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A Competitive Analysis of Fail Fast: Shakeout and Uncertainty about Consumer Tastes[1]

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Abstract

Contemporary business strategy advocates "fail fast", the practice of launching a product early, before the resolution of uncertainty about how product characteristics matter to consumers. We consider how uncertainty about consumer preferences can contribute to shakeout when moving from the infant stage of an industry, when this uncertainty is large, to the mature stage of an industry, when this uncertainty is small. We find that, consistent with the empirical literature, due to firms' uncertainty about consumers' preferences, there is excessive entry initially and, on average, positive shakeout in the number of firms in the market in the mature phase of the industry. The paper also presents a new way to model uncertain preferences in product differentiation models that may prove useful in other applications.

Keywords: Salop; fail fast; lean startup; preference uncertainty; shakeout; product life cycle; spatial competition, market structure, entry and exit.
JEL Codes: D43, L11, L13, R32

1 Introduction

Experimentation is a key component of modern entrepreneurship and start-up culture (Kerr et al. (2014)). Silicon Valley tech firms are strong proponents of experimentation through a strategy of "failing early and often" and then "pivoting" (O'Connor and Klebahn (2011)). The lean start-up movement championed by Ries (2011) takes this experimentation strategy as the central organizing principle of start-ups: launch a Minimally Viable Product as quickly as possible and focus on learning from customers.[1] The approach has been extremely successful for a range of high profile firms such as DropBox and Twitter (Stross (2013)).

This strategy, which we will simply refer to as *fail-fast*, advocates launching a product early, before the resolution of uncertainty about how product characteristics matter to consumers. "In the complex digital revolution era, trying to predict, control, and eliminate variances is a losing game. Reducing variance inevitably meets the law of diminishing marginal returns: the cost of reducing variance eventually exceeds the benefit."(Giles (2018)).[2] Developing a product early under considerable uncertainty and learning important facts about one's business environment over time through experimentation and exploratory learning is also an attractive strategy for other high tech industries/products like pharmaceuticals (Khanna et al. (2015)).

Our goal is to provide a simple competitive framework in which we can analyze the industry level implications of the fail-fast strategy. We seek to understand how uncertainty about consumers' perceived differences between products affect market structure as an industry matures — at maturity uncertainty about consumer preferences is resolved. Two issues are of particular interest. First, the issue is to identify if the shakeout typical of maturing industries in the old economy is to be expected in the new economy industries. The question is open because the traditional theories focus on cost uncertainty rather than uncertainty about how products appeal to consumers, and the latter appears to be at the heart of developments in many of the new economy industries. Second, what are the welfare implications of fail-fast?

Both the related academic and practitioner literatures tend to focus on the organizational and management aspects of the fail-fast strategy for a firm in isolation (McGrath and MacMillan (1995); McGrath (2010); Guler (2018); Eggers and Suh (2019)). McGrath (1999) is seminal in taking a broader perspective by describing these fail-fast experiments as a portfolio of real options, but even within the real

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[1] Although not the focus of this paper, an interesting literature on co-creation has emerged in marketing which focuses on the details of how firms should interact with customers. See, for example, Prahalad and Ramaswamy (2004) and Payne et al. (2008).

[2] The approach also has its detractors, for example McGinn (2012) and Kressel and Winarsky (2015).

options framework the issues of competitive equilibrium are suppressed.

We address this gap in the existing literature by developing a novel model of differentiated products oligopoly corresponding to the situations described in the fail-fast literature. Specifically, we extend the Salop (1979) circle model to 2 dimensions in order to include preference uncertainty that is separate from the technical characteristics of products. This framework then allows us to investigate equilibrium behavior and social welfare outcomes. Similar to the existing fail-fast or lean start-up literatures our competitive analysis predicts it is optimal for firms to enter before the uncertainty about preferences is resolved. However, this equilibrium strategy leads on average to a reduction in the number of firms over time as uncertainty about consumer's valuations of products is resolved.[3]

The industry life cycle (infant to maturity) has been extensively empirically studied previously, although the bulk of these studies has focused on traditional manufacturing industries. The narrowing in product diversity over the product life cycle or the reduction in the number of firms in the mature phase of an industry has been documented for a large number of industries (Abernathy and Utterback (1978); Abernathy and Clark (1985)) including, for example, propulsion, landing gear and air frames in airplane component industries (Tushman and Murmann (1998)), U.S. automobiles (Raff and Trajtenberg (1997)), lasers (Klepper and Thompson (2006)), and U.S. tires (Klepper and Simons (2000)). This phenomenon is usually termed[4] *shakeout*.[5]

The traditional theoretical models of the industry life cycle, learning, and shakeout tend to focus on unit costs. In Jovanovic (1982)'s classic model, firms learning their costs drive the industry dynamics. Firms enter a new Cournot industry uncertain of their individual costs. They learn about their costs over time, with firms receiving signals of high costs exiting soon after entry and firms which remain becoming more certain that they have low costs, and only very rarely finding that they have high costs. Product characteristics are not part of this model.

Later papers have explored the relationship between unit costs and the scale of output, with economies of scale in the mature phase of the market leading to a decrease in the number of firms (for example, Petrakis and Roy (1999) and Götz (2002)). As an alternative, Allanson and Montagna (2005) explore the role of

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[3] We explicitly exclude economies of scale, sunk cost, endogenous learning, dynamic links between periods, etc., in order to demonstrate that the reduction of uncertainty of firms about consumer preferences alone can lead to shakeout. Of course, this does not preclude other mechanisms from having an important role in the real world.

[4] The narrower term *consolidation* refers to shakeout through acquisition(s) rather than exit.

[5] Many prominent contemporary tech industries exhibit strong network externalities and hence a new winner tends to displace the incumbent, e.g. Facebook and MySpace. However, not all tech industries display this pattern, for example, online food delivery looks more like a differentiated oligopoly with a few major players and small margins. Similar to the manufacturing studies online food delivery is currently experiencing shakeout/consolidation (The Economist, 2019).

economies of scope in shakeout using a representative consumer (Dixit and Stiglitz (1977)). Other recent explanations are demand size uncertainty (Barbarino and Jovanovic (2007)) and uncertainty about relative cost positions (Bertomeu (2009)) and stochastic dynamics. However, the issues of strategic interaction in pricing and product characteristics which are fundamental to both our model and the fail-fast literature are usually side-stepped by the existing theories.

Another strand of economic research considers firms with idiosyncratic information or uncertainty, e.g. Jovanovic (1981), with the recent focus on learning, for example, Meagher (1996), Chang and Harrington (2003), Meagher et al. (2004) and Meagher and Wang (2014). This group of papers investigates dynamic models with a focus on the impact of uncertainty on the decision making process (centralization or decentralization) of an organization with a fixed industry structure.

The plan of the paper is as follows. Following the description of our model in section 2, we derive the results for the short run version and characterize the equilibrium market structure under uncertainty in section 3. In section 4, we focus on the long run version and derive the results for the industrial shakeout. In section 5, we investigate comparative statics and in section 6, we analyze welfare. In section 7, we conclude.

2 Model and Timing

This section presents the model, its assumptions and the timing of the game in both its short run and long run versions.

2.1 Extension of Salop's Circle Model

The basis for our analysis is the circular city model developed by Salop (1979). We take the Anderson et al. (1992) standard generalization of the Salop circle model in which consumers purchase one unit of their preferred variety of the differentiated product, given a class of power transport cost functions. We make two extensions to this standard framework: first, we utilize two dimensions, with firms' locations represented by rays instead of the standard points in the characteristic space; second, we introduce a common uncertainty, on the part of firms, about the preferences of consumers. This novel model may prove useful in other applications.

The 2-dimensional characteristic space is represented in polar coordinates, (θ, r), where θ is the angle in radians with the (positive part of the) horizontal axis and r is the distance of consumers from the origin or radius. A mass of N consumers is uniformly distributed on a circle C with radius $r > 0$ centered at the origin. In polar coordinate terms, this means that a consumer z is represented by the point (θ_z, r_z) with the restriction that the radius r_z takes on a common value for all consumers, say R. The assumption of a uniform distribution on the circumference of the circle with radius R means that θ_z is uniformly distributed on the interval $[0, 2\pi]$.

There are n firms each selling a single variety of the differentiated product. Each firm has a constant marginal cost of $c > 0$. The variety produced by firm i is represented by a ray emanating from the origin, $\rho(\theta_i) = \{(\theta_i, s) | s \in \mathbb{R}^+\}$, or, equivalently by the angle $\theta_i \in [0, 2\pi]$ measured in radians. Thus, in a technological sense, the difference between products of two firms is completely described by the θ coordinate (see Figure 1). However, unlike other models of spatial competition, consumer perceptions of the (relative) attractiveness of the products are not based solely on this technological parameter θ_i, but also on the circumference of the circle, $2\pi R$, which is determined by the radius R. The importance of this distinction will become clear when we introduce uncertainty.

The difference between products, in a utility sense or from the consumers perspective, as opposed to a technological sense, is described by the distance between the products (or the length of an arc) along the circle with radius R. The minimum distance between firm i's product, $\rho(\theta_i)$, and consumer z denoted by $d(z, \rho(\theta_i))$ is defined as

$$d(z, \rho(\theta_i)) = R \times \begin{cases} \theta_i - \theta_z & \text{if } \theta_i > \theta_z \text{ and } \theta_i - \theta_z \leq \pi \\ 2\pi - (\theta_i - \theta_z) & \text{if } \theta_i > \theta_z \text{ and } \theta_i - \theta_z > \pi \\ \theta_z - \theta_i & \text{if } \theta_z > \theta_i \text{ and } \theta_z - \theta_i \leq \pi \\ 2\pi - (\theta_z - \theta_i) & \text{if } \theta_z > \theta_i \text{ and } \theta_z - \theta_i > \pi \end{cases} \tag{1}$$

noting that one can go clockwise or counterclockwise around the circle with radius R. See Figure 1.

The indirect utility of a consumer located at $z \in C$ from purchasing variant i is

$$V_i(z) = y - p_i - \tau d(z, \rho(\theta_i))^{\beta}, \tag{2}$$

where y is the consumer's income, p_i is the price of variant i, $\tau > 0$ is the transport cost parameter, and $\beta > 0$ is the parameter of the power function. The parameter β measures the elasticity of the transport cost with respect to distance. Each consumer has enough income to buy one unit of the product that gives him or her the highest utility.

Note that for a given circle and $\beta = 1$, this description of indirect utility is the same as the one in Salop (1979). Our generalization replaces the point description of a firm's product, used in essentially all location models, with a ray emanating from the origin. The use of a ray means that the indirect utility of a consumer on any circle, i.e. located anywhere in the two dimensional space, is also defined. See Figure 1 for an illustration.

INSERT FIGURE 1 ABOUT HERE.

2.2 Firms' Uncertainty, Short Run

In contrast to the standard full information Salop (1979) circle model, we assume that risk neutral firms are initially uncertain as to how consumers evaluate the differences between the competing varieties and this uncertainty is resolved over time.

The difference between products, in a utility sense or from the consumers' perspectives, as opposed to a technological sense, is described by the distance between the products around the circle. To say that firms are uncertain about how consumers perceive the differences between the products is to say that firms are uncertain about the distance between products, which, for a fixed number of firms, is determined by the radius/circumference of the circle.[6]

We model this uncertainty by assuming firms have a common prior $g(\cdot)$ over the circumference L (or $2\pi R$), described by the density function $g(L)$ over the support $[a, b]$ with $0 < a < b < \infty$ when they make their initial entry and product characteristic (θ_i) decisions in period 0.[7]

The true value of L becomes common knowledge prior to price competition in period 1. Since prices are much easier to adjust than product characteristics

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[6] The group of oligopoly papers similar to the approach used here are papers on demand location uncertainty (Harter (1996); Casado-Izaga (2000); Meagher and Zauner (2004, 2005)). The key theme in Meagher and Zauner (2004, 2005) is the presence of aggregate uncertainty about demand location, expressed by a common prior about the mean of the distribution of consumer locations in the quadratic transport cost version of the Hotelling model. Competition is within a duopoly, without entry or exit, with the focus on how uncertainty affects the key strategic variables: locations and prices. Uncertainty pushes firms apart, raising average prices and profits. Increasing expected prices and expected profits are suggestive of a possible impact of uncertainty on entry. However, entry is not pursued in these papers due to the difficulty of dealing with an arbitrary number of firms in the Hotelling model. Bonein and Turolla (2009) extends the demand location uncertainty approach to duopoly with sequential moves.

[7] We make the standard assumption of a common prior to facilitate and simplify the exposition (Aumann (1976)). While the use of a common prior is a conceptual issue (Morris (1995)) and has been the subject of research in game theory (see Dekel and Siniscalchi (2015) for a broad overview of this and related issues), there is no clearly dominant alternative. Furthermore, if each firm has a distinct individual uncertainty, there may well be issues with equilibrium existence or the introduction of asymmetric equilibria. Nevertheless, even with heterogeneous priors, expected individual profits are reduced by a reduction in or the resolution of the uncertainty, for a fixed number of firms. Thus, we conjecture that in most heterogeneous priors models, the expected shakeout result would continue to hold.

or entry/exit decisions, the first line of adjustment for a firm will be its price upon learning about market conditions. We assume a polar case here in which this adjustment is instantaneous. This case approximates real markets, in which learning is very fast or the period required for entry/exit is long.

Each decision is made simultaneously by all (relevant) firms. The timing described above is summarized in Figure 2, with n_j denoting the number of firms in period j, and p_{ij}, θ_{ij} denoting respectively the price and product for firm i in period j, and where $j = 1$ in this case.

INSERT FIGURE 2 ABOUT HERE

We use the uncertainty about (the length of) the circumference of the circle to describe uncertainty on the part of firms about the importance to consumers of the differences between products. That is, the uncertainty of firms about the circumference L can, for example, model the uncertainty about brand loyalty of customers.

The transport cost parameter, τ, also describes an aspect of consumer loyalty. Since indirect utility is linear in τ, we could introduce uncertainty about the transport cost parameter, τ, instead of uncertainty about the circumference of the circle, L, given $\beta = 1$. Thus, uncertainty about the transport cost parameter is equivalent to a special case of the uncertainty about the circumference, and therefore, without loss of generality, we focus on uncertainty about the circumference L keeping in mind that the restriction to $\beta = 1$ can be interpreted as uncertainty over the transport cost parameter τ.

We assume that if firms enter the market, they incur an identical per period fixed cost of $K > 0$ in addition to the constant marginal cost of c introduced in the previous subsection.

2.3 Long Run

Stage 1, described in the previous subsection, is best thought of as a short run situation at the start of an industry's life cycle. At the inception of an industry, due to an innovation of some new class of product, firms are naturally uncertain about consumer preferences over differences in the product varieties.

Over time this uncertainty decreases as firms learn from experience (and perhaps observation of other firms' experiences). We do not model this learning process explicitly. However, if, over time, this uncertainty is eliminated, then a full information equilibrium is a reasonable end point for the industry's evolution. We add this mature state to our model as stage 2.[8]

In stage 1, firms may be making profits or losses depending on the realized consumer preferences. Given sufficient time, firms will enter or exit depending on the fierceness of competition implied by the realized values of L, which is common knowledge to firms in and out of the market. These entry and exit decisions are made simultaneously following stage 1's price competition. Entry and exit give those firms in the market incentives to adjust.

In stage 2, firms choose their product characteristics simultaneously prior to a round of simultaneous price competition. Following the majority of the literature, we shall maintain the standard assumption that it is costless for firms to change their product characteristics (θ_{ij}).[9]

INSERT FIGURE 3 HERE

The timing described above is summarized in Figure 3, with n_j denoting the number of firms in stage j, and p_{ij}, θ_{ij} denoting the price and the product of firm i in stage j, $j \in \{1, 2\}$, respectively.

We assume that if firms enter the market there is an identical per period fixed cost of K and a constant marginal cost of c. This assumption about production costs, combined with costless adjustment to product characteristics, means that firms which enter in the first stage have no advantage or disadvantage compared

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[8] If the uncertainty persists over time but it is reduced in the sense of a mean preserving, lower variance distribution over consumers preferences, then the main result of a reduction in the number of firms remains intact, as Corollary 4 below shows.

[9] If there are costs of adjusting product characteristics, then as long as the effect of the adjustment costs does not dominate the effect of an elimination/reduction of the uncertainty, the main results of the paper continue to hold. In old economy manufacturing industries, such adjustment costs may not be negligible in particular cases. However, in new economy industries, the costs of adjusting product characteristics are very likely to be much smaller if not insignificant.

If the cost of adjusting product characteristics is prohibitively large then entry or exit will no longer happen smoothly in response to changes in expectations/knowledge about L. However, the direction of any changes will still be the same as in the smooth (zero adjustment cost) case.

to firms which enter in the second stage. Thus, the decision to participate in the market in either stage is independent of participation in the other stage. These assumptions are made in order to isolate the effects of uncertainty and mean that there is no strategic link between stage 1 and stage 2.

3 The Short Run: Equilibrium Under Uncertainty

To start with, it is useful to analyze the location-then-price game for a fixed circumference $2\pi R$, that is, the two-stage game where firms choose locations or rays simultaneously, observe locations of competitors and then choose prices simultaneously. Economides (1989) (Theorem 5) shows that there exists a perfect symmetric equilibrium in the subgame starting with the choice of locations. If n firms are equally spaced around the circle, that is, at distance $2\pi R/n$ from their nearest neighbor, then the symmetric price equilibrium for all convex, power function transport costs is characterized as follows (Anderson et al. (1992, p. 177)):

Proposition 1. *For $\beta \in [1, 6.2]$ there exists a unique perfect symmetric price equilibrium with*

$$p_i^* = c + \beta 2^{1-\beta} \tau \left(\frac{2\pi R}{n} \right)^{\beta}, \tag{3}$$

where $i = 1, 2, \ldots, n$.[10]

We now turn to characterizing the equilibrium market structure under uncertainty. We begin with period 0 in which firms make their entry decisions based on a common prior over the uncertainty about consumer preferences.

Firms are risk neutral, hence they base their entry decisions in period 0 solely on expected profits. If n_1 firms enter in the first period and choose θ_{i1}'s so that there is an equal angle between any two adjacent rays describing the products of the respective firms, then the price equilibrium given in Proposition 1 holds.[11] The

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[10] Note that $\beta \geq 1$ ensures the convexity of the transport cost and guarantees that firms' market segments are connected. Generally, no symmetric pure strategy price equilibrium exists for $n > 2$ and $\beta < 1$. See Anderson et al. (1992, p. 153, footnote 10 and p. 172, footnote 24). For large values of β, in particular $\beta > 6.2$, no symmetric pure strategy price equilibrium exists because, with a high elasticity of the transport cost with respect to distance, a firm can increase its price over the candidate equilibrium without losing much demand and, therefore, increase its profit above the candidate (symmetric) equilibrium. Henceforth, in order to guarantee the existence of a symmetric pure strategy price equilibrium, we assume $1 \leq \beta \leq 6.2$. Also note that a larger circumference $2\pi R$ leads to higher equilibrium prices and profits as firms acquire greater local market power.

[11] Our analysis is significantly simplified by focusing on evenly spaced products, as is standard in the literature (cf. Economides (1989)).

following proposition shows that the location equilibrium of even spacing under certainty extends to the uncertainty case without any additional restrictions.

Proposition 2. *If evenly-spaced firm locations are part of a subgame perfect equilibrium for each $L \in [a, b]$, then evenly-spaced firm locations are part of an equilibrium when L is distributed according to $g(L)$.*

Proof. For simplicity we suppress the time subscripts. For fixed L, let $\pi_i(\theta_i, \theta_{-i}; L)$ be the profit for firm i given Nash equilibrium prices. Let $\{\theta_i^*\}_{i=1}^n$ be a set of equally spaced firm locations. Then by definition these locations satisfy the relation

$$\pi_i(\theta_i^*, \theta_{-i}^*; L) \geq \pi(\theta_i, \theta_{-i}^*; L), \forall \theta_i \in [0, 2\pi], L \in [a, b]. \tag{4}$$

Taking expectations over L

$$\int_a^b \pi_i(\theta_i^*, \theta_{-i}^*; L) g(L) dL \geq \int_a^b \pi_i(\theta_i, \theta_{-i}^*; L) g(L) dL, \forall \theta_i \in [0, 2\pi]. \tag{5}$$

This is the condition for $\{\theta_i^*\}_{i=1}^n$ to be part of a subgame perfect equilibrium for the uncertainty game. □

Given evenly spaced firms, the symmetric price equilibrium of Proposition 1 holds. This implies that firms will have symmetric market shares N/n and profits in each state of the world. A firm's expected profit in period 0 is given by

$$E[\pi_1] = \int_a^b N\beta 2^{1-\beta} \tau L^\beta n^{-\beta-1} g(L) dL - K. \tag{6}$$

Risk neutral firms will enter until the number of firms, n_1^*, gives zero expected profits. Ignoring integer problems, the resulting free entry equilibrium is characterized in the following proposition.

Proposition 3. *The number of equally spaced firms or varieties under free entry when L is uncertain and distributed according to $g(L)$ is*

$$n_1^* = \left(\frac{\beta 2^{1-\beta} \tau N E[L^\beta]}{K} \right)^{1/(1+\beta)}. \tag{7}$$

The comparative statics conform with intuition: increasing total demand by increasing the population N leads to more entry, while increasing the fixed cost K reduces the number of firms that enter. Increasing transport costs through τ increases market power of firms which, in turn, leads to more entry.

Reminiscent of the results in Meagher and Zauner (2004) and Meagher and Zauner (2005) of the linear Hotelling duopoly model, firms' uncertainty about the preferences of consumers acts as a differentiation force. The term $E(L^\beta)$ illustrates this uncertainty, as Corollary 4 highlights. Under greater uncertainty, firms will differentiate themselves more from competitors and this has a positive effect on firms' profits. In a free entry equilibrium, more firms enter the market.

Corollary 4 (Uncertainty in the Short Run)**.** *The equilibrium number of equally spaced firms or varieties n_1^* has the following comparative statics with regard to uncertainty over L, $g(L)$. Suppose we have two different distributions on L, $g(L)$ and $\hat{g}(L)$ (with the same mean) where $\hat{g}(L)$ is less risky in the sense of Rothschild and Stiglitz (1970) (p. 226), and let the respective equilibrium number of firms be n_1^* and $\hat{n}_1^*$. Then $n_1^* > \hat{n}_1^*$, i.e. a mean preserving reduction in risk (over L) reduces the short run equilibrium number of firms.*

Proof. From equation (7) if follows that $\frac{\partial n_1^*}{dE[L^\beta]} > 0$. Thus, we can restrict attention to how $E[L^\beta]$ is affected by changes in $g(L)$. Since L^β is convex for $\beta \in [1, 6.2]$, by Jensen's inequality, we have that $E_{\hat{g}}[(L)^\beta] \leq E_g[L^\beta]$. □

Corollary 4 describes a popular view of risk in new product markets using the traditional economic tool of mean preserving spreads. For $\beta > 1$ the convexity of profit in L means that the upside risk, i.e. the cases of low competition, matter more for profit than the downside risk of high competition (profits are of course bounded below).

Corollary 4 is close in spirit to the real options analysis in which markets with higher risk are accompanied by higher profits for a fixed number of firms/products, this is the situation imagined by authors such as McGrath (1999). However, if the only barrier to entry is a fixed cost then higher expected profits cause greater entry. Thus, contrary to the management and strategy literatures that do not model competitive equilibrium, increased risk does not lead to higher expected profits but rather expected profits are eroded to zero by entry.

4 The Long Run: Industrial Shakeout

In stage 2, the way in which consumers evaluate the differences between products is common knowledge. Therefore, for a realized value of the circumference of the circle, L, the standard results on the equilibrium number of firms, which we denote n_2^*, holds (Anderson et al. (1992, p. 191)):

$$n_2^* = \left(\frac{\beta 2^{1-\beta} \tau N L^\beta}{K} \right)^{1/(1+\beta)}, \tag{8}$$

with the unique equilibrium price denoted by p_2^* given in equation 3 of Proposition 1. Thus, rather naturally in stage 2 the number of firms depends on the competitive pressures that firms face. In other words, if the circumference, L, is small, consumers perceive the products as rather similar, competition is fierce, and as a result there will be a small number of firms.

The equilibrium market structure in stage 2 depends on realized consumer preferences. Thus, in a particular state, there can be more or less firms in stage 1 than in stage 2, which covers all possible empirical outcomes.

We get a more specific prediction by examining the change in industry structure over time by comparing the number of firms at industry inception, n_1^*, with the expected number of firms when the industry has matured, $E[n_2^*]$, where

$$E[n_2^*] = \int_a^b \left(\frac{\beta 2^{1-\beta}\tau N L^\beta}{K}\right)^{1/(1+\beta)} g(L)dL \tag{9}$$

$$= \left(\frac{\beta 2^{1-\beta}\tau N}{K}\right)^{1/(1+\beta)} E[L^{\beta/(1+\beta)}]. \tag{10}$$

The relationship between the market structure initially and when the market has matured is given in the following proposition.

Proposition 5. *There is expected shakeout as the industry matures:* $n_1^* \geq E[n_2^*]$, *with strict inequality if* $\beta > 1$.

Proof. The term $\left(\frac{\beta 2^{1-\beta}\tau N}{K}\right)^{1/(1+\beta)}$ can be canceled from each term which gives:

$$n_1^* \geq E[n_2^*] \Leftrightarrow E[L^\beta]^{\frac{1}{1+\beta}} \geq E[L^{\frac{\beta}{1+\beta}}]$$

Let $u(x) = x^{1/(\beta+1)}$ and $x = L^\beta$ which implies that the right-hand side becomes (under the appropriate density function for x):

$$u\left(E[x]\right) \geq E[u(x)]$$

Noting that $u(x)$ is concave since $\beta \in [1, 6.2]$, this implies that the above inequality holds (whenever the expectations exist) by Jensen's inequality. ☐

In stage 1, the initial phase of the industry, firms are uncertain how differentiated their products are, as viewed from the perspective of the consumers, and have to choose product characteristics. In stage 2, the mature phase of the industry, this uncertainty has been resolved and firms are able to choose product characteristics knowing the perceptions of consumers. The proposition shows that the number of firms in the industry in stage 1 is larger than the number of firms in stage 2, in expectation.

Thus, this model predicts that in new economy industries, where preference differences are the key strategic issue, we should see on average the pattern of shakeout. This preference-based mechanism is in contrast to unit cost effects which have been found to dominate in old economy manufacturing industries.

Corollary 6. *There is an expected increase in observed prices as the industry matures:* $p_1^* \leq E[p_2^*]$*. With strict inequality if* $\beta > 1$*.*

Proof. Prices are assumed to respond quickly so p_1^* and p_2^* are both determined by the same known level of L. Thus, any difference in price between the periods is due to the number of firms and since on average the number of firms decreases it follows that for fixed L equilibrium prices will increase. □

It is well known that consumer densities with a wider spread (Anderson et al. (1997)) and demand location uncertainty, that is, uncertainty of firms about consumer perceptions (Meagher and Zauner (2004, 2005)) act as a differentiation force and lead to higher equilibrium prices and more spread-out locations in the Hotelling model with quadratic transport costs. In these models, consumer heterogeneity or demand location uncertainty leads to higher differentiation and higher prices because, by locating further away from its competitor, in equilibrium, the positive effect of reducing the force of price (Bertrand) competition dominates the negative effect of losing demand.

The Salop (1979) circle model makes it possible to also analyze entry and exit decisions. In this model of localized competition, each firm competes directly only against two other competitors and, in equilibrium, no firm has a "hinterland" where it is shielded from competition. Firms' uncertainty about the preferences of consumers leads to higher equilibrium prices due to the differentiation force of the uncertainty. As a consequence, firms' (putative) profits are higher which allows, in turn, more firms to enter in a zero-profit equilibrium. In other words, due to the differentiation force of the uncertainty, in a free entry equilibrium, a larger number of firms is able to achieve non-negative profits under uncertainty. If the firms' uncertainty is reduced, or even eliminated, over time, the number of firms will decrease in a zero-profit equilibrium. This illustrates the shakeout result of Proposition 5.

The parametrization of the transport cost function with $\beta \in [1, 6.2]$ guarantees the existence of a unique symmetric pure strategy price equilibrium and the connectedness of the firms' market segments. It is this property that is crucial in this result.[12]

We have made two sorts of comparisons about the number of firms in the industry, using the unique symmetric subgame perfect equilibrium of the sequential entry-location-price game with firms' uncertainty about consumer preferences at specific time periods. The first comparison is between different distributions, at specific time periods, modeling firms' uncertainty about consumers preferences where the uncertainty is reduced over time. In this case, there is no dynamic link,

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[12] Recall that in the Hotelling model and in the Hotelling model with demand location uncertainty it is usually assumed that $\beta = 2$.

no state variable, no endogenous learning linking the time periods. We simply make a comparison between periods where there is considerable uncertainty and periods where there is reduced or no uncertainty. The second comparison is between the number of firms under firms' uncertainty about consumer preferences and the average or expected number of firms. In both comparisons, there is shakeout in the sense of a smaller number of firms in the latter case.

5 Comparative Statics for Entry Costs

In oligopoly theory, fixed costs typically play a major role in determining the equilibrium market structure under free entry. The following result elucidates the relationship between fixed costs and shake out when firms learn about consumer perceptions of the differences between products.

Proposition 7. *(Comparative Statics for Entry Costs)*

1. *The expected shakeout* $S \equiv n_1^* - E[n_2^*]$ *is decreasing in the per period fixed cost* K*. Specifically:*

$$\frac{\partial S}{\partial K} = -\left(\frac{\beta 2^{1-\beta}\tau N}{K^2}\right)\left(E[L^\beta]^{\frac{1}{1+\beta}} - E[L^{\frac{\beta}{1+\beta}}]\right)$$

2. *The expected shakeout as a proportion of the initial entrants is independent of* K*.*

Proof. The expected shakeout S is defined as $S = n_1^* - E[n_2^*]$. Factorizing the common terms gives $S = \left(\frac{\beta 2^{1-\beta}\tau N}{K}\right)\left(E[L^\beta]^{\frac{1}{1+\beta}} - E[L^{\frac{\beta}{1+\beta}}]\right)$ from which the result follows by differentiation. K only appears in the common factor and the common factor cancels when we divide S by the initial number of firms n_1^*. ☐

Proposition 7 comes about because firms are assumed to incur the same fixed cost K in both stage 1 and 2. Since the fixed costs are identical in both stages, a higher K will reduce the number of entrant firms by the same proportion in both stages. Therefore the expected shake out, when taken as a share of initial entrants in stage 1, is independent of K.

In addition, since the number of firms in stage 1 is on average greater than the number of firms in stage 2, a higher fixed cost will lower the level of firms in stage 1 by more than in stage 2. Thus, a higher K will reduce the level of expected shakeout in the long run.

6 Welfare Effects

In this section, we compare the zero-profit equilibrium with the choice selected by a benevolent social planner. Since firms are identical in their costs, demand is inelastic and every consumer has sufficient income to purchase in equilibrium, the welfare effects are captured by the trade-off between the benefits of diversity (in particular lower transport costs) and the fixed costs of providing diversity. That is, welfare will be maximized if loss, $\mathcal{L}$, defined as the sum of total transport costs and total fixed costs is minimized. Since firms are symmetrically located and charge identical prices in equilibrium it is sufficient for the social planner to select the optimal number of firms, n^s, and allow the market to function freely in all other respects. When the social planner's choice is made under uncertainty about the size of L, we assume that the expected loss, $E(\mathcal{L})$, is minimized.

We establish the optimal number of firms in the market when the size of the circumference of the circle L is uncertain, and also when L is later known. In stage 1, a social planner will choose the number of firms, n_1^s, in order to minimize total expected loss. Total expected loss, assuming L is uncertain, is given by

$$E(\mathcal{L}) = \int_a^b \left\{ 2n \int_0^{L/(2n)} \tau x^\beta \frac{N}{L} dx \right\} g(L) dL + nK. \tag{11}$$

Integrating, we have

$$E(\mathcal{L}) = \frac{\tau N E[L^\beta]}{(1+\beta)2^\beta n^\beta} + nK. \tag{12}$$

Differentiating this expression with respect to n and setting the resulting expression equal to 0 yields n_1^s. The second derivative with respect to n is positive, therefore n_1^s minimizes total expected loss, that is, maximizes expected welfare. The resulting socially optimum equilibrium number of firms is characterized in the following proposition.

Proposition 8. *For stage* 1*, the socially optimal number of equally spaced firms when* L *is uncertain is:*

$$n_1^s = \left(\frac{\beta N \tau E[L^\beta]}{K 2^\beta (1+\beta)} \right)^{1/(1+\beta)}. \tag{13}$$

This proposition shows increasing the population N or increasing average transport costs, or more generally average disutility from an imperfect product match (as influenced by τ or $\sqrt[1+\beta]{E[L^\beta]}$) justifies more firms from a welfare stand point, while increasing the fixed cost of a firm, K, would justify less firms than in equilibrium. The role of β is, as before, more subtle. The key economic role played by β is in the relationship between the number of firms in the free-entry equilibrium n_1^*

and the socially optimal number n_1^s. This relationship is described in the following proposition.

Proposition 9. *The relationship in stage* 1 *between the free-entry equilibrium number of firms and the socially optimal number of firms is*

$$n_1^* = [2(1+\beta)]^{1/(1+\beta)}\, n_1^s. \tag{14}$$

Since $\beta \geq 1$ *this implies there is always excess entry in the short run.*

Proof. The result follows immediately by substitution. □

As in the standard Salop model (i.e. when $\beta = 1$), Proposition 9 shows that the free market generates more firms in stage 1 than socially optimal. This identifies an important issue with the fail-fast strategy and the lean startup movement: analyzing these approaches in the context of a competitive industry equilibrium maintains the result that it is optimal for (some) firms to enter when there is still significant uncertainty about consumer preferences. However, this entry is excessive from a social perspective. While the fast pace of technological innovation and the remarkable creativity in inventing new products have changed our world in recent decades, it is likely that the accompanying uncertainty in consumer preferences has exacerbated the excess entry issue.[13]

A second point of interest in our result is that the extent to which n_1^* is greater than n_1^s depends on the β parameter. In other words, the extent of excess entry in a free market in stage 1 depends on the uncertainty that firms have regarding consumer preferences (which appears in equilibrium through the curvature of L^β). Increasing β, over the interval $[1, 6.2]$, reduces the degree of excess entry, bringing the ratio n_1^*/n_1^s closer to 1, see Figure 4. Thus in markets where consumers are more sensitive to product 'fit' (i.e. a greater β) the percentage of excess entry will be smaller.

INSERT FIGURE 4 HERE

In stage 2, the way in which consumers evaluate the differences between the

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[13] That is, we believe, as many authors have argued, that the radical and disruptive innovations of recent decades have involved much greater uncertainty about consumers perceptions and evaluations of new products than the more incremental innovation characterising the decades proceeding the information technology revolution.

products becomes common knowledge. For a realized value of the circumference of the circle, L, the socially optimal equilibrium number of firms, n_2^s, is given by:

$$n_2^s = \left(\frac{\beta\tau N L^\beta}{K2^\beta\,(1+\beta)}\right)^{1/(1+\beta)}.$$

Therefore, the expected socially optimal number of firms in the market when the industry has matured is given by:

$$\begin{aligned} E[n_2^s] &= \int_a^b \left(\frac{\beta\tau L^\beta}{K2^\beta\,(1+\beta)}\right)^{1/(1+\beta)} g(L)dL \qquad (15)\\ &= \left(\frac{\beta\tau N}{K2^\beta\,(1+\beta)}\right)^{1/(1+\beta)} E[L^{\beta/(1+\beta)}] \qquad (16)\end{aligned}$$

A comparison of the expected number of firms under free entry and the social optimal outcome in stage 2 is given in the following proposition.

Proposition 10. *(Socially Optimal Shakeout)*

1. *There is expected shakeout in the socially optimal industry structure, that is*

$$n_1^s \geq E[n_2^s.] \qquad (17)$$

2. *The expected shakeout under the free entry equilibrium is* $[2(1+\beta)]^{1/(1+\beta)}$ *times larger than the expected shakeout under the social optimum, that is*

$$[n_1^* - E\,[n_2^*]] = [2(1+\beta)]^{1/(1+\beta)}\,(n_1^s - E\,[n_2^s]). \qquad (18)$$

Proof. In order to establish 1, note that the term $\left(\frac{\beta\tau N}{K2^\beta(1+\beta)}\right)^{1/(1+\beta)}$ can be canceled from each term which gives:

$$n_1^s \geq E[n_2^s] \Leftrightarrow E[L^\beta]^{\frac{1}{1+\beta}} \geq E[L^{\frac{\beta}{1+\beta}}]$$

The result is then established by an application of Jensen's inequality as in the free entry case. In order to prove 2, we proceed as follows. Proposition 9 has already established the relationship between n_1^* and n_1^s:

$$n_1^* = [2(1+\beta)]^{1/(1+\beta)}\,n_1^s.$$

We now need to establish the equivalent relationship in the long run. Dividing expression (10) by expression (16) gives

$$\frac{E[n_2^*]}{E[n_2^s]} = [2(1+\beta)]^{1/(1+\beta)}. \qquad (19)$$

Substituting these equations into the proposition gives

$$n_1^* - E\left[n_2^*\right] = \left[2(1+\beta)\right]^{1/(1+\beta)} n_1^s - \left[2(1+\beta)\right]^{1/(1+\beta)} E[n_2^s] \tag{20}$$

$$= \left[2(1+\beta)\right]^{1/(1+\beta)} (n_1^s - E[n_2^s]). \tag{21}$$

□

Proposition 10 reveals that there is also expected shakeout in the socially optimal industry structure, as was the case with the free-entry market structure. This in part reflects the assumption about convex transportation costs (discussed earlier), which results in greater entry in stage 1 than in stage 2 on average. This implies that there will be a natural consolidation in industries with no new opportunities or growth, regardless of whether the market has free entry or is governed by a social planner.

Proposition 10 also shows the expected shakeout is greater in a free entry market than in the socially optimal solution. Intuitively, this is partly because there was less excessive entry (in expectation) in the socially optimal solution in stage 1 and therefore, less adjustment to be made in stage 2, as all costs were considered by the social planner. The extent to which expected shakeout is greater under a free entry market than in the socially optimal solution depends upon the β parameter (as discussed earlier in Proposition 9).

7 Conclusion

Motivated by the fail-fast literature and the lean start-up movement, this paper examines the evolving number of firms in a differentiated products oligopoly market structure from start-up to maturity. We focus not on cost factors, such as learning by doing or external economies of scale, nor on considering the pattern of R&D, as in the product life cycle literature, but rather we focus on firms' uncertainty about the preferences of consumers. For many new economy markets/products resolving uncertainty about how consumers perceive differences in product characteristics is more important than unit cost. Mobile phone apps in the specialist product categories of calendars, To Do list managers, note taking, and activity trackers provide canonical examples.

We extend the standard Salop (1979) circle model of spatial/characteristics competition by introducing a second dimension and allowing for uncertainty about consumer preferences. This is a more realistic portrayal of developing markets, where consumer preferences are unknown in the short-run and firms therefore must gamble on the nature of preferences when choosing to enter. In the long-run version of our model, firms are able to learn about the true nature of consumer preferences, and may enter/exit the market and adjust their prices.

Similar to the existing fail-fast literature, our competitive analysis predicts it is optimal for firms to enter before uncertainty about preferences is resolved. We find a number of new insights into the equilibrium effects of the fail-fast strategy. For example, the entry caused by preference uncertainty is socially excessive in the short run because of the potential for firms to make a positive profit. Moreover, as the market matures, there will, on average, be positive shakeout in the number of firms in the market. This finding is consistent with the existing empirical literature on product life cycles.

The expected shakeout will be greater in a free-entry market than in a market governed by a welfare maximizing planner. In addition, there is positive shakeout when the distribution of uncertainty becomes less risky (in the sense of Rothschild and Stiglitz (1970)).

Intuitive comparative statics are found, where the number of firms that initially enter the market under free-entry will rise when fixed costs fall, the number of consumers increases, and firms have a greater degree of market power. The latter factor, reflected in our extension of the Salop model, occurs when transportation costs are higher, and when firms are perceived to be more differentiated (larger size of the circumference, L).

In future research, we plan to investigate firms' active learning to reduce the uncertainty about consumers preferences and its effect on equilibrium.

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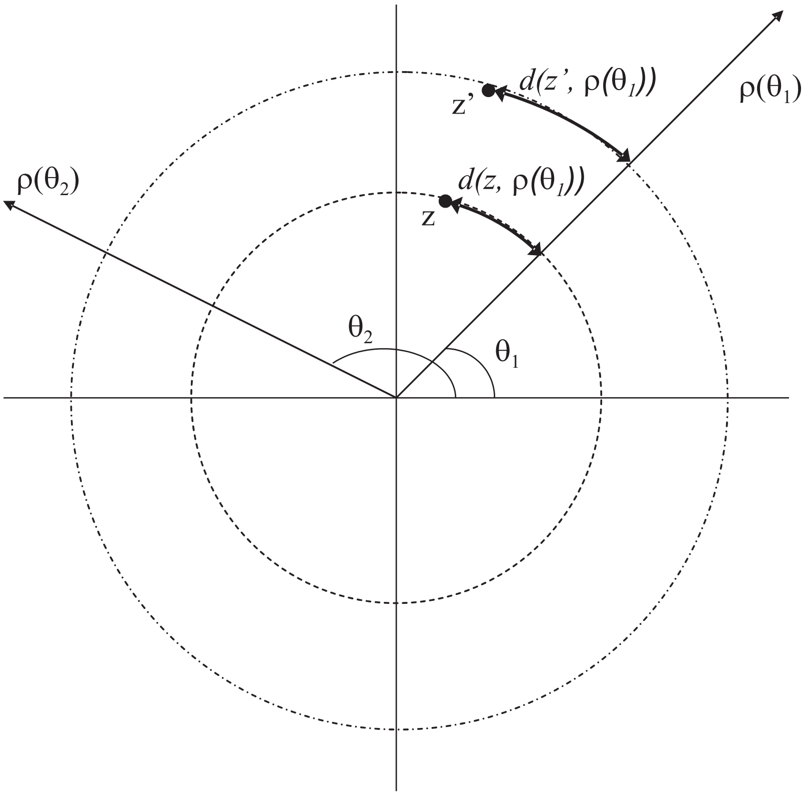

Figure 1: Firms, Consumer Locations and Distance for circles of different radii.

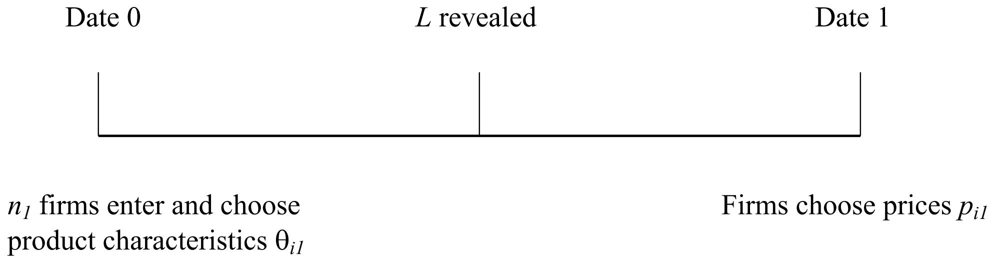

Figure 2: Timing: Entry under Uncertainty

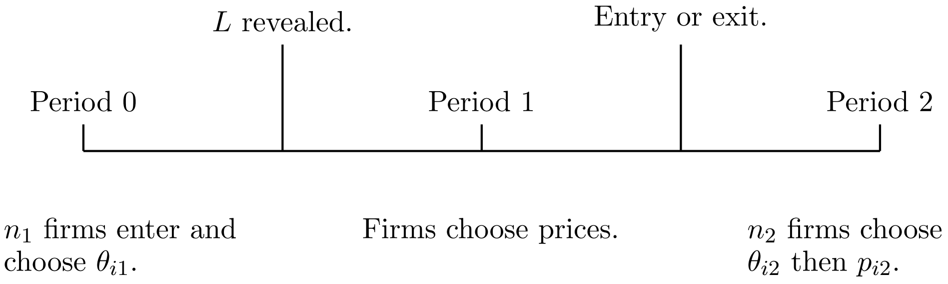

Figure 3: Timing: Short and Long Run

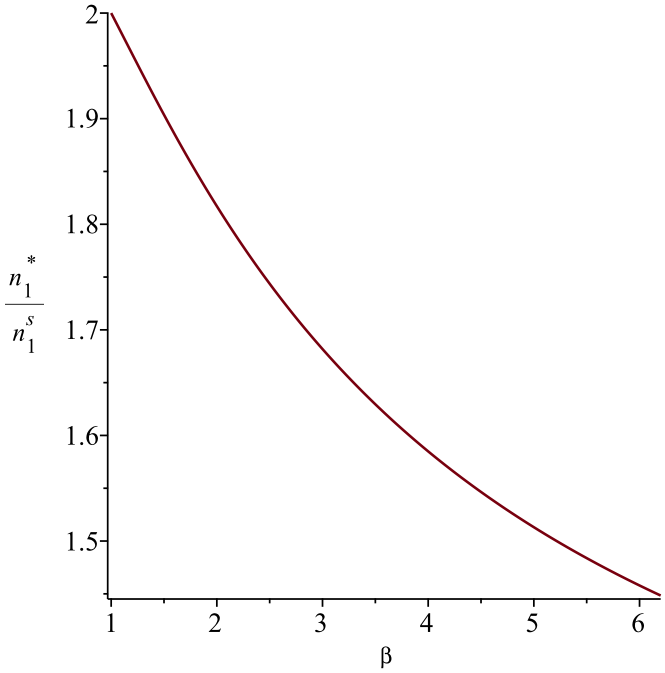

Figure 4: Excess Entry Ratio ($\frac{n_1^*}{n_1^s} = [2(1+\beta)]^{1/(1+\beta)}$) as a Function of Transport Cost Curvature (β).