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Design for procurement: What procurement driven design initiatives result in environmental and economic performance improvement?

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ABSTRACT

This study examines the role of procurement professionals in new product design. Specifically, it evaluates which factors play an important role in driving design for procurement (DFP) environmental and economic results. The factors early supplier involvement, standardization, lead time reduction, environmental sourcing, supply base maintenance, and core competence focused sourcing are regressed on diverse DFP performance outcomes. Data were collected via survey for a series of procurement focused items capturing the activities and characteristics for new product design and performance. Several major findings were supported through the analysis that enhance academic and managerial knowledge. Standardization positively impacted economic performance measures that focused on new product development and operational outcomes. Supply based maintenance was the strongest DFP initiative driving operational performance. Environmental sourcing positively affected all environmental performance measures, but was not related to economic performance.

1. Introduction

Sustainable competition for most firms requires a commitment to new product development (NPD) and innovation (Sjoerdsma and van Weele, 2015). Relying on today's products to generate tomorrow's revenue may work for basic commodities, but will result in disaster for products that rely on a greater amount of value-added manufacturing. To capture long-term revenues and sustainable competitive advantage, companies must commit to bring new products to market on a recurring basis. Carefully managing the creative process can result in product, and ultimately firm, success or failure.

NPD processes in firms vary significantly in terms of methods and functional involvement. They may be limited to R&D engineers and scientists that integrate cutting-edge technology into new products. Customer preferences today are more demanding and diverse. It is essential to understand what customers want (Holmes, 2016). Exceptional product form and function may be just enough to play in the market, but might not be enough to be the order winner. Customer concerns of total cost of ownership, long-term product support and environmental impact have placed additional requirements on new products. NPD processes must be able to design products with these diverse objectives in mind (Tracey and Neuhaus, 2013).

To address multi-objective product designs, some firms have responded with multi-functional NPD teams. These teams must include the technical experts that can integrate functions to build capabilities, but they must also include team members that can evaluate and incorporate product inputs, that understand how to move a design to the production line, that can plan for distribution, product support and recovery, and that know how design will be received by the market (Sobek et al., 1999). This new approach to product design opens the door for supply chain professionals to take a seat at the NPD table in the areas of procurement, manufacturing, and logistics.

A number of studies have focused on the role that procurement plays with respect to supplier integration and the overall supply chain framework (Droge et al., 2012; Nepal et al., 2012; Khan et al., 2012). However, a more holistic view of the role of procurement in NPD has been neglected, even though procurement is central to helping improve success for NPD projects (Eriksson, 2015). This paper focuses on the role that procurement professionals can play in NPD. Design for procurement (DFP) is a concept that procurement professionals apply to enhance procurement activities for the new product that will improve short-term NPD performance and long-term product performance in a sustainable manner to include economic and environmental concerns. This research focuses on procurement's role in design to answer the following research question: Do design for procurement decisions affect product economic and environmental performance outcomes? With this research we hope to begin filling in the gaps that exist and moving the conversation forward with respect to procurement in NPD.

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We will attempt to answer this question by presenting the results of an empirical study of procurement professionals. In the following two sections, the extant literature on design for procurement and design factors that can be implemented by or that will affect procurement professionals on design teams is reviewed and hypotheses are developed utilizing contingency theory (CT). Section 4 details methodology and results, and Sections 5 and 6 discuss these results and consider the study's contributions, limitations, and future research.

2. Literature review and hypothesis development

2.1. Design for X (DFX)

DFP springs from the design for (DFX) literature. DFX are techniques employed in NPD to ensure that the design team factors specific design goals and initiatives into the NPD process that facilitate their achievement throughout the product life cycle. Examples of DFX areas include design for manufacturability, design for disassembly, design for recovery and reuse, design for quality, design for recyclability, and design for procurement. Recent research laid out several DFX themes where research falls short: the need for theoretical frameworks to guide DFX technique application; the dearth of empirical research on the contribution of DFX techniques and how they affect performance through greater collaboration in the NPD process (Arnette et al., 2014). Each of these items will be explored in this section and extended to address DFP.

Most DFX research presumes that the implementation of design considerations during NPD will enhance product or process performance. However, a rigorous application of theory that provides conceptual definitions, domain limitations, theoretical relationships, and theory predictions (Wacker, 1998) is not found in DFX research. Theoretical frameworks have not been developed that incorporate the nature of the product, design goals, intended use, product strategy, market conditions, environmental and social conditions, and relevant business processes. These frameworks should facilitate DFX use "in many instances by explaining the who, what, when, where, how and why certain phenomena will occur" (Wacker, 1998).

Additionally, there is a lack of empirical testing for many key DFX techniques (Deshpande, 2012; Arnette et al., 2014). Creating and utilizing testable theoretical frameworks can provide the ability for data to be collected and analyzed to better understand if, and how, these design approaches can help deliver the desired performance results. This can help move discussions from the conceptual realm into a theory-based addition to the supply chain body of knowledge and to practical guidance based on tested concepts, principles, and frameworks.

2.2. Design for procurement (DFP)

DFP falls under the broader umbrella of design for supply chain that includes design for logistics and design for reverse logistics (Arnette et al., 2014). Design for supply chain can be viewed as being "concerned with designing the product while taking into account the impact on the performance and success of the supply chain" (Sharifi et al., 2006) and DFP the subordinate design initiative that focuses on the upstream supply chain. The underlying theme is to design a product with input from procurement that establishes a supply base that is responsive to the objectives and measures that would support product success. A framework for DFP was proposed based on a workshop with procurement industry professionals and academic experts that could improve value chains and facilitate the concurrent engineering process (Pulkkinen et al., 2012). However, the framework is only a proposal and lacks empirical testing. DFP research centers on suppliers' roles in product design, with case studies that indicate many problems could be avoided if suppliers were considered, or integral, in the design process. Similar research has looked at the impact of design on manufacturability, cost, lead time, and the ability to satisfy demand (Gokhan et al., 2010). DFP structure and guidelines are limited and have not been joined with the procurement related NPD research.

This more general NPD research examines the relationship between product design and supply chain design. However, the product design considerations do not contain the detail found in DFX approaches. Additionally, it focuses more on the contributions of external parties in the supply chain, without exploring internal procurement roles. Some examples of this research follow. Droge et al.'s (2012) empirical study with an Adaptive Structuration Theory lens found that supplier and customer integration provides benefit in terms of product and process modularity and positively impacts performance. Nepal et al.'s (2012) multi-objective optimization framework for matched product architecture strategy to supply chain design to determine supply chain member compatibility. Additionally, the research emphasizes the role of supply chain performance complementing technical and design performance on the overall success of the product in the marketplace. Khan et al.'s (2012) case study of a fast-growing UK fashion firm found that supply chain and product design alignment increases supply chain competitive advantage, resilience, and responsiveness. Other research examined earlier supplier involvement (ESI) and its impact on lead time, cost, or delivery (Handfield et al., 1999; Petersen, et al., 2003). The research on procurement's role in NPD is largely focused on the facilitation of ESI, often at the expense of other benefits that can lead to successful NPD (Eriksson, 2015). DFP provides procurement managers more tools for NPD engagement and the potential for broader impact. This research fuses the two fields of DFP research and procurement based supply chain research by examining the tie of design initiatives in the areas of lead time reduction, standardization, core competence focused sourcing, ESI, maintaining existing supply bases, and environmental sourcing to product performance.

2.3. Contingency theory (CT)

We employ contingency theory in this paper to make sense of DFP constructs within broader business and new product development environments. Contingency theory (CT) informs the use of design decisions; based on organizational and environmental conditions, to achieve an improved result (Ginsberg and Venkatraman, 1985). To select the appropriate decision, CT application pulls data from the market and industry, the expected product lifecycle, and the perceived level of environmental uncertainty (Porter, 1979). This data is used to create a process that drives organizational structure and systems. Success implementing the first two CT steps (context and configuration) should yield the desired performance (Doty et al., 1993; Ginsberg and Venkatraman, 1985). For DFP, firms are successful after achieving fit or congruency with configuration (structure and strategic factors) and context (Scott, 2003; Doty et al., 1993). We use contingency theory to build hypotheses that link DFP decisions or activities with expected performance outcomes.

Contingency theory has been used to study NPD in the past (Souder et al., 1998), and more recently has been used to focus on NPD with respect to modularization (Magnusson and Pasche, 2014), innovation (Duin et al., 2014), and most relevant to this research, procurement and supplier involvement (Yan and Nair, 2015). Therefore our use of CT is in congruent with recent research in NPD.

3. Theoretical model

DFP research examines design considerations that procurement personnel implement to improve product performance through enhanced procurement activities. Procurement decisions in the design process should take into consideration the major forces at play in the product's industry. Supplier power, buyer power, the competitive environment, the threat of substitutes and the possibility of new entrants are underlying drivers of profitability that firms should consider (Porter, 2008). For this research, we look at DFP initiatives as a source of buyer power, while supplier power is measured separately, and competitive environment integrates industry competition and the threat of substitutes. Additionally, the organizational method for NPD is key in the achievement of desired results. Concurrent engineering is included as a measure to distinguish firms following a sequential NPD approach from those using a simultaneous, multifunctional team approach.

In this section, we review the literature of these design considerations and formulate hypotheses that tie the implementation of these design considerations to performance. Section 3.1 discusses six factors used in the model, which are procurement decisions that design teams can make to strengthen their position as a buyer. Section 3.2 focuses on the three control variables used in the model. Section 3.3 discusses the development of performance items for use as dependent variables.

3.1. Factors

As discussed previously procurement personnel have the ability to use buyer power to influence the NPD process and product performance for the entirety of its life cycle. DFP enables a multi-faceted approach to NPD. Early supplier involvement (Birou and Fawcett, 1994) is the most common perceived procurement contribution to NPD, but this is only the tip of the iceberg. Quinn and Hilmer (1994) indicated that building a chain of competence is critical for supply chain success. Hence, core competence focused sourcing addresses that ability. Understanding supplier capabilities allows procurement to be primary proponents of lead time reduction (Tersine and Hummingbird, 1995). Procurement has the critical role of maintaining the firms supply base (Brewer, 2013). This unique responsibility enables the firm to standardize components across a wide variety of components (Fisher et al., 1999) and procurement's supplier knowledge provides environmental sourcing opportunities that can lessen NPD and product environmental impact (Tate et al., 2012). The ability of procurement to engage in NPD with these tools could drive improved procurement and product performance.

3.1.1. Environmental sourcing

Environmental impacts can merit a great deal of attention during the NPD process, and procurement can enable the achievement of these standards or goals, with increased focused on sourcing options and component selection, modification, or substitution based on environmental impact (Kopicki et al., 1993). These environmental impact assessments during procurement can lead to an increase of recycled or reused components and components that reduce waste, as well as the ability to select components that can be recycled or reused at the product's end-of-life. Environmental sourcing activities can be strengthened through improved coordination of efforts within the company and the supply chain (Carter and Carter, 1998), and a strong positive effect for environmental sourcing on firm performance has been found (Carter et al., 2000).

One reason purchasing strongly impacts a firm's environmental performance is that “a company is no more sustainable than its supply chain,” and supplier selection is crucial for the achievement of an environmentally-friendly supply base (Krause et al., 2009). Additionally, due to the magnitude of material purchases required, focusing on supplier initiatives, often coordinated through procurement personnel, represent the most powerful source of achieving real environmental improvements (Tate et al., 2012).

Using contingency theory, DFP guided procurement will implement environmental sourcing to obtain these greener inputs to configure their supply chain in a manner that will enhance the environmental position of the company and the new product. These enhancements may come at a cost to competitive advantage and drive lower levels of efficiency and product performance. From a theoretical perspective, creating greener design efforts causes procurement to seek suppliers that deliver environmentally friendly inputs and enables building a structure or supply base that will support greener processes. Creating a greener supply chain for product inputs will enhance a firm's ability to meet environmental goals. Therefore:

H1a. Environmental sourcing is negatively related to economic performance.

H1b. Environmental sourcing is positively related to environmental performance.

3.1.2. Core competence focused sourcing

The concept of supply chain management captures the ability of firms to source components from suppliers to assemble superior products. Prahalad and Hamel (1990) indicate that a firm's products should be infused with “irresistible functionality” or be products that customers need that are not imagined. They indicate the way to achieve this is by integrating core competencies into products. They define core competence as something difficult to imitate, something making a significant contribution to the customer's perception of value, and something that provides access to a wide variety of markets. In other words, core competencies can provide value to numerous products in ways that customers will seek out, providing the firm competitive advantage. Quinn and Hilmer (1994) indicate that firms can find inputs to their final products that fit that definition of core competence and that building products around these core competencies increases product competitiveness and ultimately firm competitive advantage. Thus, efforts to design products composed of suppliers' core competencies or products drives the need for core competence focused procurement. Firms rely on core products to build brand identity to achieve competitive advantage (Prahalad and Hamel, 1990). Purchased inputs for these core products and procuring suppliers' core products can be classified as strategic, highly impactful and requiring extensive procurement skill (Terpend et al., 2011; Quinn and Hilmer, 1994). Procurement functions become essential in the identification and management of these relationships to acquire world-class inputs. Acquiring access to these suppliers and their valued inputs enables firms to benefit from the characteristics of these core competencies. The procurement team member on the design team can influence design to include these core competencies and to build supplier relationships to ensure their successful integration.

Using contingency theory, DFP guided procurement will implement core competence focused sourcing to obtain these highly valued inputs to configure their supply chain in a manner that will enable competitive advantage and higher levels of product performance. Therefore:

H2a. Core competence focused sourcing is positively related to economic performance.

H2b. Core competence focused sourcing is negatively related to environmental performance.

3.1.3. Lead time reduction

One of the greatest causes for large inventory levels throughout a supply chain is long lead times. From a production standpoint, shorter lead times not only reduce inventory levels, they help improve quality, reduce negative impacts from distant forecasts, and improve operational efficiency. Sales can benefit from reduced lead times through improved customer service (Hopp et al., 1990). Reductions in lead time can provide a competitive advantage in a number of respects, including product design (Tersine and Hummingbird, 1995). With shorter lead times, a company can design a new product and introduce it to the market more quickly, often resulting in a first-mover advantage. Perry (1990) found that procurement lead times are a significant source of total lead times. Supplier selection plays a role in those procurement lead times (Bottani et al., 2008), and these issues can be even more pronounced for sourcing components in new product designs.

A DFP focused product design that focuses on pro-active involvement of procurement personnel to achieve lead time reduction should result in improved economic performance. According to contingency theory, procurement personnel based on the context of speed-based competition would configure the new product's supply chain with low lead time suppliers. Therefore:

H3a. Lead time reduction is positively related to economic performance.

H3b. Lead time reduction is negatively related to environmental performance.

3.1.4. *Early supplier involvement*

Dowlatshahi (1992) highlighted five benefits from early supplier involvement (ESI) in the NPD process: reduced lead times with fewer redesigns; better communication and reduction in duplicated efforts; cost savings; more reliable products; and improved financial performance. Birou and Fawcett (1994) found that purchasing personnel “possess specialized knowledge and experience” and can be integral to successful supplier involvement. This sentiment was echoed by Dowlatshahi (1998) in a paper focused on techniques for successful ESI, which stated that the “procurement department is not only the facilitator and catalyst for ESI implementation, but should be involved in the product design so that procurement concerns are represented.” Sjoerdsma and van Weele (2015) proposed twelve constructs essential to ESI relationship quality of trust, communication, information knowledge and sharing, cooperation and coordination, relationship-specific adaptations and investments, commitment, satisfaction, dependency and power, flexibility, reputation, loyalty, and relationship history. Though ESI has shown great potential, not all companies have been able to realize these benefits due to the extensive managerial efforts required for success (Wynstra et al., 2001), as well as changes in organizational structure and culture and commitment to the strategy (McIvor and Humphreys, 2004). Though ESI has largely been shown to have positive outcomes, two recent studies (Yan and Dooley, 2014; Yan and Kull, 2015) found that ESI can lead to decreased collaboration quality and supplier opportunism. However, the earlier study found benefits with respect to design quality, while the second study found potential negative impacts on design quality.

ESI, if implemented and managed successfully, should result in improvements to several areas, including economic performance. Using contingency theory, DFP guided procurement will implement ESI to obtain more stable designs that create efficiency and better design functionality, resulting in supply chain configurations that deliver stability at lower cost and competitive advantage. Therefore:

H4a. Early supplier involvement is positively related to economic performance.

H4b. Early supplier involvement is positively related to environmental performance.

3.1.5. *Standardization*

Firms have the choice as they engage in NPD to design products from inputs completely different from previous products or to integrate inputs already sourced for existing products into new designs. The choice to reuse inputs from existing products in NPD creates some challenges, when it comes to ensuring design freshness, but can yield some performance enhancements. A primary benefit is added leverage the procurement organization enjoys with increased input requirement levels (Duray, 2002). For firms that manage inventory and operations appropriately, this also results in lower inventory and operational costs (Salvador et al., 2002; Robertson and Ulrich, 1998). Additionally, supply assurance can typically be enhanced by sourcing from a known supplier with desired past performance in terms of delivery, flexibility, cost, quality and innovation (Bozarth et al., 2009). Standardization can also enhance the speed and lower the cost of NPD (Simpson 2004) by enabling volume related economies (Duray, 2002), resulting in more profitable products (Agrawal et al., 2013). However, caution should be taken to consider more the components with little impact on customer perceptions (Ramdas et al., 2003) or the potential exists for products to appear too similar (Simpson, 2004). Finally, the ability to share components over various products may be difficult due to the decentralized nature of NPD (Fisher et al., 1999). Nonetheless, the benefits of supply chain and operational efficiency present a real opportunity to increase product and firm profits.

Contingency theory informs that firms competing with NPD would seek to configure their design effort through standardizing inputs to lower costs, enhance quality, improve flexibility and take advantage of suppliers' capabilities to innovate within the constraints of current inputs. Therefore:

H5a. Input standardization is positively related to economic performance.

H5b. Input standardization is positively related to environmental performance.

3.1.6. *Supply base maintenance*

One of procurement's main roles is to build a supply base that functions as a competitive weapon (Lao et al., 2010; Watts et al., 1992). As such, firms invest significant time and resources in suppliers to build productive, lasting relationships (Zsidisin and Ellram, 2001). The retention of these relationships we refer to as supply base maintenance (SBM). Building strong supplier relationships is time-consuming and represents a significant investment by the firm in the human assets to develop and maintain the supply base (Brewer et al., 2013).

In the NPD process, leveraging existing supplier relations or the existing supply base reduces resource requirements and enables continuing access to a proven source of supply. Procurement members of the NPD team can influence engineers and designers to select components and subsystems that can be sourced through the existing supply base. These decisions increase volume within these suppliers enabling better relationships, and the potential for improved economic terms. Maintaining a supply base with suppliers with the desired technology, processes, capacity and design flexibility are an essential contribution for procurement professionals to the NPD process. This can be accomplished through contractual safeguarding and forming binding long-term alliances (Oxley, 1999).

From a theoretical perspective, cultivating strong relationships with suppliers that support company design efforts requires procurement to understand the NPD context and to build a structure or supply base that will support firm activities and result in enhanced performance. Although performance-based DFP research does not exist, we extend contingency theory to explain that by making the “correct” supplier choice firms build a configuration that supports the design context for a specific product or product line that results in enhanced product performance. This emphasis on SBM activities allows firms to leverage supply base strengths as a resource to build competitive advantage (Ketchen and Hult, 2007). Therefore, supply base maintenance hypotheses were developed to compare DFP decisions and performance outcomes.

H6a. Supply base maintenance is positively related to economic performance.

H6b. Supply base maintenance is positively related to environmental performance.

3.2. Control variables

We include three control variables in this research control for firm level decisions and business environment conditions. Concurrent engineering is a firm level decision that affects NPD organization and interactions. Competitive environment and supplier power are industry conditions or structure that can affect the NPD and the deployment of new products. A discussion of these control variables follows.

3.2.1. Concurrent engineering (CE)

Concurrent engineering employs cross-functional teams that holistically consider design decision implications. Proper implementation can enable competitive advantage, decrease time-to-market, reduce product cost, improve product reliability, and increase customer satisfaction. NPD analysis has estimated that 70–80% of a product's total cost is determined in the product design process and that procurement contributes to the concurrent engineering process by: developing specifications, sourcing interchangeable parts, part standardization and simplification, part substitutions, part exclusions, and value analysis (Dowlatshahi, 1992). Procurement also has a role in this process with new technology introduction, identifying technology trends and suppliers, supply base rationalization, building supplier development plans, conducting purchase material risk assessments, addressing part end-of-life issues, supplier integration, and qualification and certification (Balasubramanian, 2001). Deshpande's (2012) extensive literature of procurement and concurrent engineering determined that for this relationship there is a void of conceptual and empirical exploration. Traditional NPD organization was sequential in nature. Each function was involved in the NPD process after another function completed their work. We use this variable to control for the way a firm organizes its NPD activity.

3.2.2. Supplier power

Understanding the position of suppliers in the industry is key to making design decisions. Suppliers with power have the capability to capture a greater amount of value with the capability to control pricing, quality, levels of service, and the ability to shift costs to supply chain members (Porter, 2008). Knowing the firm's position relative to suppliers helps inform decision making in the design process.

Power can be viewed as the ability to affect another firm's behavior when asking something incompatible with a firm's desire, by getting a firm to do something they would not otherwise do, or to get a firm to act contrary to its interests (Cowan et al., 2015; Lacoste and Johnsen, 2015: Chicksand, 2015). Power asymmetries in a relationship allow the most powerful to dictate behavior and control interaction (Lacoste and Johnsen, 2015) and result from superior positions of capital, tangible and intangible assets, unique capabilities, information asymmetry, reputation, and intellectual property (Chicksand, 2015; Pazirandeh and Norman, 2014). Supplier power has been shown to negatively impact delivery, quality, innovation, and flexibility (Terpend and Ashenbaum, 2012). Buyers lose the ability to influence large powerful suppliers (Tanskanen and Aminoff, 2015) and it can negatively affect buyer-supplier collaboration and partnering (Chicksand, 2015). Buyers may not be able to select other than power suppliers. In this context, the buyer would seek to handle the power asymmetry (Lacoste and Johnsen, 2015) by seeking a more collaborative relationship with reciprocity. However, the powerful supplier will exercise that power resulting in below expectations levels of performance (Cowan et al., 2015). This variable controls for the varying levels of supplier power in procurement relationships.

3.2.3. Competitive environment

As a final consideration, the level of competition faced by an organization has a wide-ranging impact on design decisions. Competitive intensity increases with large numbers of competitors, competing product entries, the threat of substitutes, short product lifecycles and rapidly changing technologies (Fine, 1998; Porter, 1980, 1979). In these competitive environments, a firm will modify design decisions in an attempt to achieve desired performance and procurement efficiency.

High levels of competition typically limits the profitability of firms and products (Porter, 2008) and can drive price competition, especially when products are similar. Other industry aspects that result in high levels of competition are excessive amounts of capacity, availability of substitutes, high fixed and low variable costs, high exit barriers do to specialized investments, high levels of commitment by competitors and product perishability (Porter, 2008). Procurement will need to invest considerable resources to identify the best suppliers given this competitive environment, to carefully source from suppliers that will enhance the products competitive position, and to strengthen relationships with the existing supply base. Even with strong procurement actions to drive component selection and sourcing activities to obtain a favorable position to deal with high levels of competition, the increased uncertainty inherent in a highly competitive environment makes achieving success questionable. We use this variable to control for the effect of competition on procurement performance.

3.3. Performance

When examining procurement performance in the case of NPD, it is critical to take a multi-faceted approach to measuring performance. We examine three primary components of performance: environmental and economic in terms of NPD and operational measures. For environmental we focused on the use of clean technologies in the achievement of recycling, component reuse, and waste and hazardous material reduction (Tate et al., 2012; Carter et al., 2000). For economic performance to gain the benefits of DFP, it was important to take the short-term view and examine if NPD objectives were met and a long-term approach to evaluate achievement of operational performance during the post NPD life cycle of the product. NPD measures examined time to market, NPD lead time, resource requirements, post launch product changes, and regulatory compliance (Deshpande, 2012; Dooley et al., 2002; Dowlatshahi, 1992). Operational measures are cost, quality, delivery (Chen and Pulraj, 2004; González-Benito, 2006) traditionally associated with supply chain operations and as such are the appropriate long term metrics for measuring DFP influence on product success. Fig. 1 shows tested hypotheses on these multi-faceted performance variables.

4. Methodology and results

4.1. Variable operationalization and data collection

This survey-based study used extant DFP, NPD, and concurrent engineering literature to develop constructs, frameworks, and hypotheses. Part of our research effort is to develop scales for future DFP research. This research follows in the model of Brewer et al. (2013) snd Li et al. (2009, 2005), who developed scales for procurement outsourcing, supply chain agility, and supply chain management practices respectively. Constructs used for data

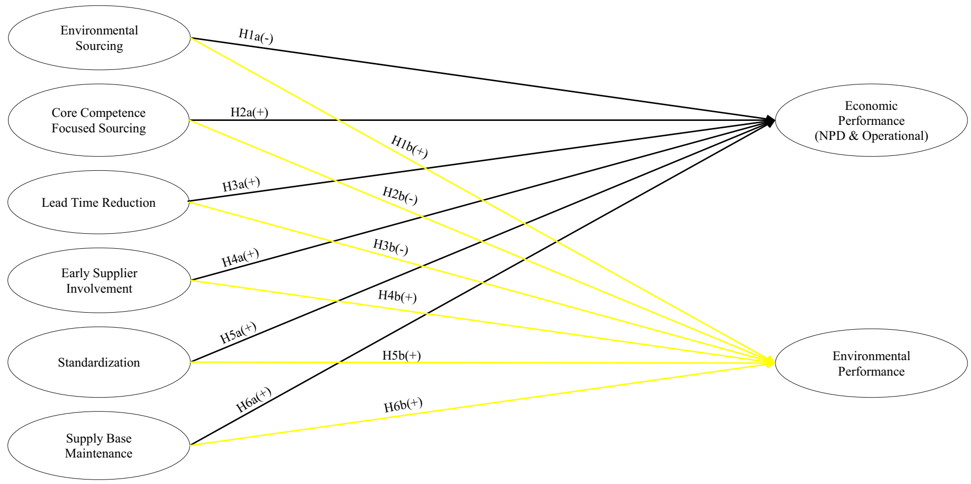

Fig. 1. Proposed regression models [(1) economic (2) environmental performance].

collection did not have scales developed to measure them; as a result, the scales are exploratory. Items were developed using concepts from the NPD procurement literature. Appendix A identifies the literature source from which items were developed. 27 procurement managers and 14 academics assessed content validity by evaluating whether scale items adequately represented the construct domain (DeVellis, 2003). They reviewed questions posed in the survey instrument, evaluating concept and instruction clarity, readability, and ambiguity. Following their review, we implemented suggested changes to ensure scale content validity had been established—see Appendix A for the scales. All items were grounded conceptually in the literature discussed in Section 2, and other relevant research (Srivastava, 2007; Blackhurst et al., 2005; Huang et al., 2005; Sharifi et al., 2006).

For this study, the unit of analysis was procurement participation in product design teams that designed or redesigned a product. Respondents were prompted to answer survey questions based on a specific design event and not to represent the firm's overall approach to NPD. Their responses to survey items were captured on a seven-point scale, indicating the degree they to which they implemented DFP activities and the level of product performance compared to other firm products.

Data collection occurred online via survey following generally the methods proposed by Dillman (2000). 920 randomly selected procurement managers, members of the Institute for Supply Management (ISM), made up the survey population. The survey response rate was 12.0% with 110 responses with 88 analyzable responses for an effective rate of 9.6%. Initially, researchers called potential respondents with accessible phone numbers to invite survey participation and to email survey links. Next respondents were mailed a letter inviting them to participate. After four weeks, a postcard was sent to nonrespondents to drive participation. We performed non-response bias (NRB) testing by comparing early and late response waves, based on the assumption that late responders approximate non-respondents (Lambert and Harrington, 1990; Armstrong and Overton, 1977). The group representing non-respondents was composed of those responding to the final mailing, while early respondents all participated based on the initial telephone contact. We performed *t*-tests to evaluate if there were differences between the first and last quartile of respondents for ten items we randomly selected from the survey, and all results were non-significant (p-values > 0.05). Based on the results we conclude that NRB is not a problem for this study.

The 88 respondents represented a number of industries and firm sizes. Industries included: lumber and wood, textiles, furniture and fixtures, leather products, rubber and plastics, stone, clay and glass products, metal products, machinery, electronic equipment, transportation equipment, instruments, and miscellaneous manufacturing. Additionally, firms varied in size from $1 million or less up to $100 billion in revenues. This ranging collection of industries and company sizes improves the generalizability of this study.

4.2. Reliability and validity assessment

Confirmatory factor analysis (CFA) using Lisrel was implemented to assess unidimensionality, convergent and discriminant validity (Anderson and Gerbing, 1991) for the factors of early supplier involvement, standardization, lead time reduction, environmental sourcing, supply base maintenance, and core competence focused sourcing. We assessed unidimensionality and convergent validity by examining standardized residuals, and by evaluating the sign, significance, and magnitude of individual factor loadings. All factor loadings were significant with a p-value less that 0.01. All standardized factor loadings were.5 or higher as suggested by Hair et al. (2010), demonstrating good convergent validity. This analysis resulted in three-item factors for all factors except environmental sourcing (five-items), supplier power, lead-time reduction and core competence focused sourcing. The overall fit statistics RMSEA of 0.012 (90% CI 0.0–0.053), TLI of 0.99, and CFI of 0.99 demonstrate excellent model fit (Kelloway, 1998). Additionally, the chi-square absolute fit test was not significant with a p-value of 0.42 indicating no significant difference between the covariance matrix and that implied by the model (Kelloway, 1998). The small sample performed well without any special procedures to account for sample size. Discriminant validity was examined via pairwise chi-square difference tests for all construct pairs and at the model level. In this test, two CFA models are run for each test, one in which correlations are allowed to vary, and another in which they are constrained to one. Statistically significant chi-square difference tests with a p-value of less than 0.01 were found at the model and pair level, providing evidence of discriminant validity (Garver and Mentzer, 1999). Additionally, a more conservative approach of comparing the average variance extracted (AVE) from each factor to the squared interconstruct correlations found that all AVE estimates exceeded the squared correlations indicating no problems with discriminant validity (Hair et al., 2010). Reliability was tested using Chronbach's coefficient alpha and composite reliability all values exceeded the minimum standard of 0.7, indicating adequate reliability (Churchill, 1979; Dunn et al., 1994; Hair et al., 2010). See Appendix A for a complete view of the factors and reliability and discriminant validity statistics.

Some proposed latent factors failed to demonstrate sufficient validity or reliability. Lead-time reduction items cross-loaded with other factors, core competence focused sourcing failed to demonstrate an adequate level of reliability, and the items for supplier power failed to load strongly as a latent variable. As a result, the most representative item was selected to represent each construct as a single item factor.

A final concern was the possibility of common methods bias, a Harman one-factor test was employed. We estimated an exploratory factor analysis with 60 survey items. Eighteen factors resulted with eigenvalues greater than one. Because items did not load on a single factor and a dominant factor did not emerge with a majority of the variance, the test failed to indicate the presence of common methods bias (Harman, 1967). Because overall model fit statistics, and construct validity analysis resulted in constructs that were so strongly distinct and unique, we conclude that common methods bias is not a concern for this study (Podsakoff et al., 2003).

4.3. Regression analysis and results

For hypothesis testing, regression analysis with SPSS was used to test H1–H9 (Hair et al., 2010). Table 1 shows the regression results for each of the DFP performance measures regressed onto the six DFP initiatives, and the three control variables. The small sample performed well without any special procedures to account for sample size.

Performance measures were regressed individually to determine the effect of DFP factors on each performance measure. Hypothesis 1a was not supported. Environmental sourcing was not significantly related to any economic performance. However, H1b was completely supported. Environmental sourcing was positively and significantly related to all environmental performance outcomes. H2a was partially supported, core competence focused sourcing was positively, significantly related to productivity. Not only was H2b not supported, but the significant relationship was positive instead of the negatively proposed relationship with the environmental performance metric of recovery and reuse of components. For lead time reduction, H3a had partial support for on-time-delivery, but no support for H3b with no significant relationships with environmental performance. This was also the case for ESI (H4b), standardization (H5b), and supply base maintenance (H6b) with no significant relationships existing with environmental performance. ESI had moderate support for H4a with three of nine positive, significant relationships for economic performance (time-to-market, post-launch product changes, procurement cost). Standardization (H5a) was by far the strongest DFP activity that supported economic performance. Six of nine performance measures were supported, while productivity, regulatory compliance, and quality were not. Finally, H6a had moderate support with three of nine relationships (productivity, quality, procurement cost) supporting the hypothesized positive relationships with economic performance. Table 2 provides a summary of the strength of support for the hypotheses.

5. Discussion and implications

One of the critical aspects of any study is to determine how strategically selected actions affect desired results. The previous analysis enables us to answer how DFP initiatives affect new product development environmental and economic performance metrics.

5.1. Environmental

The first four dependent variables listed in Table 1 correspond to the environmental performance measures utilized in the survey: recovery/reuse of components, hazards exposure, waste reduction, and recycling. The regression models for all four environmental measures produced significant results. However, the R^2 values for these models are on average lower than the R^2 values for the economic performance and NPD variables, with recovery/reuse and hazards exposure being only 0.233 and 0.254 respectively. The support for H1b was extremely strong, with environmental sourcing being a significant predictor in all four models. The impact on hazards exposure and recycling was particularly strong, with significance values for each being near-zero. Among the five other factors in the models, only recovery/reuse could be predicted by one of these factors (core competence focused sourcing), and the rest of the models and factors failed to prove significant. The desire to improve recovery and reuse of these world-class inputs, that result from core competence focuses sourcing, makes logical sense. These are components that have high value and therefore warrant the additional effort required to recover and reuse these components.

With respect to the three control variables, competitive environment was not significant in any environmental performance regression or in any of the economic performance regressions. Concurrent engineering was a predictor for waste reduction, but did not affect the three other environmental performance measures. Again, this makes sense, as the involvement of procurement personnel in a concurrent engineering-based NPD process can help achieve waste reduction, as shown in previous studies (Carter et al., 2000). Finally, supplier power was not a significant predictor of recovery/reuse and hazards exposure, but was significant for both waste reduction and recycling. However, for both performance measures, the corresponding beta coefficient values were negative, meaning that supplier power negatively relates to these dependent variables. Therefore, if a company wishes to purchase components or inputs that lead to less waste or can be recycled, powerful suppliers may prove an impediment to the achievement of such goals if they do not correspond with that supplier's own performance indicators. The use of less powerful suppliers, over which the purchasing company can exert greater influence, would be beneficial to the achievement of certain environmental goals; a company can only be as sustainable as its suppliers (Krause et al., 2009).

Overall, environmental performance measures were only significant for H1b, failing to provide any support for the other hypotheses, whether these were thought to be positively or negatively related to the survey factor.

5.2. Economic

Our examination of economic performance has two facets. First, five economic performance indicators focus on the outcomes of the product development activity. Did DFP activities enable regulatory compliance and did they reduce resource requirements, time-to-market, post-launch product changes, and NPD lead time? Second, we also analyzed performance from a more operational perspective. Did DFP activities enable improved operations performance after product launch in the areas of productivity, quality, delivery, and cost?

5.2.1. Development performance

Two DFP activities, standardization and early supplier involvement (ESI) were dominant in NPD performance. In fact, these are the only DFP activities that produced significant results.

Standardization positively impacted the reduction of resource requirements, post-launch product changes, NPD Lead time, and time-to-market. These results are consistent with Simpson (2004). He indicated that standardization increased NPD speed and lowered design cost. The speed relationship bears out with the positive relationship with time-to-market and NPD lead time. We know speed is critical, especially in fast clock speed industries. Additionally, increased development time results in higher development costs and often lost sales if first mover advantage is forfeited. By being able to leverage existing materials, component contracts, and suppliers, procurement can have a major impact on the NPD process. This, however, is not easy. Fisher et al. (1999) indicates that decentralized NPD requires a

Table 1
Regression results.

		ANOVA			**Standardization**		**Lead time reduction**		**Core competence focused sourcing**		**Early supplier involvement**		**Supply base maintenance**		**Environmental sourcing**		**Concurrent engineering**		**Competitive environment**		**Supplier power**	
	Performance metrics	R^2	F	Sig	Beta	Sig	Beta	Sig	Beta	Sig	Beta	Sig	Beta	Sig	Beta	Sig	Beta	Sig	Beta	Sig	Beta	Sig
Environmental: Hypotheses (b)	**Recovery/re-use of components**[a]	**0.233**	**2.594**	**0.011**	0.189	0.145	0.094	0.428	**0.227**	**0.034**	0.075	0.552	−0.053	0.665	**0.262**	**0.039**	0.011	0.927	−0.022	0.842	−0.040	0.706
	Hazards exposure[b]	**0.254**	**2.905**	**0.005**	0.159	0.211	0.134	0.250	0.155	0.141	−0.079	0.525	−0.103	0.397	**0.448**	**0.000**	0.035	0.776	−0.194	0.075	−0.033	0.748
	Waste reduction[a]	**0.391**	**5.419**	**0.000**	0.147	0.203	0.095	0.368	0.028	0.765	−0.109	0.334	0.213	0.055	**0.224**	**0.047**	**0.325**	**0.004**	−0.040	0.685	**−0.218**	**0.022**
	Recycling[a]	**0.332**	**4.251**	**0.000**	0.108	0.368	−0.178	0.109	−0.119	0.229	−0.084	0.473	0.108	0.346	**0.366**	**0.002**	0.161	0.166	−0.038	0.708	**−0.233**	**0.019**
Economic NPD: Hypotheses (a)	**Regulatory compliance**[c]	0.159	1.616	0.126	0.046	0.732	0.253	0.043	0.104	0.350	−0.066	0.617	−0.025	0.847	0.315	0.018	0.010	0.940	−0.096	0.404	−0.114	0.301
	Resource requirements[d]	**0.462**	**7.346**	**0.000**	**0.317**	**0.004**	0.174	0.081	0.080	0.365	−0.027	0.796	0.130	0.208	0.145	0.169	**0.308**	**0.004**	−0.046	0.613	−0.077	0.384
	Time to market[e]	**0.459**	**7.252**	**0.000**	**0.431**	**0.000**	0.032	0.749	0.111	0.215	**0.256**	**0.017**	0.155	0.135	0.035	0.736	−0.025	0.812	−0.011	0.909	**−0.247**	**0.006**
	Post-launch product changes[d]	**0.448**	**6.850**	**0.000**	**0.458**	**0.000**	0.047	0.643	0.108	0.230	**0.398**	**0.000**	0.055	0.597	−0.005	0.961	−0.166	0.121	0.083	0.373	−0.099	0.270
	NPD lead time[d]	**0.333**	**4.274**	**0.000**	**0.341**	**0.006**	0.137	0.216	0.150	0.131	0.129	0.274	0.132	0.250	−0.070	0.548	0.051	0.660	0.099	0.335	−0.132	0.180
Economic Operational: Hypotheses (a)	**Productivity**[f]	**0.411**	**5.963**	**0.000**	0.170	0.134	0.071	0.493	**0.192**	**0.041**	0.160	0.149	**0.261**	**0.017**	0.058	0.596	0.112	0.302	0.063	0.508	**−0.194**	**0.037**
	Quality[f]	**0.295**	**3.586**	**0.001**	0.195	0.115	−0.005	0.968	0.199	0.053	0.053	0.659	**0.262**	**0.028**	0.134	0.265	0.030	0.802	−0.060	0.570	−0.108	0.285
	On-time delivery[f]	**0.393**	**5.542**	**0.000**	**0.279**	**0.017**	**0.237**	**0.026**	0.089	0.348	0.125	0.265	0.163	0.138	0.043	0.699	0.100	0.364	−0.010	0.919	**−0.231**	**0.015**
	Procurement cost[f]	**0.443**	**6.806**	**0.000**	**0.348**	**0.002**	0.166	0.102	−0.054	0.549	**0.241**	**0.027**	**0.267**	**0.012**	−0.086	0.422	−0.030	0.779	0.035	0.705	**−0.272**	**0.003**

[a] Carter et al. (2000).
[b] Tate et al. (2012).
[c] Dooley et al. (2002).
[d] Dowlatshahi (1992).
[e] Deshpande (2012).
[f] Chen and Pulraj (2004).

Table 2
Level of support for hypotheses.

	(a) Economic Performance	(b) Environmental Performance
H1: Environmental Sourcing	No	Full
H2: Core Competence Sourcing	Partial	No
H3: Lead Time Reduction	Partial	No
H4: Early Supplier Involvement	Moderate	No
H5: Standardization	Strong	No
H6: Supply Base Maintenance	Moderate	No

disciplined procurement function that can integrate requirements across distinct NPD activities. Supporting processes and databases must exist to drive the appropriate level of standardization. We see the impact of standardization on cost with the reduction in resource requirements and post-launch product changes. Standardization will reduce effort and resources when existing components and materials are designed into new products. Engineering and contracting requirements are reduced and leverage is increased in existing relationships. Not only do we see an enhancement in economies of scale inherent in the firms supply chain, but we see a stabilizing force as standardization reduces changes after NPD completion. Companies are able to leverage the tried and true inputs. This action most likely assists in manufacturing activities, where familiarity with components ensures proper and efficient installation. This result validates the work of Fisher et al. (1999) and Ramdas et al. (2003) although their work took more of an operations perspective. Procurement can make a major NPD contribution with standardization. ESI works hand in hand with standardization to improve NPD speed and cost.

ESI strongly and positively contributed to reducing time-to-market and post-launch product changes. Dowlatshahi (1992) indicated that ESI reduces lead time with less redesign and reduces duplicated effort because of better communication. These characteristics definitely lead to a NPD speed that decreases time to market. The result is not only positive for speed and cost during the NPD process, but the decreased need for redesign yields great stability of design post NPD and results in reduced post-launch changes. Procurement's special knowledge of suppliers' design and delivery capabilities enhances the need to employ ESI as a DFP tactic to drive these positive benefits during the product lifecycle.

None of the other DFP initiatives were significantly related to design performance. However, this may be due to the need for procurement to gain a more prominent seat at the NPD table. Our discussions with procurement professionals during the course of this research revealed that only a small percentage have a NPD role. Because of the limited role of procurement in design activities, some of the DFP initiatives may not have received sufficient attention to demonstrate potential results.

One of the dependent variables, regulatory compliance, had no significant relationships with any of the DFP initiatives. It is possible that meeting regulatory requirements may be seen as a requirement to compete and not an outcome that is viewed as a competitive advantage. As such it may be viewed as something addressed in basic design processes and not something that is benefited by DFP influenced design.

Finally, the control variables of concurrent engineering and supplier power each were significant in one regression. Concurrent engineering was positively related to resource requirements. It is logical that simultaneous design activities by multifunctional teams would improve the use of resources as the activities of manufacturing, distribution, procurement, marketing, etc. are considered in advance and problems are solved before activities are initiated. Supplier power was negatively related to time to market. In the case of powerful suppliers that control essential product inputs, firms are beholden to the supplier for delivery of designs, information and physical inputs. Depending on the importance of the buying firm the powerful supplier may be somewhat responsive to nonresponsive. The powerful supplier can block progress in ways that inhibit design speed.

5.2.2. *Operational performance*

Once the product lifecycle moves beyond the design phase, efficiency, quality and delivery becomes more important and the DFP initiatives influencing operational performance change significantly. Supply Base Maintenance holds a strong presence, while lead time reduction and core competence focused sourcing make an appearance. However, standardization and ESI continue to play a role in operational performance.

Supply based maintenance (SBM) takes a dominant presence in operational performance. SBM is positively related to productivity, quality, and cost or the measures of efficiency and quality. SBM is a monumental effort that requires procurement personnel to develop long term relationships with suppliers that deliver the needed inputs in a manner that adds to the value of the new product and all products in a firm's portfolio of offerings. It is the most effective way to leverage the strengths of suppliers (Ketchen and Hult, 2007). When we consider its contribution to productivity much of the value is gained through quality. As suppliers deliver high quality inputs, rework and scrap are reduced. Additionally, suppliers in a well-managed supply base deliver the appropriate technology, processes, capacity and flexibility (Oxley, 1999) to ensure productivity goals are met and sustained. These same capabilities are demonstrated in the positive relationship with quality. Finally, the long term relationships enabled by SBM allow for the positive relationship generated with cost. Processes can be jointly improved, inventory better managed and deliveries fine tuned to drive cost from the system. SBM should begin with NPD and continue through out the product lifecycle and grow with each new product that is added to the firm.

Standardization plays a large role in operational performance as well as design performance. Standardized inputs stabilize input deliveries and inventory leading to better performance with respect to production schedules and ultimately resulting in a positive relationship with delivery performance. Reduced contracting requirements and familiarity with standardized inputs also leads to a positive relationship with procurement cost. Standardization is a strong DFP contributor to NPD.

Core competence focused sourcing also exhibits a positive relationship with product quality. This process of seeking world class inputs valued by customers should result in highly valued and high quality components and materials. This quality should drive up the perceived value of the product. Core competence focused procurement almost proved to have a significant relationship with productivity with a p-value equal to 0.053. In the same manner that SBM drives high quality that reduces rework and scrap, core competence focused sourcing results in quality that would support similar productivity gains.

Perhaps the most obvious relationship was that lead time reduction is positively associated with on-time delivery. Sourcing inputs with reduced lead times is critical for firms involved in time-based competition. The ability to deliver on time is critical for the survival of firms competing in fast clock speed industries.

Finally, cost is the operational performance measure most associated with procurement. Interestingly, it was the performance outcome with the most diverse DFP initiatives. Standardization, ESI, and SBM were positively related to improving procurement cost. The previous discussion detailed how these initiatives drive efficiency and cost reductions. This result strengthens the view of firm functions and business in general of the strong drive for procurement to reduce acquisition costs.

Another interesting result is how the control variable supplier power has a significant negative presence in the operational performance area. It is negatively related to productivity, on-time delivery and cost. Most likely powerful suppliers have great quality products that move buying firms to procure inputs from them. However, their power appears to perturb the buying firm's ability to operate efficiently. Most likely incoming deliveries are impacted, productivity affected and costs driven higher. This reality begs for a strong procurement function to seek alternatives and foster relationships that prevent or circumvent supplier power.

A look at the variation explained by the individual regressions for NPD and operational performance reveals higher R-squared for NPD performance (see Table 1). But in all cases the regressions have strong explanatory power. A result that changes to a small degree with environmental performance.

6. Contributions, limitations and future research

6.1. Contributions

This study contributes to the existing literature and has clear managerial implications. With respect to the gaps in previous literature, this study provides an empirical foundation in response to the lack of previous research focused on procurement in NPD (Deshpande, 2012; Arnette et al., 2014; Eriksson, 2015). Through the creation of a testable theoretical framework, several significant contributions from this study expand the current body of knowledge to tie DFP to environmental and economic outcomes. First it contributes by identifying standardization as a powerful DFP tool for driving economic performance during the NPD process and operational performance. Second, SBM makes a major contribution to operational performance. It can in deed be a competitive weapon (Lao et al., 2010) the firm can leverage. Third, ESI functioned well as described in the literature by leveraging supplier capabilities to improve NPD. Selectively inviting suppliers to participate in the development process enables firms to capture value in terms of speed to market, less engineering changes during the life of the product, improved functionality for customers and ultimately better efficiency and procurement costs (Dowlatshahi, 1992). Fourth, concurrent engineering and core competence focused sourcing appear to be a bridge for firms to develop environmentally sound products that are economically viable. Fifth, supplier power can be particularly troublesome for environmental initiatives and operational performance. Finally, cost seems to dominate as the focus for procurement.

This study's results provide a way to examine procurement's contribution to NPD and have clear managerial implications. It is critical for procurement personnel to maintain good databases and a disciplined approach to insert standard inputs into new products. Procurement has a unique capability to work with suppliers to build a strong supply base that can improve quality and drive down costs and to know which suppliers can contribute when brought into NPD. Additionally, procurement's ability to lessen the influence of supplier power through relationships, knowledge of alternative suppliers or by creating options through supplier development is a way to lessen the negative effect of power on the product. Finally, cost, though important, needs to be one of procurement's objectives not the only objective. As procurement delivers value to the NPD process that creates value for the customer through more differentiated offerings, its strategic importance will increase in the firm.

6.2. Limitations and future research

A primary limitation of this study was that we did not address CSR initiatives or the equity aspect of the triple bottom line. This equity dimension of DFX is largely underdeveloped (Arnette et al., 2014). Future research should examine the impact of product design on CSR initiatives generally. Additionally, research should examine how procurement play a role in CSR initiatives with suppliers and by leveraging the supply base.

Another opportunity for future research would be an in-depth dive into the role of procurement in the NPD process. More information on role of the procurement in NPD would be helpful for procurement leaders and education to influence the future. Knowledge such as to what extent does procurement become involved in NPD, what does this participation look like, and what can be done to improve procure participation in NPD are questions that could improve procurement's contribution. Case study research that looks closely at functional relationships and the NPD process would deliver the richest ability to accomplish this research.

A final area for future research would be to examine which economic-focused DFP initiatives could best enhance environmental objectives. Some of these initiatives drive higher efficiency and resource reductions. Knowing how these contribute to environmental success would be helpful. Additionally, knowledge of how environmental focused procurement actions in NPD contribute to economic performance is lacking.

Appendix A

See Table A1 here.

Table A1
Coefficient alpha, composite reliability (CR), average variance extracted (AVE) compared to highest squared correlation.

Latent variable (All loadings significant at a p-value < 0.01) (Items arranged by contribution)	AVE	Highest Sq Corr < AVE
Environmental Sourcing: α = 0.830 CR = 0.827	0.500	0.275
We designed the product to use inputs that would reduce waste at product disposal[a]		
We designed the product to use inputs that were recyclable[a]		
We designed the product to use inputs that could be recovered for reuse in this product or other products[a]		
We designed the product to use inputs free from hazardous or toxic materials[b]		
We designed the product to use inputs produced with clean technologies[a,b]		
Core Competence Focused Sourcing		
We designed the product so we could include world-class inputs valued by consumers[c]		
Lead Time Reduction		
We selected inputs with low lead times to rapidly meet customer demand[d]		
Early Supplier Involvement: α = 0.911 CR = 0.916	0.786	0.383
We brought suppliers with customer-valued core competence (world class capability) into the design team[c]		
We brought suppliers with industry-leading technology into the design team[e]		
We brought suppliers with the ability to improve the design into the design team[e]		
Standardization: α = 0.824 CR = 0.856	0.669	0.240
We standardized inputs with our other products as much as possible (i.e. limited screw choices to those already used by our other		

Table A1 (*continued*)

Latent variable (All loadings significant at a p-value < 0.01) (Items arranged by contribution)	AVE	Highest Sq Corr < AVE
products)[f]		
We standardized inputs as much as possible (i.e. a single screw for the product)[f]		
We tried to limit the number of new items we would need to buy[g]		
Supply Base Maintenance: α=0.814 CR=0.843	0.652	0.240
The design of the product allowed us to select suppliers we already work with[h]		
The design of the product allowed us to select suppliers on our approved vendor list[i]		
The design of the product allowed us to select suppliers that worked well with their suppliers[j]		
Concurrent Engineering: α=0.750 CR=0.778	0.515	0.383
Product designs were developed together by a team of employees from different company functions (i.e. marketing, engineering, procurement, manufacturing, etc.)[k]		
The manufacturing process was designed during product design[k]		
Product design activities were accomplished at the same time by each function on the team[k]		
Supplier Power		
Suppliers for this product are powerful[l]		
Competitive Environment: α=0.772 CR=0.778	0.556	0.189
This product faces(ed) a high level of competition from similar products[l]		
Profit margins for this product are small due to the high level of competition		
There are many substitutes in the market for this product		

[a] Carter et al. (2000).
[b] Tate et al. (2012).
[c] Quinn and Hilmer (1994).
[d] Tersine and Hummingbird (1995).
[e] Birou and Fawcett (1994).
[f] Agrawal et al. (2013).
[g] Duray (2002).
[h] Brewer et al. (2013).
[i] Bonaccorsi and Lipparini (1994).
[j] Wu and Choi (2005).
[k] Deshpande (2012).
[l] Porter (1979).

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