.238
F_{10}	0.250	0.275	0.300	0.250	0.213	0.238	0.225	0.275	0.288	0.000	0.250	0.263	0.263	0.238	0.250
F_{11}	0.434	0.300	0.288	0.238	0.250	0.350	0.263	0.238	0.225	0.225	0.000	0.175	0.175	0.263	0.200
F_{12}	0.250	0.225	0.300	0.288	0.263	0.263	0.288	0.213	0.225	0.200	0.250	0.000	0.250	0.238	0.338
F_{13}	0.218	0.313	0.334	0.238	0.275	0.288	0.338	0.238	0.163	0.250	0.263	0.238	0.000	0.275	0.263
F_{14}	0.375	0.238	0.250	0.238	0.313	0.238	0.275	0.313	0.275	0.250	0.188	0.350	0.238	0.000	0.200
F_{15}	0.250	0.263	0.313	0.313	0.275	0.263	0.238	0.300	0.263	0.263	0.288	0.213	0.213	0.300	0.000

Appendix C

Table C1. Ranking prominence of promoting factors.

Promoting factors	$R_i + C_j$	Ranking
F_1	4.526	8
F_2	4.3542	10
F_3	4.3262	12
F_4	5.4265	1
F_5	4.9392	5
F_6	4.8346	6
F_7	4.4265	11
F_8	5.2884	2
F_9	5.1497	4
F_{10}	4.4521	9
F_{11}	4.1433	14
F_{12}	5.2287	3
F_{13}	4.7809	7
F_{14}	4.2632	13
F_{15}	3.5105	15

Table C2. Ranking of cause and effect factors.

Promoting factors	$(R_i–C_j)$	Ranking
Cause set – promoting factors	$R_i–C_j$	Rank
F_8	0.8424	1
F_{13}	0.7523	2
F_{15}	0.7065	3
F_2	0.4524	4
F_9	0.3059	5
F_5	0.2698	6
F_1	0.2150	7
Effect set – promoting factors	$R_i–C_j$	Rank
F_{10}	−0.1429	1
F_{14}	−0.3316	2
F_7	−0.3431	3
F_4	−0.3709	4
F_{11}	−0.3769	5
F_{12}	−0.5591	6
F_3	−0.6768	7
F_6	−0.7432	8

Table C3. The categorization of factors into pull and push strategy factors.

Pull strategy factors	Push strategy factors
Open up and create a new market opportunity for the e-companies F_5	Environmental concerns and pressure from consumers F_1
Effective and systematic approach systems through retail electronic firms F_6	Supportive policies and legal frameworks for EPR practices adoption F_2
Rewards and incentives for greener activities by the government F_{11}	Subsidies and incentives benefit to consumers F_3
Resilient and effective resources management F_{13}	Promotion, support and collaboration with environmentally conscious partners F_4
Top management commitment F_{14}	Normative influence from suppliers, customers and associations F_7
	Adopting advanced deposit recycling refund scheme F_8
	Mimetic influence from industry competitors F_9
	Green awareness creation F_{10}
	Adopting innovative practices to manage EoL electronic products F_{12}
	Reverse supply chain practices in the electronic industry F_{15}

Appendix D

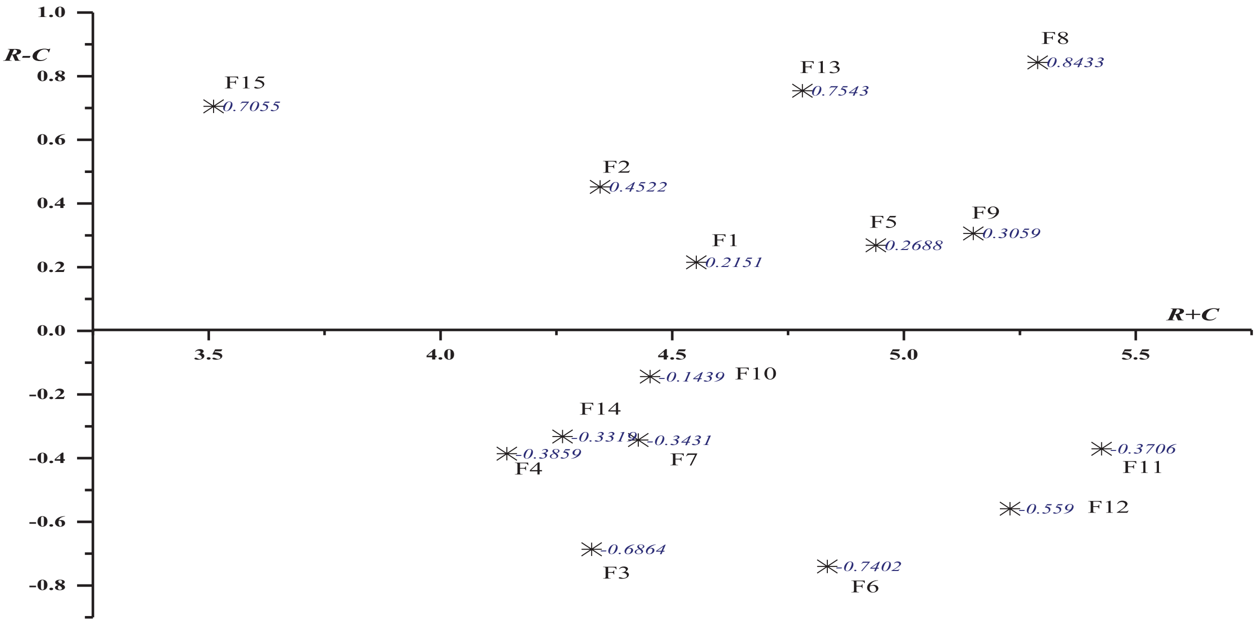

Figure D1. Causal of sensitivity analysis for case A.

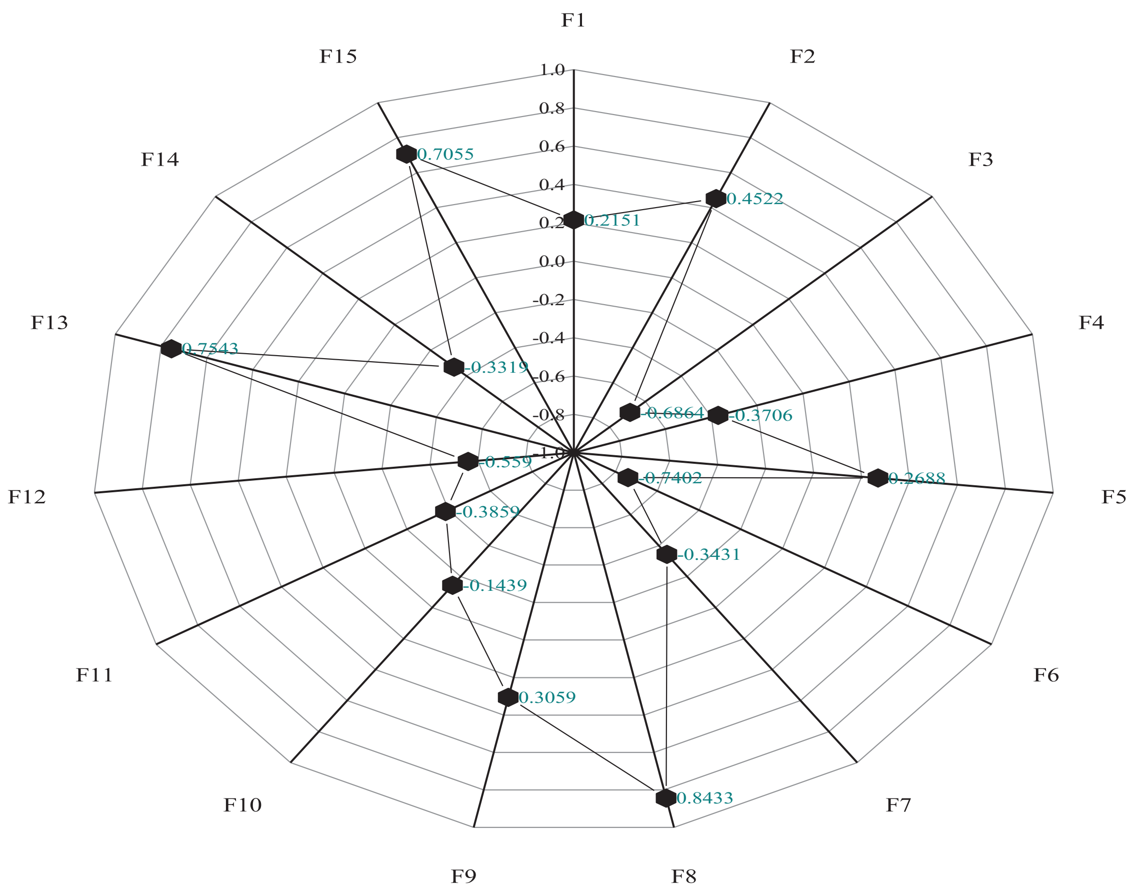

Figure D2. Causal of sensitivity analysis for case B.

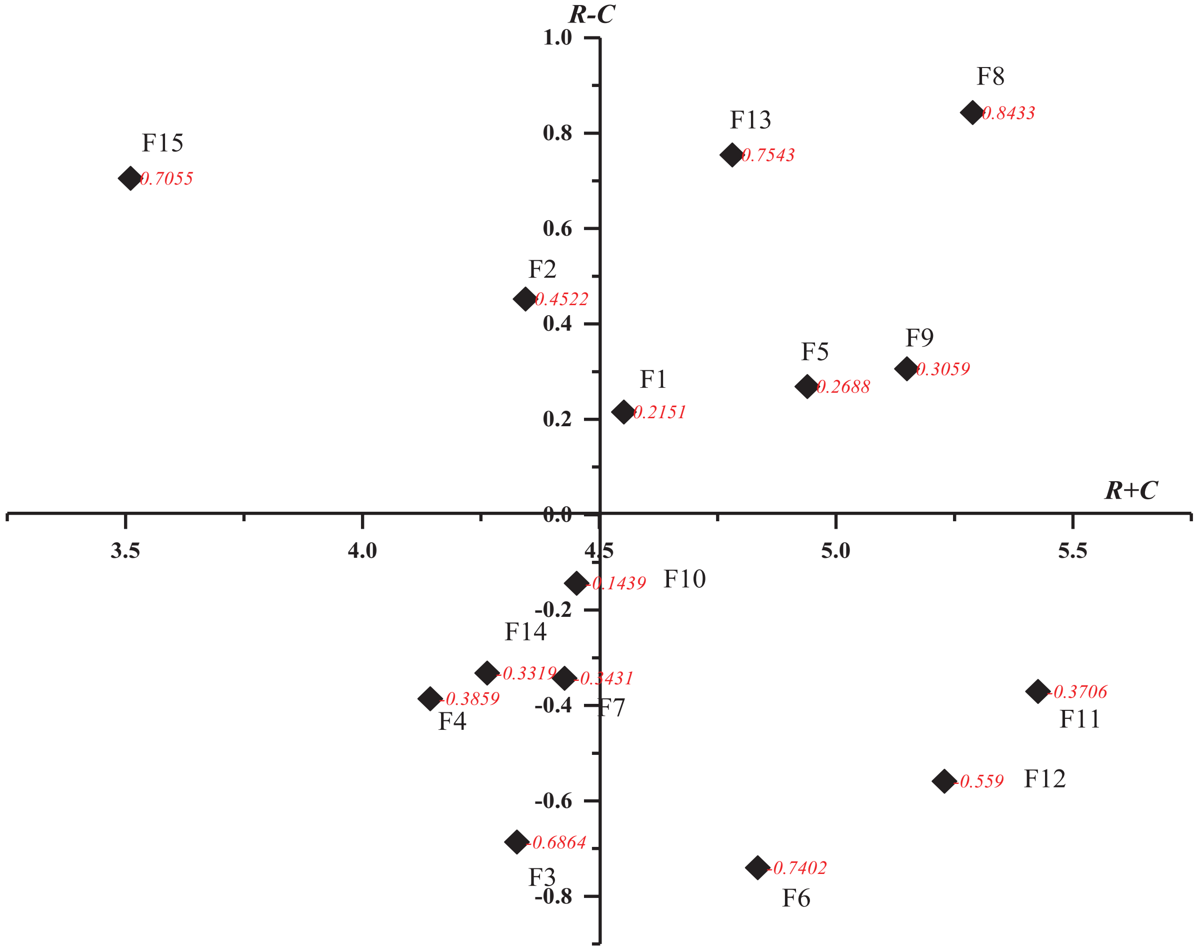

Figure D3. Causal of sensitivity analysis for case C.

Appendix E

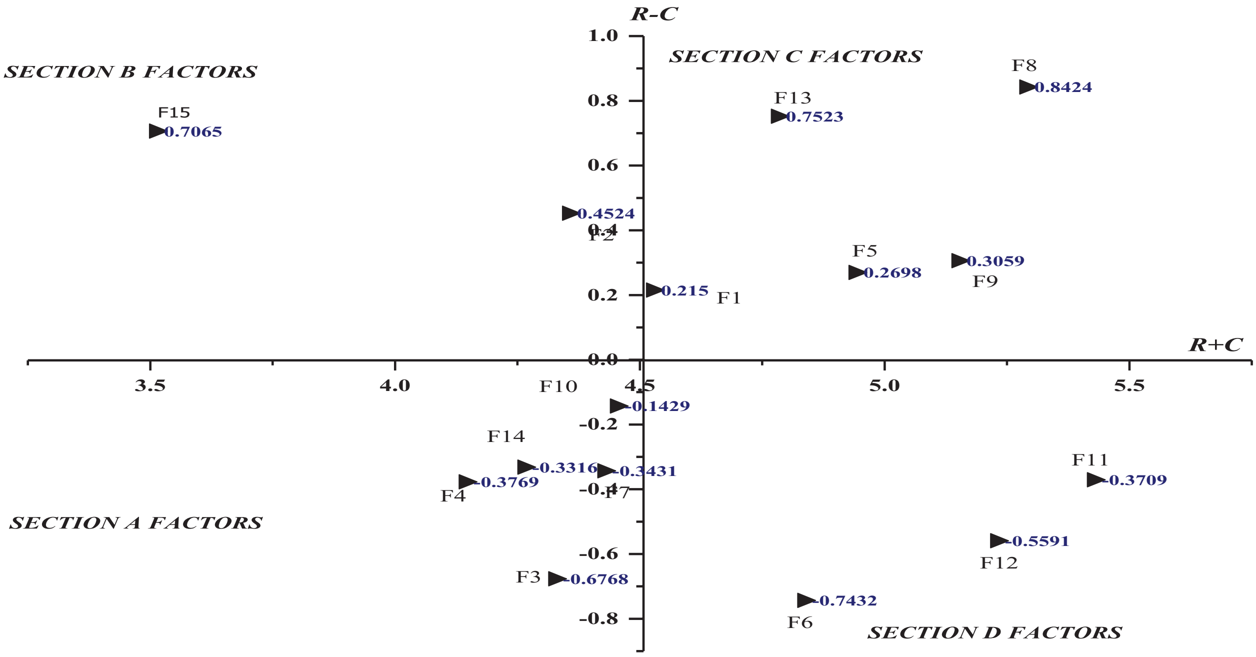

Figure E1. Sectional representations of promoting factors.