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Price Space and Product Demography: Evidence from the Workstation Industry, 1980-1996

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Abstract

This study adds to the product innovation literature by emphasizing the important yet understudied role of price distribution in shaping product demography (i.e. new product introductions and exits). While prior research has focused on market niches in the technological and geographic spaces in order to explain product demography, price space has received very limited attention despite the important role of price in the market. We posit that product dynamics are largely shaped by the existing price distribution. More specifically, we argue that local density in price space determines both the likelihood of existing products exiting the market and the rate of new products entering it. Analyzing product exit and entry in the U.S. workstation industry from 1980 to 1996, we find that while price density increases an existing product's exit rate, new products are also more likely to enter the niches where the price density is high. We also draw attention to internal price density within multiproduct firms, analyzing a product's price distance from the other products launched by the same firm. We find that this type of internal price density decreases both existing products' exit rate and new products' entry likelihood. Our emphasis on price space contributes to the literature on product innovation and demography.

Keywords: new product introduction; product exit; price space; local density; organizational ecology

Introduction

Innovation scholars have paid substantial attention to product demography that systematically investigates the rate at which new products are launched and withdrawn from the market (Khessina and Carroll, 2008; Carroll, Khessina, and McKendrick, 2010; Wang and Chen, 2018), because it plays an important role in shaping firm performance and viability (Sorenson, 2000; Cucculelli and Ermini, 2012; Barroso and Giarratana, 2013). In analyzing new product introductions and exits, the density dependence theory – proposing that product entry and exit are closely related to population density – is widely applied (Bogaert, Boone, Negro, and van Witteloostuijn, 2016; Aksaray and Thompson, 2018). Some studies assume a homogenous market for all actors and analyze global density in a whole population (Ruebeck, 2005; Ingram and Simons, 2000); others emphasize the heterogeneity of market niches and provide much finer-grained analysis on local density within niches in technological space (Dobrev, Kim, and Carroll, 2002; Podolny, Stuart, and Hannan, 1996) or geographic space (Sorenson and Audia, 2000; Greve, 2000). Emphasizing technological or geographic spaces overlooks, however, niches and local density in *price space*. Product space is multidimensional (Lancaster, 1990). While technological and geographic spaces define products in their horizontal dimension, price space concerns vertical segmentation (Vandenbosch and Weinberg, 1995). The lack of research on how price distribution affects product demography is unfortunate because price is one of the most pronounced product features in the market (White, 1981; Rao and Monroe, 1989; Baum and Mezias, 1992; Fosfuri, Giarratana, and Roca, 2015). Addressing this gap, we shift attention to price distribution (and price density in particular), and explore both how it affects the life chances of existing products (i.e. product exit) and how it creates or constrains opportunities for new products (i.e. product entry).

Product demography is determined by both internal organizational factors and external market structure (Carroll et al., 2010). On the one hand, organizations differ in their resources, strategies, and identities, and those determine the market viability of their products (Khessina and Carroll, 2008; Verhaal et al. 2015). On the other hand, product survival depends on density within the market niches to which focal products belong (Barroso et al., 2016; Cottrell and Nault, 2004). Niche in this context refers to the region of a limited resource space in which one organization form can persist (Hannan and Freeman, 1977), and so product competition intensifies as niches become denser and more crowded (Podolny et al., 1996). While the density dependence theory is well accepted for explaining product demography, empirical studies have disproportionally focused on technological or geographic space (Dobrev et al., 2002; Chesbrough, 2003; de Figueiredo and Kyle, 2006)[1], leaving niches in price space underexplored, despite the important role of price in the market. When making product decisions, most firms regard price as one of the essential dimensions in their matrix (Shaked and Sutton, 1982). They seek out a niche with respect to price for profit maximization by referring to the price niches of other products and firms (White, 1981; Beckert, 2011). However, we know little about how price distribution shapes product demography. Although price is one of the central themes of economists, their research focuses mainly on the deviation between price and quality (Stavins, 1995; Ruebeck, 2005), but overlooks the overall price distribution and niches in product space. We focus instead on a product's price niche and contend that the density of price niches has important implications for product demography. Price niches become denser when there are more similarly-priced products in the market (i.e. the overall price distance between the focal product and others is shorter).[2]

[1] We use the term 'technological niche' in a more abstract way. It indicates the horizontal category that a product belongs to. For software products, niches can be operation or application segments; for movies, they are generally genres (comedy or drama); for food, they are usually the styles of cuisine (French or Mexican).
[2] For example, there are three products in the market, A, B, and C with a price of $10, $20, and $90, respectively. Product A has a higher price density than C, because A's overall distance from B and C (i.e. $10 and $80) is shorter than C's distance from B and A (i.e. $70 and $80).

Moreover, whereas organizational ecologists focus on external density in the marketplace (Hannan and Freeman, 1989; Carroll and Hannan, 2000), we also draw attention to a product's internal niche density by analyzing its price distance from the other products launched by the same multiproduct firm. Product demography is driven not only by external market conditions, but also by internal product interdependence (Carroll et al., 2010). Multiproduct firms aim to optimize the performance of an overall product portfolio rather than any individual product (Ruebeck, 2005). So product exit and entry are usually the consequence of a multiproduct firm's strategic decision for its whole portfolio, taking into account the interdependence of its products. Focusing only on external density overlooks the interdependence of products within multiproduct firms. By examining whether internal price density introduces flexibilities or constraints to a product's life expectancy, we thus complement research on external niche density in the marketplace (Hannan and Freeman, 1989) and contribute to the product demography literature (Khessina and Carroll, 2008) by emphasizing the interdependence of products from the same firms.

Exploring price space also allows us to understand where in the price spectrum new products are likely to emerge. New products are launched as firms attempt to select and fill empty niches (Stavins, 1995; Bayus and Putsis, 1999; Greve, 2000). The existing literature on product or market entry has demonstrated how firms select niches in the horizontal dimension, by analyzing the emergence of new offerings across different technological segments (Ingram and Roberts, 1999; Hsieh and Vermeulen, 2013; Montauti and Wezel, 2016) or geographic locations (Haveman and Nonnemaker, 2000; Sorenson and Audia, 2000; Greve, 2002). We know little, however, about in which price ranges new products are likely to be launched. By analyzing how product entry is contingent on the vertical price distribution, we thus advance the literature on product entry which has predominantly focused on the horizontal dimension of product space (Stavins, 1995; Chesbrough, 2003; de Figueiredo and Kyle, 2006).

We tested hypotheses in a sample of firms in the computer workstation industry. High-tech products such as workstations are well-suited for econometric analyses because of their highly quantitative nature and buyers' quantitative evaluation of them (Ruebeck, 2005). The industry is also particularly appropriate to examine product demography because products enter and exit the market frequently (Wang and Chen, 2018). Prior studies have used this context to analyze firm-level product strategies. For instance, Sorenson (2000) examines how product variations affect firm viability; Sorenson et al. (2006) compare the product strategies of generalists and specialists. Our study shifts attention from firm-level strategies to product-level dynamics, focusing on how price space shapes the pattern through which individual products are launched and withdrawn. Empirical results show that although price density in the market increases a product's exit rate, new products are also more likely to enter the niches where the price density is high. We also find that internal price density within multiproduct firms decreases both the exit rate of existing products and new products' entry likelihood. To reiterate, this study makes major contributions to the innovation literature – and product demography in particular – by emphasizing the important role of price density. More specifically, by examining how product demography is shaped by the *vertical* price distribution, we complement prior research that focuses on product innovation as a response to product distributions in the *horizontal* dimensions (e.g. Ingram and Roberts, 1999; de Figueiredo and Kyle, 2006). Our study thus brings a novel perspective to explore where in the price spectrum new products are likely to be introduced and withdrawn.

Theory

Product demography and product space

Firms constantly adjust their product portfolios to cope with market dynamics by either introducing new products or withdrawing existing products from the market (Martin and

Mitchell, 1998; Sorenson, 2000; Carroll et al., 2010). Prior studies have well established the integral role of product dynamics and strategies in a firm’s ultimate success or failure (Barnett and Freeman, 2001; Cucculelli and Ermini, 2012; Barroso and Giarratana, 2013; Verhaal, Hoskins, and Lundmark, 2017). For instance, Sorenson (2000) shows that product culling improves firm viability, particularly in stable environments; Cucculelli and Ermini (2012) find that the release of new products enhances growth opportunities among multiproduct firms; Barroso and Giarratana (2013) provide evidence that within-niche and across-niche product proliferations have different effects on firm performance. Because of the importance of product dynamics to firms, scholars have been curious about how and why specific products are introduced and withdrawn (Stavins, 1995; Khessina and Carroll, 2008; Verhaal et al., 2015; Bayus and Putsis, 1999; Wang and Chen, 2018). Existing literature has identified a variety of factors to explain product entry and exit, ranging from product name, age, and quality (Khensina and Reis, 2016; Cottrell and Nault, 2004), to firm capabilities (de Figueiredo and Kyle, 2006; Fontana and Nesta, 2006; Khessina and Carroll, 2008), market structure, and institutional environment (Greenstein and Wade, 1998; Ingram and Roberts, 1999; Ruebeck, 2005). See Carroll et al. (2010) for a comprehensive review.

Across research on product demography, niche density in product space is one of the most studied factors. Product space is a network of relatedness between products (Hidalgo, Klinger, Barabási, and Hausmann, 2007). That is, product space concerns the relatedness or proximity of all products in the market. A product’s niche is the region in product space that provides limited resources supporting the product and its competitors (Ingram and Roberts, 1999). Products’ niches are not isolated, but often overlap with each other in the space. They become more overlapping when they are similar in technological attributes or proximate in geographic coverage (Podolny et al., 1996; Baum and Mezias, 1992; Sorenson and Audia, 2000). For instance, two semiconductor firms are more overlapping in their product space when building on similar technological antecedents (Podolny et al., 1996); two automobile models are overlapping when utilizing similar horsepower (Dobrev et al., 2002); two hotels have more overlapping businesses when locating in the same neighborhood (Baum and Mezias, 1992).

Niche density reflects the extent to which a niche overlaps with the other niches. Niche density is heterogeneous for different firms or products, as some niches are extremely crowded while others are empty. For instance, the states of Massachusetts and New York contained many shoe plants in 1940s, while several other states had no plants at all (Sorenson and Audia, 2000); Analog Devices occupied a very open niche in 1980s, while Rohm's niche was much more crowded in the semiconductor market (Podolny et al., 1996). Niche density in product space can influence product launch and withdrawal (Ingram and Roberts, 1999) as dense niches escalate the competition of exiting products and leave less empty space for new products. The denser a product's niche in product space, the greater the number of similar products in the market, the more intense its market competition, and the more likely it has a low price-cost margin (Podolny et al., 1996; Ruebeck, 2005; Carroll et al., 2010).

While product space is commonly graphed along the technological and geographic dimensions in the literature (Moutauti and Wezel, 2016; de Figueiredo and Kyle, 2006), the price dimension is quite unexplored, despite the important role of price in the marketplace (Blinder et al., 1998). We argue that niches in product space can be defined along both a horizontal and a vertical dimension (Park and Podolny, 2000). While the horizontal dimension divides the space into categories based on product properties (e.g. technological classes, industry segments, or geographical coverage) (Colombelli, Krafft, and Quatraro, 2014; Chesbrough, 2003; Sorenson and Audia, 2000), the vertical dimension divides each horizontal category further into different cells based on price or quality (Sorenson, 2000: 584). It is important to distinguish between the two dimensions because heterogeneity within a horizontal category can be as important as the heterogeneity between different horizontal categories, if not more so (Park and Podolny, 2000; Jensen, Kim, and Kim, 2011; Wang and Jensen, 2018). In the workstation industry, for instance, most differentiation across products is vertical rather than horizontal (Sorenson et al. 2006).

Price is a crucial piece of information applying to most commercial products, as signified by popular terms such as ‘price wars’, ‘price discrimination’, and ‘pricing strategy’ (Uzzi and Lancaster, 2004). Price is often used as a convenient indicator of quality by customers, particularly for relatively expensive products (Olson, 1977; Rao and Monroe, 1989). Price is, however, not a simple reflection of quality because it is also determined by many other factors such as firm status, network embeddedness, category adherence, product specialization, trust, and so on (Blinder et al., 1998; Benjamin and Podolny, 1999; Uzzi and Lancaster, 2004; Ody-Brasier and Vermeulen, 2014). That is, price acts as a proxy for a set of essential product features and provides important information about product differentiations in the vertical dimension. Competition is localized in the price dimension (Baum and Mezias, 1992), as products only compete with other products to the extent that their prices overlap in product space. Similarly-priced products often function similarly and compete in similar segments, while differently-priced products target customers with heterogeneous demands. Economy hotels, for instance, appeal to budget-minded travelers, while luxury hotels provide upscale facilities for others who are less financially constrained (Baum and Mezias, 1992). As such, price stratifies the market vertically, and products compete more intensely with each other when they are priced similarly.

A product’s price niche, which reflects the overall pattern of price distance between the product and others, becomes denser and more crowded when there are more similarly-priced products (Baum and Mezias, 1992; Kalnins, 2016). Density is heterogeneous across price niches, as products are more concentrated in certain areas of the price spectrum than others. For instance, Figure 1 illustrates the number of workstation products in different price intervals in 1990.[3] They are more concentrated at the low-price end, with the interval of 10,001-15,000 dollars peaking in terms of niche density.

INSERT FIGURE 1 AROUND HERE

The density heterogeneity of price niches can affect product entry and exit. When making decisions about their own products, mangers commonly emphasize price as one of the key dimensions in their strategy matrix (Shaked and Sutton, 1982). Firms evaluate the prices of existing products to decide whether to persist with or withdraw their own products; they conceptualize the price niches of other firms and products in order to seek out optimal niches for new products (White, 1981; Beckert, 2011). In this way, existing price density determines firms' product decisions. As such, we emphasize that price density complements technological (or geographical) density in product space. Disregarding the price dimension may lead to less-specified market niches. For instance, two workstation products in the same technological segment may face different levels of niche density when targeting customers with different budget constraints; two shoe plants from the same state may face different levels of density when producing either regular or luxury shoes.

Prior literature has established evidence about the influence of price on product decision. Stavins (1995), for instance, shows that over-pricing is significantly related to the possibility of products' exit. Fosfuri et al. (2015) find similar results in the cosmetics market – products with high entry prices are more likely to be terminated. They also add to this research by emphasizing that perception of price fairness is also important for products to stay viable in the market. A product's price is perceived as fair if it generates fair profits for the firm. While prior studies have focused mostly on the role of individual product price or its

[3] We used the discrete intervals for illustration purposes, while we adopted a continuous measure for the price density in a product's niche in our empirical analysis.

hedonic residual (Fosfuri et al., 2015; Stavins, 1995), our research shifts attention to how the overall price distribution (i.e. the niche density) in the market affects both product entry and exit.

Moreover, while the density dependence theory focuses mostly on *external* niche density in the market (Hannan and Freeman, 1989), we also emphasize *internal* niche density within multiproduct firms. Multiproduct firms supply multiple products simultaneously to the market (Bernard, Redding and Schott, 2010), which are interdependent with each other. So a product's fate is contingent on the distribution of its sister products that are launched by the same firm (Carroll et al., 2010), suggesting the importance of internal density for product demography. Products are not uniformly distributed in a firm's portfolio because multiproduct firms usually focus their businesses on particular price ranges or niches. Firms launch more products in their focused core niches than in the other peripheral niches. Figure 2 depicts the prices of workstations launched by Silicon Graphics from 1990 to 1994. It is clear that Silicon Graphics' products are more concentrated in certain price ranges and that the concentration pattern is not static over time. Internal niche density thus concerns the density of products within a multiproduct firm, which is conceptualized as a product's price distance from the other products launched by the same firm. Emphasizing the important roles of external and internal price density, we will first theorize their effects on product exit and then discuss how they may influence the emergence of new products.

INSERT FIGURE 2 AROUND HERE

Product exit

External Price density in the market may reduce a product's survival rate. Competition occurs when two products target the same set of customers (Chen, 1996). Price segmentation results in specialized patterns of resource use and localized competition (Baum and Haveman, 1997).

When price provides a meaningful dimension in the distribution of target customers, similarly-priced products compete most intensely. In nearly all industries, price stratification is salient. Products with a similar price often have similar technological function and performance and serve customers with analogous budget constraints. For instance, while low-priced cars compete for customers only looking for a means of transportation, high-priced cars compete for customers seeking a more comfortable or speedy experience (Park and Podolny, 2000). As such, when a product's price niche becomes denser and more overlapping with other products' niches, it faces greater competitive pressure which ultimately reduces its price-cost margins and returns (Ruebeck, 2002). Because firms often withdraw existing products when they produce lower marginal returns (Zuckerman, 2000; de Figueiredo and Kyle, 2006), we argue that a product's exit rate increases with its price niche density.

But a dense price niche may also indicate a large market demand for products at that price range. For instance, while economy hotels face intense competition, they serve a much larger market than luxury hotels (Baum and Mezias, 1992). If so, firms may be hesitant to withdraw those products, which might bring a large cash flow although at a low profit margin. However, the overall market size of products at a certain price does not guarantee a large sales volume for a specific product, because a greater number of products are sharing the market. Indeed, as Thiel and Masters (2014: 54) suggest, "…it is always a red flag when entrepreneurs talk about getting 1% of a $100 billion market. In practice, a large market will either lack a good starting point or it will be open to competition, so it is hard to ever reach that 1%. And even if you do succeed in gaining a small foothold, you will have to be satisfied with keeping the light on: cut-throat competition means your profits will be zero." So while price niche density decreases a product's marginal return, it does not necessarily lead to a larger demand or market share for the focal product. As such, we infer that:

> Hypothesis 1: The exit rate of a product from the market increases with its *external price density in the market* (i.e. its niche density in the whole product space).

A product's *internal price density* within a multiproduct firm may also affect its survival rate, because product withdrawal is, to a large extent, the consequence of a firm's product portfolio strategy (Ruebeck, 2005). The decision to withdraw a product is contingent not only on its relatedness with all products in the market, but also on its relatedness with the other products provided by the same firm. Multiproduct firms are concerned with the optimization of their entire product portfolios, rather than any individual product. So they often strategically change their product portfolios in order to internalize cross-price effects and optimize firm-wide profits (Ruebeck, 2005). When they reformulate strategies, the exit rates of their existing products are reset (Carroll et al., 2010).

How does internal price density affect product exit? On the one hand, products from the same firm face intrafirm competition, competing for limited labor, capital, and attention. The benefits of product proliferation depend on a firm's ability to differentiate its models from each other and disperse them in the product spectrum. A product may be withdrawn if it is being outcompeted by its sister products, even if the product is generating positive profits. Cannibalization refers to this negative impact that a firm's closely related products have on each other (Ruebeck, 2005). Cannibalization occurs when two or more products overlap with each other (Requena-Silvente and Walker, 2009). When a product's price is more overlapping with its sister products (i.e. it is high in the internal price niche), its market demand may be easily met by the sister products. If so, we may expect that a product's *internal price density* would increase its exit rate as the product is more likely to be cannibalized.

On the other hand, however, there are at least two strong mechanisms suggesting the opposite. First, products from the same firm not only compete, but also complement each other. Sharing production and operation facilities across product lines may both improve production and strategic flexibility, and allow a firm to reduce per-unit cost and achieve economies (Bailey and Friedlander, 1982). Similarly-priced products are more likely to share similar resources, but products with different prices may require differently specialized patterns of resource use (Baum and Haveman, 1997). As such, when a product is located far apart from its sister products in the price spectrum, it is less likely to share resources with the other products or to have operational synergies. The distinct product will lead to higher design costs and complexity (Lancaster, 1990; Bayus and Putsis, 1999) and increase per-unit production and operation costs, because of the loss of economies and the imposition of supply-chain market mediation costs (Bailey and Friedlander, 1982; Baumol, Panzar, and Willig, 1983; Randall and Ulrich, 2001). So sustaining a product that is priced distinctly from its sister products is not cost-efficient. By contrast, when manufacturing products are close to each other in terms of prices and product attributes, economies of scope may arise from the sharing or joint utilization of inputs (Bailey and Friedlander, 1982).

Second, when a product's is priced distinctly (i.e. it overlaps less) from its sister products, it is likely to be a peripheral product in the firm's portfolio. For instance, luxury car models are likely the peripheral products of a traditional family-car producer, while economy models are more likely its core products. The core-periphery distinction is important for product demography as firms are more likely to withdraw peripheral products and focus on their cores (Leonard-Barton, 1992). For a start, peripheral products do not fit well with the market identity of a firm (Zuckerman, 2000; Wang and Jensen, 2018). For example, a luxury model introduced by a family-car producer is less likely to be accepted by the market because the company's core identity is in the economy-car segment. Even though the model leads to less overlaps with the producer's other economy models, it might be withdrawn to clarify the producer's identity. Moreover, withdrawing a peripheral product faces less resistance than retiring a core item, as it will not reduce the synergy among the remaining products. By contrast, the market is liable to react negatively to the withdrawal of core products

(Montgomery, Thomas, and Kamath, 1984).

In sum, existing theories prompt two contrasting predictions with respect to the relationship between internal price density and product exit. More intuitively, internal price density increases the likelihood of product exit, because such a product is more likely to be cannibalized. Conversely, when a product has a larger price density within the focal firm, it is closer to the firm's core business, fits well with its market identity, and is more likely to have synergies with other products. As such, we hypothesize that,

> Hypothesis 2A: The exit rate of a product from the market increases with its *internal price density within the focal firm* (i.e. niche density within the focal multiproduct firm's product space).
> Hypothesis 2B: The exit rate of a product from the market decreases with its *internal price density within the focal firm* (i.e. niche density within the focal multiproduct firm's product space).

Product entry

Product entry here concerns where in the price spectrum new products are likely to emerge. When developing new products, managers make key decisions about how similar new products should be to existing products (Baum and Haveman, 1997). When new products are too similar to most of the existing ones (i.e. they overlap with existing product niches), it is difficult to woo the customer. However, when new products are too differentiated, firms may have to launch extensive campaigns to gain legitimacy. That is, existing products shape the market structure and niches that create or constrain opportunities for new products. Niches are the reference points around which mangers conceptualize their competitive positions vis-à-vis those of potential rivals (White, 1981; Baum and Haveman, 1997). The decisions on product entry hence mean the selection of niches for new products (Greve, 2000). However, knowledge is limited about the role of price density in determining product entry, although price is one of the key factors that firms refer to and compare in the market when making decisions of this nature (White, 1981).

Does price density increase or decrease the rate of product entry? On the one hand, as argued above, when a product's *external price niche* is dense, there exists intense competition with more overlapping product niches in the market, leading to lower marginal returns. When aware of the lower margins, firms may be hesitant to launch new products in such a niche. Moreover, according to White (1981), each firm seeks to be distinctive, and therefore to limit competition, by defining its unique niches in terms of product attributes or prices (Baum and Haveman, 1997). Launching new products in a dense niche makes it difficult for firms to distinguish their offerings from those of other firms in the market. As a result, when firms seek distinction or strong profit margins, they are less likely to enter dense price niches.

On the other hand, however, there are two reasons that suggest the opposite. First, the overall market demand in dense niches is large. When making decisions about product entry, managers usually focus on the overall attractiveness of a niche, but dwell less upon how much they can share from the niche. That is both because firms tend to follow the broad consensus of reducing uncertainty about niche choices (Pontikes and Barnett, 2017), and because their own market shares are impossible to visualize before entry. As such, firms may want to launch new products in dense price niches where they see a large demand.

Second, density-based competition may also foster new product introductions as competition drives neck-and-neck firms to innovate (Aghion, Bloom, Blundell, Griffith, and Howitt, 2005). While Schumpeter (1950) proposes a negative association between competition and firms' innovation incentive, competition, in fact, increases the incremental profits from innovating, and thereby encourages innovation (Aghion et al., 2005). Under the pressure of increased competition, firms are forced to innovate to obtain technological proficiency and win competition with its rivals (Li and Calantone, 1998; Delgado, Porter, and Stern, 2010). That is, while the returns to new products are lower in dense price niches, neck-and-neck competition leads to higher pressure to innovate and drives firms to launch more new products in the niches (Aghion et al., 2005; Delgado et al., 2010; Hashimi, 2013). Meanwhile, dense niches often contain a greater number of products and product attributes, which gives firms more opportunity to recombine various attributes and components in the form of new products in the niches (Fleming, 2001; Delgado et al., 2010). As such, dense price niches may offer more opportunities for the emergence of new products. By contrast, in a deserted niche with only a few products, recombination of existing components is limited, thus constraining new product development in the niche. As such, we have two contrasting predictions about the relationship between external price density and new product introductions.

> Hypothesis 3A: New products are less likely to enter the niches when *external price density in the market* is high (i.e. niche density in the whole product space).
> Hypothesis 3B: New products are more likely to enter the niches when *external price density in the market* is high (i.e. niche density in the whole product space).

When a product's *internal price niche* is denser, the likelihood of product entry in the niche is lower. First, the focal firm is less likely to launch new products in the niche. When it is crowded with many products from the same firm, the niche is more likely to be the firm's core. Firms often have a better set of knowledge and skills connected to their core businesses, which enables them to easily launch new products around their cores (Leonard-Barton, 1992; Martin and Mitchell, 1998). However, when a niche is well covered by a firm, market demand is often satiated by its existing products. Introducing additional products brings less added-value and is prone to escalate intrafirm competition (Ruebeck, 2005). By contrast, when a niche is less covered for a firm, launching new products is less likely to cannibalize existing products. Firms are often motivated to develop new products in their open niches in order to explore new opportunities and to improve the complementarity and flexibility of their mix of products. Indeed, Bernard et al. (2010) find that firms frequently alter their blend of products and many of them launch new products outside their existing set of industry segments. As such, we expect that a firm may be more likely to launch new products in the niches that are not densely covered by it.

Second, rival firms are also less likely to launch new products in a focal firm's dense niche. When a niche is densely covered by a set of products belonging to a firm, the firm is likely to establish competitive advantages around the niche. This makes it harder for rival firms to conquer the niche. If rival firms launch new products around the niche, they would expect more intense retaliation from the focal firm because the niche is its core (Chen, 1996). Conversely, when a niche is less crowded with products from the focal firm, the niche is vulnerable and can be more easily conquered by rival firms. Meanwhile, a niche is likely to be assiduously exploited by the focal firm which will have launched many similar products around it. The profit margin in the niche shrinks, making it less attractive to rival firms. All in all, both the focal firm and rival firms are less likely to launch new products in the niches where the focal firm's price density is high.

> Hypothesis 4: New products are less likely to enter the niches where *internal price density within the focal firm* is high (i.e. niche density in the within-firm product space).

Methods

We tested the hypotheses in the workstation industry of North America.[4] The industry is well suited to our empirical analysis for several reasons. First, product entry and exit are frequent in this industry, making it appropriate to examine product demography (Wang and Chen, 2018). Figure 3 presents product (3A) and organization demography (3B) in the workstation industry. The demography of products and firms shows quite similar dynamics. Second, product price in the industry is a good reflection of market segmentation in the vertical dimension, as "high-end machines can cost more than ten times what low-end workstations do"

[4] The sample starts from 1980 when Apollo released its very first workstation, the Apollo DOMAIN, in October 1980. It ends in 1996 when the Windows NT operation system Version 4.0 became available, closing the gap between workstations and personal computers.

(Sorenson, 2000: 584) and “the challenges involved in producing the cheapest machine possible differ greatly from those associated with maximizing performance.” (Sorenson et al., 2006: 923) Third, the industry is notable for the quantitative nature of workstations’ characteristics and buyers’ quantitative evaluation of them (Ruebeck, 2005), making econometric analyses feasible.

INSERT FIGURE 3 AROUND HERE

We accessed the database on workstation firms and products between 1980 and 1996 through the FIVES project (Helfat and Klepper, 2007). The database was originally constructed by Sorenson (2008). It was mainly coded from Data Sources, a catalog published by Information Access Company of Foster City, California, which recorded all products in the workstation industry. Other sources (e.g. the IDC Processor Survey, Lexis-Nexis) were used to supplement the primary source. The final dataset includes both firm-level (e.g. year of founding, sales, zip code, vertical integration) and product-level information (e.g. CPU, OS, and price). Although this sample has been used to analyze the effects of product scope and innovation on firm performance and industry evolution, much of the data remains unexplored (Sorenson, 2008). In particular, while prior studies have closely studied firm-level evolution (e.g., Sorenson, 2003), little has been done in respect of product-level dynamics in the industry.

This study focuses on product dynamics by utilizing the rich product-level data in the workstation industry (Wang and Chen, 2018). In particular, the complete information on products and prices allows us to examine the hypotheses on price density and product demography. The final sample for product exit includes a total of 2,402 product-years for 1,123 products from 134 firms, while the sample for product entry covers 2,109 product-years for 1,035 products from 129 firms.[5] We used a similar set of variables in the analysis of both product entry and exit (Greenstein and Wade, 1998; de Figueiredo and Kyle, 2006).

Dependent variables and Estimation Approach

Product exit. The dependent variable is the hazard rate of product exit, expressed as the exit likelihood of a product occurring at year $t+1$, conditional on the product not having been withdrawn at year t. A product enters the risk set when it first appears in the dataset. Product exit occurs when a product is no longer sold in the market. We employed discrete-time event history analyses to model product exit with clustered-robust firm-level standard errors. To avoid misspecification, we used the Cox proportional hazard model, which is more flexible when it is hard to specify the time dependence of the hazard rate (Greve and Zhang, 2017; Wang and Chen, 2018). The Cox model can be specified as:

$$H(t)=h(t)exp\{\beta X(t)\}$$

where $H(t)$ is the hazard rate of product exit, $h(t)$ is an unspecified baseline rate, and β represents a vector of parameters for explanatory variables $X(t)$. We reported clustered-robust standard errors to account for the nested nature of data structure and the potential issue of heteroscedasticity and serial correlation (Piao and Zajac, 2016).

Product entry. The dependent variable is the likelihood that new products emerge in a product niche. Product entry occurs in a product i's price niche when a new product j is introduced to the market at year $t+1$ with a price that is closest to i's price. All products (N=m) at year t enter the risk set of experiencing new product entry in their niches. They were paired with all new products (N=q) introduced at year $t+1$, generating $m \times q$ pairs. Absolute price differences were calculated for all the pairs. For each new product j, we then identified the existing product i, when the absolute price difference between i and j is lowest among all the

[5] In total, the original sample includes 175 firms (690 firm-years) and 1,276 products (2,735 product-years).

possible pairs for *j*. Product *i* was hence treated as experiencing new product entry in its niche, with a value of 1, and 0 otherwise. See Appendix A for a hypothetical example. Since the dependent variable of product entry is dichotomous, we employed the following logistic regression model to assess the effect of price density on product entry:

$$log\,\frac{\pi}{1-\pi} = \alpha + X'(t)\beta$$

where π is the dependent variable occurring ($1-\pi$ is the probability of the event not occurring), α is a constant, and β represents a vector of parameters for explanatory variables $X(t)$. We reported clustered-robust standard errors to account for heteroscedasticity and autocorrelation in the data across products (Kacperczyk, 2013). We also included year dummies to account for time variance.[6]

Independent Variables

External price density in market. Following prior approaches (Sorenson and Audia, 2000), we constructed a measure of price density for each product for each year it existed, by weighting the contribution to the measure of each alter product according to the inverse of the price distance between the focal product and each alter. We then summed these weighted contributions across all products. Specifically, we used the following equation to calculate price density, *PD*, for product *i* at year *t*:

$$PD_{it} = \frac{\sum_j \frac{1}{(1+d_{ijt})}}{N_t - 1}$$

where *j* indexes all products in the market other than *i* at *t*, d_{ijt} denotes the logarithm-transformed absolute price distance between *i* and *j* at *t*, and N_t is the number of products in

[6] Not all year dummies were included in the estimates. We controlled for the number of firms and the number of products in market, which were measured annually and hence perfectly correlated with year dummies in the same models. Stata automatically excluded two year dummies, both of which served as reference points. The selection of the specific pair of reference years, however, does not affect our results. Moreover, all results remain consistent if we drop year dummies.

the market at t.[7] We standardized the traditional density measure with N_t in order to distinguish price density from population density (Kalnins, 2016). The unstandardized density measure will be highly contingent on population density (i.e. the number of products).[8] The fact that the number of products might well increase competition is handled by including population density measures (Kalnins, 2016). According to this measure, external price density in 1990 is highest (= 11.19) at the price of $15,000, and lowest (= 7.59) at the price of $174,900. This is consistent with the simple illustration in Figure 1.

Internal price density within focal firm. Similarly, we created a measure of a product's price density within its firm. We used the same equation as above, but only compared a product's price with the other products introduced by the same firm. According to this measure, internal price density for Silicon Graphics in 1990 is highest (= 10.12) at the price of $54,900, and lowest (8.53) at the price of $72,400.

Control Variables

We controlled for a set of firm-level variables because product strategy is contingent on a firm's competition positions and strategy. First, we included a density measure in geographic space. **Spatial density for focal firm** was controlled for by calculating the extent to which a firm is located close to its competitors (Sorenson and Audia, 2000). Thus, we measured spatial density, *SD*, for firm i at t using the following equation:

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[7] We have no information on the product and sales volumes of workstations, making it impossible for us to control for the market performance of each workstation (Wang and Chen, 2018). It limits our operationalization of density measures. With available data, researchers may refine the measures of niche density by weighing products' volumes, because products with smaller volumes would contribute less to the niche density of other products.

[8] For example, imagine a market at t with three products (i, a, and b) with the same price. The unstandardized price density for the focal product i is 2. At $t+1$, product a and product b change their price, and four other products enter the market. All of the six alter products have the same market price, that is at a distance of 1 from the focal product i. The unstandardized price density for the focal product i is 3 at $t+1$, which is larger than t, because of the additional products. But the price space for the focal product i is intuitively denser at t. However, standardizing leads to a lower variation of this measure. In an unreported analysis, we used an unstandardized measure, which had a larger coefficient of variation, and found quite consistent results.

$$SD_{it} = \frac{\sum_j \frac{1}{(1+d_{ijt})}}{N_t - 1}$$

where j indexes all firms in the market other than i at t, d_{ijt} denotes the spatial distance between i and j at t, and N_t is the number of firms in the market at t. d_{ijt} was calculated as:

$$d_{ijt}=C\{acrcoss[sin(lat_i)sin(lat_j)+ cos(lat_i)cost(lat_j)cos(|long_i-long_j|)]\},$$

where latitude (*lat*) and longitude (*long*) are measured in radians and C is 34.37 (hundreds of miles) and represents the constant based on the radius of the globe that converts the result into linear units of measure (Sorensen and Stuart, 2001; Kacperczyk, 2013; Wang, 2018). Competition at the product-level may not localize geographically, because workstations produced by spatially distant firms would still compete fiercely when sold in the same shops. However, workstation firms in the neighborhood are still likely to compete more on the labor side (Sorenson, 2005).

We used two variables to control for the fact that product exit is driven by intrafirm competition (Ruebeck, 2005; Requena-Silvente and Walker, 2005). **Number of products by focal firm** counts the total number of products supplied by the focal firm at t (Cottrell and Nault, 2004)**; Proportion of new products by focal firm** divides the number of new products by the total number of products produced by the focal firm at t. Introducing a large proportion of new products simultaneously can affect products' and firms' success or failure (Cottrell and Nault, 2004; Barnett and Freeman, 2001).

Firm size was measured as the logarithm-transformed firm sales across all markets in U.S. dollars; **Firm age** was calculated as the difference between the focal year and a firm's founding year. **Vertical integration**, which may buffer activities within firms against instability, was included by counting the number of key component categories (i.e. CPU, RAM, OS, software applications, communication hardware, monitor, hard disk drive, and motherboard) that a firm internally supplies (Sorenson, 2003). ***De novo*** firms (entrepreneurial start-ups) differ from *de alio* firms (entrants from another industry) in their initial resource endowments and experience, which leads to different product dynamics (Khessina and Carroll, 2008). A firm was defined as *de novo* (with a value of 1) if its founding year is the same as the year when it first entered the workstation market.

We controlled for a set of factors in technological space. Specifically, we focused on CPUs used in workstations. The CPU is the brain of workstations because it contains the arithmetic and logic component, core memory, and control unit, which dictate a workstation's computation capability (Hui, 2004; Bayus and Agarwal, 2007). As such, CPU is the most rudimentary way to describe the technological performance of computers. We controlled for a product's **technology density** by counting the number of workstations using the same CPU as the focal product at *t*, which captures the density in technological space. We included a variable of **CPU age** by calculating the difference between focal year and the first year when the CPU was first used by any firms in the workstation industry. It captures the extent to which a product adopts novel technologies. While staying near the technological frontier is important for success (Fontana and Nesta, 2009), research also finds that firms who trail the leader innovate more (Lerner, 1997). However, CPU information is not available for all products, so we added a dummy variable, **CPU unknown**.[9] We controlled for density in the marketplace. **Number of products in market** counts the number of all workstation products provided by all firms at *t*; **number of firms** counts the number of firms that supplied workstation products at *t*. Finally, we added two dummy variables to capture if a product belongs to the **high-end segment** or the **low-end segment** because product dynamics may differ across vertical product segments (Requena-Silvente and Walker, 2005). A product is defined as belonging to the high-end segment (low-end segment) if its price is at the top

[9] In addition to the CPU, the OS (operation system) is another important component for workstations (Sorenson et al., 2006), as the CPU and OS collectively determine how much RAM can be utilized. In an unreported analysis, we added a similar set of variables (i.e., technology density in OS and OS age) and found consistent results.

(bottom) 25% of all product prices, and the middle-end segment (middle 50%) is left as the comparison group. We used different cutoffs for sensitivity tests, and the results are robust.

RESULTS

INSERT TABLE 1 AROUND HERE

Product exit

Descriptive statistics and correlations are presented in Table 1.[10] Table 2 provides results on product exit from Cox proportional hazard regressions. Model 1 includes only control variables. Model 2 includes *external price density in market*, which is positive and significant ($\beta = 0.208$, $p < 0.001$; hazard ratio =1.23). It suggests that as external price density increases by one unit, and all other variables are held constant, the rate of product exit increases by 23%. The effect is substantial. Specifically, a 1% increase of a product's external price density leads to an increase in its exit rate of between 1.06% (4.63 × 1% × 23%) and 3.13% (13.61 × 1% × 23%). Its effect size becomes even larger in the later models. Our Hypothesis 1 – that the exit rate of a product from the market increases with its *external price density* – is supported.

INSERT TABLE 2 AROUND HERE

Model 3 includes *internal price density within the focal firm*, which is negative and marginally significant ($\beta = -1.381$, $p = 0.067$; hazard ratio =0.25). As the internal price density increases by one unit, and all other variables are held constant, the rate of product exit decreases by 75%. Specifically, a 1% increase of a product's internal price density leads to a decrease in its exit rate of between 0.0075% (0.01 × 1% × 75%) and 0.375% (0.50 × 1% ×

[10] Several variables show high pairwise correlations (e.g. number of firms and number of products in market, vertical integration and firm age). We conducted VIF test for both samples and found that multicollinearity is less likely to bias our estimates. In the product exit sample, VIFs range from 1.28 to 6.42, with a mean VIF of 2.48; in the product entry sample, VIFs range from 1.28 to 4.85, with a mean of 2.30. In an unreported analysis, we ran regression with and without each collinear variable (Kalnins, 2018) and found consistent results.

75%). This (marginally) supports our Hypothesis 2B, that the exit rate of a product from the market decreases with its *internal price density*, rejecting Hypothesis 2A on the cannibalization effect. Results are further confirmed in the full Model 4.[11]

Models 5-12 provide several extensions and robustness checks. First of all, while we theorize a general effect of price density, we extended our analysis to see if the effect is asymmetric. Because price is vertical rather than horizontal, it raises the question of whether one considers price density above the product price in the same way as density below. So following prior methods (Bothner, Kang, and Stuart, 2007), we split the price density measures into two: one for products above the focal product in price, the other for those below. Results are shown in Model 5. Interestingly, the effect of price density is indeed asymmetric. While price density above a focal product's price increases its exit rate ($\beta = 0.195$; s.e. = 0.089), the density below decreases the likelihood of its exit ($\beta = -0.011$; s.e. = 0.005). This seems counterintuitive since cheaper products should intensity competition even more. However, if price is the indicator of product quality, cheaper products mean lower-quality ones. An increase in the density of lower-quality products would not challenge the focal product's market position, but rather lend greater significance to its high quality, thereby increasing its market viability. Nevertheless, the interesting asymmetry nature of price density demands more theoretical extension and empirical demonstration.

Second, the industry went through two major generations: RISC (reduced instruction set computer) and CISC (complex instruction set computer). RISC emerged in 1988 and became dominant in 1993. Products' dynamics may be different across architecture generations, so we added a variable of RISC in Model 6, to control for whether a workstation uses the RISC architecture (Wang and Chen, 2018). Moreover, product decisions may be

[11] In an unreported analysis, we also controlled for the potential influence of outliers, by winsorizing the two key explanatory variables at the 1st and 99th percentiles of their distributions (Liu, Sherman, and Zhang, 2014). The results stay robust. More specifically, the coefficient of *external price density* stays significant and positive ($\beta = 0.306$, $p < 0.001$), and the coefficient of *internal price density* is significant and negative ($\beta = -2.797$, $p < 0.001$).

contingent on how concentrated market competition is. So in Model 7 we controlled for *product concentration in competitors*. As we do not have sales data, we built a Herfindahl index based on the number of products, with the following formula:

$$\textit{product concentration in competitors}_{\,i} = \sum_{j \neq i} \left(\frac{n_j}{N}\right)^2$$

where n_j is the number of products by competitor j, N is the number of products in the market excluding the products by firm i. Results stay consistent.

Third, our observations end in 1996, which leads to two potential issues (Wang and Chen, 2018). On the one hand, it is unknown whether and when the products in 1996 exited the market. So we removed all observations in 1996 and reported the results in Model 8. On the other hand, the products introduced in 1996 had a much shorter observation period than other products. So we removed all the products entering in 1996 and reported the results in Model 9. Both specifications provide consistent results.

Fourth, we limited our sample to firms with at least three products in a year in order to analyze the effect of *internal price density*. When a firm has two products, their internal price density would be identical. To test if our results are biased by this issue, we conducted an additional analysis in Model 10. Finally, Model 11 removed all products with unknown CPUs, to check if missing information biased our estimates. Results in Models 10 and 11 are consistent with our main findings.

Finally, an important assumption in our estimation is that price density is exogenous. This is less problematic in the analysis of external density, because it is unlikely that the overall price distribution in the market is endogenously shaped by individual firms. The assumption may not hold well for internal density, because a product's internal price density is likely to be contingent on a set of firm-level factors, which may, in turn, affect the product's exit. Trying to address this concern, we stratified Cox models with a stratum for each firm, which allows each strata or firm to have its own baseline hazard rate of product exit (Vittinghoff et al., 2011). This allows us to emphasize the within-firm variance and minimize the concern about across-firm heterogeneity. Results are reported in Model 12 where the effect of internal price density stays negative and significant.

Product entry

Table 3 provides results on product entry from logistic regressions. Model 13 includes only control variables. Model 14 includes *external price density in market*, which is positive and significant ($\beta = 0.228$, $p < 0.05$; odd ratio =1.26). It suggests that as external price density increases by one unit, and all other variables are held constant, the odd ratio of product entry increases by 26%. Specifically, a 1% increase of a product's external price density leads to an increase in its exit rate of between 1.20% ($4.63 \times 1\% \times 26\%$) and 3.54% ($13.61 \times 1\% \times 26\%$). Its effect size becomes larger in the later models. This supports our Hypothesis 3B – that new products are more likely to enter the niches where *external price density in the market* is high – and rejects Hypothesis 3A.

INSERT TABLE 3 AROUND HERE

Model 15 includes *price density within the focal firm*, which is negative and marginally significant ($\beta = -1.766$, $p = 0.099$; hazard ratio =0.17). As the internal price density increases by one unit, and all other variables are held constant, the odd ratio of product entry decreases by 83%. Specifically, a 1% increase of a product's internal price density leads to a decrease in its exit rate of between 0.0083% ($0.01 \times 1\% \times 83\%$) and 0.415% ($0.50 \times 1\% \times 83\%$). Our Hypothesis 4 – that new products are less likely to enter the niches where *internal price density within the focal firm* is high – is hence (marginally) supported

Results are further confirmed in the full Model 16.[12] We conducted several robustness checks and extensions. In Model 17, we controlled for production concentration in competitors. In Model 18, we limited our sample to firms with at least three products in a year. Model 19 removed products with unknown CPUs. In Model 20, we employed conditional (fixed-effects) logit estimation and conditioned our analysis on firms, which allows us to emphasize within-firm variance and minimize the concern about firm heterogeneity (Greve, 2000; Long, 2004). Results stay robust.

We also distinguished product entry by the focal firm from product entry by rival firms. New products entering a product's niche may be launched by either the focal firm or its rivals, and, depending on the initiator, price density may have contrasting effects. We find support for Hypothesis 3 and 4 in Model 21 that predicts product entry by rival firms. However, in Model 22, that analyzes product entry by the focal firm, while *internal price density* stays significant, the effect of *external price density* turns non-significant. This suggests that while rival firms are sensitive to both kinds of price density, the focal firm attends more to internal price density within the firm but cares less about external price density in the market.

Discussion

This paper highlights the effect of price distribution on new product introductions and terminations. While previous studies focus on geographic and technologic concentration to explain product entry and exit, we shift attention to niche density in the price dimension. Specifically, we explored how price niche density affects the likelihood of a product exiting the market and investigated where in the price spectrum new products are more likely to

[12] In an unreported analysis, we also mitigated the potential influence of outliers, by winsorizing the two key explanatory variables at the 1st and 99th percentiles of their distributions (Liu, Sherman, and Zhang, 2014). The results are similar. More specifically, the coefficient of *external price density* is significant and positive (β = 0.425, $p < 0.001$), and the coefficient of *internal price density* is significant and negative (β = -4.391, $p = 0.001$).

emerge. Analyzing a sample of workstation products from 1980 to 1996, we found that while external price density in the market increases an existing product's exit rate, new products are also more likely to emerge where the price density is high. We also considered internal price density within multiproduct firms, analyzing a product's price distance from the other products launched by the same firm. We found that internal price density decreases both existing products' exit rate and new products' entry likelihood. Our emphasis on price space provides important contributions to the existing literature on product demography.

First, we stress the important role of price space in shaping product demography. Product space determines product exit and entry because existing products shape market structure and niches that may create or constrain opportunities. While current studies focus mainly on technologic and geographic distribution in the product space (Ingram and Roberts, 1999; Greve, 2000; Dobrev et al., 2002), price distribution is much less explored. We emphasize that price, as a proxy for a set of key product attributes (e.g. quality, brand, location, and status) (Uzzi and Lancaster, 2004; Beckert, 2011), plays a pronounced role in product decisions. Prices vertically segment products in each horizontal category (e.g. technological segment or geographic location), such that differently-priced products target customers with different budget constraints and quality preferences (Baum and Mezias, 1992; Sorenson, 2000). The vertical distribution of products along the price dimension may thus have important implications for product demography. Supporting this, we find that product entry and exit are both contingent on how product prices are distributed in the market. This suggests that a more complete product space includes both technological and geographic spaces as the horizontal dimension and price space as the vertical dimension.

While we frame price and technology (or geography) as the vertical and horizontal dimensions in product space, respectively, they are not necessarily completely orthogonal. The price of a product depends on its quality, which, in turn, may be related to its technological attributes. However, technology and price are oftentimes independent product decisions, as product price commonly varies according to both technology category and geographic location. For instance, upon entry into certain locations, a hotel company can still choose between luxury and economy offerings; whilst adopting certain technological standards, a firm can still decide whether to introduce high-end or budget applications. That is, while price and technology dimensions may not be completely decoupled, price is frequently independent of technological attributes because it is also affected by many other variables such as product novelty, firm status, and category adherence (Benjamin and Podolny, 1999; Uzzi and Lancaster, 2004; Ody-Brasier and Vermeulen, 2014). Nevertheless, the interdependence between price and technology dimensions should be an important contingency in the produce space framework. While we controlled for geographic and technologic concentration in order to test the effect of price density, future studies may further explore the intersectional cells of the horizontal and vertical dimensions, which allows for finer-grained analysis.

Second, we highlight the internal niche density of products within multiproduct firms. While organizational ecology and demography focuses more on interfirm competition or niche density in the market (Hannan and Freeman, 1989; Bogaert et al., 2016), product demography allows us to explore intrafirm relations between products within multiproduct firms. Emphasizing internal niche density is important for product demography because product exit and entry is the consequence of a firm's strategic decision for its whole portfolio – focusing only on a product's external niche overlooks its relatedness with the other products belonging to the same firm. By analyzing the effect of internal density on the ultimate fates of products, this study emphasizes the interdependence of products from the same firm and hence contributes to the product demography literature.

Third, while scholars in product demography pay substantial attention to product exit (Khessina and Carroll, 2008; Verhaal et al., 2015; Wang and Chen, 2018), the pattern of product entry is not equally covered. Whereas the market entry literature tends to focus on entry into technological or geographic niches (Hsieh and Vermuelen, 2013; Greve, 2000; Haveman, 1993), we extended it to the price dimension. Our findings suggest that the distribution of product prices is indeed a significant factor in determining the emergence of new products. This has important practical implications, as managers are able to adopt our framework to foresee which price ranges are more likely to be 'attacked' by new products. Interestingly, we find that entry occurs in the crowded price niches in the market where we also observe the highest exit rates. This may suggest that producers place too much emphasis on trying to win the product niches that have the greatest consumer demand, but overlook the constraints in those niches. Possibly this is also explained by resource partitioning theory (Carroll and Swaminathan, 2000): when the increased dominance of certain firms or products drives out peripheral generalists (organizations or products) in the crowded price niches, the niches open more spaces to specialists.

There are several caveats that deserve attention and could be addressed in future research. First of all, in analyzing product entry, we mainly examined the entry of new products into existing niches in product space. However, our research design does not allow us to explore the creation of completely new niches. If products are introduced to create a new – and thus empty – niche, the initial density would be zero.[13] In line with our findings that new products are more likely to emerge where the price density is high, one may deduce that when the initial density nears zero, niches are least likely to have new product entries. That is, most firms are less likely to create new niches than to introduce new products to existing

[13] We thank an anonymous reviewer for pointing out this important issue.

niches. Nevertheless, our research does not provide direct evidence about the creation of new niches, which is a key limitation of its generalizability.

Second, while we focus on product-level attributes, firm-level heterogeneity was unfortunately overlooked. That is, while we explored where new products emerge and exit, we paid little attention to who introduces and withdraws those new products. Firms make product decisions in line with their experience, capability, and strategy, which may be markedly different from firm to firm (Stavins, 1995). In particular, de alio firms, those that already operate in other markets, have superior resources and capabilities than de novo firms, especially in emergent industries (Carroll et al., 1996). These abundant resources both enable de alio firms to better establish their market positions, and provide them with a longer period of immunity from market competition (Khessina and Carroll, 2008). As a result, de alio and de novo firms may make different product entry and exit decisions (Carnabuci et al., 2015). For instance, de novo firms may be more likely to create new niches or enter empty niches, in order to avoid fierce competition. Unfortunately, only a few firms in our sample were de novo, which does not allow us to make a meaningful comparison between de novo and de alio firms. Future studies may want to analyze price space together with firm features, bringing firm heterogeneity (in terms of organization form and decision making) back into the equation.

In addition, while we use evidence from the workstation industry, a well-studied context (Sorenson, 2000), the single industry analysis leaves its generalizability uncertain. It would be interesting to explore if our findings are contingent on certain industry-specific features. And because of data limitations, we did not control directly for market demand in the industry. It is, however, well documented that product innovations are also contingent on heterogeneity in market demand (Adner and Levinthal, 2001). Market demand is important to be included in future studies, in order to explore the exact mechanisms through which price density affects product demography. More specifically, in the market niches where price density is high, market demand is likely large. While we observed more product dynamics in such niches, we cannot assert whether this is only driven directly by price density, or is also caused indirectly through the influence of market demand. So we encourage future research to take into account market demand and other confounding factors in order to better understand the relationship between price niches and product demography. Finally, product entry and exit may be tightly connected (Bernard et al., 2010), even though some empirical studies fail to confirm this prediction (e.g. Greenstein and Wade, 1998). So future studies may wish to focus on the interdependence between entry and exit.

Despite the aforementioned limitations, this study emphasizes the important role of price space in shaping product demography, highlights the effects of both external price density in the market and internal price density within multiproduct firms, and establishes empirical evidence on how existing price distribution affects both product exit and entry.

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Table 1A. Descriptive statistics for product exit

	Variables	N	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	External price density in market × 100	2,402	9.60	0.93	4.63	13.61	1.00															
2	Internal price density within focal firm	2,152	0.10	0.05	0.01	0.50	0.38	1.00														
3	Spatial density for focal firm	2,402	1.15	0.85	0.14	3.69	0.04	0.01	1.00													
4	Vertical integration	2,402	2.93	2.51	0.00	7.00	-0.02	-0.06	-0.14	1.00												
5	# products by focal firm (ln)	2,402	2.39	0.99	0.69	3.87	0.13	0.13	0.33	0.57	1.00											
6	% new products by focal firm	2,402	0.46	0.32	0.00	1.00	0.09	0.05	0.01	-0.04	-0.01	1.00										
7	Firm age	2,402	25.11	22.42	0.00	116.00	0.03	-0.02	-0.09	0.65	0.33	-0.06	1.00									
8	Firm size (ln)	2,402	18.88	5.94	0.00	25.04	-0.02	-0.04	0.08	0.59	0.44	-0.10	0.50	1.00								
9	De novo	2,402	0.08	0.27	0.00	1.00	0.01	0.06	-0.01	0.13	0.22	-0.13	-0.22	0.11	1.00							
10	CPU age	2,402	5.76	4.52	0.00	16.00	0.00	-0.16	-0.05	-0.21	-0.38	-0.16	-0.11	-0.15	0.09	1.00						
11	Technology density	2,402	15.58	16.22	0.00	51.00	0.08	0.09	0.25	0.08	0.39	-0.02	-0.02	0.10	0.21	-0.26	1.00					
12	CPU unknown	2,402	0.31	0.46	0.00	1.00	-0.08	-0.14	-0.25	-0.25	-0.58	-0.04	-0.11	-0.23	-0.15	0.62	-0.65	1.00				
13	High-price segment	2,402	0.25	0.43	0.00	1.00	-0.57	-0.16	-0.11	-0.02	-0.14	-0.08	-0.08	-0.01	0.07	0.03	-0.08	0.10	1.00			
14	Low-price segment	2,402	0.26	0.44	0.00	1.00	0.39	0.16	0.21	-0.10	0.16	0.10	0.06	-0.06	-0.13	0.06	0.05	-0.06	-0.34	1.00		
15	# products in market (ln)	2,402	5.45	0.55	2.64	5.91	0.14	-0.03	0.47	0.10	0.42	-0.02	0.20	0.14	-0.08	0.15	0.29	-0.30	-0.17	0.30	1.00	
16	# firms (ln)	2,402	4.00	0.30	2.20	4.38	0.11	-0.09	0.08	0.19	0.20	-0.05	0.17	0.18	0.04	0.24	0.17	-0.14	-0.04	0.10	0.75	1.00

Table 1B. Descriptive statistics for product entry

	Variables	N	Mean	S.D.	Min	Max	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	New product entry	2,109	0.45	0.50	0.00	1.00	1.00																
2	External price density in market × 100	2,109	9.65	0.93	4.63	13.61	0.11	1.00															
3	Internal price density within focal firm	1,872	0.10	0.05	0.01	0.50	-0.01	0.38	1.00														
4	Spatial density for focal firm	2,109	1.01	0.70	0.14	3.30	-0.01	0.13	-0.02	1.00													
5	Vertical integration	2,109	2.97	2.50	0.00	7.00	0.00	-0.01	-0.06	-0.07	1.00												
6	# products by focal firm (ln)	2,109	2.30	0.98	0.69	3.87	-0.02	0.18	0.11	0.29	0.61	1.00											
7	% new products by focal firm	2,109	0.48	0.33	0.00	1.00	-0.04	0.09	0.07	0.07	-0.06	0.03	1.00										
8	Firm age	2,109	24.62	22.10	1.00	115.00	-0.01	0.04	-0.02	-0.08	0.64	0.35	-0.04	1.00									
9	Firm size (ln)	2,109	18.81	5.88	0.00	24.96	0.00	0.00	-0.04	0.09	0.60	0.45	-0.11	0.50	1.00								
10	De novo	2,109	0.09	0.29	0.00	1.00	0.03	-0.01	0.06	0.06	0.14	0.27	-0.16	-0.24	0.13	1.00							
11	CPU age	2,109	5.83	4.44	0.00	15.00	0.02	-0.01	-0.16	-0.03	-0.19	-0.35	-0.18	-0.10	-0.13	0.09	1.00						
12	Technology density	2,109	14.79	16.02	0.00	51.00	-0.06	0.09	0.06	0.26	0.12	0.39	0.03	-0.02	0.13	0.25	-0.24	1.00					
13	CPU unknown	2,109	0.34	0.47	0.00	1.00	0.05	-0.11	-0.13	-0.24	-0.27	-0.56	-0.07	-0.11	-0.23	-0.18	0.61	-0.66	1.00				
14	High-price segment	2,109	0.26	0.44	0.00	1.00	-0.08	-0.58	-0.15	-0.11	-0.04	-0.13	-0.11	-0.08	-0.01	0.06	0.04	-0.06	0.09	1.00			
15	Low-price segment	2,109	0.23	0.42	0.00	1.00	0.12	0.38	0.13	0.18	-0.07	0.13	0.16	0.06	-0.07	-0.12	0.06	-0.01	-0.05	-0.32	1.00		
16	# products in market (ln)	2,109	5.39	0.56	2.64	5.91	-0.05	0.20	-0.04	0.46	0.13	0.40	0.03	0.21	0.14	-0.05	0.18	0.28	-0.28	-0.16	0.29	1.00	
17	# firms (ln)	2,109	4.02	0.32	2.20	4.38	-0.04	0.10	-0.08	0.19	0.19	0.27	-0.08	0.20	0.20	0.02	0.26	0.21	-0.17	-0.06	0.15	0.84	1.00

Table 2. Proportional Hazard Regressions Predicting Product Exit

VARIABLES	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9	Model 10	Model 11	Model 12
Internal price density within focal firm			-1.381†	-2.750***		-2.670***	-2.607***	-2.056**	-2.642***	-2.192**	-4.380***	-2.098*
			(0.755)	(0.716)		(0.705)	(0.721)	(0.698)	(0.707)	(0.762)	(1.022)	(0.940)
External price density in market × 100		0.208***		0.287***		0.287***	0.252***	0.154**	0.265***	0.267***	0.345***	0.175**
		(0.041)		(0.054)		(0.053)	(0.050)	(0.050)	(0.052)	(0.057)	(0.066)	(0.063)
Spatial density for focal firm	-0.180	-0.170	-0.185	-0.174	-0.178	-0.180	-0.183	-0.128	-0.152	-0.179	-0.163	-0.205
	(0.118)	(0.116)	(0.117)	(0.114)	(0.117)	(0.114)	(0.117)	(0.104)	(0.113)	(0.115)	(0.117)	(0.386)
# products by focal firm	0.206*	0.180†	0.173	0.158	0.195†	0.147	0.180	0.157	0.155	0.072	0.185	0.479
	(0.101)	(0.097)	(0.126)	(0.118)	(0.101)	(0.121)	(0.125)	(0.110)	(0.116)	(0.153)	(0.143)	(0.322)
% new products by focal firm	0.462**	0.444**	0.475*	0.438*	0.481**	0.432*	0.417*	0.172	0.345†	0.532*	0.473†	0.069
	(0.165)	(0.164)	(0.200)	(0.198)	(0.166)	(0.195)	(0.200)	(0.183)	(0.192)	(0.232)	(0.280)	(0.351)
Firm age	-0.002	-0.002	0.000	0.000	-0.002	0.000	-0.001	-0.000	0.000	0.001	-0.002	-0.024*
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.005)	(0.012)
Firm size	-0.022†	-0.021†	-0.026†	-0.026†	-0.022†	-0.027†	-0.026†	-0.021†	-0.025†	-0.030†	-0.034*	0.106
	(0.012)	(0.012)	(0.015)	(0.014)	(0.012)	(0.014)	(0.014)	(0.011)	(0.013)	(0.016)	(0.017)	(0.157)
Vertical integration	-0.036	-0.028	-0.043	-0.040	-0.035	-0.039	-0.041	-0.042	-0.040	-0.038	-0.043	-0.227
	(0.043)	(0.042)	(0.049)	(0.046)	(0.043)	(0.046)	(0.048)	(0.045)	(0.045)	(0.050)	(0.056)	(0.212)
De novo	-0.429**	-0.464**	-0.339†	-0.380*	-0.386*	-0.388*	-0.342†	-0.435**	-0.381*	-0.274	-0.373*	
	(0.165)	(0.162)	(0.178)	(0.174)	(0.167)	(0.167)	(0.178)	(0.167)	(0.174)	(0.188)	(0.189)	
CPU age	0.026†	0.025†	0.021	0.017	0.023	0.014	0.016	0.017	0.017	0.017	0.015	0.023
	(0.015)	(0.015)	(0.016)	(0.016)	(0.015)	(0.015)	(0.016)	(0.014)	(0.016)	(0.017)	(0.014)	(0.016)
Technology density	-0.010†	-0.010*	-0.009†	-0.009†	-0.010*	-0.010*	-0.009*	-0.009*	-0.010*	-0.010*	-0.011*	-0.009
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.006)
CPU unknown	-0.276	-0.286†	-0.210	-0.206	-0.261	-0.169	-0.180	-0.184	-0.212	-0.172	-	-0.223
	(0.174)	(0.171)	(0.179)	(0.171)	(0.179)	(0.161)	(0.169)	(0.168)	(0.173)	(0.180)		(0.184)
High-price segment	-0.012	0.209**	0.041	0.330***	-0.016	0.329***	0.293***	0.229**	0.317***	0.318***	0.340***	0.242**
	(0.076)	(0.077)	(0.078)	(0.079)	(0.077)	(0.080)	(0.075)	(0.081)	(0.077)	(0.081)	(0.094)	(0.075)
Low-price segment	-0.153	-0.251*	-0.124	-0.242*	-0.130	-0.211†	-0.221†	-0.173	-0.245*	-0.300*	-0.345*	-0.117
	(0.123)	(0.119)	(0.123)	(0.121)	(0.109)	(0.117)	(0.119)	(0.119)	(0.121)	(0.126)	(0.144)	(0.098)
# products in market	-0.441	-0.377	-0.412	-0.356	-0.514†	-0.400	-0.490	0.288	-0.258	-0.219	-0.346	-0.623
	(0.298)	(0.301)	(0.323)	(0.320)	(0.300)	(0.322)	(0.320)	(0.322)	(0.320)	(0.381)	(0.380)	(0.682)
# firms	1.069*	0.981*	1.057*	0.977†	1.201*	1.036*	1.632**	-0.177	0.798	0.916	1.305*	1.523
	(0.471)	(0.469)	(0.509)	(0.499)	(0.483)	(0.497)	(0.523)	(0.533)	(0.503)	(0.570)	(0.552)	(1.010)
External price density-above					0.195*							
					(0.089)							
External price density-below					-0.011*							
					(0.005)							
CISC						0.121						
						(0.119)						
Product concentration in competitors							11.893**					
							(4.256)					
Observations	2,402	2,402	2,152	2,152	2370	2,152	2,152	1,872	2,067	1,970	1,644	2,152

Robust standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Note: Model 8 removed all observations in 1996; Model 9 removed all the products entering in 1996; Model 10 limited our sample to firms with at least three products in a year; Model 11 removed all products with unknown CPUs; Model 12 employed stratified Cox estimation.

Table 3. Logistic Regressions Predicting Product Entry

VARIABLES	Model 13 PE	Model 14 PE	Model 15 PE	Model 16 PE	Model 17 PE	Model 18 PE	Model 19 PE	Model 20 PE	Model 21 Rivals' PE	Model 22 Focal's PE
Internal price density within focal firm			-1.766†	-3.469***	-3.604***	-4.308*	-5.047***	-3.092**	-3.017**	-6.106**
			(1.069)	(0.966)	(1.024)	(1.989)	(1.318)	(0.986)	(0.949)	(2.125)
External price density in market × 100		0.228*		0.367***	0.373**	0.455***	0.557**	0.344**	0.393***	-0.014
		(0.092)		(0.111)	(0.114)	(0.136)	(0.186)	(0.125)	(0.090)	(0.202)
Spatial density for focal firm	0.069	0.076	0.079	0.086	0.070	0.097	0.116	0.256	-0.020	0.576**
	(0.116)	(0.117)	(0.113)	(0.115)	(0.114)	(0.132)	(0.130)	(0.379)	(0.099)	(0.177)
# products by focal firm	0.010	-0.012	0.090	0.092	0.130	0.188	-0.000	0.085	0.027	0.620**
	(0.097)	(0.095)	(0.119)	(0.122)	(0.117)	(0.144)	(0.156)	(0.231)	(0.126)	(0.239)
% new products by focal firm	-0.407*	-0.413*	-0.472*	-0.487*	-0.506*	-0.572*	-0.633*	-0.591*	-0.529*	-0.563
	(0.178)	(0.174)	(0.231)	(0.228)	(0.231)	(0.275)	(0.310)	(0.281)	(0.266)	(0.399)
Firm age	-0.000	-0.000	-0.002	-0.002	-0.003	0.000	-0.002	0.008	0.001	-0.010†
	(0.003)	(0.003)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.006)	(0.003)	(0.006)
Firm size	-0.003	-0.003	-0.010	-0.010	-0.010	-0.010	-0.013	-0.061	-0.018	0.058†
	(0.013)	(0.013)	(0.016)	(0.016)	(0.016)	(0.020)	(0.019)	(0.124)	(0.015)	(0.033)
Vertical integration	0.006	0.013	0.018	0.017	0.022	-0.014	0.026	-0.025	0.013	-0.068
	(0.040)	(0.040)	(0.042)	(0.041)	(0.042)	(0.049)	(0.054)	(0.114)	(0.042)	(0.099)
De novo	0.349*	0.314*	0.261	0.208	0.241	0.144	0.323	-	0.204	-0.119
	(0.154)	(0.156)	(0.182)	(0.192)	(0.199)	(0.203)	(0.231)		(0.178)	(0.327)
CPU age	-0.022	-0.021	-0.021	-0.022	-0.019	-0.018	-0.041*	-0.024	-0.009	-0.073
	(0.017)	(0.017)	(0.019)	(0.019)	(0.019)	(0.020)	(0.019)	(0.020)	(0.020)	(0.051)
Technology density	-0.001	-0.001	-0.000	-0.001	-0.001	-0.000	-0.000	0.005	-0.001	-0.003
	(0.004)	(0.003)	(0.004)	(0.003)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.008)
CPU unknown	0.356†	0.344†	0.305	0.279	0.262	0.295	-	0.395†	0.238	-0.002
	(0.204)	(0.197)	(0.216)	(0.206)	(0.213)	(0.236)		(0.230)	(0.213)	(0.454)
High-price segment	-0.291*	-0.062	-0.274†	0.068	0.065	0.141	0.232	-0.100	0.088	-0.252
	(0.127)	(0.126)	(0.141)	(0.137)	(0.139)	(0.155)	(0.182)	(0.150)	(0.121)	(0.428)
Low-price segment	0.736***	0.644***	0.797***	0.665***	0.656***	0.655***	0.637***	0.833***	0.614***	1.029**
	(0.152)	(0.145)	(0.152)	(0.148)	(0.150)	(0.166)	(0.176)	(0.147)	(0.152)	(0.336)
# products in market	-5.234***	-4.794***	-6.171***	-6.037***	-5.068**	-6.626***	-5.648**	-5.989*	-6.455***	-7.149**
	(1.380)	(1.404)	(1.451)	(1.582)	(1.821)	(1.758)	(1.843)	(2.394)	(1.536)	(2.666)
# firms	8.368**	7.044**	10.938***	10.897***	10.019***	12.168***	10.398**	9.747*	11.803***	12.244*
	(2.623)	(2.660)	(2.657)	(2.930)	(2.936)	(3.237)	(3.597)	(4.526)	(2.864)	(5.047)
Product concentration in competitors					13.205					
					(14.933)					
Constant	-3.304	-2.804	-8.005***	-12.080***	-15.148**	-14.790***	-13.693**		-13.347***	-12.145*
	(3.293)	(3.349)	(2.184)	(2.997)	(5.125)	(3.240)	(4.720)		(3.119)	(4.993)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,109	2,109	1,872	1,872	1,872	1,708	1,390	1,843	1,872	1,872

Robust standard errors in parentheses; *** p<0.001, ** p<0.01, * p<0.05, † p<0.10

Note: Model 18 limited our sample to firms with at least three products in a year; Model 19 removed all products with unknown CPUs; Model 20 employed conditional logit models; Model 21 analyzed product entry by rival firms while Model 22 analyzed product entry by focal firm.

Figure 1. External price density in 1990 and product entry and exit in 1991

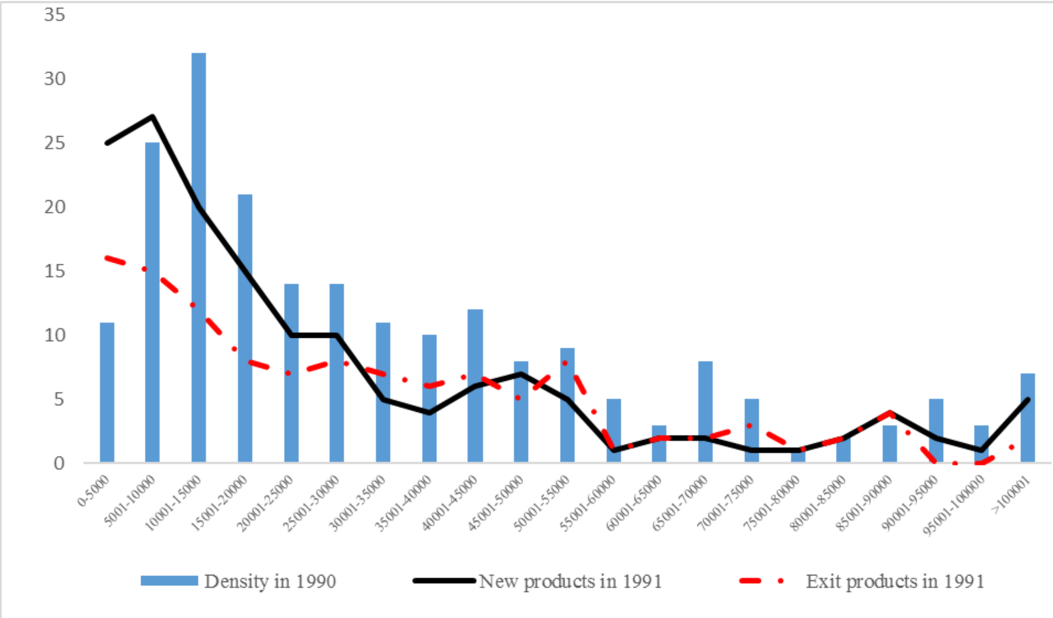


Figure 2. Internal price density in Silicon Graphics, 1990-1994

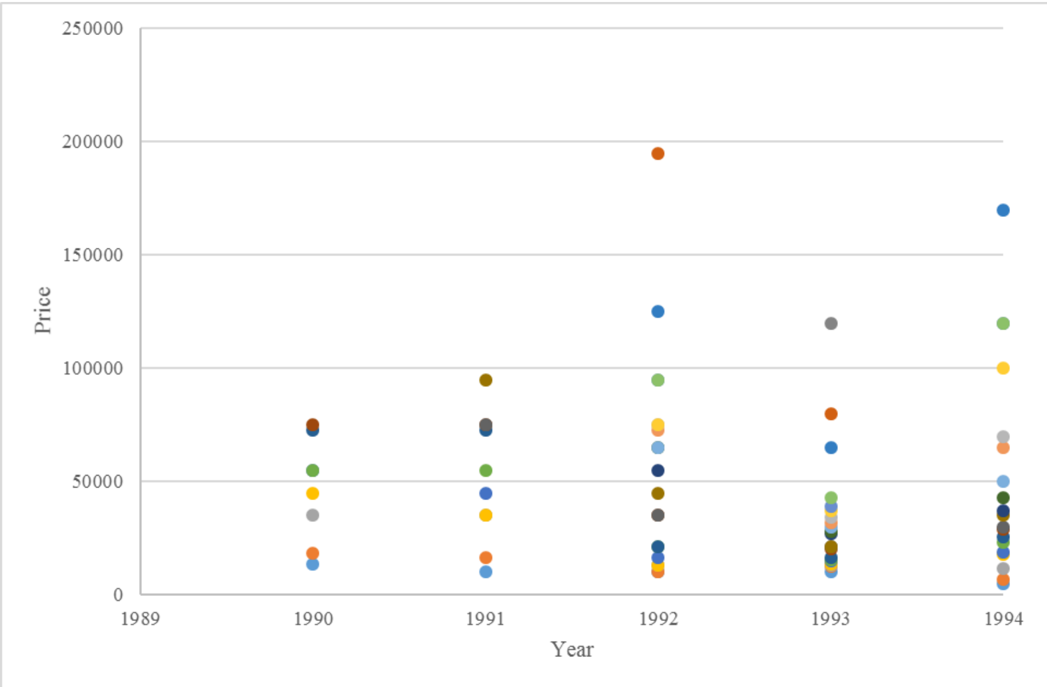


Figure 3A. Product entry and exit

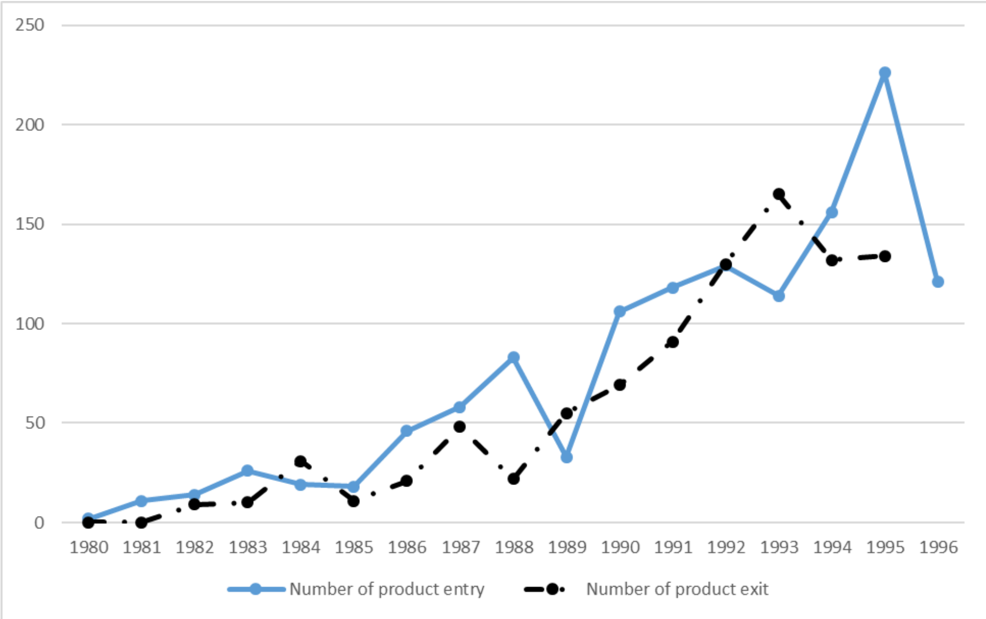
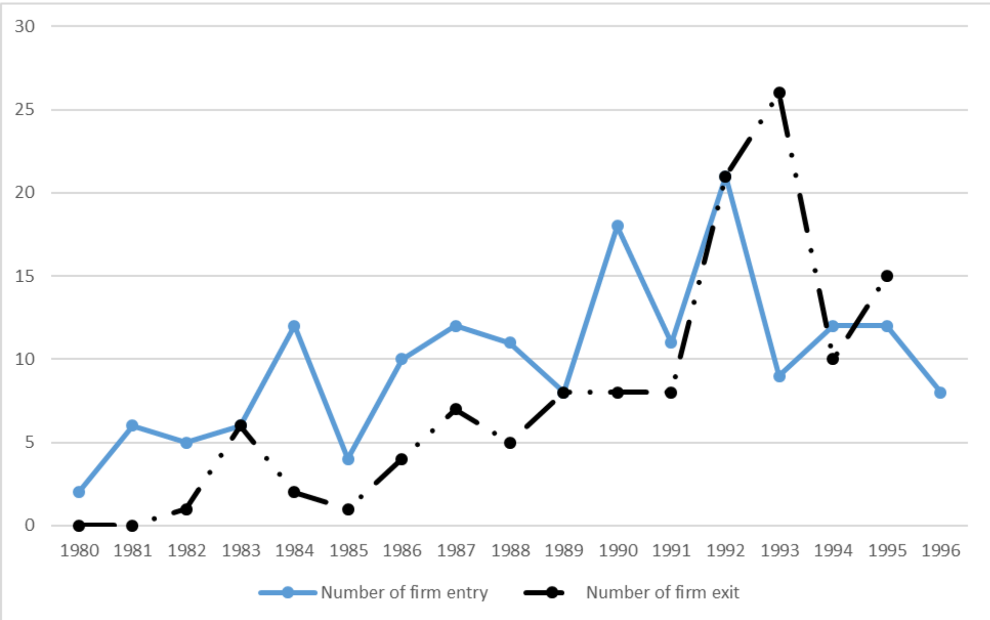


Figure 3B. Firm entry and exit



Appendix A. Measures of Product Entry

Suppose that there are three products *a*, *b*, and *c* in the market at *t*, with prices of 100, 200, and 300 dollars, respectively, as shown in Table A1. A new product *d* is introduced at *t+1* with a price of 220 dollars. *d* is identified as entering the vicinity of product *b*'s price niche because the absolute price difference between products *b* and *d* is smallest (i.e. 20 dollars). The dependent variable will be 1 for product *b*, and 0 for *a* and *c*.

Table A1. Measures of Product Entry

Products at *t-1*	Price	New product at *t*	Product-pair	*d*'s Price	Price difference	Product entry (DV)
a	100	*d*	*a-d*	220	120	0
b	200	*d*	*b-d*	220	20	1
c	300	*d*	*c-d*	220	80	0