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Suppliers versus Lead Users: Examining Their Relative Impact on Product Variety

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Collaboration with parties external to the new product development (NPD) process is seen as a means to reduce costs and improve the product offering to customers. On the suppliers' side, collaboration during the NPD process may lead to a faster and more efficient process. On the users' or customers' side, collaboration may provide ideas for entirely new products and/or modifications to existing ones. This paper examines how collaboration with suppliers and a group of users that experience needs unknown to the public, the so-called lead users, affects the resulting variety of the products offered. The paper focuses on product variety because of its increasing perceived importance in the satisfaction of changing customer needs. Hierarchical regression analysis of survey data collected from 313 U.K. manufacturers revealed a significant positive relationship between collaboration and product variety. The key findings are that increasing the extent of collaboration with lead users and with suppliers during the NPD process will increase the variety of products offered to customers, and that lead users have a higher impact on product variety to suppliers. Previous studies have found that collaboration increases NPD performance, but to the best of the authors' knowledge, this is the first to explicitly explore the link with product variety. The paper concludes by discussing the findings' practical implications, limitations, and recommendations for future studies.

Introduction

The realization over the past 30 years that the production of large volumes of standardized products can no longer lead to increased market share and profits has led many manufacturing companies to increase the variety of the products they offer to their customers (MacDuffie and Sethuraman, 1996). Increased product variety increases the chances that a customer will find something that matches his/her preferences (Dowell, 2006; Kai-Lung, 2004; Kekre and Srinivasan, 1990), and thus may assist an organization to gain a competitive advantage. Furthermore, product variety provides a good measure of an operation's flexibility, which, along with quality, cost, and speed of delivery, is a key operational capability (Da Silveira and Cagliano, 2006; Devaraj, Hollingworth, and Schroeder, 2004; Hayes, Pisano, Upton, and Wheelwright, 2005; Slack, Chambers, and Johnston, 2005). As a consequence, companies often seek ways to increase the variety of their products, mainly in terms of product lines and product variants (Cottrell and Nault, 2004). To achieve sufficiently high variety, and thus to fulfill customer requirements and improve the business profitability (Quelch and Kenny, 1994), manufacturers have traditionally attempted to introduce a constant stream of new ideas into their new product development (NPD) process, which in turn will lead to new products.

New product ideas originate both from internal (such as other divisions of the same company—research and development staff, etc.) and external (e.g., customers, suppliers, competitors, universities) parties (Salter and Gann, 2003; Tidd, Bessant, and Pavitt, 2005). Both external and internal sources of innovation have been found to be very important in the overall success of the product development process (Cooper, 2001; Cooper and Kleinschmidt, 1993). Consequently, various collaborative product development models have been developed in an attempt to encourage the effective generation and implementation of such ideas into the NPD process (Cooper, 2001; Cooper and Kleinschmidt, 1987; Crawford and Di Benedetto, 2005). The promised merits of these models (e.g., more successful products, reduced product development costs and time, and increased productivity [Sanchez and Mahoney, 1996]) have encouraged many firms to explore the implementation of such approaches to develop their products and to catalyze innovation.

The nature and extent of collaborators' input to the NPD process has been the subject of several studies as such input has been heralded as a critical strategy for the successful introduction of new products (Day, 1994). With a few notable exceptions (discussed below), these studies have generally found that increased collaboration is beneficial to the collaborating companies. The benefits that accrue from collaboration include financial, techno-

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logical, managerial, and strategic (Ellram, 1991; Ellram and Cooper, 1990). Financial benefits relate to the reduction of cost, due to factors such as the elimination of duplication in the manufacturing and development processes, and price reductions throughout the supply chain. Technological benefits relate to the sharing of technological advances and knowledge across the supply chain (McCarthy, Tsinopoulos, Allen, and Rose-Anderssen, 2006; McFarlan and Nolan, 1995; Tsinopoulos, 2007; von Hippel, 1988). Management benefits relate to the simplification and increased loyalty that may result from the reduction of the numbers of suppliers (Christopher and Towill, 2000; Rackham, Friedman, and Ruff, 1996). Finally, strategic benefits relate to the potential of improving the core competencies through an enhanced product development process (Lei, 1993). These benefits can be achieved through collaborations on both sides of an organization's supply network—users and suppliers.

However, some studies have argued that, in some situations, collaboration, particularly with suppliers, may be problematic, as weaknesses of product grade, technology, or availability can become a burden to the buyer company (Wasti and Liker, 1997). Furthermore, failure of the purchasing company to provide a finished product for decision and design processes can affect the collaboration (Wynstra, Van, and Weggemann, 2001). Veloso and Fixson (2001) warned that increased dependence on strategic suppliers might affect the performance of the buyer company and have a negative impact in the long term. In addition, they outlined the risks faced by a collaborating company in knowledge management, whereby internal implicit and explicit knowledge might become vulnerable for imitation by rivals. Furthermore, increased standardization of components through the specified interfaces, and the risk of reducing internal competencies are possible drawbacks (Mikkola, 2003). Despite these potential limitations, several models have been developed that aim to improve collaboration with external parties.

In tandem with the development and implementation of models that enhance collaboration, research studies have examined the motivations for collaboration and the nature of the influence of external parties on the product development process (Cooper, 1984; Rothwell, 1994). The literature surrounding this subject confirms that increased collaboration across the supply chain leads to increased performance of the NPD processes (Frohlich and Westbrook, 2001; Petersen, Handfield, and Ragatz, 2005). In this study, new product development is defined as the entire process of generating and bringing to the market both entirely new products and variations to existing ones. Previous studies have examined how collaboration with various parties at different stages of the NPD process can lead to increased market success (Petersen et al., 2005). Among the collaborating parties that have been examined are suppliers (Petersen et al., 2005; Song and Di Benedetto, 2008), competitors, and universities (Deeds, Decarolis, and Coombs, 2000). Customers have long been identified as valuable collaborative partners, with recent work extolling the value of the specialized group of lead users (von Hippel, 1988). These studies have largely focused on how varying degrees of collaboration impact NPD performance in terms of costs, time, and product quality, but not product variety.

Product variety relates to the mixture of products offered by an organization to the marketplace (Randall and Ulrich, 2001), and is manifested across several dimensions (Dowell, 2006; MacDuffie and Sethuraman, 1996). Kotler and Keller (2006) identified four product variety dimensions: width (number of product lines), length (items in the mix), depth (variants of each product), and consistency (closeness of relationship between products). MacDuffie and Sethuraman (1996), who studied the international automotive industry, identified two dimensions: fundamental and peripheral. Fundamental variety refers to inherently different models (e.g., a Honda Accord versus a Honda Civic). Peripheral variety refers to the options offered for the same core design (e.g., satellite navigation and electronic stability control on a Ford Focus).

These two popular classifications of product variety do, of course, overlap. For instance, fundamental variety

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would include different product lines (width) and items in the mix (length), whereas peripheral would include product variants (depth) and relationship of products (consistency). As MacDuffie and Sethuraman's classification is broader, in this paper, product variety is defined along these two dimensions. These two dimensions of product variety were, therefore, used to develop the measure of product variety, which will be explained and used later in the paper.

The aim of this paper is to examine how collaboration during NPD with two external parties, suppliers and lead users, can increase an organization's ability to develop a high variety of products. The focus is on suppliers and lead users for two reasons. First, both partners are being increasingly viewed both by practitioners and theoreticians as key stakeholders in the NPD process (Handfield, Ragatz, Petersen, and Monczka, 1999; Olson and Bakke, 2001; Petersen et al., 2005; von Hippel, 1986). Accordingly, this study will contribute to this line of research by explicitly exploring the relationship between the extent of involvement of these parties and a firm's ability to develop a wide variety of products. To the authors' knowledge, such links have not previously been explored. Second, a firm directly collaborates with both suppliers and customers, and an examination and comparison of their impacts on product variety will, therefore, provide useful guidance to practitioners looking to develop long-term strategic alliances in order to increase the variety of products offered to the market.

The paper is structured as follows. The following section reviews the literature concerned with collaboration with suppliers and lead users, and develops a conceptual framework and three hypothesized relationships with product variety. Then, the measures developed to assess product variety and the extent of collaboration with lead users and suppliers are explained, followed by a description of the process of data collection and analysis. The final section outlines the implications of this study for practice, and discusses the limitations and directions for future research.

Conceptual Framework

As argued in the introduction, the impact of collaborative product development on product variety is relatively unexamined. This section examines the theoretical reasons for expecting a link. It first explains how collaboration during the NPD process with suppliers and lead users can affect a company's product variety. Then, it discusses the relative contribution of the two collaborating parties to argue that lead users should have a greater impact. Finally, it discusses some additional factors examined in previous studies that may also impact product variety.

The Effect of Collaboration with Suppliers on Product Variety

The impact of suppliers' collaboration during the NPD process on a company's product variety stems from two key premises: that they can provide technical knowledge for improvement, and that they are more likely to commit to the success of the products they have helped develop.

On the technical side, closer collaboration with key suppliers can provide a forum for the evaluation and improvement of ideas and products during both the early and late stages of the NPD process. Key suppliers are those with similar or superior capability whose objectives do not conflict with those of the buyer company (Littler, Leverick, and Bruce, 1995; Sako and Helper, 1998). Key suppliers can, therefore, provide the technical expertise to evaluate the feasibility of new product ideas during the early stages of NPD before large financial investments have been made. This expertise can be valuable in avoiding costlier modification at later stages (Crawford and Di Benedetto, 2005; Song and Di Benedetto, 2008). During the middle and later stages of the development process, suppliers can be involved in designing and testing the manufacturing processes (Millson, Raj, and Wilemon, 1992), which in turn may provide the greater flexibility necessary to improve a company's ability to provide higher product variety.

Close collaboration gives suppliers the technical autonomy to invest in and develop subsystems that can then be used by a buyer during the final assembly (Kamath and Liker, 1994). Larger manufacturers are, in fact, increasingly depending on their suppliers to deliver large modules to simplify the assembly process (Alford, Sackett, and Nelder, 2000; Perez and Sanchez, 2001). Modularity enables standard and common parts to be combined in various ways that can then form the basis for a product family (Ramdas and Sawhney, 2001; Sawhney, 1998). Increased modularity should lead to a higher number of products in a product family (Alford et al., 2000; Halman, Hofer, and van Vuuren, 2003), and thus increased product variety.

With respect to a greater commitment to the development of new products, closer involvement with suppliers may imply mutual investment and sharing of risk. Joint development efforts for new products increase the market orientation of both the supplier and the buyer. When a supplier and a buyer work together more closely, they are more likely to develop close communication, joint problem-solving techniques, and to better coordinate their activities in response to changing market needs. Buyers can easily communicate the changing market needs, and consequently, in a market environment where customers have more fine-grained preferences (Dowell, 2006), both will respond to the market needs by increasing product variety. Finally, close collaboration with suppliers may lead to long-term commitment of a supplier to a buyer. This commitment may, in turn, lead to openness to adaptation as circumstances change (Heide and Miner, 1992), which should lead to higher product variety.

The investment of time, effort, and funding from both companies (suppliers and buyers) should reduce the risk of knowledge sharing with competitors (Petersen et al., 2005), although it may increase the overall product development time (Eisenhardt and Tabrizi, 1995). In addition, early supplier involvement can ensure that suppliers will be able to provide any specified components (Dowlatshahi, 1997), and consequently make any appropriate investments in equipment, tools, and training (Song and Di Benedetto, 2008). If suppliers invest resources in the development of new products with specific buyers, they are more likely to commit to these firms, and thus they will be less likely to share product knowledge with other competing parties (Dyer and Singh, 1998). Furthermore, suppliers who are more involved in the NPD process are more likely to be committed to the buyer company for future business (Gassenheimer, Calantone, and Scully, 1995).

Therefore, from the above arguments, the first hypothesis is:

H1: Higher collaboration with suppliers during the NPD process will lead to higher product variety.

The Effect of Collaboration with Lead Users on Product Variety

The value of collaboration with general users during NPD stems from the fact that they can provide ideas for new products or modifications to existing ones, and can test their functionality and durability.

The traditional view of users' involvement is that users have needs that can be satisfied by new products. Accordingly, identification of these needs can lead to new ideas that can feed into the NPD process. For this purpose, user input is often encouraged at the beginning and end of the process. In the early stages, users express their needs, while in the final stages, they test the end product to confirm that it meets their needs. Such an approach should, in theory, result in products that are more likely to succeed. This approach flourished in the 1980s and 1990s (Cooper and Kleinschmidt, 1987, 1993), and has persisted until the present (Callahan and Lasry, 2004; Enkel, Perez-Freije, and Gassmann, 2005; Salter and Gann, 2003). However, critics of this process argue that it may lead to decreased creativity and the introduction of products that only improve existing lines, to the exclusion of entirely novel products (e.g., Bonner, Ruekert, and Walker, 2002).

More recently, an alternative user collaboration approach has been developed involving the concept of lead users, that is, users of a product who experience needs unknown to the public, who also benefit greatly if they obtain a solution to these needs (von Hippel, 1988). Research on lead users has identified them as individuals who possess greater consumer knowledge and user experience in the underlying field, with the tendency to exhibit "innovative personalities" (Schreier and Prugl, 2008). They will, therefore, use their own innovative approach to provide new solutions, often unknown to the manufacturer (Luthje and Herstatt, 2004; Morrison, Roberts, and Von Hippel, 2000).

The lead user approach to NPD collects information about both the needs and solutions of users (Schreier and Prugl, 2008). Lead users demand unique solutions to their needs, and as a result, they devise attractive user innovations (von Hippel, 1986). They identify a new set of design possibilities and begin to explore them (Baldwin, Hienerth, and von Hippel, 2006). This is possible because lead users often have more knowledge about the product attributes and have experience of using the relevant products (Schreier and Prugl, 2008). The task of a firm's NPD team is to identify this group of users from their customer base, and work with them to develop their solutions to complete products.

Advocates of the formal integration of lead users into the NPD process argue for a four-stage process, which comprises goal generation and team formation, trend research, pyramid networking, and workshop and idea generation (Lilien, Morrison, Searls, Sonnack, and Von Hippel, 2002). Although the development and integration of such a formal process with current NPD processes is relatively rare (Olson and Bakke, 2001), informal processes for identifying and integrating ideas from this group of users are frequently employed, as evidenced by several studies that have explored these groups in various industrial contexts (Franke and von Hippel 2003; Franke, von Hippel, and Schreier, 2006; Herstatt and von Hippel 1992; Luthje, Herstatt, and von Hippel, 2002; Morrison, Roberts, and Midgley, 2004). Such studies have also

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examined the performance of product ideas that originate from lead users, and have consistently found that success rates are higher in terms of product attractiveness (Foxall and Johnston, 1987; Lilien et al., 2002) but not product variety.

Involvement of lead users during the NPD process assists in the identification of newer consumer needs while simultaneously increasing the chances of introducing a new product line (Lilien et al., 2002) that will become a commercial success (Hienerth, 2006). On a smaller scale, lead users provide ideas for modifications to existing products to meet their new needs (e.g., adding foot straps to standard windsurfing equipment to enable windsurfers to perform aerial tricks [Shah, 2000]), and thus they extend the current product family of a company. In both cases of novel products and improvements to existing products, it is reasonable to expect that lead user involvement in the NPD will increase the number of product variants offered by a company.

The above arguments lead to the second hypothesis:

H2: Higher collaboration with lead users during the NPD process will lead to higher product variety.

The Relative Effect of Collaboration with Suppliers and Lead Users on Product Variety

The final hypothesis relates to the comparison of the relative impacts of the two parties on product variety. The comparative effect of each party will, of course, vary across industrial sectors. The development of new products in the pharmaceutical sector is more likely to be influenced by suppliers (Tsinopoulos, 2007) than, for example, in the sports equipment sector, which is often dominated by lead users (Schreier and Prugl, 2008). As explained in this section, however, there are good theoretical and intuitive reasons to expect that, in general, the influence on product variety of the latter is higher than that of the former.

For most industrial sectors, the rapid changes in customer needs (Flynn, Huo, and Zhao, 2010) and the uncertainty of emerging technologies (Petersen et al., 2005) are given. To deal with the former, closer collaboration on the customer side has often been advocated. A close relationship between customers and manufacturers improves the accuracy of demand information, which in turn reduces the response time both in terms of production and NPD (Flynn, Sakakibara, Schroeder, Bates, and Flynn, 1990). Therefore, closer integration with customers makes manufacturers more responsive to their needs. To deal with the latter, many companies monitor or scan the market for the development of new technologies (Monczka, Petersen, Handfield, and Ragatz, 1998) that have promising applications. To benefit from these, buyer firms collaborate with the owners of these technologies. As the core competencies of the collaborating suppliers are often closely associated with these technologies, their knowledge and experience can also be used to evaluate what is feasible from a technology perspective (Petersen et al., 2005). As a result, collaboration with suppliers provides buyers with a selection of promising technologies and relevant expertise, which helps them deal with technology uncertainty and associated risks.

Lead users, by definition, are a special group of customers that experience needs unknown to the public, which they address by creatively using their technical expertise (Luthje et al., 2002; von Hippel, 1988). As they are the first to experience these new needs, they can provide more accurate knowledge of the changing customer trends than that provided by suppliers. As these trends are often associated with modifications to existing product lines (e.g., new applications for the iPhone), collaboration with lead users is likely to increase the peripheral dimension of product variety more than collaboration with suppliers.

As found by several empirical studies, lead users are, in general, "ahead of the field" in the use and adoption of new technology compared with nonlead users (Morrison et al., 2004; Urban and Von Hippel, 1988). This tendency for early adoption makes them aware of new and emerging technologies. Similar to the suppliers, this knowledge makes them able to assess the technical feasibility of new ideas. Therefore, collaboration with lead users provides companies with expertise that is often similar to that of the suppliers, and an in-depth knowledge of emerging customer trends. This combination may, therefore, lead to the introduction of entirely new products using these technologies, increasing the fundamental dimension of product variety.

From the above discourse, it can be deduced that both users and suppliers are likely to have a profound impact on the final outcome of the NPD process. Lead users, however, combine technical expertise (often associated with suppliers) with accurate and prompt knowledge of new customer trends, and consequently, it would be expected that collaboration with them will increase product variety to a greater extent than with suppliers.

Therefore the third and final hypothesis is:

H3: Collaboration with lead users during the NPD process will lead to greater product variety than with suppliers.

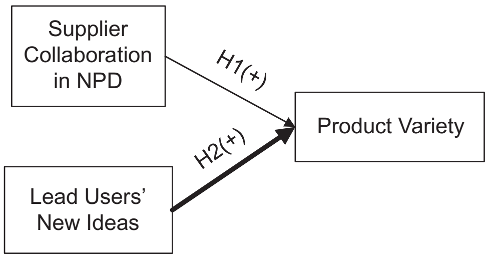

Figure 1. Suppliers and Lead Users' Impact on Product Variety (The Thicker Line Depicts the Higher Hypothesized Impact)

Other Factors That May Affect Product Variety

The extent of product variety is also affected by industry-related factors and customer expectations. First, the level of technological turbulence will affect the rate of new product introductions (Buganza, Dell'Era, and Verganti, 2009; Slater and Narver, 1994). As found by Pavitt (1984) and confirmed by several later studies (de Jong and Marsili, 2006; Klepper, 1996; Souitaris, 2002), companies that belong to different technological trajectories will have different rates of innovation. Companies in industries with higher technological turbulence may more frequently develop new products with more options, and therefore both dimensions of product variety may be higher. Similarly, the nature and extent of collaboration may vary across different industrial sectors and across different tiers of the supply chain. For instance, manufacturers in the automotive industry have been accustomed to significant input from their suppliers across the supply chain, whereas the input of lead users is a relatively common phenomenon in the software industry. The open software revolution, for example, has often been attributed to the enthusiasm of lead users.

The age and size of the organization may also affect the resulting product variety. Older and larger organizations may have the ability to develop more products for longer periods of time. The methodology section of this paper explains the actions taken to control the effect of these factors on the measurement of product variety.

A summary of the hypotheses developed in this section are shown in Figure 1.

Methodology

The aim of this paper is to examine the relative impacts of collaboration with suppliers and lead users during the NPD process on a company's product variety. To meet this aim and to ensure the generalizability of the findings, a questionnaire survey was conducted. Similar studies in the past have also employed questionnaire surveys, and are increasingly seen as an established research technique for operations and technology management studies (e.g., Da Silveira and Cagliano, 2006; Frohlich and Westbrook, 2001; Leenders, van Engelen, and Kratzer, 2007).

The conceptual framework developed and tested in this paper concerns the collaboration of lead users and suppliers with a company during the NPD process. Accordingly, the unit of analysis is the company, and data have been collected at the company level as explained below. To avoid any confusion and any problems of inference arising from collecting data at levels inappropriate to the theoretical propositions under study (Markus and Robey, 1988), the control (see below), dependent, and independent variables were all measured at the company level. Furthermore, to ensure that the responses received were all at the company level, in the introductory text sent with the questionnaire, it was explained that *"[the study focuses] on the collaboration between companies and their suppliers and/or lead users in the new product development process*."

The scales used in the survey were found in the literature (e.g., Mikkola, 2003; Welborn, 1988) but were later modified to measure the variables of the study. To ensure that the scale modifications did not affect the validity of the measures, they were subjected to a review by a panel of experts consisting of operations managers, NPD managers, and academics. This process resulted in some minor modifications and clarifications. Several statistical validity and reliability tests were also conducted, explained in the next section.

Collaboration Measures

A company's product development process typically consists of several activities that span the areas from product definition to launching the product to the

Table 1. Collaboration Measures for Suppliers and Lead Users

Please rate the extent to which your suppliers/lead users are involved in the following activities: (1 = Very Low, 2 = Low, 3 = Medium, 4 = High, 5 = Very High)

1. Setting general product definition
2. Setting lead time requirements
3. Setting product specifications
4. Generating products' blueprints/drawings
5. Designing product detailed component specifications
6. Product prototyping
7. Product testing
8. Overall new product development process

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market. The construct used to measure the extent of collaboration consists of eight items that assess the respondent's perception of the involvement of suppliers and lead users in the company's NPD process. This construct is shown in Table 1. The first three activities—setting a product's definition, specifications, and the general lead times of the development process—focus on the front end of the NPD process. The second group of activities (4 and 5) focuses on the detailed specification of the project and the development of any drawings or blueprints. The third group of activities focuses on the prototyping and testing of the product. These activities are usually found at the later stages of the NPD process. Finally, a question was included to capture the perception of the overall collaboration of suppliers and lead users during the company's NPD process.

The validity and reliability tests for this measure are shown later in the paper. In the instrument, the eight-item construct appeared twice. The first time, respondents were asked to rate their perceptions in relation to supplier collaboration, and in the second instance, they were asked about their perceptions in relation to the lead user collaboration. To ensure that the concept of lead users was understood, a short description was provided at the beginning of the questionnaire, which explained their key characteristics. In addition, the concept of lead users was verbally discussed with 65 respondents who were contacted for missing information, to ascertain their understanding of the concept. In each case, the respondent indicated that the questionnaire provided a very clear idea of the nature of lead users, and confirmed that it was in agreement with any existing understanding of the concept.

Product Variety Measure

As explained earlier, product variety relates to the mixture of products offered by an organization to the marketplace, and is manifested across several dimensions. The product variety measure used (also the dependent variable) focused on capturing the two dimensions of fundamental and peripheral variety explained earlier in the paper (MacDuffie and Sethuraman, 1996) at the company level. To do so, respondents were asked to compare their operations relative to competition in terms of the number of product lines (fundamental variety) and the scope of features offered (peripheral variety). Finally, they were asked to provide an overall comparison of the range of products offered. The product variety construct is shown in Table 2.

Table 2. Product Variety Measure

Please indicate your opinion of how your company compares to its competitors in your industry in terms of: (1 = Poor, 2 = below competition, 3 = equal to competition, 4 = better than competition, 5 = superior)
Range of products produced by existing facilities
Scope of features offered to final customers
Number of product lines

Several concerns have previously been expressed for the use of perceptual measures that require respondents to compare themselves against competition (e.g., Ketokivi and Schroeder, 2004). The key issues center on the use of a single informant, which is the case in this study. When relying on only one informant, there is a risk of underestimating the true parameters due to dishonesty and/or systematic bias (Ketokivi and Schroeder, 2004). Although it is acknowledged that there is such a risk in this study, and thus this is a potential limitation, any risk of bias has been minimized for the following two reasons. First, the questionnaire was answered by someone in charge of product development activities. As explained later in the paper, the questionnaire was sent to named individuals who had been identified prior to the distribution of the survey. A person in charge of product development should know how the product variety of their company compares with that of competition because the number of different products produced by an operation can be easily measured. Second, higher product variety is not an explicit indicator of good performance, and thus respondents are less likely to be dishonest when providing a comparison (see, for instance, Quelch and Kenny [1994] for arguments against focusing on product variety). The second argument is also supported by the descriptive statistics (Table 3), which show that the average score of the summated variable of product variety across the sample is 3.6, with a standard deviation of .9. That is, the mean product variety of the sample is close to equality with the competition. As with the items explained above, validity and reliability tests for this measure are discussed later.

Control Variables

As discussed earlier, there are several industry-related variables that could affect product variety. The first relates to the different technological trajectories and industrial sectors. To capture any effect this may have on product variety, respondents were classified using Pavitt's (1984) sectoral technological trajectories—supplier-dominated, production-intensive, and science-based. This classification was used because firms in different trajectories may experience different technological turbulence, and consequently respond with increased product variety; and second, each trajectory includes a comprehensive list of core sectors (e.g., the supplier-dominated trajectory includes agriculture, housing, and traditional manufacture), and thus would identify any variations attributed to different industrial sectors. The second relates to the age and size of the organization, which were measured in terms of years and number of employees, respectively.

Data and Results

A random sample of 1000 U.K. manufacturing companies was selected based on the European 1992 Standard Industrial Classification codes. Classification codes for manufacturing companies (code D) were included in the sample selection. Names and addresses of NPD managers and (in their stead) production/operations managers of the companies in this random sample were provided from a U.K.-based marketing company.

The 1000 companies were first contacted by phone or e-mail to ascertain their interest. As a result, 603 questionnaires were sent out to production/operations or product development managers. Of this group, 328 completed questionnaires were returned (125 during the first month and the remaining during the second month following a reminder e-mail). After contacting 65 companies in person to complete missing data, 313 questionnaires were accepted. This represents a response rate of 51.9%, which is above the average in this field of research (32%) and is generally considered an acceptable rate for such studies (Frohlich, 2002).

Descriptive statistics and correlations between the variables are shown in Table 3.

To evaluate possible nonresponse bias, the valid questionnaires were categorized into early and late responses (Armstrong and Overton, 1977). As explained by Armstrong and Overton (1977), those who respond later in a survey do so because of the increased stimulus, and are thus expected to be similar to nonrespondents. Therefore, the last 40 responses were considered (all received after the reminder e-mail was sent out) similar to nonrespondents and the first 40 similar to respondents, and conducted a Kolmogorov–Smirnov test (Hair, Black, Babi, Anderson, and Tatham, 2006; Molina, Lloréns-Montes, and Ruiz-Moreno, 2007). The results indicated no significant difference between the two groups in terms of company size, company age, and industrial sector. There is, therefore, sufficient confidence that the data are free from nonresponse bias. Finally, the data were examined for outliers by visually inspecting the histograms and scatter plots for each of the dependent and independent variables for normality, linearity, and homoscedasticity (Hair et al., 2006). No violations of the key assumptions were detected.

Reliability and Validity Tests for the Measurement Model

The reliability and validity of the measurement model were examined by calculating the Cronbach's alpha coefficients, and subjecting the constructs to confirmatory

Table 3. Descriptive Statistics and Correlations, Alpha Coefficients

	α	Mean	*SD*	CS	CA	I1	I2	I3	SCNPD	LUCNMP	PV
Company size (CS)		922	533.6	1							
Company age (CA)		32.6	17	.003	1						
Industry dummy 1 (I1) Production-intensive		.17	.38	.048	.052	1					
Industry dummy 2 (I2) Science-based		.60	.49	.096	−.122*	−.560**	1				
Industry dummy 3 (I3) Supplier-dominated		.23	.42	−.156*	.096	−.247**	−.664**	1			
Supplier collaboration in new product development	.94	3.09	.895	.245**	−.086	.004	.022	−.029	1		
Lead user collaboration in new product development	.93	2.98	.999	.149**	−.234**	−.063	.102	−.063	.453**	1	
Product variety	.93	3.60	.936	.128*	−.002	−.053	.013	.033	.283**	.350**	1

n = 313.
*Correlation is significant at the .005 level (two-tailed).
**Correlation is significant at the .01 level (two-tailed).

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Table 4. Confirmatory Factor Analysis

Variable		Standardized Loadings	Unstandardized Loadings	Critical Ratio
Supplier collaboration	Setting general product definition (SC1)	.812	1.000	
AVE = .66 CR = .94	Setting lead time requirements (SC2)	.763	.987	14.080
	Setting product specifications (SC3)	.852	1.081	15.958
	Generating product's blueprint/drawings (SC4)	.797	1.049	12.960
	Designing product detailed component specification (SC5)	.864	1.120	12.207
	Product prototyping (SC6)	.819	1.096	11.894
	Product testing (SC7)	.769	1.104	12.646
	Overall NPD process (suppliers) (SOVERALL)	.839	1.097	14.266
Lead user collaboration	Overall NPD process (lead users) (LUOVERALL)	.850	1.000	
AVE = .74 CR = .96	Setting lead time requirements (LUC7)	.776	.940	14.929
	Setting product specifications (LUC6)	.877	1.062	17.702
	Generating product's blueprint/drawings (LUC5)	.926	1.091	18.579
	Designing product detailed component specification (LUC4)	.873	1.004	16.630
	Product prototyping (LUC3)	.878	.933	15.004
	Product testing (LUC2)	.798	.884	13.459
	Setting general product definition (LUC1)	.888	.988	15.105
Product variety	Range of items produced by existing facilities (PV2)	.891	1.000	
AVE = .73 CR = .89	Scope of features offered to final customers (PV3)	.800	1.006	15.930
	Number of products lines compared with competitors (PV1)	.874	.654	17.651
Model statistics	Chi-square/d.f.	1.921		
	GFI	.912		
	CFI	.956		
	RMSEA	.057		
	N	313		

All loadings are significant at $p < .001$.
CR = composite reliability; AVE = average variance extracted; NPD = new product development; GFI = goodness of fit index; CFI = comparative fit index; RMSEA = root mean square error of approximation.

factor analysis, which is reported in Table 4.[1] As shown in Table 3, Cronbach's alpha coefficients range from .8 to .9, which are above the acceptable level of .7 (Hair et al., 2006). The confirmatory factor analysis results were consistent with the relationships expected between individual items and their respective constructs (Gerbing and Anderson, 1988).

The overall fit of the model was satisfactory (comparative fit index = .956 and root mean square error of approximation = .057) (Hair et al., 2006). For each construct, the composite reliability was calculated and the average variance extracted, and in all cases were higher than the thresholds .7 and .5, respectively (Janssens, Wijnen, De Pelsmacker, and Van Kenhove, 2008), indicating convergent validity and reliability of the measurement model. Finally, the square of the correlations between each construct was computed. In all cases, the squared correlation was lower than the variance extracted, indicating convergent validity for the constructs (Janssens et al., 2008). The measurement model, therefore, indicates acceptable convergent and discriminate validity, in addition to reliability, thus allowing us to proceed further with the analysis.

[1] The data set was divided also randomly into two halves, and subjected the first half to exploratory factor analysis and the second to confirmatory factor analysis (Gerbing and Anderson, 1988). Exploratory factor analysis indicated that the items' loadings on the corresponding constructs are satisfactory (>.7 [Hair et al., 2006]). Similar to the results for the whole data set, the confirmatory factor analysis results were consistent with the relationships expected between individual items and their respective constructs.

Analysis

Due to the relative simplicity of the relationships under study and the need to include nonlatent control variables (age and size of companies, and industry type), hierarchical regression analysis was used to eliminate any alternative explanations of the model. The results of this analysis are presented in Table 5. Table 5 also reports collinearity statistics. As shown in the table, tolerance is higher than .1, and the variance inflation factor is less than 10, which are the commonly accepted cutoff points for accepting that collinearity does not impact the results (Hair et al., 2006).

Model 1 is the baseline model with only the constant and the control variables *industry dummies*, *company size, company age*. According to this model, company

Table 5. Hierarchical Regression. Dependent Variable: Product Variety

	Unstandardized Coefficients		Standardized Coefficients		Collinearity Statistics	
	B	Standard Error	Beta	t	Tolerance	VIF
Model 1						
(Constant)	3.490**	.175		19.953		
Company size (number of employees)	.000*	.000	.137	2.399	.975	1.025
Company age	−.001	.003	−.004	−.070	.984	1.016
Industry dummy 1 (I1)[a] Production-intensive	−.217	.170	−.088	−1.281	.676	1.480
Industry dummy 2 (I2)[a] Science-based	−.096	.132	−.050	−.724	.663	1.509
R	.147					
R^2	.022					
Adjusted R^2	.003					
Regression F-value	1.697					
Model 2						
	2.188**	.253		8.659		
Company size (number of employees)	.000	.000	.058	1.052	.914	1.094
Company age	.004	.003	.076	1.395	.932	1.072
Industry dummy 1 (I1)[a] Production-intensive	−.186	.158	−.075	−1.176	.675	1.482
Industry dummy 2 (I2)[a] Science-based	.113	.123	−.059	−.913	.661	1.513
Supplier collaboration	.150*	.063	.143	2.372	.761	1.314
Lead users collaboration	.277**	.057	.296	4.870	.750	1.334
R	.393					
R^2	.154					
Adjusted R^2	.138					
R^2 change	.111					
Regression F-value	9.316					

[a]With science-based as a reference category.
$*p < .05$, $**p < .01$.
VIF = variance inflation factor.

size has a statistically significant impact on product variety. Model 2 includes the two independent variables *supplier collaboration* and *lead user collaboration*. Compared with the baseline model, supplier and lead user collaboration increases the adjusted R^2 from .022 to .154, while the impact of level of sales between a company and the suppliers involved in the NPD process on product variety is no longer significant. These results indicate that collaboration with external parties improves product variety.

In terms of the impact of the collaboration with each of the two parties, collaboration with the supplier has a positive statistically significant regression coefficient as hypothesized in the first hypothesis. This provides support for H1, which predicts that increasing the collaboration with suppliers can lead to increased product variety. Lead user collaboration (H2) also has a positive and statistically significant regression coefficient. Thus, H2, which predicts that collaboration with lead users also increases product variety, is also supported.

The third hypothesized relationship predicted that lead users' collaboration will lead to greater product variety than suppliers. As shown in Table 5, the coefficient of lead user collaboration is almost double that of supplier collaboration, with both exhibiting statistical significance. To confirm that the difference between the two coefficients is statistically significant, the Wald test using STATA's *test* command was performed. The results show that the null hypotheses can be rejected, that is, that $B_1 - B_2 \leq 0$ at $p < .05$ level, where B_1 and B_2 are the coefficients for lead user and supplier collaboration, respectively. Therefore, collaboration with lead users has a higher impact on product variety than collaboration with suppliers, providing support for H3.

Discussion and Conclusions

Organizations often attempt to increase the variety of the products they offer in order to fulfill increasing customer requirements. This study has examined the effect of collaboration during the NPD process with two key external parties (lead users and suppliers) on the resulting variety of products. Its key finding is that increasing the extent of collaboration with both lead users and with suppliers during the NPD process will increase both dimensions of product variety (fundamental and peripheral) offered to customers. Previous studies have found that collaboration increases NPD performance, but this is the first study to explicitly explore the link with product variety. Furthermore, lead users were found to have a greater impact on product variety than suppliers.

The above findings generate some important theoretical and practical implications. The first relates to collaboration on the suppliers' side. This study has added to the growing literature that advocates early collaboration of suppliers during the NPD process by confirming that it leads to higher product variety. Product variety is increasingly becoming an important strategic tool, as end users search for highly specialized products that address their unique needs. Suppliers can provide technical knowledge for improvement of existing products and processes, and are more likely to commit to the success of the products they have helped develop. Furthermore, adopting modern supply chain practices would imply that increasing collaboration would increase modularity, further increasing the variety of new products.

The second implication for product development practice relates to collaboration with users. Lead users can provide ideas for new products and/or modifications to existing products to satisfy new needs. As a result, when involved in the NPD process, lead users can support the development of new ideas, which in turn will lead to higher product variety, particularly in terms of higher product range.

The final implication relates to the comparison of the effects of the two parties. It was found that the coefficient of the collaboration with lead users on product variety is higher than that of suppliers. Lead users combine the technical expertise (often associated with suppliers) with accurate and prompt knowledge of new customer trends, and consequently, collaboration with them increases product variety more than with suppliers.

Previous studies have shown that increased collaboration with suppliers leads to increased flexibility (Day, 1994; Gassenheimer et al., 1995; Heide and Miner, 1992; Krause, Scannell, and Calantone, 2000), which, when combined with the new product and new market ideas brought in by the lead users, leads to increased product variety. It is, therefore, important to employ a combination of suppliers and lead users to achieve increased product variety, rather than focus on just one partner. Similar to the findings of Frohlich and Westbrook (2001), this study helps validate the metaphor of a supply "chain" as integration of both parties in the NPD process will lead to increased performance in terms of number of products.

As a result of these findings, a key recommendation to the NPD practitioner who desires to increase the variety of his/her products is to implement a strategy that encourages the integration first of lead users and then of suppliers in the NPD process. Integration with suppliers will provide the technical expertise and commitment, while integration with lead users will provide information about the new needs and ideas about the solutions to those needs.

Limitations and Future Work

There are a few limitations that need to be considered in applying the findings of this study. The sample was collected from companies based in the United Kingdom. Companies in the United Kingdom are largely owned by larger companies that are not necessarily based in the United Kingdom, nor are their suppliers or their customers. Therefore, the results should be generalizable across geographical boundaries. Nevertheless, it is acknowledged that a sample taken from manufacturing plants beyond the borders of the United Kingdom would provide further support to the findings.

The second limitation relates to the single response bias. As explained earlier, several steps were taken to minimize any bias arising from using only one informant from each company. However, the risk of underestimating the true parameters due to dishonesty and/or systematic bias has not been entirely eliminated (Ketokivi and Schroeder, 2004).

Future Work

Future studies can first be driven by the limitations of this study. First, the study can be repeated with companies from countries outside the United Kingdom. A confirmation of the findings would further support the importance of collaboration with suppliers and lead users on product variety. Second, the study could be repeated by collecting data from at least two informants from each responding company as recommended by Ketokivi and Schroeder (2004).

Future studies could also focus on some of the implications of the findings. First, collaboration with suppliers could increase the ability of a company to change the configuration of its products, as argued earlier. Therefore, future studies could explore more explicitly this link, that is, the impact of collaboration on flexibility. Future studies could explore the details of how this flexibility is generated and how lead users' new ideas can be facilitated through this flexibility.

An additional avenue of future research relates to the ability of manufacturers to implement the changes requested or suggested by lead users. The findings of this study indicate that when lead users collaborate closely with a manufacturer, product variety increases. There must, however, be a limit to this increase. In fact, previous studies have confirmed that increasing product variety may also lead to greater costs due to higher inventory needs (Kekre and Srinivasan, 1990), increased process complexity (MacDuffie and Sethuraman, 1996), higher design costs (Bayus and Putsis, 1999), and increased order processing time (Zhang, Chen, and Ma, 2007). A future study might, therefore, examine if and how such a limit is ever reached, and whether it is affected by the extent of collaboration.

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