The Impact of Uncertainty about Demand Growth on Preemption

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Abstract

In this article, I analyze the ability of an incumbent firm to preempt a new market before a new entrant does, when the firms face uncertainty about demand growth. I show that entry of the outside firm occurs with nonzero probability when the entry threat is sufficiently low. Eaton and Lipsey (1979)'s intuition that "the more erratic and unpredictable is market growth, the greater the possibility of new firms entering to serve part of the expanding market" is not always confirmed. The probability of entry of the outside firm might either increase or decrease with the degree of uncertainty.

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1 Introduction

The preemption literature states that an incumbent firm may maintain as a monopoly by preempting new markets or products before a new entrant does.[1] The intuition for the *persistence of monopoly* is that the incumbent has more incentives to deter entry than the entrant has to enter. Eaton and Lipsey (1979, p. 157) suggest that this result might not be robust to uncertainties:

> "the more stable and easily predictable is market growth, the more will the expanding market be served by new branches of existing firms, while the more erratic and unpredictable is market growth, the greater the possibility of new firms entering to serve part of the expanding market."

The aim of this article is to provide a formal framework to analyze the impact of uncertainty about demand growth on the ability of an incumbent firm to preempt a new market, when it faces an entry threat from an outside firm. In this setting, I show that entry of the outside firm occurs with nonzero probability when the entry threat is sufficiently low. I also show that Eaton and Lipsey's intuition does not always work. There are cases in

[1] For instance, see Tirole (1988, Chapter 8).

which the probability of entry of the outside firm decreases, as the degree of uncertainty increases.

In many industries, it is often difficult to anticipate accurately the demand for new products or markets. For instance, in the early years of the mobile telephony industry, in 1982, AT&T thought that there would be 1 million mobile subscribers in the United States in 2000. In 1997, there were already more than 50 millions subscribers.[2]

However, only a few papers have examined the impact of uncertainty on the persistence of monopoly. The question is at the heart of the debate between Gilbert and Newbery (1982, 1984) and Reinganum (1983, 1984) but their frameworks are different, hence it is not possible to measure the impact of uncertainty on the ability of the incumbent to preempt its rival.[3] McGahan (1993) analyzes the impact of incomplete information about demand on preemption in a game of capacity investment. She shows that if the probability that demand is high is sufficiently low, there may be entry after observation of the realization of demand. However, McGahan focuses on the impact of asymmetric information about demand growth and does not study whether increased uncertainty increases preemption incentives. This

[2] See "Millenium forecast is for 1bn cellular users", Financial Times, 18 November 1998.

[3] Gilbert and Newbery demonstrate that there is persistence of monopoly in a deterministic framework, whereas Reinganum shows that there is entry when the R&D technology is stochastic.

paper is an attempt to provide a formal analysis of the issue.

The rest of the paper is organized as follows. I begin by describing the model in Section 2. In Section 3, I solve the simultaneous entry subgame, which occurs after the realization of demand. In Section 4, I characterize the equilibrium. In Section 5, I study the impact of uncertainty on the outcome of the game. Finally, I conclude.

2 The model

The model incorporates two periods. In the first period, demand is 'low' and the incumbent is a local monopolist in a captive market. In the second period, demand may grow. A new entrant can enter an imperfectly substitute "new market" in the second period if demand grows sufficiently.[4] The incumbent can decide to enter the new market either in the first period - in which it faces no rival - or in the second period - in which it faces the new entrant. Hence, the incumbent has a stronger first-mover advantage.[5] However, in the first period, the incumbent does not know the level of demand in the second period. Demand in the second period is revealed to both firms

[4] In the paper, I assume that uncertainty relates to the density of consumers. Alternatively, one could assume that the marginal cost might fall with some probability. This would not change the essence of the analysis.

[5] I will make the appropriate assumption to ensure that the entrant has no incentives to enter in period 1.

at the beginning of the second period.[6]

There are two possible outcomes in this game: *persistence of monopoly*, in which the incumbent preempts the new market, and *entry*, in which the entrant enters the new market. Persistence of monopoly occurs either in the first or second period. Entry occurs only in the second period.

2.1 Firms

The incumbent (I) and the entrant (E) produce at constant marginal cost, which I normalize to zero, and there is no fixed cost. There are two markets, 1 and 2. Without loss of generality, I assume that at the beginning of the game, firm I operates in market 1. Market 1 and market 2 might represent two geographical markets, or alternatively two slightly different products, 1 and 2. Firms find it profitable to produce in market 2 only if demand increases sufficiently.[7]

To enter any market, a firm incurs a fixed cost, $F > 0$. The firms have the same discount factor, $\delta \in (0, 1]$. Finally, I assume that once a firm has entered, exit costs are sufficiently high so that staying in the market is a

[6] I assume that the incumbent cannot search to discover the state of demand in the first period.

[7] Note that I introduce two separate markets, because it corresponds to the Hotelling model of product differentiation that I will provide as an example. However, one could also consider that entry occurs in an existing market (market 1) as long as profit flows satisfy assumptions P1-P5 below.

credible commitment.[8]

2.2 Consumers

In the first period, demand is 'low'; the density of consumers is equal to 1. In the second period, demand may either *decrease* or *increase*. The density of consumers in the second period, γ, is distributed on the interval $[\theta - \sigma, \theta + \sigma]$, where $\theta > 0$ and $\theta - \sigma \geq 0$. I denote $h(\gamma)$ the density function of this distribution and $H(\gamma)$ the cumulative.

In section 4, the results hold with any distribution h. However, in section 5 I will use a uniform distribution to interpret σ as the degree of uncertainty. With a uniform distribution, we have $h(\gamma) = 1/2\sigma$ and the density of consumers has mean θ and variance σ^2. I will interpret a higher variance, hence a higher σ, as a higher degree of uncertainty.

2.3 Profit flows

Let π_j^i denote the profit flow of firm $i \in \{I, E\}$ when the density of consumers is equal to 1 and no firm enters market 2 ($j = 0$), firm $j \in \{I, E\}$ enters market 2 or both firms enter ($j = b$). When the density of consumers is γ, I will assume that profit flows are given by $\gamma\pi_j^i$. The net discounted profits

[8] Hence, I avoid Judd (1985)'s critique about the credibility of preemption.

will be denoted by Π_k^i, where $k = 1$ when firm I preempts the new market in the first period and $k = 2$ when it waits until the second period.

I make the following assumptions on profit flows.

Assumption P1 $\pi_I^I > \pi_0^I$.

This assumption means that firm I makes more gross profit when it operates in both markets than when it operates in market 1 alone.

Assumption P2 $\pi_0^I > \pi_E^I$.

This assumption means that firm I's local monopoly profit in market 1 is reduced if firm E enters market 2.

Assumption P3 $\pi_E^I > \pi_b^I$.

This assumption states that when firm I operates in both markets and competes with firm E in market 2, it would be better off exiting market 2. This is a *cannibalization effect*: intense competition in market 2 not only shrinks firm I's profit in market 2 but also cannibalizes its profit in market 1.

Assumption P4 $\pi_0^E = \pi_I^E = \pi_b^E = 0$.

The entrant makes no profit when it stays outside the market; it makes also no profit when it faces firm I in market 2, due to fierce competition.

Assumption P5 $\pi_E^E \geq \pi_I^I - \pi_0^I$.

This assumption states that firm E has more incentives to enter market

2 than firm I. This is a standard assumption in the R&D literature, which is often referred to as the *replacement effect*.[9]

In Appendix A, I provide a model of product differentiation, which satisfies assumptions P1-P5. I also make the following assumptions on F.

Assumption F1 $F > (1+\delta\theta)\left(\pi_I^I - \pi_0^I\right)$.

This assumption implies that when there is no entry threat in the second period, firm I does not enter market 2 in the first period.

Assumption F2 $F < \pi_I^I - \pi_0^I + \delta\theta\left(\pi_I^I - \pi_E^I\right)$.

This assumption means that when there is an entry threat in the second period with (ex ante) probability 1, firm I decides to enter market 2 in the first period. Notice that the set of F that satisfy assumptions 1 and 2 is not empty, as $\pi_E^I < \pi_0^I$ by assumption P2.

Assumption F3 $F > (1+\delta\theta)\,\pi_E^E$.

This assumption ensures that firm E has no incentives to enter market 2 in the first period. As we have $\pi_I^I - \pi_0^I \leq \pi_E^E$, assumption F3 is stronger than assumption F1.

In the example provided in Appendix A, assumptions F1 and F3 are equivalent as $\pi_I^I - \pi_0^I = \pi_E^E$.

[9] The "replacement effect" was introduced in the R&D literature by Arrow (1962), who states that an incumbent firm has less incentive to invest in R&D because, by increasing its R&D investment, it hastens its own replacement (see Tirole, (1988)).

2.4 The timing

The timing of the game is as follows.

1. Firm I decides whether or not to enter market 2 based on the expected level of demand. Then, it chooses the price of its product(s) for the first period and sells it (them).

2a The level of demand in period 2 is revealed to both firms.

2b Firms I and E decide simultaneously whether or not to enter market 2. Then, firm I and firm E (if it has entered market 2) choose the prices of their products simultaneously.

The sequence of the game can be interpreted as follows. In the first period, the incumbent can preempt market 2 but it ignores the state of demand in the second period. If the incumbent decides to wait until the second period and demand increases, there is a possibility that the firms play a simultaneous entry game, as if the incumbent had not enough time to preempt the entrant.

The idea is that there are cases in which entry into new markets becomes suddenly profitable. In such cases, incumbent firms may have no time to preempt the new markets and prevent entry from outside rival firms. For instance, an exogenous innovation might attract new consumers;[10] a macroeconomic shock might affect demand positively or negatively. This will particularly be true in innovative markets, in which demand evolves rapidly.

In this setting, the incumbent faces the following trade-off. On the one hand, if it enters in the first period and demand in the second period appears to be so low that there is no entry threat, it has invested more than justified. On the other hand, if it does not enter in the first period and demand in the second period appears to be high, it competes with the entrant to enter market 2.

Finally, notice that whether or not firm I's preemption decision conveys information on the state of demand does not affect the outcome of the game. Indeed, when the incumbent enters market 2 in the first period, the entrant cannot enter in the second period (as entry is deterred).

I look for the subgame perfect equilibrium of this game. I solve it backwards and start by the second period.

[10] In the computer industry, converters allowed Mac users to use software designed for the PC platform, hence increased the demand of PC software.

3 Entry in the second period

In this section, I determine the equilibrium of the simultaneous entry game of the second period, conditional on firm I's entry decision in the first period. If firm I entered market 2 in the first period, firm E chooses to remain out of the market, since its gain from entering ($\pi_b^E = 0$) is lower than the entry cost ($F > 0$). Now, assume that firm I did not enter market 2 in the first period. The firms decide simultaneously whether or not to enter market 2. The payoff matrix of this subgame is shown below. Remember that γ represents the density of consumers in the second period.

		Firm I	
		Enters	Does not enter
Firm E	Enters	$\left(\gamma\pi_b^I - F, \gamma\pi_b^E - F\right)$	$\left(\gamma\pi_E^I, \gamma\pi_E^E - F\right)$
	Does not enter	$\left(\gamma\pi_I^I - F, 0\right)$	$\left(\gamma\pi_0^I, 0\right)$

First, assume that both firms choose to enter market 2. Firm $i \in \{I, E\}$ is better off not entering market 2, as we have $\pi_b^i \leq \pi_E^i$ and $F > 0$, which implies that $\gamma\pi_b^i - F < \gamma\pi_E^i$.

Second, assume that only one firm enters market 2. I will say that firm i is *willing to enter* market 2 if and only if $\gamma\left(\pi_i^i - \pi_0^i\right) \geq F$. If find that this condition is satisfied if and only if the density of consumers in the second period, γ, is sufficiently high.

Lemma 1 *There exists* $\widetilde{\gamma}_E$ *and* $\widetilde{\gamma}_I$*, where* $\widetilde{\gamma}_E \leq \widetilde{\gamma}_I$*, such that firm* $i \in \{I, E\}$ *is willing to enter market 2 in the second period if and only if* $\gamma \geq \widetilde{\gamma}_i$*.*

Proof. Firm E is willing to enter market 2 in the second period if and only if $\gamma\pi_E^E \geq F$, or $\gamma \geq F/\pi_E^E$; hence $\widetilde{\gamma}_E = F/\pi_E^E$. Similarly, firm I is willing to enter market 2 in the second period if and only if $\gamma(\pi_I^I - \pi_0^I) \geq F$, or $\gamma \geq F/(\pi_I^I - \pi_0^I)$; hence $\widetilde{\gamma}_I = F/(\pi_I^I - \pi_0^I)$. Finally, as $\pi_E^E \geq \pi_I^I - \pi_0^I$, we have $\widetilde{\gamma}_E \leq \widetilde{\gamma}_I$. ■

This result means that the firms are willing to enter market 2 in the second period if and only if demand grows sufficiently. The fact that $\widetilde{\gamma}_E \leq \widetilde{\gamma}_I$ stems from the fact that in the present setting, there is a replacement effect (assumption P5).

In the rest of the text, to simplify notations, I will use $\widetilde{\gamma}$ instead of $\widetilde{\gamma}_E$. There are three possible entry situations, depending on γ. First, when $\gamma < \widetilde{\gamma}$, no firm is willing to enter market 2. Hence, I obtain the following result (see also payoff matrix).

Lemma 2 *Assume that firm* I *did not enter market 2 in the first period and that* $\gamma < \widetilde{\gamma}$*. At the equilibrium, no firm enters market 2.*

Second, for intermediate values of γ (i.e., $\gamma \in [\widetilde{\gamma}, \widetilde{\gamma}_I)$), firm E is willing to enter market 2, whereas firm I is not. Hence, there is a unique equilibrium in pure strategies such that firm E enters market 2 alone.

Lemma 3 *Assume that firm I did not enter market 2 in the first period and that $\gamma \in [\widetilde{\gamma}, \widetilde{\gamma}_I)$. At the equilibrium, there is entry of firm E.*

Third, when demand grows sufficiently, i.e., when $\gamma \geq \widetilde{\gamma}_I$, the two firms are willing to enter. Therefore, there are two Nash equilibria in pure strategies: either firm I enters market 2 alone or firm E. I adopt the concept of *risk dominance* of Harsanyi and Selten (1988) to determine which equilibrium is the focal equilibrium of the subgame. Risk dominance captures the following intuition. When there are two Nash equilibria in a game, the players do not necessarily know which equilibrium their rival expects them to play. Therefore, each player might take into account the *risk* of a given strategy. The risk for a player can be defined as the payoff earned if he plays according to one equilibrium, while his rival plays according to the other equilibrium. In the present setting, risk dominance suggests that there is a trade-off between the gain in case of successful entry and the risk that the two firms compete head-to-head.

Lemma 4 *Assume that firm I did not enter market 2 in the first period and that $\gamma \geq \widetilde{\gamma}_I$. In the risk dominant equilibrium of the second period, there is entry of firm E.*

Proof. See Appendix B. ■

The intuition of this result is the following. With the risk dominance concept, the firms take into account their incentive to enter market 2 when their rival does not enter, and the cannibalization of their existing activities when they both enter market 2. In the present setting, firm E has more incentive to enter the market than firm I, as $\pi_I^I - \pi_0^I \leq \pi_E^E$. Besides, face-to-face competition cannibalizes firm I's existing activities in market 1, but does not affect firm E, as it is out of the market prior to the entry game. Because these two effects favor firm E, the risk dominant equilibrium is the one in which firm E enters market 2 alone.

Lemmas 3 and 4 imply that when firm I does not preempt market 2 in the first period and $\widetilde{\gamma} \in (\theta - \sigma, \theta + \sigma)$, the probability of entry in the second period, $1 - H(\widetilde{\gamma})$, is strictly positive. Hence, the only means for the incumbent to maintain its monopoly with certainty is to preempt market 2 in the first period.

4 The equilibrium

In this section, I determine the equilibrium of the game and study whether there is entry or persistence of monopoly at the equilibrium. If firm I enters market 2 in the first period, it gets $\pi_I^I - F$ in the first period. In the second period, entry is deterred and its expected profit is $\theta \pi_I^I$; hence, firm I's discounted expected profit is

$$\Pi_1^I = \pi_I^I - F + \delta\theta\pi_I^I.$$

If firm I waits until the second period, the outcome of the simultaneous entry game is as given by Lemmas 2 -4. Firm I's discounted expected profit is

$$\Pi_2^I = \pi_0^I + \delta \times \left[\int_{\theta-\sigma}^{\widetilde{\gamma}} \gamma \pi_0^I h(\gamma)\, d\gamma + \int_{\widetilde{\gamma}}^{\theta+\sigma} \gamma \pi_E^I h(\gamma)\, d\gamma \right]. \tag{1}$$

Equation (1) can be interpreted as follows. If $\gamma \in [\theta - \sigma, \widetilde{\gamma})$, no firm enters market 2 in the second period, hence firm I gets monopoly profit from market 1, $\gamma \pi_0^I$. If $\gamma \in [\widetilde{\gamma}, \theta + \sigma)$, firm E preempts market 2 in the second period, hence firm I gets duopoly profit, $\gamma \pi_E^I$.

Equation (1) can be rewritten as follows:

$$\Pi_2^I = \pi_0^I + \delta \times \left[(\theta - \varphi)\, \pi_0^I + \varphi \pi_E^I \right], \tag{2}$$

where

$$\varphi = \int_{\widetilde{\gamma}}^{\theta+\sigma} \gamma h(\gamma)\, d\gamma.$$

If $\widetilde{\gamma} \in (\theta - \sigma, \theta + \sigma)$, we have $\varphi \in (0, \theta)$. In equation (2), φ represents the "weight" attached to the entry threat, hence its *magnitude*; the higher φ, the stronger the entry threat.

Firm I chooses to preempt market 2 in the first period if and only if $\Pi_1^I \geq \Pi_2^I$. Hence, there is entry at the equilibrium if and only if $\Pi_1^I < \Pi_2^I$ and $\widetilde{\gamma} \in (\theta - \sigma, \theta + \sigma)$.

Intuitively, if the entry threat is high, firm I will decide to preempt market 2 in the first period. Indeed, according to assumption F2, if the probability of entry is equal to 1, firm I preempts market 2. On the contrary, if the entry threat is sufficiently low, then firm I will stay out of market 2 in the first period. Indeed, if the probability of entry is nil, firm I stays out of market 2 (assumption F1). The following proposition confirms this intuition.

Proposition 1 *There exists $\widetilde{\varphi} \in (0, \theta)$ such that there is entry of firm E at the equilibrium with strictly positive probability if and only if $\varphi \in (0, \widetilde{\varphi})$.*

Proof. Firm I preempts market 2 in the first period if and only if $\Pi_1^I \geq \Pi_2^I$ or

$$\pi_I^I - F + \delta\theta\pi_I^I \geq \pi_0^I + \delta \times \left[(\theta - \varphi)\,\pi_0^I + \varphi\pi_E^I\right].$$

Rearranging this equation yields

$$\delta\varphi\left(\pi_0^I - \pi_E^I\right) \geq F - (1+\delta\theta)\left(\pi_I^I - \pi_0^I\right).$$

Since $\pi_0^I > \pi_E^I$ (assumption P2), this condition is equivalent to $\varphi \geq \widetilde{\varphi}$, where

$$\widetilde{\varphi} = \frac{F - (1+\delta\theta)\left(\pi_I^I - \pi_0^I\right)}{\delta\left(\pi_0^I - \pi_E^I\right)}.$$

Notice that $\widetilde{\varphi} \in (0, \theta)$. Indeed, $\widetilde{\varphi}$ increases with F. When F goes to $(1+\delta\theta)\left(\pi_I^I - \pi_0^I\right)$ (its lower bound according to assumption F1), $\widetilde{\varphi}$ goes to 0. When F is the highest, i.e., when F goes to $\pi_I^I - \pi_0^I + \delta\theta\left(\pi_I^I - \pi_E^I\right)$ (its higher bound according to assumption F2), $\widetilde{\varphi}$ goes to θ. ■

Proposition 1 states that when the entry threat is low, the incumbent may choose not to use its first-mover advantage, hence that there may be entry in the second period with nonzero probability. The idea is that when the entry threat is uncertain and the "cost" of a preemption strategy is high, the incumbent is better off not preempting market 2 in the first period, which suggests the possibility of entry by firm E in the second period.

This result contrasts with the standard result in the preemption literature, according to which at the equilibrium the incumbent preempts the new market or product whenever there is an entry threat.[11] The difference between the standard result and my result lies in the stochastic nature of the entry threat. In standard models of preemption, the entry threat is deterministic; in the present setting it means that we have $\varphi = \theta$, hence that there can never be entry of firm E. In my setting, the entry threat is stochastic. Hence, the magnitude of the entry threat, φ, can be very low but not nil, which leads to entry of firm E with non zero probability.

McGahan (1993) has a similar result to Proposition 1. In her model, the incumbent is a first-mover which can install capacity in the first period, before the entrant enters the market in the second period. Demand can be either low or high, and firms have prior beliefs about the state of demand. She shows that the incumbent installs a large capacity in the first period, only if the probability that demand is high is sufficiently high.

However, there are differences among the result of McGahan and Proposition 1. First, in McGahan's model, without threat of entry, the incumbent installs a large capacity if it expects that demand is high. In the present setting, the incumbent does not enter in the first period if there is no threat of entry (assumption F1). Second, when the incumbent does not install a large capacity in the first period, it has the opportunity of investing at the

[11] For instance, see Tirole (1988, Chapter 8).

beginning of the second period, which "mitigates the cost of being wrong in the first period" (McGahan, 1993, p. 338). In the present setting, if the incumbent is "wrong", it cannot preempt market 2 in the second period, i.e., entry occurs. Hence, incentives to preempt in the first period are higher in the present setting than in McGahan's. Proposition 1 shows that, even in this case, there is entry with non zero probability if φ is sufficiently low.

5 The impact of uncertainty on preemption

In this section, I study whether increased uncertainty about demand growth favors entry or persistence of monopoly. To do that, I analyze whether the probability of entry at the equilibrium increases or decreases when σ becomes higher. To proceed with this analysis, it proves necessary to specify the distribution h. In order to derive analytical expressions, I assume that it is uniform. However, simulations showed that the results in this section are also valid for a normal distribution.

To begin with, I analyze how firm I's preemption strategy evolves as σ increases. Remember that firm I does not preempt market 2 in the first period when φ is strictly positive and sufficiently low (proposition 1). The following lemma shows that the effect of an increase of σ on φ depends on whether $\theta < \widetilde{\gamma}$ or $\theta > \widetilde{\gamma}$.

Lemma 5 *Assume that h is uniform. When $\theta < \widetilde{\gamma}$, φ increases with σ. When $\theta > \widetilde{\gamma}$, φ decreases then increases with σ.*

Proof. Replacing $h(\sigma)$ by its value $(1/2\sigma)$ into φ, I find that

$$\frac{\partial \varphi}{\partial \sigma} = \frac{\widetilde{\gamma}^2 - \theta^2 + \sigma^2}{4\sigma^2}.$$

When $\theta < \widetilde{\gamma}$, then $\partial\varphi/\partial\sigma > 0$. When $\theta > \widetilde{\gamma}$, then $\partial\varphi/\partial\sigma < 0$ for low values of σ and $\partial\varphi/\partial\sigma > 0$ for high values of σ. ■

The intuition is the following. An increase of σ has two effects on the magnitude of the entry threat, φ. First, when σ increases, the density of consumers takes higher values, which increases φ. Second, σ affects the probability of entry. When $\theta < \widetilde{\gamma}$, the probability of entry is nil for low values of σ, hence it increases as σ becomes higher. When $\theta > \widetilde{\gamma}$, the probability of entry is equal to 1 for low values of σ, hence it decreases as σ becomes higher. This is why φ increases with σ when $\theta < \widetilde{\gamma}$ and φ is U-shaped when $\theta > \widetilde{\gamma}$.

Lemma 5 implies that we have to consider two different cases.

Case 1: $\theta < \widetilde{\gamma}$. For σ sufficiently low, firm E does not find it profitable to enter market 2 in the second period, hence ex ante there is no threat of entry ($\varphi = 0$). Now, suppose that σ increases sufficiently such that firm E finds it profitable to enter market 2 for high values of the density of consumers. As long as the ex ante threat of entry remains low, firm I does not preempt market 2 in the first period, hence the probability that there is entry at the equilibrium increases with σ, since the support of the distribution becomes larger. Once the incumbent starts preempting market 2, the probability of entry at the equilibrium falls to zero.

Case 2: $\theta > \widetilde{\gamma}$. For σ sufficiently low, since it knows that there will be entry with probability 1 if it does not preempt market 2, firm I enters market 2 in the first period. Therefore, the probability that there is entry at the equilibrium is equal to zero. As σ increases, lemma 5 shows that the ex ante threat of entry, φ, decreases then increases with σ. Therefore, there might be cases in which firm I stops preempting market 2 for intermediate values of σ, then resumes preempting this market for high values of σ. For the range of σ such that firm I stops preempting market 2, a higher σ implies a lower probability of entry at the equilibrium. Indeed, starting from a situation in which the entry threat is high, a higher variance means that demand may decrease, which reduces the probability that there is entry at the equilibrium.

This analysis is formalized in the following proposition.

Proposition 2 *Assume that h is uniform and that firm I does not preempt* *market 2. The probability that there is entry by firm E at the equilibrium increases with σ when $\theta < \widetilde{\gamma}$, whereas it decreases with σ when $\theta > \widetilde{\gamma}$.*

Proof. See Appendix C. ■

In their seminal article, Eaton and Lipsey (1979) showed that an incumbent firm threatened by a potential entrant preempts a new market or product before its rival does. They obtained this result in a deterministic setting and mentioned that it might not hold if the entry threat were uncertain. Their intuition was that "the more erratic and unpredictable is market growth, the greater the possibility of new firms entering to serve part of the expanding market" (Eaton and Lipsey, 1979, p. 157).

Proposition 2 analyzes how an increase in the degree of uncertainty, σ, affects the probability of a new firm entering the market. Therefore, it might be viewed as a test of Eaton and Lipsey's intuition.

Proposition 2 shows that this intuition does not always work in the present setting. In some cases, it does. Indeed, when market 2 is not profitable on average (i.e., when $\theta < \widetilde{\gamma}$), the probability that firm E enters market 2 at the equilibrium increases with the degree of uncertainty σ. This is true until firm I starts preempting market 2. However, Eaton and Lipsey's intuition does not work when market 2 is profitable on average (i.e., when $\theta > \widetilde{\gamma}$). In this case, if there is entry for some values of σ, then the probability that firm E enters market 2 at the equilibrium *decreases* with the degree of uncertainty σ.

Under which condition the case $\theta > \widetilde{\gamma}$ can occur? Recall that Assumption F3 requires that $F > (1 + \delta\theta)\, \pi_E^E$ and that Lemma 1 shows that $\widetilde{\gamma} = F/\pi_E^E$. Thus, $\widetilde{\gamma} > 1 + \delta\theta$, so $\theta > \widetilde{\gamma}$ can only occur when $\theta > 1 + \delta\theta$, or $\theta > (1 - \delta)^{-1}$. Therefore, case $\theta > \widetilde{\gamma}$ occurs either when demand grows sharply (θ is high) or when period 1 is a very early stage of the market, compared to period 2 (δ is small).

Numerical example To illustrate Proposition 2, consider the following numerical example. I use the model of competition with differentiated products of Appendix A. Let $t = 1$, $r = 3$, $\theta = 2$, and $\sigma \in [0, \theta]$. We have $\widetilde{\gamma} = 2F/t$. To illustrate the first case, in which $\theta < \widetilde{\gamma}$, suppose that $F = 1.4$ and $\delta = 0.8$, hence $\widetilde{\gamma} = 2.8$. One can find that there is *no entry* for $\sigma \in [0, 0.8)$, *entry* for $\sigma \in [0.8, 0.85)$ and *preemption* for $\sigma > 0.85$. When $\sigma \in [0.8, 0.85)$, the probability of entry increases with σ.

To illustrate the second case, in which $\theta > \widetilde{\gamma}$, suppose that $F = 0.95$ and $\delta = 0.15$, hence $\widetilde{\gamma} = 1.9$. I find that there is *preemption* for $\sigma \in [0, 0.43)$, *entry* for $\sigma \in [0.43, 0.9)$ and *preemption* again for $\sigma > 0.9$. When $\sigma \in [0.43, 0.9)$, the probability of entry decreases with σ (see figure 1).

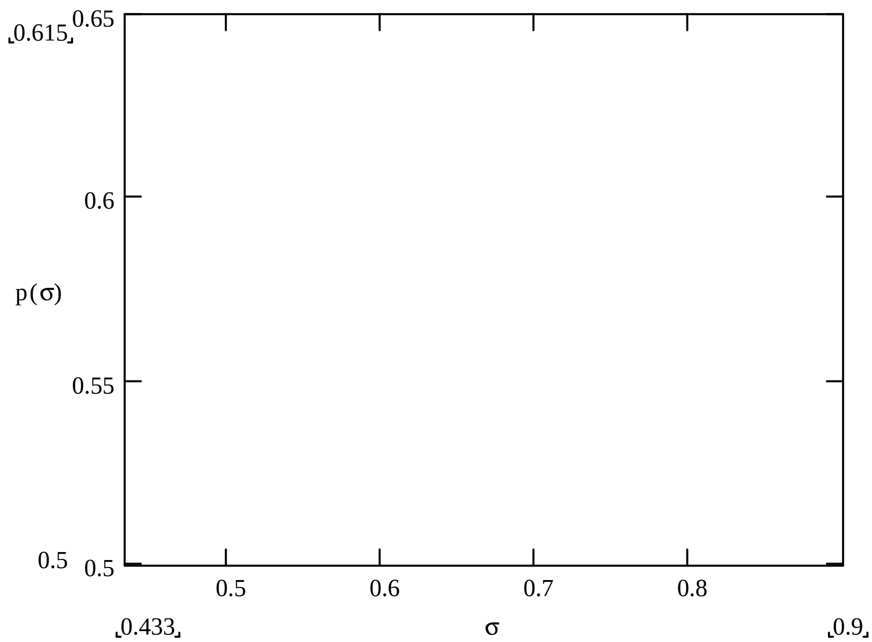

Figure 1: Probability of entry for case $\theta > \widetilde{\gamma}$

6 Conclusion

In this article, I propose a model to analyze the ability of an incumbent firm to preempt a new market before a rival firm does, when the firms face uncertainty about demand growth. In this setting, entry of the outside firm occurs with nonzero probability when the entry threat is sufficiently low.

Increasing the degree of uncertainty has ambiguous effects on the probability of entry. On the one hand, if a higher degree of uncertainty means higher realizations of demand, the probability of entry might increase with the degree of uncertainty. On the other hand, if a higher degree of uncertainty means lower realizations of demand, the probability of entry tends to decrease with the degree of uncertainty.

This work could be extended in various directions. In particular, I studied a simple game of entry, without capacity investment. It would be interesting to study how the degree of uncertainty affects the capacity choice of the incumbent.

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A A model of product differentiation

In this appendix, I provide a Hotelling model of product differentiation which satisfies assumptions P1-P5.

Consider that market 1 is located at the left of the unit interval, at $x_1 = 0$, and that market 2 is located at the right of the interval, at $x_2 = 1$. Consumers are distributed uniformly along the interval $[0, 1]$. Each consumer buys at most one unit of the product in each period. If consumer $x \in [0, 1]$ purchases a product in market i, its total cost is $p_i + t \times |x - x_i|$, where p_i represents the price of the product and t is the transportation cost for unit distance. Each consumer chooses the product which minimizes its total cost, subject to a reservation price, r. I assume that all consumers are served at any equilibrium, which is satisfied when $r > 2t$.

One can show that in this setting, we have $\pi_0^I = r - t$, $\pi_I^I = r - t/2$, $\pi_E^E = \pi_E^I = t/2$, $\pi_b^I = t/8$ and $\pi_0^E = \pi_I^E = \pi_b^E = 0$.

To see that, first assume that firm E has entered market 2 but firm I has not; firm I is located at $x_1 = 0$ and firm E is located at $x_2 = 1$. The resolution of the price equilibrium is standard (e.g., see Tirole, 1988). It is found that the two firms charge the same equilibrium price, t, and share the demand, hence, $\pi_E^E = \pi_E^I = t/2$.

Second, assume that the two firms have entered market 2. As they offer homogeneous goods in market 2, competition drives firms' prices in market 2 to zero. Hence, $\pi_b^E = 0$. Firm I sets a price for its product in market 1 which maximizes its profit, knowing that the equilibrium price in market 2 is equal to zero. I find that this optimum price is equal to $t/2$ and that the product sold in market 1 serves 1/4 of demand, hence, $\pi_b^I = t/8$.

Third, consider that firm I is a monopolist in market 1, at $x_1 = 0$. If it decides to serve every consumer, it charges the highest price such that the farthest consumer, at $x_2 = 1$, derives positive surplus. Since all consumers are served at this price, which is equal to $r - t$, firm I obtains profit flows $\pi_0^I = r - t$. Firm I might also decide to cover the market partially. I find that the former strategy (full coverage) yields higher profits than the latter (partial coverage) if and only if $r > 2t$. I assume that this condition is satisfied.

Finally, if firm I is a monopolist in markets 1 and 2, firm I sets the highest price such that a consumer at the middle of the segment (i.e., at $x = 1/2$) obtains positive profit. Hence, the optimum price is equal to $r - t/2$ and $\pi_I^I = r - t/2$.

Demand is covered if every consumer consumes a product, hence, if every consumer obtains positive surplus at the equilibrium. In the four cases studied above, the limit case is the one in which firm I operates in market

1 alone. Hence, demand is covered in every entry configuration if and only if $r > 2t$.

It is easy to show that the profit flows satisfy assumptions P1-P5.

B Proof of Lemma 4

The proof follows that of Aron (1993). There are two equilibria: (S_I) in which firm I enters alone and (S_E) in which firm E enters alone. To begin with, I calculate the resistance of equilibrium (S_I) against equilibrium (S_E). Let λ be the highest probability such that firm I is indifferent between playing (S_I) and (S_E) when firm E plays (S_E) with probability λ and (S_I) with probability $1-\lambda$. If firm I plays (S_I), its payoff is

$$\lambda \times \left(\gamma \pi_b^I - F\right) + (1-\lambda) \times \left(\gamma \pi_I^I - F\right), \tag{3}$$

while if it plays (S_E), it obtains

$$\lambda \times \gamma \pi_E^I + (1-\lambda) \times \gamma \pi_0^I. \tag{4}$$

Assumptions P1 and P3 imply that $\pi_I^I - \pi_0^I + \pi_E^I - \pi_b^I$ is strictly positive, hence the difference between equations (3) and (4) decreases with λ. Therefore, the highest probability such that firm I is indifferent between (S_I) and (S_E) is

$$\lambda = \frac{\gamma\left(\pi_I^I - \pi_0^I\right) - F}{\gamma\left(\pi_I^I - \pi_0^I + \pi_E^I - \pi_b^I\right)}.$$

Similarly, I calculate the highest probability β such that firm E strictly prefers to play (S_I) when firm I plays (S_E) with probability β and (S_I) with probability $1-\beta$. Taking into account that $\pi_b^E = 0$ (assumption P4) yields $\beta = F/\left(\gamma \pi_E^E\right)$.

The resistance of equilibrium (S_I) against equilibrium (S_E) is $\min(\lambda, \beta)$. Similarly, the resistance of equilibrium (S_E) against equilibrium (S_I) is $\min(1-\lambda, 1-\beta)$. It follows that equilibrium (S_E) risk dominates equilibrium (S_I) if and only if $\lambda < 1-\beta$. I replace λ and β by their values, which shows that (S_E) risk dominates (S_I) if and only if

$$\left(\gamma\pi_E^E - F\right)\left(\pi_E^I - \pi_b^I\right) > \left[\left(\pi_I^I - \pi_0^I\right) - \pi_E^E\right] F. \tag{5}$$

We have $\gamma\pi_E^E > F$ and $\pi_E^I > \pi_b^I$ (assumption P3), which implies that the left-hand side is strictly positive. Besides, we have $\pi_I^I - \pi_0^I \leq \pi_E^E$ (assumption P5), hence the right-hand side is non positive. It follows that equation (5) is always satisfied, i.e. (S_E) risk dominates (S_I) for all $\gamma \geq \widetilde{\gamma}$.

C Proof of Proposition 2

There are two cases.

Case 1: $\theta < \widetilde{\gamma}$. For σ sufficiently low (i.e., $\theta + \sigma < \widetilde{\gamma}$), we have $\varphi = 0$, hence the probability of entry is equal to zero, as firm E is not willing to enter market 2. Besides, since φ increases with σ and $\widetilde{\varphi} > 0$, then $\varphi(\sigma)$ intersects $\widetilde{\varphi}$ at most once. For σ such that $0 < \varphi(\sigma) < \widetilde{\varphi}$, there is entry, and the probability of entry *increases* with σ. If $\varphi(\sigma)$ intersects $\widetilde{\varphi}$ at $\widetilde{\sigma}$, then $\varphi(\sigma) > \widetilde{\varphi}$ for all $\sigma > \widetilde{\sigma}$. This means that for all $\sigma > \widetilde{\sigma}$, firm I preempts market 2 in the first period, hence the probability of entry falls to zero. If $\varphi(\sigma)$ does not intersect $\widetilde{\varphi}$, firm I never preempts market 2.

Case 2: $\theta > \widetilde{\gamma}$. For σ sufficiently low (i.e., $\theta - \sigma \geq \widetilde{\gamma}$), $\varphi = \theta$. Therefore, the probability of entry is equal to zero. Besides, as φ decreases then increases with σ (lemma 5), then $\varphi(\sigma)$ intersects $\widetilde{\varphi}$ at most twice. Assume that there are two intersects, at $\widetilde{\sigma}_1$ and $\widetilde{\sigma}_2$. For $\sigma \in (0, \widetilde{\sigma}_1)$, we have $\varphi(\sigma) > \widetilde{\varphi}$, hence the probability of entry is equal to 0. For $\sigma \in (\widetilde{\sigma}_1, \widetilde{\sigma}_2)$, we have $\varphi(\sigma) < \widetilde{\varphi}$, hence the probability of entry is strictly positive; besides, it *decreases* with σ, as by enlarging the distribution one introduces low values of σ such that entry is not profitable. Finally, for $\sigma > \widetilde{\sigma}_2$, we have $\varphi(\sigma) > \widetilde{\varphi}$, hence the probability of entry falls to 0, as the incumbent preempts market 2 in the first period.