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How Customer Portfolio Affects New Product Development in Technology-Based Entrepreneurial Firms

This article focuses on how the customer portfolios of technology-based entrepreneurial firms affect new product development. Drawing on knowledge-based, resource dependence, and relational theories, the authors argue that the impact of a firm's customers on new product development depends on the size and relational embeddedness of the customer portfolio and the extent to which the firm is dependent on one or a few dominant customers for a majority of its revenues. The authors test the research model using longitudinal data on young firms operating in business-to-business markets in six technology-based industries. The results indicate that customer portfolio size has an inverse U-shaped relationship to the number of new products developed and that the more relationally embedded the customer set, the more new products the firm develops. Dependence stemming from revenue concentration has a negative impact on new product output. Furthermore, the authors find that relational embeddedness can compensate for too small of a customer portfolio and can help offset the negative effects of a highly concentrated portfolio. These results make important theoretical and empirical contributions to the new product development literature, helping uncover some of the antecedents of innovative productivity particularly relevant for young, technology-based firms. The results also contribute to the broader discourse on how customers affect new product development.

Keywords: new product development, customer portfolio, entrepreneurial firms, relational embeddedness, resource dependence

Firms introduce new products to stay competitive and to meet the constantly changing market needs. The ability to develop new products is particularly vital for survival and growth in technology-based industries, in which competitive technologies abound and customer needs can develop and change rapidly (Shan, Walker, and Kogut 1994; Sivadas and Dwyer 2000). Since the pioneering work of Schumpeter (1942), the sources of innovation have been extensively studied in the fields of marketing and management. Studies have established that factors such as firm size (e.g., Scherer 1980), a firm's willingness to cannibalize its own investments (Chandy and Tellis 1998), acquisitions (Prabhu, Chandy, and Ellis 2005), organizational capabilities and structures (e.g., Moorman and Slotegraaf 1999; Olson, Walker, and Ruekert 1995), and market dominance (Sorescu, Chandy, and Prabhu 2003) all affect a firm's capability to innovate.

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However, these factors are of limited relevance for young firms. Such firms are typically small, do not have existing investments to cannibalize or resources for conducting acquisitions, have organizational capabilities and structures that are still emerging, and do not have enough market share to exert market power. Yet young firms can successfully develop and introduce new products (Katila and Shane 2005), thus raising the question, What explains a young firm's capability to innovate?

Recent research has suggested that the answer could lie in external relationships. Scholars have examined how various kinds of interorganizational relationships enable firms to gain access to other organizations' knowledge bases and resources (Jarillo 1987; Varadarajan and Cunningham 1995) and have argued that such access can enable novel connections (Kogut and Zander 1992), stimulate broader perspectives and synthesis (Dewar and Dutton 1986), and spread out the risks and costs associated with innovation (Sivadas and Dwyer 2000). This translates into benefits for a firm's innovative capability, which is observable as outcomes such as a higher number of patents or new products (Ahuja 2000; Wuyts, Dutta, and Stremersch 2004), the perceived success of new product development (Sivadas and Dwyer 2000), creativity (Im and Workman 2004), new product development speed (Rindfleisch and Moorman 2001), and profitability (Wuyts, Dutta, and Stremersch 2004). External relationships have been thought to be of particular relevance for young firms with limited internal resources and experi-

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ence (Jarillo 1989) and for those in technology-based industries, in which knowledge creation and application are key to achieving competitive advantage (Eisenhardt and Schoonhoven 1990; Sorensen and Stuart 2000).

Of all the relationships a firm has with other organizations, whether formal alliances or channel exchanges, its customer relationships are the most central to its profit-generating purpose and market value (Gupta, Lehmann, and Stuart 2004; Srivastava, Shervani, and Fahey 1998). However, although alliances have received significant attention in the literature, the role of customers on a firm's new product development is still surprisingly ambiguous. Whereas the market orientation literature supports the notion that customer-oriented behavior yields greater success with new product development (e.g., Griffin and Hauser 1993; Im and Workman 2004; Joshi and Sharma 2004), others have cautioned that firms that listen too carefully to their existing customers fail to be innovative (Christensen and Bower 1996; Leonard-Barton and Doyle 1996; MacDonald 1995). A well-known stream of research by Von Hippel and colleagues (Franke, Von Hippel, and Schreier 2006; Von Hippel 1986, 1988) has emphasized the importance of involving particular "lead-user" customers in the innovation process.

In this article, we uncover how the customer portfolios of young, technology-based firms influence the firms' new product development output. Our research model integrates insights from knowledge-based, resource dependence, and relational perspectives and argues that the impact of a young, technology-based firm's customers on new product development depends on the size, revenue concentration, and relational embeddedness of the customer portfolio. We first discuss the effects of portfolio size, addressing the question whether it is always better to have more customers. We then argue that new product development is also affected by how evenly a firm's revenues are spread across the customer portfolio and the relational embeddedness of customer relationships. Finally, we examine interaction effects among the portfolio characteristics to explain how relational embeddedness may compensate for an otherwise suboptimal customer portfolio. We test our hypotheses with longitudinal data on young, technology-based firms operating in business-to-business markets in six industries in the United Kingdom.

Our level of analysis is the firm and its customer set.[1] By taking a portfolio approach, we expand on previous research that has focused on the effects of select influential customers or partners on specific new product development projects (Bonner and Walker 2004; Ganesan, Malter, and Rindfleisch 2005; Rindfleisch and Moorman 2001; Sivadas and Dwyer 2000). Our approach enables us to examine the broader, collective effects of a firm's customer set on its new product development as a whole, and we answer recent calls by marketing scholars for studying exchange relationships at the portfolio level (Johnson and Selnes 2004; Wuyts, Dutta, and Stremersch 2004).

Our focus is on the new product development portion of the innovation process. That is, if innovation is conceptualized as encompassing all the stages from idea generation and concept design; to prototype development and testing; to market launch, sales, and marketing; and finally to adoption by customers (Katila and Shane 2005; Schon 1967), we constrain our scope to examining the prelaunch part of this process and accordingly use the term "new product development" to refer to it. Doing so enables us to focus on the key phenomenon of interest—how customers affect new product development—without the potentially confounding effects of the commercialization and adoption process. For young, technology-based firms, commercialization typically involves long sales and implementation cycles, heavy reliance on commercial partners, and high levels of uncertainty due to rapidly changing competitive technologies and industry standards (Oakey 1995; Teece 1986); these factors could obscure the effects of customers on new product development.

Prior research has used several proxies to measure a firm's research-and-development (R&D) output, such as the number of scientific publications, patents, or new products (e.g., Katila and Ahuja 2002; Shan, Walker, and Kogut 1994; Sorescu, Chandy, and Prabhu 2003). Following precedent, we focus on the number of new products developed by the young, technology-based firms.[2] This measure represents the potential commercial value of a firm's R&D activities (Katila and Ahuja 2002) and is a highly relevant metric for young, technology-based firms; it has been associated with sustained growth, profitability, and survival of such firms (Schoonhoven, Eisenhardt, and Lymman 1990; Stalk and Hout 1990; Zahra and Bogner 2000).

This article makes three unique contributions to the new product development literature. First, we attempt to uncover antecedents of new product development in a context (young, technology-based firms) in which many of the extant perspectives on sources of innovation are not applicable. Young, technology-based firms have been shown to be an important driver of technological renewal in an economy; they complement large firms in innovation networks (Rothwell 1983), give birth to new industries (Rothwell 1991), create new employment (Kirchhoff 1994), and offer opportunities for wealth creation for entrepreneurs and investors (Cooper 1986). New product development is both critical and particularly challenging for these types of firms because they operate with limited resources and organizational capabilities in dynamic, knowledge-intensive environments. Thus, understanding the antecedents of innova-

[1]The term "customers" refers to the next channel members in the value chain—that is, the parties to which the firm sells to generate revenues. Customers may or may not be the end users of the product.

[2]Our use of the term "new product" encompasses all new offerings that a firm develops whether they are new products, new technologies the firm can license out, or new services.

tion for young, technology-based firms is highly valuable, not only from the entrepreneurs' perspective but also from the perspective of incumbent firms, policy makers, and investors.

Second, we extend the research on interorganizational relationships and new product development beyond the context of formal alliances. In formal alliances, the participating organizations have the common goal of acquiring and using information and know-how for new product development (Rindfleisch and Moorman 2001); such alliances have received the bulk of attention in the literature (e.g., Hagedoorn and Schakenraad 1990; Wuyts, Dutta, and Stremersch 2004). However, there is a paucity of research on firms' interorganizational knowledge acquisition beyond formal alliances and the effects of such informal information sharing on new product development (Ganesan, Malter, and Rindfleisch 2005). Prior research has indicated that during the course of conducting business, a firm is likely to acquire significant amounts of external knowledge from its exchange partners (Allen 1979; Von Hippel 1987) and that such knowledge acquisition may be more prevalent than the learning that takes place through formal alliances (Ganesan, Malter, and Rindfleisch 2005). We contribute to this literature by investigating how a firm's portfolio of customer exchange relationships influences new product output.

Third, our research contributes to the broader discourse on the role of customers in innovation by developing a theoretically grounded research model and providing empirical evidence to elucidate some of the ways a firm's customer portfolio affects its new product development. Our focus on the firm's aggregate new product development output and its entire customer portfolio complements the prior literature on the impact of lead users (Franke, Von Hippel, and Schreier 2006; Von Hippel 1986) or influential customers (Bonner and Walker 2004; Yli-Renko, Sapienza, and Hay 2001) in new product development.

Theory and Hypotheses

The Role of Customers in New Product Development

Customer involvement has been shown to improve the effectiveness of new product development (Cooper and Kleinschmidt 1987; Griffin and Hauser 1996). As buyers of current and future products, customers contribute to all three phases of the new product development process: idea generation, development, and testing (Lettl, Herstatt, and Gemuenden 2006). First, in the idea generation phase, customers are often the source of new product ideas, particularly in business-to-business settings (Von Hippel 1978). Customers face problems with the existing solutions in the marketplace, which leads them to search for new technologies and products through discussions with suppliers. For ideas originating with suppliers, customers provide important input into the market research process used to evaluate and refine new product ideas (Griffin and Hauser 1993). Second, in the development stage, customers often play an important part in building and organizing the network of organizations participating in the innovation. Rarely is new product development confined to one firm; rather, it is typically conducted as a collaboration among technology experts, customers, and suppliers (Chesbrough 2003; Von Hippel 1988). Customers often play a central role in the establishment of these innovation networks. Because they stand to benefit from the new product by obtaining a solution to their needs, customers are willing to participate actively in the development process, bringing in required resources, industry contacts, or complementary technologies. Customer involvement may improve the efficiency of the process by decreasing the development time and costs (Lettl, Herstatt, and Gemuenden 2006) and improving the decision quality in the process (Griffin and Hauser 1993). For example, early negative feedback can be used to redirect a project. Third, in the testing phase of new product development, customers can serve as the testing ground for the new product's relevance and acceptance in a variety of user contexts.

Given the important contributions customers can make to new product development, how should a firm manage its customer portfolio? In the next section, we address this question by developing hypotheses pertaining to (1) the size of the customer portfolio, (2) revenue concentration within the portfolio (i.e., the extent to which a firm is dependent on one or a few key customers for the majority of its revenues), and (3) the relational embeddedness of customer relationships.

Size of the Customer Portfolio

In the alliance literature, the size of a firm's R&D alliance portfolio has been found to have a positive effect on innovation (Pennings and Harianto 1992; Powell, Koput, and Smith-Doerr 1996; Shan, Walker, and Kogut 1994). The underlying rationale is that a larger portfolio provides more exposure to external knowledge bases (Dewar and Dutton 1986), leads to scale effects in development (Ahuja 2000), and enables the firm to learn to better extract value from its interfirm agreements (Gulati, Nohria, and Zaheer 2000). Applying this logic to customer relationships would suggest that the more customers a firm has, the broader is the external information base available to the firm, the more new ideas for products it is likely to get, the larger is the number of customers involved in development projects, and the more customer settings are available for testing the applicability and functionality of the new product. These benefits should enable a firm to develop new products more quickly and cost effectively, resulting in an increased number of new products.

However, as the number of customer relationships increases, firms are likely to face difficulties in effectively using those relationships for new product development. Two mechanisms underlying these difficulties are transaction costs and limited available managerial attention. First, significant costs are involved with building and managing a large customer portfolio. An understanding of these costs has led marketing scholars to move away from focusing on customer portfolio growth to emphasizing the importance of retaining and deepening a firm's existing customer relationships (e.g., Morgan and Hunt 1994; Palmatier et al.

2006; Storbacka, Strandvik, and Grönroos 1994). By focusing its efforts on the limited number of existing customers, a firm can decrease the search and acquisition costs for new customers and reduce administrative transaction costs by achieving economies of scale within exchange relationships (Barringer 1997). If a firm can sell as much to one customer as to ten others, the firm will spend fewer resources on customizing design, delivery, and service or on negotiating, implementing, and managing exchange relationships (Kalwani and Narayandas 1995). We also expect these transaction costs to come into play when a firm uses customer relationships for new product development. As a firm's customer base grows beyond a certain point, the marginal benefit the firm can achieve for new product development from each additional customer is likely to be negated by the costs involved with managing the increasing number of relationships.

Second, firms are limited in the amount of managerial attention devoted to using external sources of knowledge for new product development (Koput 1997). This is a particularly relevant issue in young, technology-based firms with small, often-inexperienced management teams. Having too many customers can result in information overload and confusion (Ahuja and Lampert 2001) because management spreads its attention and efforts across a broad set of customer information sources. In other words, the firm has limited "absorptive capacity" (Cohen and Levinthal 1990) to take in new ideas, to choose between those ideas, and to devote the required attention and effort to bring the ideas into implementation (Koput 1997).

Thus, we propose that there is an inverted U-shaped relationship between the size of a firm's customer portfolio and its new product output. Customer relationships serve as an important source of knowledge and resources, and the larger the customer set, the more benefits are potentially available. However, we expect this relationship to exhibit diminishing and eventually decreasing returns; that is, if the number of customer relationships grows beyond a certain point, transaction costs and limited managerial capacity will begin to hinder the firm's ability to extract value from customer relationships for new product development. Thus:

H_1: The relationship between the size of a firm's customer portfolio and the number of new products developed by the firm has an inverted U shape.

Revenue Concentration Within the Customer Portfolio

Beyond size, an important characteristic of a firm's customer portfolio is the extent to which the firm is dependent on one or a few key customers for the majority of its revenues. Although the marketing literature has extensively studied dependence and its antecedents and consequences in channel relationships (e.g., Anderson and Narus 1990; Ganesan 1994; Heide and John 1988), little work has been conducted to examine how dependence on exchange partners affects innovation. In the following discussion, we draw on resource dependence theory to discuss the effect of dependence stemming from highly concentrated revenues in a firm's customer set on new product development.

Resource dependence theory posits that organizations are dependent on other players in their task environment for essential inputs, such as capital, materials, know-how, and reputation. These resource interdependencies with other organizations are viewed as constraints and restrictions (Jacobs 1974); that is, being dependent on an exchange partner means that the partner has increased bargaining power (Emerson 1962). Therefore, to survive and succeed, firms should take action to minimize threats to organizational autonomy and attempt to control the resources needed by other organizations to make others more dependent on themselves (Aldrich 1979; Pfeffer and Salancik 1978).

Prior research has shown that firms—in particular, young, technology-based firms—often become dependent on dominant customers who account for a disproportionately large share of a firm's revenues (Venkataraman et al. 1990; Yli-Renko, Autio, and Sapienza 2001; Yli-Renko, Sapienza, and Hay 2001). Studies have indicated that this dependence may have significant outcomes for a firm. For example, dependence may isolate a firm and prevent its reputation from spreading in the industry (Uzzi 1997) and decrease the firm's chances of survival (Venkataraman et al. 1990). Dependence implies that a key customer can exert its power over the firm, resulting in a loss of organizational autonomy because the firm must consider the key customer in all its major decisions. Firms allocate resources to new product development projects on the basis of their customers' needs (Christensen and Bower 1996). Thus, if a firm is highly dependent on one or a few customers for its revenues, these customers are likely to drive its new product development efforts. Indeed, in a qualitative study of entrepreneurial firms, Fischer and Reuber (2004, p. 691) find that chief executive officers (CEOs) were cognizant of the dangers of dependence in terms of innovation, viewing themselves as being "in a constant struggle with dominant customers to maintain control over the direction of innovation." Focusing on one or a few customers' needs is likely to constrain and hinder the firm's development efforts because the time and resources required to meet key customers' demands may curtail opportunities to develop new and diverse products for other customers or new markets. Development activities are more likely to be focused on customization of existing products and tailored to the unique needs of the specific customers (Fischer and Reuber 2004). Dominant customers tie up managerial and technical attention, which limits the resources available for new product development projects, thus decreasing the productivity of the firm's R&D and resulting in fewer new products. Thus:

H_2: The more concentrated a firm's revenues in its customer portfolio, the smaller is the number of new products developed by the firm.

Relational Embeddedness of the Customer Portfolio

Customer relationships can be characterized on a continuum ranging from impersonal, constantly shifting, arm's-length ties to close, cooperative, relationally embedded

relationships (Dwyer, Schurr, and Oh 1987; Larson 1992; Uzzi 1997). Arm's-length ties are characterized by discrete transactions, opportunistic profit-seeking behavior, and explicit contractual governance, whereas embedded ties typically involve a longer-term perspective, joint problem solving, trust, and reciprocity (Macneil 1980; Uzzi 1997). Research has shown that the nature of a firm's exchange relationships can have a significant impact on economic action and outcomes (Granovetter 1985). In particular, relational embeddedness has been shown to facilitate information sharing among social actors (Granovetter 1973). For example, Rindfleisch and Moorman (2001) find that relational embeddedness has a positive impact on information acquisition in new product development alliances. In a similar vein, we argue that the quality of a firm's customer relationships has a positive effect on new product development; the more cooperative and close the customer relationships are, the higher are (1) the incentives for, (2) the opportunities for, and (3) the efficiency of knowledge exchange, resulting in an increased level of new product output.

First, relational embeddedness increases the willingness of the exchange parties to share information (Larson 1992; Nahapiet and Ghoshal 1998). With a long-term perspective on the relationship, expectations of reciprocal benefits, and a low likelihood of opportunistic actions by the exchange partner, both the customer and the focal firm will be motivated to share information and engage in joint problem solving (Dyer and Singh 1998). The firms can try new things, experiment, and take risks in information sharing, leading to broader and more in-depth relational learning. The focal firm will be more willing to pursue new product ideas stemming from customer needs, and the customer will be more willing to assist the firm by providing knowledge and resources for the development process or by helping solve problems that arise.

Second, the closer the firm and its customers are, the greater are the frequency and intensity of information exchange. Larson (1992) observes that the greater the social interaction of an entrepreneurial firm with an exchange partner, the more intense is the business-related exchange of information. Lane and Lubatkin (1998) argue that interactive learning enables a firm to get close enough to acquire not just the observable but also the deeper, tacit components of knowledge. In a study of product development teams, Hansen (1999) finds that emotional closeness and frequent contact enhance the amount of complex knowledge transferred.

Third, relational embeddedness increases the efficiency of information exchange. The closer the firm and its customers are, the less time is spent on monitoring and bargaining activities (Dyer and Singh 1998), and the more the parties can focus on information exchange and processing. Furthermore, the closer the firm and its customers are, the better they will understand each other's specialized systems, requirements, and capabilities and will be able to tap into the external knowledge more quickly (Dyer and Singh 1998).

In summary, relational embeddedness facilitates frequent and efficient knowledge acquisition from customers, resulting in benefits such as faster product development cycles, more informed decision making, and lower costs—all of which enable the firm to be more productive in its R&D activities, resulting in more new products. Thus:

H_3: The more relationally embedded the firm's customer portfolio, the larger is the number of new products developed by the firm.

Interaction Effects of Relational Embeddedness

In addition to hypothesizing a direct effect of relational embeddedness on new product output, we examine whether relational embeddedness moderates the effects of portfolio size and revenue concentration on new product output. In doing so, we address the question, Can young, technology-based firms with suboptimally sized or highly concentrated customer portfolios use relational embeddedness to improve their new product output?

In H_1, we proposed that customer portfolio size has an inverse U-shaped relationship to new product output, arguing that firms with a moderate number of customers have the benefit of a sufficient number of external knowledge sources without being impeded by excessive transaction costs or dispersed managerial attention. We now address the problems associated with each end of the portfolio size continuum and discuss how relational embeddedness may (or may not) help solve those problems.

A young, technology-based firm with a small customer portfolio is limited in the number of available sources of new ideas and feedback for new product development. In this situation, relational embeddedness can help the firm make the most of the limited number of relationships. By increasing the incentives for, the opportunities for, and the efficiency of knowledge exchange (H_3), a firm can derive more benefits from each relationship. Furthermore, strong relational ties with customers can be leveraged to gain access to the customers' industry networks (Yli-Renko, Autio, and Sapienza 2001); that is, the customers can serve as "bridging ties" (Granovetter 1973) for the young firm to tap into other, indirect sources of knowledge, effectively increasing the number of external sources of knowledge available. This translates into more new product ideas and more sources of feedback and assistance in R&D and therefore should result in the young firm developing more new products. Thus, relational embeddedness can help a firm compensate for the downsides of a small customer portfolio.

At the other end of the continuum, a firm with a large customer portfolio is likely to suffer from excessive transaction costs and thinly spread managerial attention. Embedded ties have lower contractual governance costs due to a decreased need for negotiating and monitoring activities (Beale and Dugdale 1975; Ring 1997) and therefore can help a firm more efficiently manage and extract value from a large portfolio. However, maintaining and building embedded ties involves significant time and effort from the young firm's management (Dwyer, Schurr, and Oh 1987; Uzzi 1997). Instead of contractual governance activities, management will focus on fostering social interactions, building trust, and maintaining continuous and frequent dialogue with customers (Larson 1992). These activities will

give rise to some transaction costs and take up managerial attention. Thus, we expect relational embeddedness to have a less significant compensating effect for the problems associated with a large customer portfolio. That is, firms with a small customer portfolio will benefit more from fostering relationally embedded ties with their customers. For firms with a large customer portfolio, relational embeddedness will have less of a positive impact on new product development. Thus:

H_4: The larger a firm's customer portfolio, the less positive is the relationship between relational embeddedness and the number of new products developed by the firm.

In H_2, we proposed that dependence on one or a few customers (measured as the degree of revenue concentration in the firm's customer portfolio) has a negative effect on new product output. Next, we discuss the effects of relational embeddedness in high- and low-dependence situations.

For highly dependent, young, technology-based firms, relational embeddedness is likely to benefit new product development by offsetting some of the risks and constraints of dependence. Close, cooperative relationships involve the exchange of reciprocal favors and a long-term time horizon (Larson 1992; Uzzi 1997). Because customers in close, cooperative relationships have an interest in the young, technology-based firm succeeding in the long run, they are more likely to provide assistance for new product development, even if it is not directly related to their current purchasing needs. Furthermore, norms of mutual adjustment and concern in the relationship decrease the likelihood that a customer will exert market power and take opportunistic actions to the detriment of the young firm (Ring and Van de Ven 1994), resulting in fewer constraints on the young firm's innovative autonomy. In line with this reasoning, the CEOs of young firms in Fischer and Reuber's (2004) qualitative study identified "developing close relationships" as one of the key tactics they employed to deal with a customer's dominance over innovation. Developing a deeply embedded relationship with a dominant customer enables the firms to maximize learning benefits from the relationship (H_3) and increases governance flexibility and continuity in the relationship (Fischer and Reuber 2004). Such benefits enable a young, technology-based firm to develop more new products because the firm can better leverage knowledge acquired from its key customers and is freer to pursue its own innovative agenda without being limited by constraints set by key customers.

For firms whose revenues are evenly spread across the customer base, resulting in a low level of revenue dependence on any given customer, relational embeddedness is not as critical. A particular customer is not likely to dominate innovative activities, because the firm spreads its activities more evenly across the customer base. Thus, such firms face lower risks of opportunism and fewer constraints on organizational autonomy and therefore have less to gain from embedded customer ties than firms with highly concentrated revenues (Yli-Renko, Sapienza, and Hay 2001).

Therefore, we propose that relational embeddedness of customer ties has a stronger impact on new product development for firms with a high level of dependence on revenues from one or a few customers than for firms with a low level of dependence. This interaction effect arises from the norms of reciprocity, continuity, and governance flexibility in embedded relationships that help buffer a young firm from the risks and constraints of dependence and help maintain a higher level of new product output. Thus:

H_5: The higher the level of revenue concentration in a firm's customer portfolio, the more positive is the relationship between relational embeddedness and the number of new products developed by the firm.

Data and Methods

We tested the hypotheses using longitudinal data from young, technology-based firms in the United Kingdom. We collected the original data, comprising 180 firms, with a mail survey in 1998. We conducted the follow-up study in spring 2004 with telephone interviews, Web searches, and archival data.

We drew the original sample from the Dun & Bradstreet database, the most comprehensive database on company information in the United Kingdom. We had three sampling criteria: The firms needed to be (1) at least one year but not more than ten years old; (2) independent (i.e., not a subsidiary of another firm); and (3) involved in developing, commercializing, or manufacturing advanced technology in one of six industry sectors (defined according to 1992 U.K. Standard Industrial Classification codes): pharmaceuticals, medical equipment, communications technology, electronics, energy, and environmental technology. We excluded firms less than a year old because they were less likely to have established a customer portfolio. The ten-year upper limit is consistent with previous research on entrepreneurial firms (e.g., Covin and Slevin 1990). The independence criterion ensures that the effects of customer relationships are not mixed with those of a corporate parent; a corporate subsidiary might tap into its parent's knowledge and resources for new product development, potentially clouding the effects examined here. To ensure that sample firms were involved in technology creation, we checked their business descriptions in the source database. We excluded firms that operated in sales and distribution with no R&D or manufacturing; we also excluded firms that offered only nontechnical services.

We identified 1140 firms that matched the selection criteria and sent a questionnaire to their managing directors (the British equivalent of a CEO) in May 1998. We had thoroughly pretested and revised the questionnaire as a result of discussions with ten firms. We called all 1140 firms to motivate the entrepreneur to participate and to ensure that the firm fulfilled the sampling criteria; this resulted in the elimination of 204 ineligible firms. We received responses from 225 of the remaining 936 firms, yielding a response rate of 24%. This compares satisfactorily with similar mail surveys in entrepreneurial settings (e.g., Chandler and Hanks 1994) and in new product development studies (e.g., Sivadas and Dwyer 2000). Of the 225 returned questionnaires, we excluded 30 because they did not meet all sampling criteria and an additional 15 because of incomplete answers, leaving 180 usable responses.

Location and age data on nonrespondents from the source database indicated no significant differences between respondents and nonrespondents. Because those responding late have been argued to be similar to nonrespondents (Armstrong and Overton 1977), we also tested for nonresponse bias by comparing early and late respondents. We found no significant differences in terms of age, number of employees, sales, or number of customers.

In 2004, the 180 firms were first researched in the Dun & Bradstreet database and on the Web to identify their current contact information; we then called them to establish their survival status and to request a telephone interview with the original respondent or, if that person was no longer with the company, with the current managing director. According to these initial telephone calls, Web searches, and the Dun & Bradstreet archival data, 121 of the firms were still operating independently, 25 had been acquired, 18 had gone bankrupt or closed down, and 16 could not be located. We conducted telephone interviews with 111 of the 146 independent or acquired companies, yielding a response rate of 76%. Again, we tested for nonresponse bias by comparing the responding firms and the nonrespondents and found no significant differences.

Reliability of the Empirical Data

The design of the study allowed for measuring the independent variables in 1998 and the dependent variable—number of new products developed—for the six-year period of 1998–2003. The six-year time lag alleviates the common method variance issue that is often a concern in cross-sectional, single-respondent studies (e.g., Phillips 1981). Six years is long enough to capture customer portfolio effects on the number of new products developed, considering that R&D projects in young, technology-based firms typically take several years to complete (Oakey 1995). Conversely, the period is not so long that unobserved factors or changes in the independent variables would mask the effects under consideration. We checked for the presence of such unobserved factors or changes with an open-ended question at the end of the interviews.

In the data collection process, we took several steps to ensure the reliability of the empirical data. First, by targeting the survey to the managing directors, we used the most knowledgeable source of information on the firm's customers and new product development projects. In young, small firms (our sample firms had a median of nine employees in 1997), the managing director is typically responsible for both of these areas. It would not have been possible to identify another person in each of the firms with comparable firm-level knowledge of the customer portfolio and new product development. Second, to minimize potential bias in the data, we formulated most survey items to measure tangible matters, and we carefully designed the questionnaire with several rounds of revisions and a pilot test. Whenever possible, we used previously validated measurement items for each of the theoretical constructs. Third, the coverage and quality of the obtained data were good. In general, there were few unanswered items and no systematic patterns of missing values.

Finally, to assess the reliability of our self-reported data, we obtained secondary data on a subset of the sample firms from the Financial Analysis Made Easy database. Sales and employee figures were available for 42 of the sample firms. These secondary data were nearly identical to the self-reported sales and employee figures (for both, $r = .98$, $p < .001$), helping confirm the general accuracy of the survey data.

Measures and Validation

New product development. The dependent variable in our study, new product development, is the count of new products developed by each firm during the 1998–2003 period. The number of new products as a measure of innovation has been used in prior literature (e.g., Katila and Ahuja 2002; Sorescu, Chandy, and Prabhu 2003) and has been argued to represent the potential commercial value of a firm's R&D activities (Katila and Ahuja 2002). It is a highly relevant metric for young, technology-based firms; the number of new products has been associated with sustained growth, profitability, and survival of such firms (Schoonhoven, Eisenhardt, and Lyman 1990; Stalk and Hout 1990; Zahra and Bogner 2000). In the 2004 follow-up telephone survey, respondents estimated how many new offerings, including new products, services, and technologies (for firms that generate revenues by licensing out technologies), the firm had developed in the 1998–2003 period. Consistent with our focus on the prelaunch part of the innovation process, we defined new products as the output of the R&D process—that is, the number of new products that had been developed to the point at which they could be commercially launched; we did not specify that any marketing or sales had to have taken place. Responses ranged from 0 to 30, with a mean of 4.30.[3]

Size of the customer portfolio. We measured the size of a firm's customer portfolio in the original survey as the number of customers the firm had in 1997. Previous research has emphasized the significance of the number of customers as an important variable in customer relationship theories (Johnson and Selnes 2004). To ensure consistency across firms in defining an active customer (rather than potential marketing leads or customers in the sales cycle), we asked respondents for the number of customers their firms sent an invoice to in 1997. Our sample firms operate in business-to-business markets.

Revenue concentration within the customer portfolio. We measured the extent to which a firm's revenues are concentrated versus evenly spread out in its customer portfolio

[3]To examine the validity of this self-reported measure, we obtained patent data on the firms for the same 1998–2003 period by conducting a search on the European Patent Office Web site. We did not expect to observe an excessively high correlation between the patent measure and the number of new products developed, because not all new products are patentable, several new products may result from one patent, and not all firms choose to patent their innovations. Nonetheless, the patent measure correlated with our self-reported measure ($r = .27$, $p < .10$), providing evidence of face validity and convergent validity.

using the Herfindahl index, a measure of concentration commonly used in the economics literature. By means of the Herfindahl index, our measure of revenue concentration for firm i is as follows:

$$\text{Revenue concentration}_i = \sum_j s_{ij}^2, \quad (1)$$

where s_{ij} is the share of sales from customer j in the customer portfolio of firm i. The index has a value close to one if a firm is highly dependent on revenues from one dominant customer, and it approaches zero if a firm receives an equal share of revenues from a large number of customers. In our 1998 survey, we asked respondents the percentage of total revenues in 1997 that came from the firm's single-largest customer, the next-largest customer, and the third-largest customer. To calculate the revenue concentration index, we assumed that the revenues from the remaining customers were distributed equally. The proportion of total exchange that an exchange partner accounts for is the most commonly used measure of dependence in the extant literature (e.g., Heide and John 1988; Jacobs 1974; Nooteboom, Berger, and Noorderhaven 1997).

Relational embeddedness of the customer portfolio. We used three items to measure the extent to which the young firms' customer relationships in 1997 were relationally embedded versus arm's length. In designing these items, we adopted the terminology the entrepreneurs in Larson's (1992) study used to describe their firms' supplier and customer relationships. Our items were as follows: (1) "Which of the following best characterizes your company's customer relationships? (a. All of our customer relationships are arm's-length in nature; b. We have a few close, cooperative customers, the majority are arm's-length; c. We have about the same number of close customers as arm's-length customers; d. We have a few arm's-length customers, the majority are close, cooperative customers; e. All of our customer relationships are close, cooperative relationships)"; (2) "The majority of our revenues comes from customers with whom we have a close, cooperative relationship"; and (3) "The majority of our revenues comes from customers with whom we have an arm's-length relationship" (reverse coded). We measured the two latter statement-style items with a Likert scale ranging from 1 ("do not agree") to 7 ("completely agree"). We standardized and combined the three items, which yielded a Cronbach's alpha of .83.

We relied on an aggregate measure that focused on the perceived overall closeness and cooperative nature of the firm's customer portfolio because it would have been impossible to ask respondents to evaluate various dimensions of embeddedness for each of their (tens of) customer relationships. We designed the relational embeddedness measures to be easily understood by entrepreneurs; the measures used the terminology "close" and "cooperative" relationship as in previous research (e.g., Anderson and Narus 1990; Heide and Miner 1992; Larson 1992) and the business literature (e.g., Nonaka and Takeuchi 1995). The accepted use of the terms in the literature, together with the confirmatory feedback from entrepreneurs in the pilot test, provides evidence of the face validity of the relational embeddedness measure. To assess the validity of this measure further, we followed Salvendy and Carayon's (1997) recommendations and examined the correlations between our measure and other operationalizations of the underlying embeddedness concept. We had available detailed information on the nature of the young firm's single-largest customer relationship. Measures of trust, social interaction, and the extent of R&D cooperation in this key relationship correlated significantly with the aggregate measure of relational embeddedness, providing evidence of convergent and content validity (Salvendy and Carayon 1997).

Control variables. In our analyses, we control for firm age, firm size (measured as the number of employees), and the level of R&D spending (measured in pounds sterling) in 1997. To ensure that the effects of portfolio size, revenue concentration, and relational embeddedness are not clouded by the level of diversity in the firm's customer set, we also include as a control variable the proportion of customers located in the United Kingdom (versus abroad); this variable captures aspects of customer portfolio homogeneity. Customers that are located in foreign operating environments are likely to provide a firm with more heterogeneous knowledge. Furthermore, to control for the effect of the newness of the firm's technology, we included a control variable, technology newness, which was measured as the respondents' evaluations of their companies' core technology on a five-point scale ranging from "widely used" to "completely new, never before applied in industry." Finally, to control for the environmental conditions under which the firms operate, we included variables for market size (measured as respondents' estimates of the total number of potential customers available to the firm) and industry sector (dummy variables for electronics, environmental technology, pharmaceutical, medical equipment, and energy industries). Table 1 presents the descriptive statistics and correlations among our variables.

Model

The dependent variable in our model is the number of new products that each of the firms developed. We denote the new products developed by each firm i as y_i. Because this number is discrete and nonnegative, consistent with prior literature, we assume that y_i follows a Poisson distribution with a mean rate λ_i (Hausman, Hall, and Griliches 1984), as presented in Equation 2:

$$\Pr(Y_i = y_i|\lambda_i) = \frac{\lambda_i^{y_i} e^{-\lambda_i}}{y_i!}. \quad (2)$$

In addition to the challenge of developing new products, young firms face the basic challenge of surviving in the market. As a result, whereas some firms may survive but yet have no new products, others may not survive and have no new products. In other words, zero counts of new products in our sample can arise in two distinct ways, and thus the data-generating process of zero counts in the Poisson model has two states. Therefore, in the tradition of zero-inflated Poisson model (Lambert 1992), we modify Equation 2 to account for the preponderance of zeros and to split the sample into firms that survived and those that did not. We

TABLE 1
Descriptive Statistics and Correlations of the Variables in the Model

Variable	1	2	3	4	5	6	7	8	9	10	11
1. New products developed											
2. Revenue concentration	−.15*										
3. Portfolio size[a]	.12	−.40***									
4. Relational embeddedness	.13†	.33***	−.33***								
5. Technological competitiveness[b]	.27**	.06	−.10	.09							
6. R&D spending[c]	−.07	.07	−.12	.05	.14†						
7. Firm size	.05	−.04	.10	−.02	.01	.61***					
8. Firm age	−.05	−.16*	.09	.01	−.01	−.06	.06				
9. Proportion of domestic customers	−.05	−.18*	.25**	.05	−.29**	−.13†	−.09	−.09			
10. Market size[d, e]	.13†	−.21**	.48***	−.25**	−.06	−.11	.01	−.10	.17*		
11. Technological newness	.00	−.19**	.17*	.01	−.47***	−.18*	.04	.15*	.21**	.01	
12. Electronics	−.01	−.13†	.00	−.06	.13†	−.10	−.13†	.11	.03	.07	.07
13. Environmental technology	−.07	−.11	.11	−.03	.12	−.04	.13†	−.08	.18*	.11	.05
14. Pharmaceutical	.01	.14†	−.15*	.01	.07	.17*	.13†	.10	−.25**	−.09	−.16*
15. Medical equipment	−.03	.07	−.05	.08	.01	.11	.01	−.12	.05	−.12	.01
16. Energy	.13†	.00	.24**	−.10	.03	−.07	−.07	.02	−.06	.20**	−.15*
17. Communications technology	−.03	.07	−.05	.08	.11	.01	−.12	.05	−.12	.01	−.03
M	4.30	.19	9.94	−.01	4.70	218.39	24.45	6.06	.68	13.07	3.58
SD	5.32	.24	1.17	.86	1.34	535.47	49.43	2.78	.34	31.01	.97
Maximum	30.00	1.00	50.00	.90	7.00	3300.00	380.00	10.00	1.00	150.00	5.00
Minimum	.00	.00	.10	−2.51	1.00	.00	.00	1.00	.00	.02	1.00

†$p \leq .10$.
*$p \leq .05$.
**$p \leq .01$.
***$p \leq .001$.
[a]In units of ten customers.
[b]Correlations with technological competitiveness are reported only for firms that survived.
[c]Descriptives in thousands of pounds sterling.
[d]Descriptives in thousands of potential customers.
[e]Logarithm used in correlations and analyses due to variable skewness.

viewed firms as having survived if they still operated as independent entities at the end of 2003. This variable is equal to 1 for the 121 firms still operational and 0 for all others. We modeled the probability that firm i would not survive, ω_i, as a logistic function of the observed set of covariates, z_i:

$$\omega_i = \frac{\exp(z_i'\gamma)}{1+\exp(z_i'\gamma)}. \quad (3)$$

Therefore, the distribution of the number of new products, y_i, follows the mixture distribution:

$$\Pr(Y_i = 0) = \varpi_i + (1-\varpi_i)e^{-\lambda_i}, \quad (4)$$

$$\Pr(Y_i = y_i) = (1-\omega_i)\frac{\lambda_i^{y_i}e^{-\lambda_i}}{y_i!}, \quad y = 1, 2, ...$$

Consistent with prior literature (e.g., Winkelmann 2003), we model the Poisson-state mean parameter, λ_i, as an exponential function of independent variables related to a firm's customer portfolio (portfolio size, revenue concentration, and relational embeddedness [RE]) and a set of firm-specific control variables (R&D spending [RD], size, age, proportion of domestic customers, technology newness, market size, and the industry indicators):

$$\begin{aligned}\lambda_i = \exp(&\beta_{0i} + \beta_1\text{Portfolio size}_i + \beta_2\text{Portfolio size}_i^2 \\ &+ \beta_3\text{Revenue concentration}_i + \beta_4\text{RE}_i \\ &+ \beta_5\text{RE}_i \times \text{Portfolio size}_i \\ &+ \beta_6\text{RE}_i \times \text{Revenue concentration}_i + \beta_7\text{RD}_i \\ &+ \beta_8\text{Size}_i + \beta_9\text{Age}_i + \beta_{10}\text{Domestic customers}_i \\ &+ \beta_{11}\text{Technology newness}_i + \beta_{12}\text{Market size}_i \\ &+ \beta_{13}\text{Electron}_i + \beta_{14}\text{Environ}_i + \beta_{15}\text{Pharma}_i \\ &+ \beta_{16}\text{Mediceq}_i + \beta_{17}\text{Energy}_i). \end{aligned} \quad (5)$$

We allow the intercept in Equation 5 to be firm specific to account for unobserved firm factors (McFadden and Train 2000), such as differences in managerial ability. We accomplish this by following the approach of random coefficients, allowing the intercept to vary across firms—that is, $\beta_{0i} \sim N(\beta_0, \sigma^2_\beta)$.

Prior literature has documented that young firms' chances of survival tend to be influenced by age and available resources (e.g., Hannan and Freeman 1984; Levinthal 1991). Accordingly, we use the age and size of the firm to model the probability of a firm's survival. Including these variables in z_i, we derive the following expression for $z_i'\gamma$:[4]

$$z_i'\gamma = (\gamma_{0i} + \gamma_1\text{Age}_i + \gamma_2\text{Size}_i). \quad (6)$$

[4]The effects of these or other variables on a firm's probability of survival are beyond the focus of our paper, and therefore we do not hypothesize on the effects of the variables but merely use them to help account for the differences in survival probabilities across firms.

Again, we account for unobserved firm factors that might affect survival by assuming that the intercept γ_{0i} is normally distributed across the firms—that is, $\gamma_{0i} \sim N(\gamma_0, \sigma^2_\gamma)$.

Let $I(y_i = 0)$ denote an indicator variable that is equal to 1 if $y_i = 0$ and 0 if otherwise. The joint log-likelihood for firm i, $LL_i(\beta, \gamma)$, after we omit the constants, is as follows:

$$\begin{aligned}LL_i(\beta, \gamma) = I(y_i = 0)&\ln\{\exp(z_i'\gamma) \\ &+ \exp[-\exp(x_i'\beta)]\} \\ &+ [1 - I(y_i = 0)][y_i x_i'\beta - \exp(x_i'\beta)] \\ &- \ln[1+\exp(z_i'\gamma)]. \end{aligned} \quad (7)$$

The final log-likelihood, $LL(\beta, \gamma)$, is as follows:

$$LL(\beta, \gamma) = \sum_i LL_i(\beta, \gamma). \quad (8)$$

We estimate the final parameters by maximizing the likelihood function in Equation 8 with a simulated maximum likelihood approach (e.g., McFadden and Train 2000). The simulated maximum likelihood estimator is consistent, asymptotically normal, and efficient (Train 2003).

Results

The results of our analyses appear in Table 2. In Model 1, we included only the control variables. In Model 2, we added the hypothesized direct effects variables. Model 3 includes all the hypothesized variables, including the interaction terms. We first centered the variables of the interaction terms to reduce multicollinearity (Aiken and West 1991).

The overall fit of our hypothesized model, Model 3, is good with a statistically significant chi-square ($p < .01$). The log-likelihoods for Model 1, Model 2, and Model 3 are –656.73, –624.12, and –617.95, respectively. The likelihood ratio test rejects Model 1 in favor of Model 2 (the calculated $\chi^2 = 65.22$, whereas the critical $\chi^2(4, .01) = 13.28$). A comparison of the fit between Model 2 (with no interaction effects) and Model 3 (with interaction effects) shows that the likelihood ratio test favors Model 3 (the calculated $\chi^2 = 12.34$, whereas the critical $\chi^2(2, .01) = 9.21$). Because Model 3 has the best fit, we describe the results of each hypothesis in terms of this model.

H_1 predicted an inverse U-shaped relationship between customer portfolio size and the number of new products developed. The results of the model provide support for this hypothesis ($\beta_1 = .64$, $p < .001$; $\beta_2 = –.05$, $p < .001$). H_2 predicted a negative relationship between the revenue concentration in a firm's customer set and the number of new products developed. The results of the model provide support for this hypothesis ($\beta_3 = –.22$, $p < .05$). H_3 is also supported: Relational embeddedness of a firm's customer portfolio has a positive effect on the number of new products developed ($\beta_4 = .23$, $p < .001$).

The interaction effects of relational embeddedness with portfolio size and revenue concentration show support for both H_4 and H_5. H_4 predicted that relational embeddedness would have a greater positive effect the smaller the cus-

TABLE 2
Number of New Products Developed: Results from the Zero-Inflated Poisson Model

Variable	Model 1	Model 2	Model 3
Portfolio size		.49***	.64***
Portfolio size^2		–.04***	–.05***
Revenue concentration		–.28*	–.22*
Relational embeddedness		.25**	.23***
Relational embeddedness × portfolio size			–.06*
Relational embeddedness × revenue concentration			.10*
R&D spending	.13	.18	.19†
Firm size	–.15**	–.19**	–.18**
Firm age	–.12	–.17***	–.15***
Proportion of domestic customers	–.25***	–.26***	–.23***
Market size	.04**	.03**	.06**
Technology newness	.08	.07	.03
Electronics industry indicator	.13	–.02	.02
Environmental technology industry indicator	–.22**	–.45**	–.57***
Pharmaceutical industry indicator	.15***	.17***	.32***
Medical equipment industry indicator	.45**	.41**	.39**
Energy industry indicator	–.12	–.05	–.05
Constant (β_0)	1.72***	1.31***	1.31***
Unobserved heterogeneity (σ^2_β)	1.03†	.92†	1.14†
Log-likelihood	–656.73	–624.12	–617.95

†$p \leq .10$.
*$p \leq .05$.
**$p \leq .01$.
***$p \leq .001$.
Notes: With respect to the logistic part of the model accounting for differences in survival probabilities across firms, we find that younger firms are more likely not to survive ($\gamma_1 = -.08$, $p < .001$). Firm size has no significant effect on survival ($\gamma_2 = -.16$, not significant).

tomer portfolio. The negative interaction term between relational embeddedness and portfolio size supports this hypothesis ($\beta_5 = -.06$, $p < .05$). H_5 predicted that relational embeddedness would have a greater positive effect the higher the level of revenue concentration. The positive interaction term between relational embeddedness and revenue concentration supports this hypothesis ($\beta_6 = .10$, $p < .05$).

In the control variable effects, we find that within our sample of young firms, both firm age and firm size have a significant, negative effect on the number of new products developed, indicating that as firms reach their "adolescence" and grow beyond the initial small start-up stage, they may become more focused on commercializing and selling their existing products rather than on developing new ones. Furthermore, we find that a higher proportion of domestic customers has a negative effect on new product development. This finding is in line with Ganesan, Malter, and Rindfleisch's (2005) recent study, which challenges the cluster theorists' view that geographic proximity is beneficial for new product development.

Our results suggest that the newness of the firms' technology does not directly influence the number of new products developed. This is consistent with research by Bonner and Walker (2004), who find that rather than a direct effect, product newness moderates the effects of relational embeddedness on new product advantage. As an additional analysis, we tested for such an interaction effect in our data. In line with Bonner and Walker's research, we find that the newer the technology, the less positive is the relationship between relational embeddedness and the number of new products developed. All our hypothesized relationships remain stable with the inclusion of this additional interaction effect.

With respect to the environmental control variables, we find that market size is positively related to the firms' new product output. Firms in the medical equipment and pharmaceutical industries have a higher number of new products developed, whereas firms in the environmental technology industry have a lower number of new products developed. Our comparison or base industry is communications technology. With regard to the control variables used to explain firms' probability of survival, we find that, consistent with prior literature (e.g., Hannan and Freeman 1984; Levinthal 1991), younger firms are more likely not to survive.

Supplementary Analysis

The primary goal of our study was to understand the effects of customer portfolio characteristics on young, technology-based firms' new product development output (i.e., the productivity of R&D, measured as the number of new products developed). However, a firm's customer portfolio can influence not only the quantity but also the nature, or quality, of the firm's R&D output. In the following discussion, we present a supplementary analysis that addresses the question of how customer portfolio can affect both the quantity and the quality of new product output.

We examine how the customer portfolio influences the quality of R&D by focusing on the overall technological competitiveness of the firm.[5] Defining the company's core technology as "the company's technological skills and knowledge as well as the products, services, and processes based on these skills and knowledge," we measured the superiority of firms' technology on three items designed from Wernerfelt's (1984) and Conner's (1991) studies: (1) "Our technology is better than competitors' technology"; (2) "Our competitive advantage is based on our technology"; and (3) "We invest very heavily in R&D" (Cronbach's $\alpha = .79$). We measured the technological competitiveness of the firms in both the original and the follow-up surveys. This enabled us to develop a model to analyze the impact of customer portfolio characteristics on the number of new products developed (quantity of R&D output) weighted by the technological competitiveness (quality of R&D output) of the firms over the six-year study period.

Model development. We again denote the number of new products produced by firm i as y_i and the technological competitiveness of firm i as TC_i. Our new dependent variable is then $y_i \times TC_i$. We operationalize TC_i as the average of firm i's technological competitiveness in 1997, TC_i^{1997}, and 2003, TC_i^{2003}. Although we observe TC_i^{1997} for all the firms, we observe TC_i^{2003}, and therefore TC_i, only for the firms that survived until 2003. To address this data-censoring problem, we develop a Type II Tobit model (Heckman 1978). The independent variables in this model are identical to those in our main model (Model 3 in Table 2). Thus, we can express the dependent variable $y_i \times TC_i$ as follows:

$$
\begin{aligned}
(9)\quad y_i \times TC_i = {} & \delta_{0i} + \delta_1 \text{Portfolio size}_i + \delta_2 \text{Portfolio size}_i^2 \\
& + \delta_3 \text{Revenue concentration}_i + \delta_4 RE_i \\
& + \delta_5 RE_i \times \text{Portfolio size}_i \\
& + \delta_6 RE_i \times \text{Revenue concentration}_i \\
& + \delta_7 RD_i + \delta_8 \text{Size}_i + \delta_9 \text{Age}_i \\
& + \delta_{10} \text{Domestic customers}_i + \delta_{11} \text{Market size}_i \\
& + \delta_{12} \text{Technology newness}_i + \delta_{13} \text{Electron}_i \\
& + \delta_{14} \text{Environ}_i + \delta_{15} \text{Pharma}_i + \delta_{16} \text{Mediceq}_i \\
& + \delta_{17} \text{Energy}_i + u_{1i},
\end{aligned}
$$

where u_{1i} is a normally distributed error term. However, we observe TC_i only when firm i survives. Let S_i denote an indicator variable that is equal to 1 if firm i survives and 0 if otherwise. Accordingly,

$$
\begin{aligned}
(10)\quad & y_i \times TC_i \text{ is not observed iff } S_i = 0, \text{ and} \\
& y_i \times TC_i = x_i'\delta + \varepsilon_i > 0 \text{ iff } S_i = 1,
\end{aligned}
$$

where δ is the vector of the parameters δ_0 to δ_{17} and x_i denotes the set of covariates given in Equation 9. The probability of firm i's survival, S_i, is formulated as a binary probit model:

$$
(11)\quad S_i = 1 \text{ if } z_i'\theta + u_{2i} \geq 0, \text{ and } S_i = 0 \text{ if } z_i'\theta + u_{2i} < 0,
$$

where u_{2i} is a normally distributed error term and z_i is the same set of covariates as before (i.e., the age and size of a firm). The Type II Tobit model then models the effects of the covariates, conditional on the probability that the observation is noncensored. Furthermore, the model allows for the correlation of the error terms, and accordingly the error term is assumed to be bivariate normal:

$$
(12)\quad \begin{bmatrix} u_{1i} \\ u_{2i} \end{bmatrix} \sim N\left(\begin{bmatrix} 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_1^2 & \sigma_{12} \\ \sigma_{12} & \sigma_2^2 \end{bmatrix} \right),
$$

where σ_1^2 is the variance of the error term of u_{1i}, σ_2^2 is the variance of the error term of u_{2i}, and σ_{12} is the covariance between the two error terms. For the purposes of identification, we set $\sigma_2^2 = 1$. All these assumptions are consistent with the setup of a Type II Tobit model. The final likelihood function of each firm i, $L_i(\delta, \theta)$, is then given by the following (see Amemiya 1985, pp. 385–87):

$$
\begin{aligned}
(13)\quad L_i(\delta, \theta) = {} & \left[1 - \Phi(z_i'\theta)\right]^{(1 - S_i)} \\
& \left\{ \Phi\left[z_i'\theta + \rho\sigma_1^{-1}(y_i \times TC_i - x_i'\delta)(1 - \rho^2)^{-\frac{1}{2}} \right] \right. \\
& \left. \phi\left(\frac{y_i \times TC_i - x_i'\delta}{\sigma_1} \right) / \sigma_1 \right\}^{(S_i)},
\end{aligned}
$$

where ρ is the correlation between the two error terms u_{1i} and u_{2i} (i.e., $\rho = \sigma_{12}/\sigma_1\sigma_2$), and $\Phi(.)$ and $\phi(.)$ represent the standard normal cumulative and the standard normal probability density functions, respectively. We estimate the parameters by maximizing the likelihood function in Equation 13.

Results of the supplementary model. The parameter estimates of the Tobit II model appear in Table 3. The overall model fit is good, as determined by the likelihood ratio test, which supports the proposed model at a .01 significance level. With respect to the effects of our covariates of interest, we find evidence for an inverted U-shaped relationship between customer portfolio size and the new weighted dependent variable ($\delta_1 = 1.04$, $p < .01$; $\delta_2 = -.19$, $p < .05$). Furthermore, as we expected, the results suggest a signifi-

[5]Whereas prior literature has tended to focus on the distinction between radical and incremental innovation (e.g., Chandy and Tellis 1998), in our context, this would have been problematic for several reasons. First, defining radical versus incremental innovations for young, technology-based firms is complicated; most innovations are likely to be incremental applications of the firm's core technology, which in turn may be highly radical compared with incumbent technologies in the market. Second, focusing on the type of innovation would raise the question of which type of innovation is better; from a young, technology-based firm's perspective, developing radical new products may be a better basis for long-term competitive advantage, but it is also a riskier strategy that may lead to firm failure; an incremental product strategy may be more advantageous for profitability and sustainability of the firm. Third, the general theories our hypotheses are based on should be applicable to both types of new products.

TABLE 3
Number of New Products Developed × Technological Competitiveness: Results from the Tobit II Model

Variable	Parameter Estimates
Portfolio size	1.04**
Portfolio size^2	–.19*
Revenue concentration	–1.23*
Relational embeddedness	1.54**
Relational embeddedness × portfolio size	–.72
Relational embeddedness × revenue concentration	.35*
R&D spending	9.12***
Firm size	–1.39***
Firm age	–1.83***
Proportion of domestic customers	2.27
Market size	.94
Technology newness	.52
Electronics industry indicator	–1.42
Environmental technology industry indicator	–4.59*
Pharmaceutical industry indicator	3.26*
Medical equipment industry indicator	1.32***
Energy industry indicator	–2.01
Intercept	17.06***
σ_1	.84**
σ_2	.73
ρ	.32†
Log-likelihood	–375.25

†$p \leq .10$.
*$p \leq .05$.
**$p \leq .01$.
***$p \leq .001$.

cant, negative effect for the revenue concentration in a firm's customer set ($\delta_3 = –1.23$, $p < .05$) and a significant, positive effect for relational embeddedness ($\delta_4 = 1.54$, $p < .01$). The interaction term between relational embeddedness and portfolio size is in the right direction but is not statistically significant ($\delta_5 = –.72$, n.s.). Finally, we find a significant, positive interaction effect between relational embeddedness and revenue concentration similar to the model for the number of new products ($\delta_6 = .35$, $p < .05$). These results are consistent with the results of our main model, indicating that the basic arguments of our hypotheses also hold when the quality of R&D output is taken into account.

Discussion

New product development is not an isolated, confined process but rather a collective process that takes place through a "web of communications" between various internal and external parties (Brown and Eisenhardt 1995). Because of the growing complexity and costs involved in developing new products, firms need to seek knowledge and expertise beyond their organizational boundaries (Wind and Mahajan 1997). Both the research literature and the business press have extolled the importance of "network innovation" (*The Economist* 2007a), "open innovation" (Chesbrough 2003), or "democratized innovation" (Von Hippel 2006). *The Economist* (2007b) recently wrote about the "rise and fall of corporate R&D," noting that for modern technology firms, R&D has become splintered across networks consisting of suppliers, assemblers, and, importantly, customers. In these user-centered models of innovation, customers—both firms and individual consumers—play a key role in driving innovation (Von Hippel 2006).

Although much has been written recently about "open-source" communities in which large numbers of individual users contribute to innovation (e.g., Lakhani and Von Hippel 2003; Von Hippel 2006), little is still known about the effects of a firm's basic set of customer exchange relationships on new product development. In this article, we focused on how young, technology-based firms' customer portfolios influence their new product output. Our research model integrated knowledge-based, resource dependence, and relational theories to develop hypotheses on the direct and interactive effects of the size, revenue concentration, and relational embeddedness of a firm's customer portfolio on new product output.

Theoretical Implications

Portfolio size. A premise in much of the network and alliance literature streams is that the higher the number of external relationships, the more benefits the firm can realize (e.g., Gulati, Nohria, and Zaheer 2000; Pennings and Harianto 1992; Powell, Koput, and Smith-Doerr 1996; Shan, Walker, and Kogut 1994). Few studies have examined whether there is an upper limit to this argument, even though other research in marketing and management has emphasized the importance of focusing on a more limited number of high-value relationships (e.g., Lettl, Herstatt, and Gemuenden 2006; Storbacka, Strandvik, and Grönroos 1994) and has addressed the transaction costs and managerial effort required in maintaining and utilizing relationships (Kalwani and Narayandas 1995; Koput 1997). Drawing on these perspectives, we argued and found that customer portfolio size has an inverse U-shaped relationship to new product output. In other words, interaction with more external parties may become counterproductive beyond a certain point. It is not simply that "more is better"; there are costs and trade-offs involved in using external relationships for innovation. Transaction costs and limited managerial capacity lead to diminishing and, ultimately, negative returns to the number of relationships.

Although this finding may seem to contradict the basic tenets of open-source innovation, it is consistent with recent research on successful open-source innovation projects. Far from being wide-open communities, successful open-source projects tend to have, at their heart, a small, close-knit group of expert participants. For example, in the case of Apache software, the number of active code writers is only in the tens (compared with the thousands who participate in discussions) (*The Economist* 2006). Similarly, in the case of developing new windsurfing equipment, the key innovations came from a small group of competitive windsurfers (Von Hippel 2006). Recent research has also highlighted the need for formal, hierarchical governance systems and structured leadership to manage the quality and productiveness of open-source innovation (Weber 2004); the costs of such

governance are likely to be significant, but they remain largely unstudied.

Dependence stemming from revenue concentration. We found that the dependence stemming from a highly concentrated customer portfolio has a constraining impact on new product development. This finding sheds light on the mechanisms underlying the concerns about relying on customers in innovation (Christensen and Bower 1996; Leonard-Barton and Doyle 1996; MacDonald 1995) and is also consistent with Singh's (1997) finding that interorganizational collaborations can lock high-technology firms in to obsolete capabilities. Furthermore, our finding expands our understanding of the consequences of dependence in channel working partnerships. Previous research has shown that dependence affects relationship characteristics such as the level of influence (Anderson and Narus 1990), long-term orientation (Ganesan 1994), and the effectiveness of influence strategies (Payan and McFarland 2005), but the firm-level outcomes of dependence are not well understood. Heide and John (1988) find that dependence is negatively related to financial performance under conditions of high asset specificity, and Venkataraman and colleagues (1990) suggest that dependence on one or a few customers increases the failure risk for young firms. Our result that revenue concentration in a customer portfolio hinders new product development explicates one of the mechanisms at work behind these previous findings.

Direct and moderating effects of relational embeddedness. Our results regarding relational embeddedness indicate that the innovation outcomes for firms with a small or highly concentrated customer portfolio are not a foregone conclusion. We found that relational embeddedness not only has a direct, positive impact on new product output but also can compensate for an otherwise suboptimal portfolio. Relational embeddedness is found to have a greater impact the smaller or more concentrated a firm's customer portfolio. Although still beneficial for firms with a large or well-balanced portfolio, relational embeddedness is not as critical for them. This finding that relational embeddedness can buffer a young firm against the downsides of a small or concentrated portfolio is consistent with previous studies that have shown relational ties to moderate the acquisition of knowledge in interfirm relationships (Ganesan, Malter, and Rindfleisch 2005) and to be effective in protecting firms against opportunism (e.g., Nooteboom, Berger, and Noorderhaven 1997; Uzzi 1997). Our findings on the direct and moderating effects of relational embeddedness also have implications for the relationship marketing stream of research (for a recent meta-analysis, see Palmatier et al. 2006); in addition to the often-studied performance outcomes, such as a seller's sales and profits, researchers could examine improvement in new product development as a potential outcome of relationship marketing efforts.

Taken together, our results contribute to the new product development literature by (1) focusing on the understudied but important context of young, technology-based firms; (2) extending the research on interorganizational relationships in innovation to the context of customer relationships; and (3) contributing to the understanding of the role of customers in innovation by developing an integrative model that takes the level of analysis from the single project/customer level to the firm/portfolio level. Our focus on the entire customer portfolio of a firm enabled us to examine descriptors that cannot be examined by studying individual customer relationships in isolation. By integrating insights from various theoretical perspectives, our study highlights the importance of looking beyond just the number of relationships or the quality of individual relationships and emphasizes the need for a holistic understanding of the interplay between the various facets of a customer portfolio.

Managerial Implications

This study offers a diagnostic framework for entrepreneurs and managers to evaluate their firms' customer portfolio and its impact on new product development. Through a careful analysis of where a firm is positioned on the dimensions of portfolio size, revenue concentration, and relational embeddedness, entrepreneurs can direct business development and marketing efforts to maximize benefits for new product development. Although the prescriptions arising from the study reflect unique features of young, technology-based firms, our recommendations may also offer valuable insights for marketing managers in established companies who want to leverage customers for innovation.

Optimize portfolio size. In contrast to the common belief among entrepreneurs, it is not always better to have more customers. Pursuing new customers should be the result of thoughtful consideration of the trade-offs involved in diverting managerial attention from existing customer relationships. Entrepreneurs should have a clear sense of where on the portfolio size continuum their firm operates: Is the number of customers so small that the firm has limited sources of revenue and gets insufficient input into the new product development process, or has the customer set grown so large that it is cumbersome to deal with and managerial attention is spread too thinly to enable learning from customers? According to the results of our study, entrepreneurs should strive to optimize portfolio size to a point at which the number of customers is as large as possible (to maximize revenues and enable access to a broad range of external knowledge) while still remaining manageable. Firms at the lower end of the spectrum should continue cultivating new customers, and firms at the suboptimal upper end should consider either reducing their number of customers or setting up new organizational structures and systems (e.g., expanding top management, hiring customer relationship managers) to enable more effective value extraction from customer relationships.

Manage dependence. Most entrepreneurs are instinctively conscious of the risks of overreliance on one or a few key customers (Fischer and Reuber 2004). However, our data show that such dependence is highly common among young, technology-based firms. The firms in our sample realized an average of 46% of their sales revenues from their three largest customers alone; for half the sample firms, the single largest customer accounted for 20% or more of revenues. Our results show that dependence arising

from revenue concentration in the customer portfolio is problematic for new product development. Therefore, entrepreneurs should strive toward maintaining a balanced portfolio that provides broad exposure to new ideas and technologies and avoid becoming locked in with dominant customers who tend to constrain a firm's new product development activities. When allocating managerial attention to existing customer relationships, entrepreneurs should resist their natural inclination to focus on the largest customers and instead focus on relationships that may be second tier in terms of sales but have the potential to grow in volume (to balance out currently dominant customers) and to contribute new perspectives to product development.

Foster relational ties with customers and use learning opportunities in customer relationships. The quality of relationships matters. Our results suggest that the relational embeddedness of a customer portfolio has a positive impact on a firm's new product output. Close relationships can help the young firm acquire valuable knowledge on, for example, customer needs, market trends, competitors' offerings, and complementary technologies from customers. Thus, entrepreneurs should treat customer relationships not just as sources of revenue but also as valuable learning opportunities. Closer relationships with customers not only directly help in a firm's innovation process but also compensate for the negative effects of both dependence and small portfolio size. The implication of these findings is that entrepreneurs should strive to forge closer, more cooperative relationships with customers—particularly if the firm is dependent on key customers or has few customers. Although our study did not explicitly address the various elements of close, cooperative relationships, prior research has shown that frequent communication, flexibility rather than strict contract adherence, and social rather than pure business interactions are some of the mechanisms through which relational embeddedness can be developed (Larson 1992; Yli-Renko, Autio, and Sapienza 2001; Yli-Renko, Sapienza, and Hay 2001).

Together, these insights illustrate the complexity of issues involved in the management of a firm's customer portfolio and suggest that when making decisions about establishing and fostering customer relationships, entrepreneurs and managers should consider not only the economic aspects but also the dependence, knowledge acquisition, and relational elements involved. A thorough evaluation of these dimensions of the customer portfolio can help entrepreneurs and managers make the difficult trade-offs between focusing efforts on gaining new customers and cultivating existing customer relationships, thus helping focus managerial attention on the customers with the greatest impact.

Limitations and Future Directions

Several limitations exist in terms of the generalizability and interpretation of the results of the study. First, the sample was taken from one country, over a particular period, and from a set of young firms operating in technology-based sectors. Focusing on a limited number of sectors and one country helped us control for environmental differences, and the study focused on young firms in technology-based sectors because we believed that external influences on new product development would be particularly relevant in settings with high uncertainty, technological complexity, and limited internal resources and capabilities. The six-year period allowed for the long product development cycles that are typical in technology-based sectors. Future studies could examine whether our results are valid for low-tech and older firms and address the question whether the impacts of the customer portfolio on new product development vary over time in the different stages of an entrepreneurial firm's life cycle. For example, what is the role of first reference customers in shaping the customer portfolio development and innovation agenda of early-stage start-up firms?

Second, we focused on the number of new products developed as our dependent variable. Although the rate of new product development is an important and often-used measure, it is only one aspect of a firm's innovative output. Future studies could expand our findings by examining, for example, the level of creativity or the commercial success of the new products developed; however, such measures are difficult to capture in the context of young, technology-based firms because of a lack of objective data and the typically long and complex commercialization processes (Oakey 1995; Teece 1986). Furthermore, we conceptualized and measured relational embeddedness as an aggregate construct. Embeddedness is a multidimensional phenomenon that includes distinct (but correlated) facets, such as trust, long-term orientation, information exchange, shared problem solving, and restraint in the use of power (Dwyer, Schurr, and Oh 1987; Heide and Miner 1992; Uzzi 1997). Although prior research would not lead us to expect differential effects of the various aspects of relational embeddedness, future studies might benefit from more fine-grained conceptualization and measurement.

Third, our focus was on the customer set as a whole—its size, revenue concentration, and relational embeddedness. Although beyond the scope of our study, the composition of the portfolio, including the mix of capabilities, reputations, and resources of the customers, is likely to affect new product development. Future studies could address (on both the dyadic and the portfolio levels of analysis) the question of which customer characteristics are beneficial for new product development. Finally, the various mediating mechanisms through which customers affect new product development, such as knowledge acquisition, transaction costs, and managerial attention, deserve further study. Particularly worthwhile research questions would include, for example, the effects of knowledge heterogeneity and different types of learning.

In conclusion, our study provides new insights into the role of customers in new product development. We drew on knowledge-based, resource dependence, and relational perspectives to elucidate the mechanisms through which a young, technology-based firm's customer portfolio influences new product output. We attempted to provide both conceptual and empirical bases for further investigation of this important topic and hope that our results will prompt further research in the area.

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