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Why entrepreneurs choose risky R&D projects - but still not risky enough*

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Abstract

This paper examines how entrepreneurs and incumbents differ in their R&D strategies. We show that entrepreneurs have incentives to choose projects with a higher risk and a higher potential in order to reduce expected entry costs. If products are not too differentiated, entrepreneurs will select projects that are too safe from a social point of view, since they do not internalize the business stealing effect on incumbents. Entry support induces entrepreneurs to choose safer projects, whereas R&D support encourages entrepreneurship without affecting the type of entrepreneurship.

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Entrepreneurs are important for economic progress as providers of "breakthrough" inventions. As pointed out by Scherer and Ross (1990, **p.??**), 'new entrants without a commitment to accepted technologies have been responsible for a substantial share of the really revolutionary new industrial products and processes'. Along these lines, Baumol (2004) documents that in the US, small entrepreneurial firms have created a large share of breakthrough inventions whereas large established firms have provided more routinized R&D. Further, in a review of the empirical literature on firm size and innovative activity, Cohen (2010,**p.??**) concludes that 'the key findings are that larger, incumbent firms tend to pursue relatively more incremental and relatively more process innovation than smaller firms.'[1]

These observations raise important questions: (*i*) Why do small independent firms (entrepreneurs) embark on radical R&D projects characterized by large uncertainties but high value in cases of success? (*ii*) Do the projects chosen by the entrepreneurs differ from the optimal research projects from a social point of view?, and (*iii*) What are the expected induced effects of policies towards entrepreneurship that have been used in practice? These issues are addressed in this paper.

The starting point of the paper is that small independent firms have no complementary assets nor any experience when commercializing and, therefore, face much higher costs of commercializing an invention than do incumbents. As highlighted by Gans and Stern (2003,p.333), 'a key management challenge is how to translate promising technologies into a stream of economic returns for their founders, investors and employees. In other words, the main problem is not so much invention but commercialization'. We will capture this difference by assuming that the entrepreneur will face an entry cost when commercializing the invention in a product market.

We develop a model where an incumbent and an entrepreneur both invest in R&D that might lead to the creation of an invention. There are different types of R&D projects to choose among where a project with a lower probability of success is associated with a higher payoff if it succeeds. A key feature of the model is that if the entrepreneur turns out to be successful with her chosen research project, she will face an entry cost when commercializing the invention. However, the incumbent is already active in the market and, therefore, will not have to pay any cost to commercialize an invention.

We first establish that the entrepreneur will choose a project with a lower probability of success than the incumbent. There are two effects which explain this result. First, the *entrepre-*

[1] Prusa and Schmitz (1991) provide evidence from the personal computer software industry that new firms tend to create new software categories, while established firms tend to develop improvements in existing categories. Henkel, Rønde and Wagner (2014), on the other hand, undertake a qualitative empirical study of the electronic design automation (EDA) industry, concluding that start-ups opt for R&D projects characterized by high risk and return.

neurship hurdle effect: the entry cost associated with commercialization for the entrepreneur implies that the entrepreneur opts for a project that involves more risk since, by so doing, she reduces the expected entry cost (since the entry cost is only paid when the project succeeds). Second, the *entry deterring effect*: being successful with a minor invention, the incumbent might be able to block entry by an entrepreneur. Thus, for an incumbent, a successful innovation does not only give rise to cost savings but also to entry deterrence and, therefore, the incumbent will choose less risky projects.

How does the optimal project chosen by the entrepreneur relate to the socially optimal research project? There are two important externalities involved in the entrepreneur's choice of project. When the entrepreneur innovates, she does not internalize the expected profit stealing (the entry deterring value from the perspective of the incumbent) which hurts the incumbents. The expected profit stealing increases when projects become more certain since entry hurts rivals. This implies that the entrepreneur tends to choose too safe R&D projects from a social point of view. However, there is also an expected consumer surplus gain from entry, which increases the safer the project becomes, since entry *per se* benefits consumers. Consequently, the social planner would, in the latter respect, prefer the entrepreneur to choose projects with less risk (thus, entering with higher probability).

We show that in a model with symmetric firms and homogeneous goods, the profit stealing effect outweighs the increase in the consumer surplus. The entrepreneur then chooses a project which is too safe from a social perspective. Moreover, in a model with differentiated goods, we show that this finding holds unless the products are sufficiently differentiated.

In the last few decades, entrepreneurship has emerged as a key issue in the policy arena. In addition, governments and policy makers have been playing a key role as facilitators of innovations by firms. An important policy debate concerns the optimal design of government policies to facilitate and stimulate R&D and entrepreneurship. This paper will contribute to this debate by investigating the induced effects of the two following types of policies which have been used in practice: (*i*) R&D support and (*ii*) entry support.

First, a typical example of a pro-entrepreneurial policy is that of R&D subsidies targeted at small and medium sized enterprises (SMEs). According to a report by the OECD (OECD 2007), in the year 2007, several countries offered tax subsidies for R&D specifically targeted at SMEs. Examples are: the UK, Canada, Japan, the Netherlands, Norway and Poland. In our proposed theoretical model, a tax subsidy for R&D reduces the R&D cost paid ex ante, before the outcome of the R&D project has been realized.

Second, government policy can also be geared towards supporting the entry of small innovative firms. Examples of this type of policy are financial support for incubators, and loans specifically designed to facilitate the entry process in new firms. Recently, there has been a substantial increase in spending on such policies. For example, in 2009, the US Small Business Administration had approved over $13 billion in loans and $2.7 billion in surety guarantees to small businesses in a year.[2] In our proposed model, this second type of pro-entrepreneurial policy corresponds to a decrease in the entry cost that an entrepreneur must pay (ex-post) in case she succeeds with the R&D project and decides to enter the market with her invention.

In this paper, we undertake a comparison of the impact of each of these policies on the type of R&D projects that the entrepreneur as well as the incumbent will choose. We show that subsidies for R&D can induce an increase in the amount of R&D, but the type of R&D project which is carried out by the entrepreneur remains unaffected. The reason is that the commercialization cost is unaffected.

As for entry support, we show that, following the decrease in the entry cost, the entrepreneur embarks on an R&D project with a higher probability of success and a lower payoff (less-breakthrough) since the entrepreneurship hurdle effect is reduced. Moreover, the incumbent's response to a decrease in the entrepreneur's entry cost is to also choose projects with a higher probability of success. Then, we show that if the profit shifting effect of entry dominates the consumer effect, both agents will choose too safe projects and the optimal policy is then to subsidize R&D and tax entry.

A main finding in the paper is the entrepreneurship hurdle effect described above. But how robust is this finding? We generalize this result to a model with marginal cost reductions and relax some of the assumptions made in the benchmark model. First, we analyze the case when the entrepreneur can enter the market and both firms succeed. Second, we consider the cases where a second entrepreneur or a second incumbent exists. Finally, we also allow the entrepreneur to commercialize her invention through sale to the incumbent, instead of entering with it into the product market. We show that it is still true that as the commercialization (transaction) cost increases, the entrepreneur has a stronger incentive to embark on R&D projects with low probabilities of success but high payoffs if the projects succeed.

There are a number of empirical predictions emerging from the entrepreneurship hurdle effect. These predictions can be summarized as follows: (i) Higher entry costs result in more entrepreneurial failures, since high entry barriers imply that the entrepreneur opts for an R&D project with a lower probability of success; (ii) if the project succeeds, it will be of a higher quality, since a low success probability results in a higher payoff; (iii) the expected quality will be lower for entrepreneurs with higher entry costs, since their choices are further away from the choice that maximizes the expected quality.

[2] Source: 2009 Summary of Performance and Financial Information, US Small Business Administration, 2009.

Åstebro *et al.* (2014) describe an empirical puzzle of entrepreneurship, where the expected return from entrepreneurship tends to be low on average but exhibits large dispersion because most startups fail and only a few are very successful. In addition, calculations show that for normal degrees of risk aversion, the expected returns from entrepreneurship are even negative. Åstebro *et al.* (2014) discuss behavioral explanations to this puzzle, such as entrepreneurs being driven by overconfidence or low risk aversion, or by there being non-pecuniary benefits associated with entrepreneurship. In contrast, the mechanisms in this paper provide a neo-classical explanation for why the returns from entrepreneurship exhibit large dispersion. The hurdle effect predicts that the entrepreneur opts for R&D projects with a lower probability of success but higher quality if the project succeeds. In addition, the hurdle effect predicts that the expected quality will be lower for entrepreneurs with higher entry costs. This provides an additional explanation for why the average expected returns are low, which can complement the behavioral explanations put forth by Åstebro *et al.* (2014).[3]

This paper can be seen as a contribution to the literature on entrepreneurship (entry) and the product market (e.g. Baumol, 2004; Gans and Stern, 2000, 2003; Hellmann and Puri, 2000; Hvide, 2009; and Norbäck and Persson, 2012). Our paper is close in spirit to that of Mankiw and Whinston (1986) which shows that if an entrant causes incumbents to reduce output in a homogenous Cournot model (i.e. the business effect is positive), entry is more desirable to the entrant than it is to society in a free entry setting, whereas there can be insufficient entry in a differentiated product model, due to a positive product variety effect of entry. Examining the probability of entry, we add to this literature by showing that entrants may choose projects that are too safe from a social perspective if entry generates a larger profit reduction for incumbents than it increases the consumer surplus. This can be shown to hold if the products are not too differentiated. Moreover, we differ from this literature by also examining how (innovation) policy affects the riskiness of the undertaken (R&D) projects, taking into account the interaction between entrepreneurs and incumbents and undertaking a welfare analysis taking into account market power effects. This enables us to show that R&D support can be preferred to entry support since it stimulates the amount of entrepreneurship but does not distort the type of entrepreneurship.

The paper is also related to the literature on R&D and market structure. There are several papers studying the types of R&D projects to be undertaken.[4] However, to our knowledge,

[3] A large share of this literature is focused on post-entry risk, i.e. the risk of failing in the commercialization phase. Our model might therefore seem less suitable for explaining these stylized facts since it focuses on pre-entry failure, i.e. the risk of failing in the R&D phase. However, as we discuss in the concluding section, the identified hurdle effect would also be present in a set-up with post-entry risk.

[4] For a survey, see Gilbert (2006). See, for instance, Bhattachrya and Mookherjee (1986) for an early contribution.

there are only a few papers that consider asymmetries between firms in such a context. Cohen and Klepper (1996*a,b*) put forward (and test empirically) a model where differences in R&D behavior stem from the fact that larger firms have a larger output to which they can apply their innovation results. This then implies that large firms have a relative advantage in pursuing process innovation rather than product innovation since process innovations can more easily directly be used in existing businesses. Akcigit and Kerr (2015) use an endogenous growth framework and show that exploration R&D (creating new products) does not scale as strongly with firm size as exploitation R&D (improving existing products) due to a replacement effect. They use forward citations as a measure of quality to compare and quantify the distribution of innovation quality for different groups of firms and find support for empirical predictions from their model. In oligopolistic settings, Rosen (1991) and Cabral (2003) show that small firms may have an incentive to choose the risky strategy due to strategic output effects in the product market, i.e. small firms do not take on low risk-return projects since they cannot exploit the improvements on large output. In these papers, the difference in R&D behavior between small and large firms stems from the difference in post innovation outputs in the product market. In our paper, the difference stems from the fact that the entrepreneur has not yet sunk a large part of its entry (commercialization) costs before the outcome of the R&D process has been determined.

The key difference can be illustrated in a simple example: consider a situation where there are two research projects among which firms can choose. Project A has an associated payoff of 20 with probability 0.5 and 0 with probability 0.5. Project B has an associated payoff of 10 with probability 1. An incumbent facing zero entry cost is indifferent between projects A and B, irrespective of whether it is small or large. Now consider an entrepreneur who faces an entry cost of 1 if she decides to commercialize the invention. Because $(20-1)\times 0.5+0\times 0.5>10-1$, the entrepreneur prefers the risky project A over B. Using this distinction between entrepreneurship and incumbency, we add to the literature by showing that entrepreneurs have an incentive to choose risky R&D projects in order to optimize on expected entry costs (i.e., the hurdle effect).[5] Moreover, we show that incumbents have an incentive to choose safe R&D projects in order to reduce the likelihood of entry.[6] We also show that incumbents have an incentive to choose safe

[5] There are some recent papers studying what type of R&D projects entrepreneurs choose in situations where (instead) innovation for sale is an option. Henkel, Rønde and Wagner (2015) show that independent entrepreneurs which innovate for sale choose R&D projects with a higher risk than incumbents, since incumbents have an incentive to opt for safer R&D projects so as to improve their bargaining power in subsequent acquisitions. Haufler, Norbäck and Persson (2014) show that the limited loss offset feature of the tax system reduces the incentive for entrepreneurs to choose risky R&D projects. We differ from these studies by focusing on the importance of the entry cost, the strategic interaction between the R&D choices by the entrepreneur and the incumbent, and by undertaking a welfare analysis. This enables us to show that, due to the entrepreneurship hurdle effect and the business stealing effect, entrepreneurs choose risky R&D projects – but still not risky enough.

[6] The paper is also related to the literature on financial structure and firm behavior. There, it has been shown that increased debt levels should make firms undertake more risky investments (e.g. Stiglitz and Weiss,

R&D projects in order to reduce the likelihood of entry

The rest of the paper is organized as follows. Section 1 presents the model and characterizes the equilibrium research projects chosen by the entrepreneur and by the incumbent. Section 2 establishes why entrepreneurs choose risky R&D projects – but still not risky enough. Section 3 investigates the effects of pro-entrepreneurial policies on firms' choices of research projects. Section 4 generalizes our main result, the entrepreneurship hurdle effect, to a model with a more general set-up in which an invention can take several forms, all of which increase the firm profits; it can be a new product, a product of higher quality or a new or improved production process. This section also relaxes some of the other simplifying assumptions of our benchmark model. We analyze the case when the entrepreneur can enter the market when both firms succeed. We consider the cases where a second entrepreneur or a second incumbent exists. Finally, we also allow the entrepreneur to commercialize its invention through sale to the incumbent instead of entering it into the product market. Section 5 concludes the paper.

1 The Model

Consider a market with a unique incumbent firm. Outside this market, there is an entrepreneur which can potentially enter the market. The sequence of events is shown in Figure 1.1.

In stage 1, both firms can invest in an R&D project at a cost R which, if successful, generates an invention. The invention can take several forms, all of which increase the profits of the possessor: it can be a new product, a product of higher quality or a new or improved production process. To highlight our mechanism of interest, namely how entry costs affect the type of R&D conducted by firms, we will use a model where the innovation reduces the fixed cost of production, denoted $\overline{F}$, and which is identical for the entrepreneur and for the incumbent. In Section 4, we generalize the model to allow for innovations that improve product quality or reduce the variable costs of production.[7]

Each agent can choose among an infinite number of independent R&D projects. There is a cost of running a project and, to capture this, we assume that each firm can only undertake one project.[8] Each project (say, project l) is characterized by a certain probability of success,

1981) and more risky product market decisions (Brander and Lewis, 1986; Maksimovic and Zechner, 1991). Our results concerning R&D project type and commercialization costs are conceptually similar. Increasing the commercialization cost in our set-up (corresponding to increased debt or interest rate in that literature) implies that a larger amount of the low risk projects have negative returns which implies that the entrepreneur will put more weight on high risk projects. However, our mechanism is distinct by not relying on asymmetric information problems, but rather on the fact that the outcome of the uncertain decision is realized before some of the costs of exploiting the investment are taken.

[7] In addition, Section 4 adds additional entrepreneurs and incumbents and relaxes a simplifying assumption regarding the entry process.

[8] See Gilbert (2006) for a motivation.

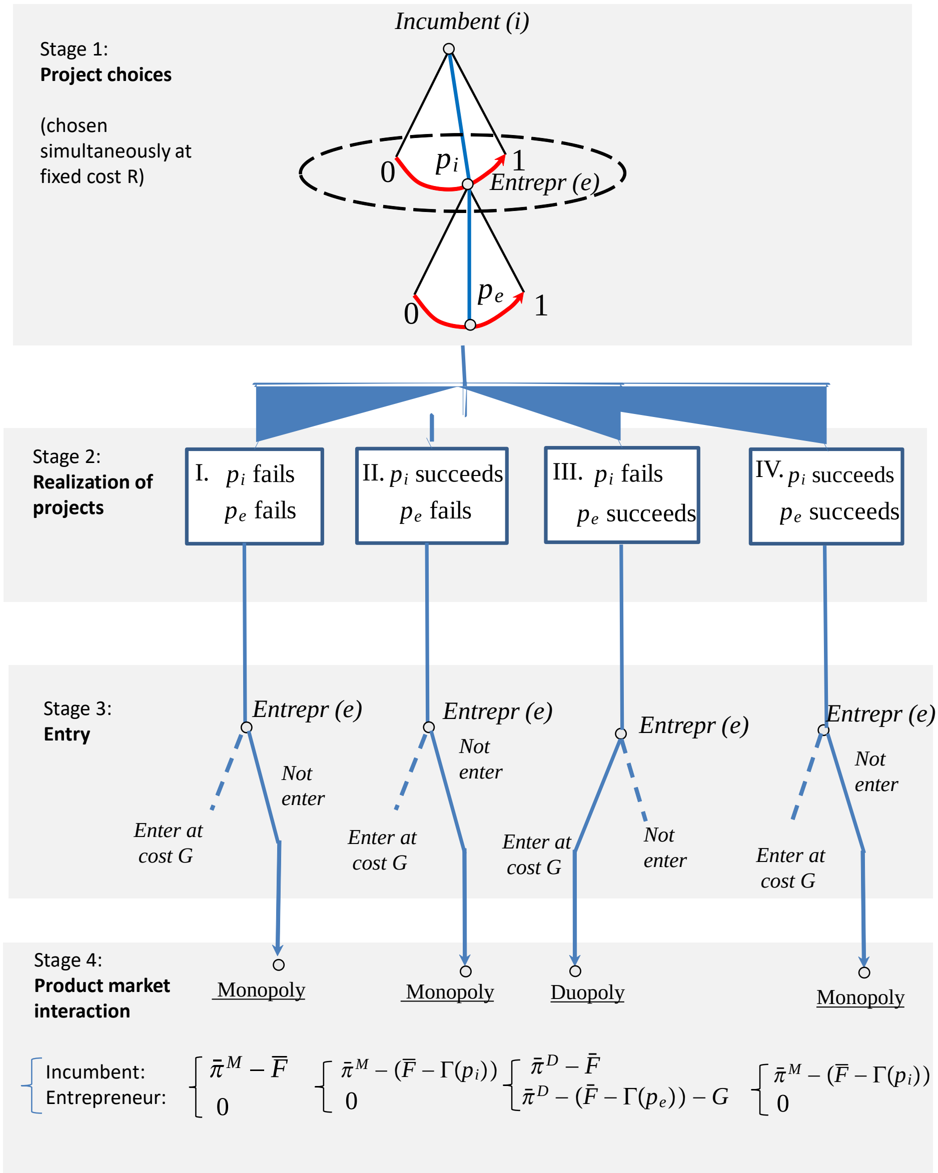

Figure 1.1: The structure of the model.

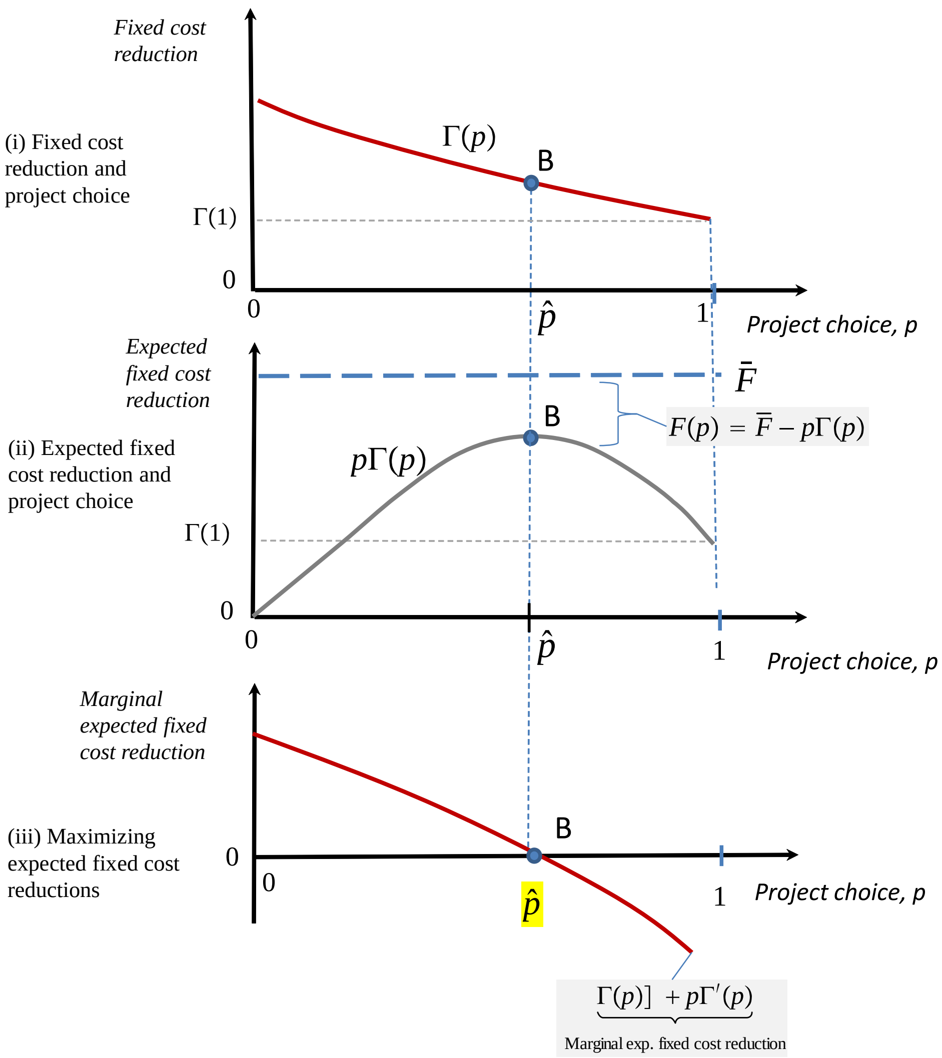

Figure 1.2: The fixed cost saving model: R&D projects and fixed cost reduction.

denoted p_l, and a corresponding reduction in the fixed cost $\Gamma(p_l)$, where $\Gamma_l'(p_l) < 0, p_l \in (0,1)$. Along the technological frontier, the agents face a choice between projects that have a high probability of success but deliver a small reduction in fixed costs in case of success, and projects that are more risky but also have a higher cost reduction if successful.[9] Omitting the project index, the fixed cost reduction $\Gamma(p)$ is illustrated in Figure 1.2(i). As shown in Figure 1.2(ii) and (iii), the expected fixed cost reduction $p\Gamma(p)$ is then assumed to be strictly concave in p with a unique project $\hat{p}$ maximizing the expected fixed cost reduction, $\hat{p} = \arg\max_p p\Gamma(p)$. The expected fixed production costs are $F(p) = \overline{F} - p\Gamma(p)$.

In stage 2, the outcomes of the agents' R&D projects p_j are revealed. Since a project either succeeds or fails, there are two symmetric outcomes, $\{p_i$ fail, p_e fail$\}$ and $\{p_i$ succeed, p_e succeed$\}$ and two asymmetric outcomes, $\{p_i$ fail, p_e succeed$\}$ and $\{p_i$ succeed, p_e fail$\}$.

[9] An interesting avenue for further research would be to investigate a setting in which the incumbent and the entrepreneur could have access to different pools of available projects to choose from (say, different technological frontiers). However, this is outside the scope of the present paper.

In stage 3, given the outcome of the R&D projects, the entrepreneur makes a decision regarding whether or not to enter the market at a fixed entry cost G (already sunk by the incumbent). In general, commercialization may differ from entry as the commercialization of a successful invention may also take place through a sale or through licensing. In the robustness section, we examine the case of commercialization through sale.

Finally, in stage 4, the product market interaction takes place where competition may be in quantities or in prices. The product market profit will then depend on whether the entrepreneur enters the market, on whether the firm succeeds with its selected project and on the type of project undertaken.

In what follows, we analyze the equilibrium of the proposed game, following the usual backward induction procedure.

1.1 Stage 4: Product Market Interaction

Let $\pi_j(x_j, x_{-j}) - F_j$ be the product market profit of firm $j = \{i, e\}$, net of fixed costs $F_j = F(p_j)$, from the outcome of stage 2. The product market profit $\pi_j(x_j, x_{-j})$ depends on the action taken by firm j, x_j, and the action taken by its opponent, x_{-j}. Then, we assume the existence of a unique Nash equilibrium, $\{x_j^*, x_{-j}^*\}$, defined from the condition:

$$\pi_j(x_j^*, x_{-j}^*) \geq \pi_j(x_j, x_{-j}^*), \tag{1.1}$$

for all $x_j \neq x_j^*$, which is unaffected by fixed costs $F(p_j)$. Since firms are symmetric, the reduced-form product market profit of each firm is $\bar{\pi}^D = \pi_j(x_j^*, x_{-j}^*)$ under entry by the entrepreneur. If the entrepreneur does not enter and the incumbent acts a monopolist, the reduced-form product market profit is $\bar{\pi}^M = \pi_i(x_i^M, 0)$. We take the usual assumption that profits decrease in the number of firms and that consumers are better off when entry occurs, i.e. $\bar{\pi}^M > \bar{\pi}^D$ and $CS^D > CS^M$ where CS denotes the consumer surplus. An example which fulfils these assumptions is the model involving quantity competition in a differentiated products market proposed by Singh and Vives (1984). This model is described in detail in the Appendix.

1.2 Stage 3: Entry by the Entrepreneur

At this stage, given the outcome of the projects, the entrepreneur chooses whether or not to enter the market. We assume that in the no innovation benchmark situation, the entrant has no incentives to enter the market.

Assumption A1. *When there is no innovation (or if innovation fails), the net profit from entry by the entrepreneur is negative, $\bar{\pi}^D - \bar{F} - G < 0$, where $\bar{\pi}^D - \overline{F} > 0$.*

As illustrated in Stage 3 in Figure 1.1(iii), since $\bar{\pi}^D - \overline{F} - G < 0$, the entrepreneur will not enter the market if its R&D project fails. In addition, the fact that $\bar{\pi}^D - \overline{F} > 0$ implies that the incumbent will not exit the market even if its R&D project fails.

As also shown in Stage 3 in Figure 1.1, we further assume that the entrepreneur can only enter when its R&D project is successful and the incumbent's project has failed.[10] This mirrors the fact that one major benefit for incumbents from innovating is that a successful innovation often serves as an entry deterring activity (Crampes and Langinier, 2002; Gilbert and Newbery,1982). In particular, being successful in innovating implies that the incumbent gains technical experience which makes it more likely to succeed in copying the entrepreneur's innovation, thereby reducing the likelihood of entry by the entrepreneur. Moreover, even if the entrepreneur has patented its product, high legal costs and limited access to financing may deter the entrepreneur from suing for infringement.[11]

1.3 Stage 2: Uncertain Projects Revealed

At this stage, the incumbent's and the entrepreneur's project outcomes are revealed. Again, since each agent can succeed or fail, there are four outcomes to consider.

1.4 Stage 1: Project Choices

We now examine the project choices of the agents. We start with the entrepreneur.

1.4.1 The entrepreneur's optimal R&D project

As explained above, the entrepreneur will only enter at stage 3 (upon payment of the fixed entry cost, G) if its selected R&D project turns out to be successful in stage 2 while the incumbent's project fails. This outcome occurs with probability $p_e(1 - p_i)$ and generates the net profit $\bar{\pi}^D - \left(\overline{F} - \Gamma(p_e)\right) - G$ for the entrepreneur. In addition, there is a fixed cost R of conducting R&D which has to be paid irrespective of whether the entrepreneur succeeds or not.

The entrepreneur's expected profit is therefore given by:

$$\mathrm{E}[\Pi_e] = p_e(1 - p_i)[\bar{\pi}^D - \left(\overline{F} - \Gamma(p_e)\right) - G] - R. \tag{1.2}$$

[10] In Section 4, we extend the analysis so as to allow the entrepreneur to enter when it succeeds with the selected R&D project.

[11] We can incorporate this formally by assuming that the incumbent infringes on the entrepreneur's patent, and suing for infringement involves legal costs, L. Then, we can find an L such that $\bar{\pi}^D - \left(\overline{F} - \Gamma(p_e^*)\right) - G - L < 0$, whereas $\bar{\pi}^D - \left(\overline{F} - \Gamma(p_i^*)\right) - L > 0$, since $G > 0$. For expositional reasons, however, this is not pursued here.

The corresponding first-order condition, $dE[\Pi_e]/dp_e = 0$, is

$$(1-p_i)[\bar{\pi}^D - (\overline{F} - \Gamma(p_e^*)) - G] + (1-p_i)p_e^*\Gamma'(p_e^*) = 0. \tag{1.3}$$

The first term gives the increase in expected profit from choosing a marginally safer project. The second term, on the other hand, represents the reduction in expected profit from choosing a safer project since, if successful, the safer project will provide a smaller fixed cost reduction. It will be convenient to rewrite this first-order condition as follows:

$$\Gamma(p_e^*) + p_e^*\Gamma'(p_e^*) = \underbrace{G - \underbrace{(\bar{\pi}^D - \overline{F})}_{(+)}}_{\substack{(+)\\ \text{Hurdle effect}}} > 0. \tag{1.4}$$

As illustrated in Figure 1.3, the left-hand side represents the increase in profits resulting from a lower expected fixed cost from choosing a marginally safer project. Then, turn to the right-hand side. From Assumption A1, $G - (\bar{\pi}^D - \overline{F}) > 0$. So, the entrepreneur faces a loss if entering without the invention. We label this *the (entrepreneurship) hurdle effect.* Note that because of the hurdle effect, the entrepreneur will always choose a project which is riskier than the project $\hat{p}$ maximizing the expected fixed cost reductions, i.e. $p_e^* < \hat{p} = \arg\max_p p\Gamma(p)$. To see why, suppose that the entrepreneur would choose $\hat{p}$. From (1.2), this cannot be optimal since by marginally reducing the probability of success from $\hat{p}$, the entrepreneur would trade off a first-order reduction of the expected net cost of commercialization, $(1-p_i)\hat{p}[G - (\bar{\pi}^D - \overline{F})]$, against a second-order reduction of the expected fixed-cost reduction $(1-p_i)\hat{p}\Gamma(\hat{p})$.

Hence, by choosing a riskier project than $\hat{p}$, the entrepreneur can increase her expected profit by lowering the expected entry cost. As shown by Figure 1.2(ii), at an increasing distance from the cost-efficient project $\hat{p}$, the loss in profits from lower expected fixed cost reductions will increase in size. At the optimum $p_e^* < \hat{p}$ (point E in Figure 1.3), the implied loss in expected profits from a lower expected fixed cost reduction and the increase in expected profits from lower expected (net) entry costs then balance each other out.

What happens if the entry hurdle is increased? Differentiating (1.4) in p_e and G, we obtain

$$\frac{dp_e^*}{dG} = \frac{1}{2\Gamma'(p_e^*) + p_e^*\Gamma''(p_e^*)} < 0 \tag{1.5}$$

where $2\Gamma'(p_e^*) + p_i^*\Gamma''(p_e^*) < 0$ holds from our assumption that the expected fixed cost reduction $p\Gamma(p)$ is strictly concave in p. If the entry cost G increases, the entrepreneur will choose a riskier project. This can be seen in Figure 1.3 by shifting the locus for the hurdle effect $G - (\bar{\pi}^D - \overline{F})$

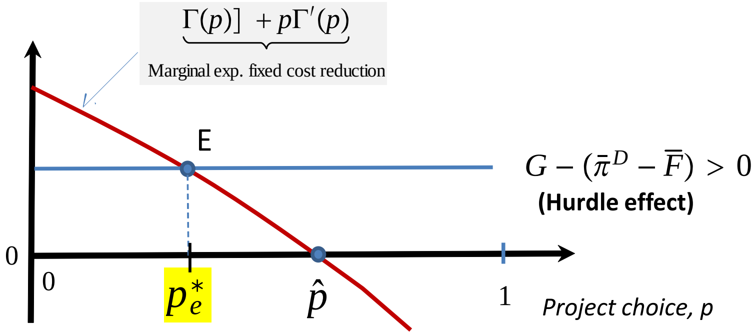

Figure 1.3: The entrepeneur's optimal project (p_e^*).

upwards and noting that p_e^* must then decrease. We thus have the following proposition:

Proposition1If the entry cost G increases, the entrepreneur chooses an R&D project with a lower probability of success and a higher payoff if successful (a "breakthrough" invention of higher quality).

To sum up, the entry cost is paid ex-post (in stage 3), conditional upon the success of its selected R&D project (in stage 2). The entrepreneur therefore responds to the increase in the entry cost by choosing a project with a lower probability of success in order to reduce the expected net entry cost.

1.4.2 The incumbent's optimal R&D project

Let us now examine the choice of the incumbent. The expected incumbent's profit is

$$\mathrm{E}[\Pi_i] = p_i[\bar{\pi}^M - \left(\overline{F} - \Gamma(p_i)\right)] + (1 - p_i)\{p_e\left(\bar{\pi}^D - \overline{F}\right) + (1 - p_e)\left(\bar{\pi}^M - \overline{F}\right)\} - R. \quad (1.6)$$

Consider again Figure 1.1. The incumbent's R&D project will succeed with probability p_i, in which case it earns a monopoly profit $\bar{\pi}^M$ and incurs a fixed production cost equal to $\overline{F} - \Gamma(p_i)$. Recall that, by assumption, the entrepreneur cannot enter when the incumbent succeeds. This payoff is therefore independent of p_e. With probability $(1 - p_i)$, the incumbent's R&D project fails. Then, if the entrepreneur's project has succeeded, the incumbent obtains a duopoly profit $\bar{\pi}^D$ and incurs a fixed production cost $\overline{F}$. If the entrepreneur's project has instead also failed, the incumbent earns a monopoly profit $\bar{\pi}^M$ and still incurs a fixed production cost $\overline{F}$. In addition, the fixed cost of R&D, paid ex-ante, is R.

The corresponding first-order condition, $dE[\Pi_i]/dp_i = 0$, is given by

$$\bar{\pi}^M - \left(\overline{F} - \Gamma(p_i)\right) + p_i\Gamma'(p_i) - \{p_e\left(\bar{\pi}^D - \overline{F}\right) + (1 - p_e)\left(\bar{\pi}^M - \overline{F}\right)\} = 0. \quad (1.7)$$

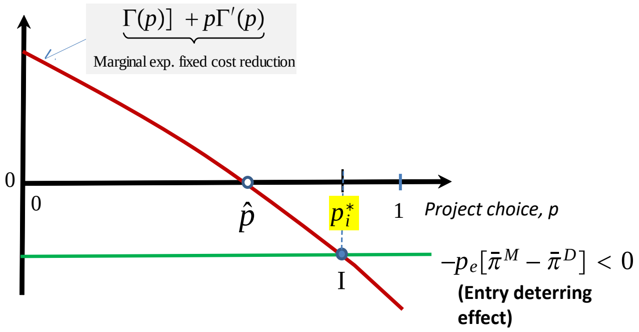

Figure 1.4: The incumbent's optimal project (p_i^*).

The first term shows the increase in the incumbent's expected profit from choosing a safer project, where $\bar{\pi}^M - \left(\overline{F} - \Gamma(p_i)\right)$ is the net profit and $p_i\Gamma'(p_i) < 0$ represents the decrease in the expected fixed cost reduction. As usual, the incumbent also has to consider a "replacement effect". If the incumbent fails, its expected profit is $p_e\left(\bar{\pi}^D - \overline{F}\right) + (1-p_e)\left(\bar{\pi}^M - \overline{F}\right)$ where this profit depends on whether the entrepreneur fails or not. Choosing a marginally safer project implies a higher probability of this profit being replaced, which explains the second term in (1.7).

It is once more convenient to rewrite (1.7) as follows:

$$\Gamma(p_i^*) + p_i^*\Gamma'(p_i^*) = -p_e \underbrace{\left[\bar{\pi}^M - \bar{\pi}^D\right]}_{\substack{(+) \\ \text{Entry Deterring}}} < 0 \tag{1.8}$$

This condition is illustrated in Figure 1.4. The left-hand side is again the marginal expected fixed cost reduction. The term $\bar{\pi}^M - \bar{\pi}^D > 0$ on the right-hand side mirrors the fact that the monopolist will lose its monopoly position if the entrepreneur succeeds and enters the market. We denote this the *entry deterring effect*. Note that because of the entry deterring effect, the incumbent will choose a project which is safer than the project $\hat{p}$ maximizing expected fixed cost reductions, i.e. $p_i^* > \hat{p} = \arg\max_p p\Gamma(p)$. To see why, suppose that the incumbent would instead choose $\hat{p}$. This cannot be optimal since by marginally increasing the probability of success from $\hat{p}$, the incumbent would trade off a first-order reduction in the expected loss from entry by the entrepreneur, $(1-\hat{p})p_e[\bar{\pi}^M - \bar{\pi}^D]$, against a second-order reduction of the expected fixed-cost reduction $(1-p_i)\hat{p}\Gamma(\hat{p})$.

So, by choosing a marginally safer project than $\hat{p}$, the incumbent can increase its expected profit by lowering the expected loss from entry (since the entrepreneur cannot enter if the incumbent succeeds). But yet again, as shown by Figure 1.2(ii), at an increasing distance from the cost-efficient project $\hat{p}$, the loss in profits from lower expected fixed cost reductions will increase in size. At the optimum $p_i^* > \hat{p}$ (point I in Figure 1.4), the implied loss in expected profits from a lower expected fixed cost reduction and the increase in expected profits from lower expected loss from entry, balance each other out.

1.4.3 The Nash equilibrium in project choices

Let us now characterize the market solution in terms of the Nash-equilibrium in project choices. From (1.4), the entrepreneur's choice of project is independent of the incumbent's choice. Thus, the reaction function of the entrepreneur is simply $R_e = p_e^*$. This is depicted as the vertical line in Figure 1.5 (ii).

The reaction function of the incumbent $R_i(p_e)$ is implicitly given by eq. (1.8). Differentiating this in p_e and p_i, we obtain the corresponding slope $R_i'(p_e)$:

$$\frac{dp_i^*}{dp_e} = \mathcal{R}_i'(p_e) = -\frac{(\bar{\pi}^M - \bar{\pi}^D)}{2\Gamma'(p_i^*) + p_i^*\Gamma''(p_i^*)} > 0 \tag{1.9}$$

where once more $2\Gamma'(p_i^*) + p_i^*\Gamma''(p_i^*) < 0$ follows from our assumption that $p\Gamma(p)$ is strictly concave in p.

Then, we state the following proposition:

Proposition2For the incumbent, the two firms' probabilities of success are strategic complements: $R_i'(p_e) > 0$.

The intuition for this result is already apparent from (1.8): if the entrepreneur chooses a higher probability of success, this increases the expected entry deterring effect, which induces the incumbent to choose a higher probability of success so as to avoid losing its monopoly position.

The reaction function of the incumbent $R_i(p_e)$ is depicted as the upward-sloping solid line in Figure 1.5 starting from the cost-efficient project, $\hat{p}$, which can be obtained by substituting $p_e = 0$ into (1.8). The unique Nash-equilibrium $\{p_e^*, p_i^*\}$ is then represented by point N where the reaction functions $R_i(p_e)$ and R_e intersect. Note that the Nash-equilibrium N is located to the north of the 45 degree line, implying that the entrepreneur chooses a riskier R&D project, $p_e^* < p_i^*$.

We can then formulate the following proposition:

Proposition3In equilibrium, the entrepreneur will choose a project with a lower probability of success than the incumbent, $p_e^* < p_i^*$. In case of success, the entrepreneur's selected project is therefore associated with a larger fixed cost reduction than the incumbent's selected project, $\Gamma(p_e^*) > \Gamma(p_i^*)$.

The proof of the previous proposition directly follows from Figures 1.3 and 1.4: through the existence of entry costs, the hurdle effect $(G - \left(\bar{\pi}^D - \overline{F}\right) > 0)$ induces the entrepreneur to

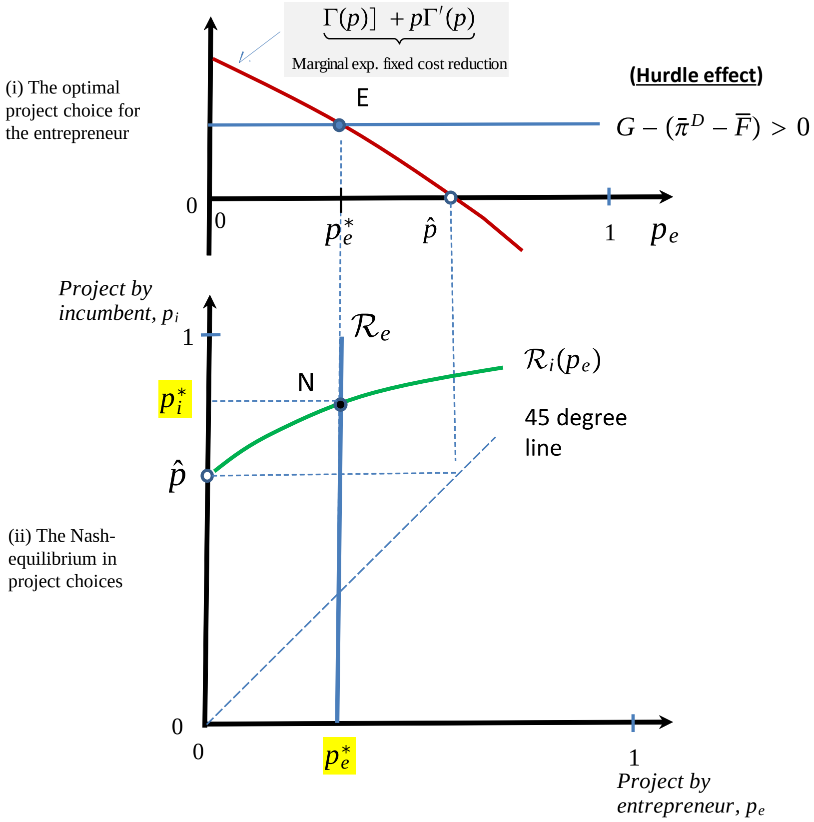

Figure 1.5: Deriving the Nash-equilibrium in project choices (N).

choose a project with a lower probability of success than the cost-efficient project $p_e^* < \hat{p}$, in order to decrease the expected net entry cost. The incumbent, on the other hand, faces no cost of entry. Instead, through the entry deterring effect $(-p_e^* \left[\bar{\pi}^M - \bar{\pi}^D\right] < 0)$, it takes into account the risks of losing the monopoly profit if its R&D project fails and that of the entrepreneur succeeds – this induces the incumbent to choose a project with a higher probability of success than the cost-efficient project, $p_i^* > \hat{p}$. Since $p_e^* < p_i^*$, it also follows that, in case of success, the entrepreneur's selected project contains a larger fixed cost reduction than the incumbent's selected project, $\Gamma(p_e^*) > \Gamma(p_i^*)$.

2 Why Entrepreneurs Choose Risky R&D projects – But Still Not Risky Enough

Let us now compare the market solution to the first-best solution chosen by a social planner. We define welfare under the assumption of partial equilibrium and consider the expected total surplus. We can then consider the social planner in a Stage 0 calculating the expected total surplus taking into account how the game evolves given the R&D outcomes shown in Figure 1.1.

Thus, let $\bar{W}^M$ be the total surplus when no firm's R&D project succeeds, where superscript M denotes monopoly. In this case, the incumbent earns net profits equal to $\bar{\pi}^M - \overline{F}$, consumers enjoy a surplus equal to CS^M and total R&D costs equal $2R$. Let $W^M(p_i)$ be the total surplus when the incumbent succeeds with project p_i. Now, the incumbent earns net profits equal to $\bar{\pi}^M - \big(\overline{F} - \Gamma(p_i)\big)$, the consumer surplus is CS^M and total R&D costs equal $2R$. Finally, let $W^D(p_e)$ be the total surplus when the entrepreneur succeeds with project p_e and the incumbent's project fails, where superscript D denotes duopoly. The entrepreneur then earns net profit $\bar{\pi}^D - \big(\overline{F} - \Gamma(p_e)\big) - G$, while the incumbent earns net profit $\bar{\pi}^D - \overline{F}$. The consumer surplus is CS^D and the total R&D costs equal $2R$. As noted in Section 1.1, increased competition in the market is assumed to increase the consumer surplus, $CS^D > CS^M$. Finally, there are positive (exogenous) externalities from research, ξ. To incorporate these spillovers of R&D in a simplified way, let the spillovers from R&D accrue across sectors in the economy and across time. Spillovers are also assumed to be independent of the probabilities of success. Then, we want to capture spillovers that the research process generates in terms of knowledge, the gains of research per se, which arise irrespective of the outcome of the particular project.

Formally, we define the total surpluses for the different outcomes as

$$\begin{cases} \bar{W}^M = \bar{\pi}^M - \overline{F} + CS^M - 2R + 2\xi, \\ W^M(p_i) = \bar{\pi}^M - \big(\overline{F} - \Gamma(p_i)\big) + CS^M - 2R + 2\xi, \\ W^D(p_e) = \bar{\pi}^D - \big(\overline{F} - \Gamma(p_e)\big) - G + \bar{\pi}^D - \overline{F} + CS^D - 2R + 2\xi. \end{cases} \tag{2.1}$$

First, we note that $W^M(p_i) - \bar{W}^M = \Gamma(p_i)$: if the incumbent innovates successfully, there is no increase in the consumer surplus, the only effect is a decrease in the incumbent's fixed cost of production. Consequently, there are no positive externalities benefiting the consumers resulting from innovation by the incumbent. Second, $W^D(p_e) - \bar{W}^M = \big[CS^D - CS^M\big] + \bar{\pi}^D - \overline{F} - G - \big[\bar{\pi}^M - \bar{\pi}^D\big]$: if the entrepreneur innovates, there is an increase in the consumer surplus equal to $CS^D - CS^M$, in addition to the effects on the two firms' profits. Hence, innovation by the entrepreneur confers a positive externality on consumers which the social planner takes into account.

The expected total surplus when both firms invest in R&D is then:

$$E[W(p_i, p_e)] = p_i W^M(p_i) + (1 - p_i)\{p_e W^D(p_e) + (1 - p_e)\bar{W}^M\} \tag{2.2}$$

where the first term is the total surplus if the incumbent succeeds and the second term is the total surplus if the incumbent fails. The second term consists of two parts: $(1 - p_i)p_e W^D(p_e)$ is the surplus if the entrepreneur succeeds whereas $(1-p_i)(1-p_e)\bar{W}^M$ is the status quo surplus when neither firm succeeds.

In what follows, we will assume that the externalities from research ξ are such that the social planner prefers that both the incumbent and the entrepreneur invest in R&D. Let $E\left[W(p_i)\right] = p_i W^M(p_i) + (1-p_i)\bar{W}^M$ be the expected welfare when only the incumbent does R&D. Then,

Assumption A2. $E[W(p_i, p_e)] > E[W(p_i, 0)]$

2.1 First-Best Choice for the Entrepreneur

Let us start with the first-best choice of probability of success for the entrepreneur. It is given from the first-order condition $dE[W(p_i, p_e)]/dp_e = 0$. Using (2.2), this condition becomes

$$W^D(p_e) + p_e W^{D\prime}(p_e) = \bar{W}^M \tag{2.3}$$

where the left-hand side is the expected increase in the total surplus when the entrepreneur chooses a marginally safer project and the right-hand side is the cost in terms of replacing the status quo total surplus. Using the expressions for total surplus in (2.1), we can rewrite (2.3) as follows

$$\Gamma(p_e^S) + p_e^S\Gamma'(p_e^S) = \underbrace{\left[G - \left(\bar{\pi}^D - \overline{F}\right)\right]}_{\substack{(+) \\ \text{Hurdle effect}}} + \underbrace{\left(\bar{\pi}^M - \bar{\pi}^D\right) - \left(CS^D - CS^M\right)}_{\substack{(?) \\ \text{Business stealing effect}}} \tag{2.4}$$

where p_e^S is the optimal choice of probability of success from a social point of view. Comparing (1.4) and (2.4), we see that whether the entrepreneur chooses too safe a project or too risky a project depends on the second term in (2.4), labeled the *business stealing effect*. The first component of this business stealing effect, $(\pi^M - \pi^D)$, is the entry deterring effect. The second component, $CS^D - CS^M$, represents the increase in the consumer surplus that occurs when the market goes from monopoly to duopoly. If the incumbent loses more from entry than what consumers gain, $\pi^M - \pi^D > CS^D - CS^M$, the business stealing effect is positive and the entrepreneur ends up choosing a project that is too safe from a first-best perspective, $p_e^S < p_e^*$. This case is illustrated in Figure 2.1.

Proposition4For any p_i, if the business stealing effect is positive, i.e. if $\pi^M - \pi^D > \left(CS^D - CS^M\right)$, the entrepreneur chooses too safe projects from a social point of view: $p_e^S < p_e^*$.

If the business stealing effect is positive, the costs of entry in terms of lost profit for the incumbent outweigh the benefits to consumers and a social planner would prefer the entrepreneur to take more risk and enter the market less often. Conversely, if the business stealing effect is

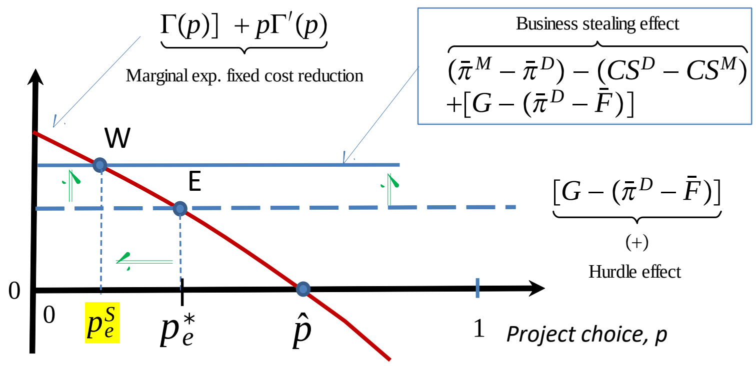

Figure 2.1: Comparing the first-best project (p_e^S) and the privately optimal project (p_e^*) for the entrepeneneur when the business stealing affect is positive, $\pi^M - \pi^D > CS^D - CS^M$.

negative, the benefits of entrepreneurial entry outweigh the costs in terms of lost profit for the incumbent and a social planner would prefer the entrepreneur to enter the market more often, which corresponds to choosing a higher probability of success.

2.2 First-Best for Incumbent

Let us now examine the first-best choice of the incumbent, which results from the first-order condition $dE[W(p_i, p_e)]/dp_i = 0$. Using (2.2), this condition becomes

$$W^M(p_i) + p_i W^{M\prime}(p_i) = p_e W^D(p_e) + (1 - p_e)\bar{W}^M \tag{2.5}$$

where the left-hand side is the expected increase in welfare when the incumbent chooses a marginally safer project and the right-hand side is a weighted replacement cost, where $p_e W^D(p_e)$ is the expected total surplus under entry and $(1 - p_e)\bar{W}^M$ is the expected total surplus under the status quo.

Using the expressions for total surplus in (2.1), it will be useful to write (2.5) as follows

$$\Gamma(p_i^S) + p_i^S \Gamma'(p_i^S) = -p_e \underbrace{(\bar{\pi}^M - \bar{\pi}^D)}_{\text{Entry deterring}} + \underbrace{p_e[\underbrace{\bar{\pi}^D - \left(\bar{F} - \Gamma(p_e)\right) - G}_{\text{Entrant's profit}} + \underbrace{CS^D - CS^M}_{\text{Consumer gain}}]}_{\text{Entry effect }(+)}. \tag{2.6}$$

In eq. (2.6), we denote the second part of the right-hand side the *entry effect*. It consists of the induced effect of entry by the entrepreneur on: (i) the entrepreneur's profit and (ii) the consumer surplus. Even though the effects (i) and (ii) are considered by the social planner in order to determine the optimal probability of success for the incumbent, these effects are, however, not taken into account by the incumbent who only considers the first part of the right-hand side of (2.6), namely the business stealing effect.

If we examine the terms comprising the entry effect, it is clear that the first part, namely $\bar{\pi}^D - \left(\overline{F} - \Gamma(p_e)\right) - G$, is positive. If it were not, the entrepreneur would not enter the market. The second part, $CS^D - CS^M$, is also positive. Thus, comparing (1.8) to (2.6), it is clear that for the same level of $p_{e,}$ it must be the case that the incumbent chooses projects with a higher probability of success than would the social planner. Then, we can formulate the following proposition:

Proposition5For any given $p_e > 0$, the incumbent chooses too safe projects: $p_i^S < p_i^*$

The intuition from this result is the following. There are no positive effects on consumers from innovation by the incumbent. On the contrary, since the entrepreneur can only enter in case the incumbent's project fails, innovation by the incumbent precludes entrepreneurial entry, which has a positive effect on consumers. Therefore, for a given value of p_e, such that $p_e > 0$, the social planner prefers the incumbent to choose riskier projects which succeed less often.

It will also be useful to examine the incumbent's reaction function in the first best solution. Define this optimal probability of success for the incumbent as $p_i^S = \Psi_i(p_e)$. To examine the shape of $\Psi_i(p_e)$, first note that from (2.6), $\Psi_i(0) = R_i(0)$: the first best choice for the incumbent's project coincides with the market solution p_i^* if $p_e = 0$. Then, note that for $p_e > 0$, Proposition 5 implies that $\Psi_i(p_e) < R_i(p_e)$: for a given value of p_e, by ignoring the entry effect the incumbent chooses too safe a project from the social planner's point of view. Differentiating (2.6) in p_e and p_i, we can also obtain an expression for the slope of the first-best choice

$$\frac{dp_i^S}{dp_e} = \Psi_i'(p_e) = \frac{\pi^D - \left(\overline{F} - \Gamma(p_e)\right) - G + p_e\Gamma'(p_e) - \{(\pi^M - \pi^D) - \left(CS^D - CS^M\right)\}}{2\Gamma'(p_i^*) + p_i^*\Gamma''(p_i^*)}.$$

Now, from (1.4), $\Psi_i'(p_e)$ can be re-written making use of the first-order condition for the entrepreneur's project

$$\frac{dp_i^S}{dp_e} = \Psi_i'(p_e) = \frac{dE[W]/dp_e}{\left[2\Gamma'(p_i^*) + p_i^*\Gamma''(p_i^*)\right](1 - p_i^*)}. \tag{2.7}$$

Then, as shown in Figure 2.2, it follows from (1.4) and (2.7) that $\Psi_i(p_e)$ is U-shaped and reaches a minimum for $\Psi_e = p_e^S$. The properties of the function for the social planner's optimal choice of p_i^S can be summarized as follows:

Lemma1(i) $\Psi_i(0) = R_i(0) = \hat{p}$, (ii) for $p_e > 0$, $\Psi_i(p_e) < R_i(p_e)$ and (iii) $\Psi_i(p_e)$ is U-shaped with $\Psi_i'(0) < 0$, $\Psi_i'(p_e^S) = 0$ and $\Psi_i'(p_e) > 0$ for $p_e > p_e^S$.

2.3 When Does the Market Provide Too Safe Projects?

Next, we turn to the equilibrium outcomes, comparing $\{p_e^*, p_i^*\}$ chosen by the firms to $\{p_e^S, p_i^S\}$ chosen by the social planner. Proposition 4 shows that two cases can be identified, depending

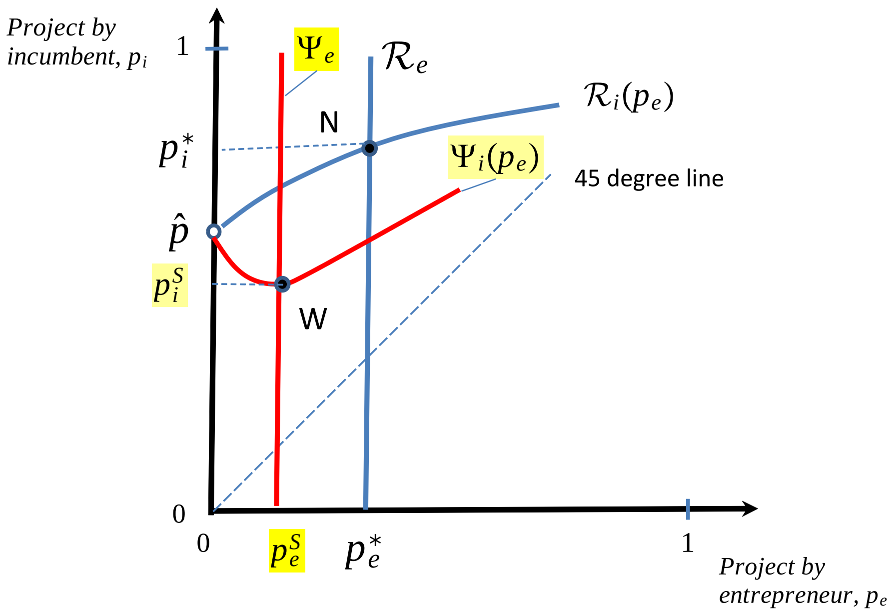

Figure 2.2: Comparing the first-best project choices (W) and Nash-equilibrium project choices (N) when the business stealing effect is positive, $\pi^M - \pi^D > CS^D - CS^M$.

on whether the business stealing effect is positive or negative.

Suppose first that the business stealing effect is positive. From Proposition 4, we have that $p_e^S < p_e^*$. Together with Proposition 5, which shows that $p_i^S < p_i^*$, we find that the market solution implies that both the entrepreneur and the incumbent choose projects with too low risk. This case is shown in Figure 2.2. The first-best solution $\{p_e^S, p_i^S\}$ is given by the intersection of the vertical line Ψ_e, which defines the social planner's optimal choice of p_e^S, and the U-shaped function $\Psi_i(p_e)$, which occurs at point W in Figure 2.2. The market solution $\{p_e^*, p_i^*\}$, on the other hand, is once more given from the intersection of the reaction functions $R_i(p_e)$ and R_e, which occurs at point N. By construction, it must be the case that the first-best solution W is located south-west of the market solution N.

We can formulate the following Corollary:

Corollary1If the business stealing effect is positive, $\pi^M - \pi^D - \left(CS^D - CS^M\right) > 0$, the market solution provides projects with too little risk, $p_e^S < p_e^*$ and $p_i^S < p_i^*$.

If the business stealing effect is positive, the entrepreneur takes too little risk from a social planner point of view, since it does not take into account that its entry into the market reduces the incumbent's profits. In addition, from Proposition 5, we have that the incumbent takes too little risk from a social planner point of view, since there are no benefits to consumers from innovation by the incumbent and, in addition, innovation precludes entrepreneurial entry. Hence, if the business stealing effect is positive, the market solution will provide projects with too little risk.

Suppose now that the business stealing effect is negative, such that $p_e^S > p_e^*$. Now the market solution implies that the incumbent takes too little risk while the entrepreneur takes too much risk and the net effect is ambiguous. To explore the scenario where the market provides too little risk in more detail, we will in the following example use a linear Cournot model which can give closed form expressions for the business stealing effect. Following Singh and Vives (1984), let us assume that the utility of a consumer is given by:

$$U(q_e, q_i, I) = aQ - \frac{1}{2}\left[q_i^2 + 2\gamma q_i q_e + q_e^2\right] + I \tag{2.8}$$

where q_i is the output of the incumbent, q_e is the output of the entrepreneur, $Q = q_e + q_i$ denotes total output, I is a composite good of other goods and a is a constant. The parameter γ measures the substitutability between products. If $\gamma = 0$, each firm has monopolistic power, whereas if $\gamma = 1$, the products are perfect substitutes. Firms have identical marginal costs c. We show in the Appendix that the following Proposition applies:

Proposition6In the Singh and Vives' (1984) model of Cournot competition with differentiated goods, the following applies:(i) when goods are not too differentiated, i.e. if $\gamma \in (\frac{2}{3}, 1]$, the business stealing effect is positive, $\pi^M - \pi^D - (CS^D - CS^M) > 0$. As a result, the entrepreneur chooses too safe a research project, $p_e^S < p_e^*$, as does the incumbent, $p_i^S < p_i^*$. (ii) When goods are sufficiently differentiated, i.e. if $\gamma \in (0, \frac{2}{3})$, the business stealing effect is negative, $\pi^M - \pi^D - (CS^D - CS^M) < 0$, implying that the entrepreneur chooses too risky projects, $p_e^S > p_e^*$, while the incumbent chooses projects with too little risk $p_i^S < p_i^*$.

In this example, entry will increase total output, while the incumbent will contract its output to dampen the reduction in the product market price. The consumer surplus will then increase by adding consumers with a decreasing willingness to pay, whereas the loss for the incumbent contracting its sales will occur at a constant price cost margin. In the homogenous goods case, this will cause the business stealing effect to be positive and, from Proposition 1, the market will provide projects with too little risk. However, when product differentiation increases, the entrepreneur steals less of the incumbent's profits upon entry and, in addition, creates a larger increase in the consumer surplus, thus implying that the business stealing effect is negative. Consequently, when goods are sufficiently differentiated, the business stealing effect becomes negative and the social planner prefers that the entrepreneur takes less risk. However, the incumbent still takes too little risk from a social welfare perspective.

3 Entrepreneurial Policies

In the last few decades, entrepreneurship has emerged as a key issue in the policy arena.[12] This marks a distinct break against traditional industrial policy which has focused on large established firms. An example of a more pro-entrepreneurial policy is R&D subsidies which are targeted to small and medium sized enterprises, SMEs.[13] Other government policies are more geared towards supporting the entry of new firms. Examples of this type of policy are financial support for incubators, and loans specifically designed to facilitate the entry of new firms.[14] In this section, we will use our model to examine how these types of policies affect the agents' R&D projects. Then, we turn to the policy chosen by the social planner.

Let us add a stage zero where the entrepreneur can decide to conduct R&D or abstain from doing so. From Assumption A2, the social planner wants the entrepreneur to conduct R&D, and enter the market if it succeeds. In addition, the planner can affect the entrepreneur's decisions by subsidizing the fixed R&D cost R by an amount r and/or the entry cost G by an amount s. Then, we assume that a subsidy is a lump-sum transfer between the government and the entrepreneur. The first best solution is therefore not altered. We can then write the reduced-form expected profit for the entrepreneur as follows:

$$E[\Pi_e(p_e^*, p_i^*)] = (1 - p_i^*)p_e^*[\pi^D - \left(\overline{F} - \Gamma(p_e^*)\right) - (G - s)] - (R - r). \tag{3.1}$$

In order to induce the entrepreneur to conduct R&D and enter when successful, it must be that entry is profitable in stage 3. Thus, the entry cost must fulfil:

$$G \leq \bar{G}(s) = \pi^D - \left(\overline{F} - \Gamma(p_e^*)\right) + s. \tag{3.2}$$

Furthermore, it must be profitable for the entrepreneur to take on the investment cost R. From (3.1) and (3.2), the R&D cost must fulfil:

$$R \leq \bar{R}_E(r, s) = p_e^*(1 - p_i^*)[\underbrace{\pi^D - \left(\overline{F} - \Gamma(p_e^*)\right) + s}_{\bar{G}(s)} - G] + r. \tag{3.3}$$

Let us then assume that the entrepreneurial R&D is not profitable without subsidies, while

[12] On March 14 2009, *The Economist* published a special report on entrepreneurship, "Global Heroes", describing this phenomenon.

[13] A report by OECD (2007) shows that, in the year 2007, several countries offered tax subsidies for R&D targeted specifically at SMEs. Examples are: the UK, Canada, Japan, the Netherlands, Norway and Poland.

[14] Recently, there has been a substantial increase in spending on such policies. For example, in 2009, the US Small Business Administration had approved over $13 billion in loans and $2.7 billion in surety to small businesses in a year. (Summary of Performance and Financial Information, US Small Business Administration, 2009).

the incumbent always conducts R&D:

Assumption A3. $R > \bar{R}_E(0,0)$ and $G < \bar{G}(0)$.

Under Assumption A3, only the incumbent does R&D. From (1.8), the incumbent will then choose the cost-efficient project, $p_i^* = R_i(0) = \hat{p}$.

3.1 R&D subsidies

Let us first examine subsidies to R&D. An R&D subsidy r paid before the project choice in stage 1 then implies that the entrepreneur starts to invest in R&D, $R < \bar{R}_E(r,0)$, choosing the project p_e^*, given from (1.4). Since projects are strategic complements for the incumbent $R_i'(p_e) > 0$ as shown in Proposition 2, this will induce the incumbent to choose a safer project, $p_i^* > \hat{p}$. From the entry-deterring effect, the incumbent can increase its expected profit when choosing a safer project as this reduces the expected loss from entry.

We have the following Lemma.

Lemma2Let $R > \bar{R}_E(0,0)$ so that only the incumbent innovates, $p_i^* = \hat{p}$. Then, when the entrepreneur has been subsidized by an amount r such that $R < \bar{R}_E(r,0)$, it will start undertaking R&D choosing the project p_e^* , and the incumbent responds to the entrepreneur's R&D investment by choosing an R&D project with a higher probability of success, $p_i^* > \hat{p} > p_e^*$
.

3.2 Entry subsidies

Let us now examine a subsidy s to the entry cost G in stage 3. As this policy implies that $R < \bar{R}_E(0,s)$, the same outcome is reached: the entrepreneur invests in R&D. Proposition 1 then tells us that the entrepreneur will respond by choosing a safer project (a project with less breakthrough potential in terms of lower quality) and from Proposition 2 the incumbent will respond by also choosing a project with a lower level of risk. Thus, compared to the policy subsidizing R&D, the entry subsidy will induce both the entrepreneur and the incumbent to choose safer projects.

Thus, we can state the following Lemma:

Lemma3Suppose that an R&D subsidy r or an entry subsidy s can induce the entrepreneur to invest into R&D, $R < \bar{R}_E(r,0)$ and $R < \bar{R}_E(0,s)$. Then, both agents will choose safer projects (with less potential quality if they succeed) under the subsidy to entry as compared to when the R&D subsidy is used, $p_h^*|_{r>0=s} < p_h^*|_{s>0=r}$ for $h = \{e, i\}$.

In sum, subsidy policies can be used to induce the entrepreneur to conduct R&D which will increase the welfare from Assumption A2. However, this will also influence the project choice by the incumbent. When a policy aimed at subsidizing entry costs is used, it will affect the type of R&D project chosen by the entrepreneur which, in turn, affects the project that the incumbent firm chooses. We will now use these results to make some observations on optimal policy.

3.3 When Should Entrepreneurial R&D be Subsidized and Entry Taxed?

From Proposition 4, we know that how the market outcome $\{p_e^*, p_i^*\}$ differs from the first-best $\{p_e^S, p_i^S\}$ will depend on the effect of entry by the entrepreneur on the consumer surplus and on the incumbent's profit, as measured by the aggregate business stealing effect, $\pi^M - \pi^D - (CS^D - CS^M)$.

Suppose that the business stealing effect is positive. As shown in the Appendix, this may arise when the incumbent's and the entrant's products are close substitutes, generating a tough product market competition. Corollary 1 then shows that the entrepreneur – as well as the incumbent – will choose too safe projects from a social point of view. The planner should then tax entry. To see this, define the auxiliary variable $\tilde{G} = G - s$. Then, differentiating the expected welfare and evaluating at the Nash-equilibrium $\{p_e^*, p_i^*\}$ (and making use of eqs. (1.5), (1.9) , (2.4), (2.6) and (3.1)), yields:

$$\frac{dE[W(p_e^*, p_i^*)]}{ds} = \left[\underbrace{\frac{\partial E[W(p_e^*, p_i^*)]}{\partial p_e}}_{\text{(-)}} + \underbrace{\frac{\partial E[W(p_e^*, p_i^*)]}{\partial p_i}}_{\text{(-)}} \underbrace{\mathcal{R}_i'(p_e^*)}_{(+)} \right] \underbrace{\frac{dp_e^*}{dG}}_{(-)} \underbrace{\frac{d\tilde{G}}{ds}}_{(-)} < 0. \tag{3.4}$$

The optimal entry tax $s^S < 0$ is then given from $\frac{dE[W(p_e^*, p_i^*)]}{dt} = 0$, given $G < \bar{G}(s^S)$, otherwise the tax $s < 0$ should be set such that $G = \bar{G}(s)$. Figure 3.1 illustrates this graphically: In Figure 3.1(i), a tax $(t = -s > 0)$ on entry increases the hurdle effect, inducing the entrepreneur to choose a higher risk. Then, as shown in Figure 3.1(ii), the incumbent will react by also choosing a more risky project and the market outcome will shift from point N to Ñ, which is closer to the first-best solution W (which is unaffected by a subsidy). A subsidy to entry, on the other hand, will take the market solution further from the first best solution; moving point N further to the north-east which increases the distance from the first-best solution W.

In order to have the entrepreneur conducting R&D, the planner will complement the entry tax $s < 0$ with an R&D subsidy $r >$, such that $R < \bar{R}_E(r, s)$. We can now formulate this result as follows:

Proposition7 Suppose that Assumption A3 holds and $R > \bar{R}_E(0, 0)$. If the aggregate business stealing effect is positive $\pi^M - \pi^D - (CS^D - CS^M) > 0$, the optimal policy is to subsidize R&D

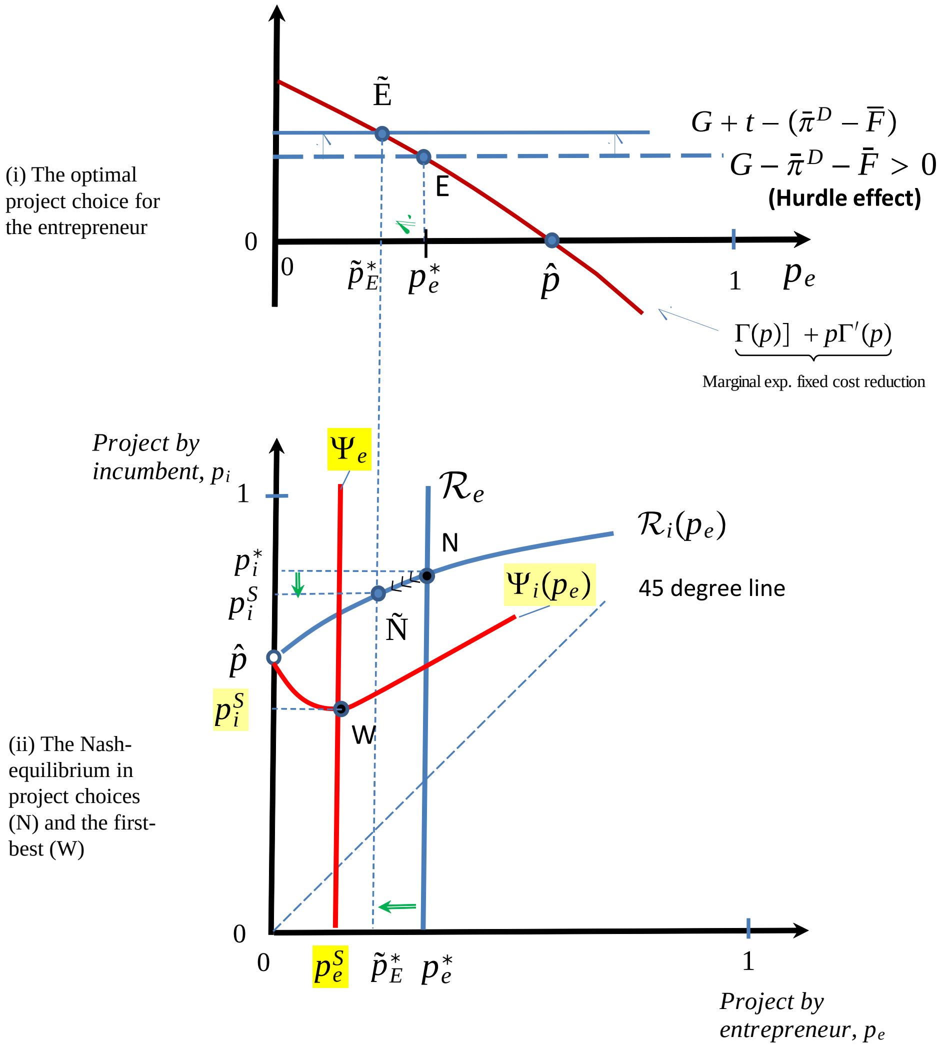

Figure 3.1: A small tax on entry will increase welfare when the business stealing effect is positive, $\pi^M - \pi^D > CS^D - CS^M$.

by the entrepreneur by an amount $r > 0$ and tax entry $t = -s > 0$, such that $R < \bar{R}_E(r, s)$.

In general, the social planner takes the externalities ξ from research into account and, therefore, finds it optimal to subsidize the fixed cost of R&D. When the business stealing effect is *positive*, the social planner wants the entrepreneur to conduct R&D, which generates positive effects for society as a whole, but also to choose more risky projects, implying that the entrepreneur will actually enter the market less often. The planner will therefore complement the R&D subsidy with a tax on entry in order to have the private incentives regarding project choices in line with social incentives.[15]

What policies should be adopted if the business stealing effect is negative? One might in that case expect that the R&D subsidy should be complemented with a subsidy of entry ($s > 0$), since the positive effect on consumers of entry is then larger than the loss inflicted on the incumbent. However, Proposition 2 shows that project choices are strategic complements for the incumbent firm: if the entrepreneur chooses a higher probability of success, the incumbent will also choose a higher probability of success. Thus, if the government subsidizes entry to induce the entrepreneur to choose safer projects, the incumbent will also go for safer projects. This increases the inefficiency in the incumbent's projects choice, since we know from Proposition 5 that the incumbent always chooses projects that are too safe from a social perspective. In effect, when the business stealing effect is negative, we cannot *a priori* determine whether entry should be taxed or subsidized.

When would we expect the business stealing effect to be positive or negative? A full exploration is outside the scope of this paper. The parametric model in Proposition 6 indicates that the sign of the business stealing effect is related to the degree of product differentiation. When products are strongly differentiated, consumers gain significantly from entry by having an additional variety to consume. At the same time, the strong product differentiation shields firms from competition, so the profit loss for the incumbent from entry is limited. In contrast, under low product differentiation, market rivalry is fierce, and incumbent losses from entry are significant, while consumer gains predominately stem from a lower consumer price.

Summing up, in markets with strong competition (where the business stealing effect from entry is positive) the planner would want to tax entry. In markets with weak competition (where the business stealing effect from entry is negative), the planner may want to subsidize entry. However, as noted above, in the latter case, the planner would also need to take into account the response in project choice of the incumbent.

[15] Even if the entrepreneur were to conduct R&D without a subsidy r, if the aggregate business stealing effect is positive, the planner will always want to tax entry in order to have the private incentives regarding project choices in line with social incentives.

4 Robustness of the Hurdle Effect

A main finding in this paper is the entrepreneurship hurdle effect; compared to incumbents, entrepreneurs choose R&D projects which are potentially of higher quality but which also involve more risk (since succeeding less often reduces the expected net entry cost). In this section, we generalize this result to a more general setting where a successful invention simply increases a firm's product market profit (an invention can then be interpreted as a new product, a product of higher quality or a new or improved production process). We also relax some of the other simplifying assumptions in the benchmark model: we analyze the case when the entrepreneur can enter the market and both the entrepreneur and the incumbent succeed. We consider the cases where a second entrepreneur or a second incumbent exist. Finally, we also allow the entrepreneur to commercialize her invention through sale to the incumbent, instead of entering with it into the product market. In all these extensions, we show that our main result holds true: the entrepreneur has a stronger incentive to embark on R&D projects with a low probability of success and a high payoff (i.e. aim at breakthrough innovations) when the commercialization (entry or transaction) cost increases.

We also use the linear Cournot model with homogenous goods in a setting where a successful invention now leads to a reduction in the marginal cost to show that other results derived in the main analysis are not specific to the fixed cost saving model. We establish that the results in Propositions 2-4 hold in this Cournot model with homogenous goods. We also provide an example which shows that Proposition 6(i) holds when successful inventions reduce the marginal costs.

4.1 Generalization

Let us now use a more general formulation of R&D projects, where an invention can take several forms, all of which increase the firm profits; it can be a new product, a product of higher quality or a new or improved production process. As before, each project is characterized by a probability of success $p_l \in (0,1)$. Let $k_l = k(p_l)$ denote the corresponding project quality, where a higher quality increases the pay-off associated with a successful invention $\frac{d\pi}{dk_l} > 0$, but project quality and probability of success are inversely related, $\frac{dk}{dp_l} < 0$. Hence, a project with a lower probability of success is then associated with a higher quality and a higher payoff, whereas a project with a higher probability of success is associated with a lower quality and a lower payoff. That is, the more profitable an invention is, the more difficult it is to develop $\frac{d\pi(p_l)}{dp_l} = \frac{d\pi}{dk}\frac{dk}{dp_l} < 0$. We define a reduced-form pay-off function as $\pi(p_l) \equiv \pi\left(k(p_l)\right)$. In addition, in order to have a well-behaved model, we will assume that the profit function has the following properties:

Assumption A4. *Monopoly profits. (i)* $\pi(p_l) \in (\bar{\pi}, \infty)$, *(ii)* $\pi'(p_l) < 0$ *and* $\pi'(p_l) > -\infty$, *and (iii)* $\frac{d^2(p_l \pi(p_l))}{dp_l^2} = 2\pi'(p_l) + p_l \pi''(p_l) < 0$.

Assumption A4(i) states that a successful project always gives a higher profit than the incumbent's status-quo profit, while the profit is bounded from infinity. Assumption A4(ii) states that a project with a higher probability of success has a correspondingly lower profit. Finally, Assumption A4(iii) states that the expected pay-off function $p_l \pi(p_l)$ is strictly concave, implying that $p_l^* = \arg max_{p_l} p_l \pi(p_l) \in (0, 1)$.

We define the duopoly profits as follows: $\pi_i^D(p_e)$ is the incumbent's duopoly profit, and $\pi_e^D(p_e)$ is the entrepreneur's duopoly profit, where the superscript D denotes duopoly. Note that the duopoly profits are independent of p_i, since the duopoly competition only occurs if the incumbent's R&D project has failed. Moreover, we make the following assumption about duopoly profits:

Assumption A5. *Duopoly profits. (i)* $\pi_i^D(p_e) \in (0, \bar{\pi})$, *(ii)* $\frac{d\pi_i^D(p_e)}{dp_e} = \pi_i^{D\prime}(p_e) \in (0, \infty)$, *and (iii)* $\frac{d^2(p_e \pi_e^D(p_e))}{dp_e^2} = 2\pi_e^{D\prime}(p_e) + p_e \pi_e^{D''}(p_e) < 0$.

Assumption A5(i) states that the incumbent's profit is reduced by entry, but it is still positive. Assumption A5(ii) states that the incumbent's profit increases when the entrepreneur chooses a project that is more likely to succeed (since the associated quality is lower). Finally, Assumption A5(iii) states that the expected duopoly profit for the entrepreneur is strictly concave.

In what follows, we characterize the firm's optimal behavior in this extended setting.

4.1.1 The entrepreneur's optimal R&D project

The entrepreneur's expected payoff is given by:

$$\mathrm{E}[\Pi_e] = p_e(1 - p_i)[\pi_e^D(p_e) - G] - R \tag{4.1}$$

which is identical to (1.2), apart from the formulation of profits from a successful invention. The first-order condition, $dE[\Pi_e]/dp_e = 0$, is then:

$$\pi_e^D(p_e^*) + p_e^* \pi_e^{D\prime}(p_e^*) = G. \tag{4.2}$$

Differentiating (4.2) in p_e and G, we obtain $\frac{dp_e^*}{dG} < 0$ just as in the benchmark model with fixed cost innovation.

4.1.2 The incumbent's optimal R&D project

Turning to the incumbent, we have that the incumbent's expected payoff is given by:

$$\mathrm{E}[\Pi_i] = p_i\pi(p_i) + (1-p_i)[p_e\pi_i^D(p_e)(1-p_e)\bar{\pi}] - R \tag{4.3}$$

which is once more identical to (1.6), apart from the formulation of profits from a successful invention. The corresponding first-order condition, $dE[\Pi_i]/dp_i = 0$, is

$$\pi(p_i^*) + p_i^*\pi'(p_i^*) = \bar{\pi} - p_e[\bar{\pi} - \pi_i^D(p_e)]. \tag{4.4}$$

Compared to the expression in (1.8), the term on the r.h.s now contains two terms: (i) the loss of the status quo profit $\bar{\pi}$ which we denote the monopoly replacement effect; and (ii) the duopoly profit (when the entrepreneur succeeds and the incumbent fails) $\pi_i^D(p_e)$, which we denote the duopoly replacement effect, where the first effect is absent in the fixed cost model, since the incumbent's invention only affects the fixed cost of production and not the good sold. In the main model, Proposition 3 shows that $p_e^* < p_i^*$. In this case, comparing the first-order condition for the entrepreneur and that of the incumbent, (4.2) and (4.3), we note that the left-hand side of the expressions is strictly decreasing in p_l, $l \in \{e, i\}$. Turning to the right-hand sides, we cannot determine whether $p_e^* < p_i^*$. The intuition is that the incumbent now takes into account that by innovating, he will to some extent replace his own profits, which may make him choose a project with a higher risk than that of the entrepreneur. However, we have that $\lim_{F \to \pi_e^D(0)} p_e^*(G) = 0$. When the entry cost for the entrepreneur G approaches $\pi_e^D(0)$, the project chosen by the entrepreneur approaches $p_e^* = 0$. In the limit, the incumbent acts as a monopolist, choosing the success probability $p_i^M > 0$. Consequently, we can show that when $F \to \pi_e^D(0)$, then $p_i^* > p_e^*$.

The entrepreneur's reaction function $R_e = p_e^*$ is then given from equation (4.2), while equation (1.8) implicitly defines the incumbent's reaction function $R_i(p_e)$, whose slope is given by:

$$\mathcal{R}_i'(p_e) = -\frac{\bar{\pi} - \pi_i^D(p_e) - p_e\pi_i^{D'}(p_e)}{2\pi'(p_i^*) + p_i^*\pi''(p_i^*)} \tag{4.5}$$

and comparing it to (1.9), we see that the sign of the reaction function is now ambiguous.

Turning to the analysis of socially optimal project choices, expected welfare is

$$E[W] = p_iW(p_i) + (1-p_i)[p_eW^D(p_e) + (1-p_e)\bar{W}] \tag{4.6}$$

where $\bar{W} = \bar{C}S + \bar{\pi} - 2R + 2\xi$, $W(p_i) = CS(p_i) + \pi(p_i) - 2R + 2\xi$ and $W^D(p_e) = CS^D(p_e) +$

$\pi_e^D(p_e) - G + \pi_i^D(p_e) - 2R + 2\xi$. The first-order condition $dE[W]/dp_i = 0$ then determines the incumbent's first best project choice $p_i^S = \Psi_i(p_e)$ and $dE[W]/dp_e = 0$ determines the entrepreneur's first-best project choice p_e^S.

4.1.3 Illustration: The Cournot model with marginal cost reductions

In order to show the coherence between the model with fixed cost innovation and this more general one, we use the linear Cournot model with homogenous goods, i.e. let $\gamma = 1$ in eq. (5.1) in the Appendix. Then, assume that a successful invention leads to a reduction in the marginal cost level. Making a distinction between firm types, we then have:

$$c_i^{Nosucc} = c, \qquad c_i^{Succ} = c - (1 - p_i), \qquad c_e^{Succ} = c - (1 - p_e) \tag{4.7}$$

where we once more note the trade-off faced by firms; choosing a safer project reduces the marginal cost less. Reduced-form profits are once more quadratic in output, $\pi_j = \left[q_j^*\right]^2$ and the optimal quantities are given by $\bar{q} = \frac{\Lambda}{2}$, $q_i^*(p_i) = \frac{\Lambda+1-p_i}{2}$, $q_i^D(p_e) = \frac{\Lambda-(1-p_e)}{3}$, and $q_e^D(p_e) = \frac{\Lambda+2(1-p_e)}{3}$, where $\Lambda = a - c > 1$. Inserting these profits into (4.2) and (4.4), we obtain

$$p_e^*(\Lambda, G) = \tfrac{\Lambda+2}{3} - \tfrac{\sqrt{\Lambda^2+4\Lambda+27G+4}}{6}, \;\; p_i^*(\Lambda, G) = \tfrac{2\Lambda+2}{3} - \tfrac{\sqrt{\Lambda^2+2\Lambda+12\Phi(\Lambda,G)+11}}{3} \tag{4.8}$$

where $\Phi(\Lambda, G) = p_e^*(\Lambda, G)\left(\frac{\Lambda-(1-p_e^*(\Lambda,G))}{3}\right)^2 + (1 - p_e^*(\Lambda, G))\left(\frac{\Lambda}{2}\right)^2$.

It is also straightforward to derive expressions for the first-best projects. Tedious but straightforward calculations then show that the following results hold:[16]

Lemma4In the Cournot model described with homogenous goods, (i) $p_e^* < p_i^*$, (ii) if $\Lambda = a - c > 8/5$, $R_i'(p_e) > 0$, (iii) if $\Lambda = a - c \geq 2$, $p_e^S < p_e^*$.

Hence, if the net willingness to pay $\Lambda = a - c$ is not too low (which implies that we are not too close to monopoly), the entrepreneur will undertake a project with higher risk than that chosen by the incumbent, $p_e^* < p_i^*$, and the two firms' success probabilities are strategic complements, $R_i'(p_e) > 0$. In addition, the entrepreneur chooses too little risk from society's point of view; $p_e^S < p_e^*$. That is, the central results in Propositions 2 and 3 which were derived for the benchmark model where an innovation consists of a fixed cost reduction also hold in this model. In addition, the business stealing effect is positive so that the result in Proposition 4 holds. An illustration of Proposition 6(i) is also given in Figure 4.1. Consequently, the main mechanisms in the model with fixed cost innovation remain valid when innovations lead to variable cost reductions in the linear Cournot model.

[16]Proofs are available upon request.

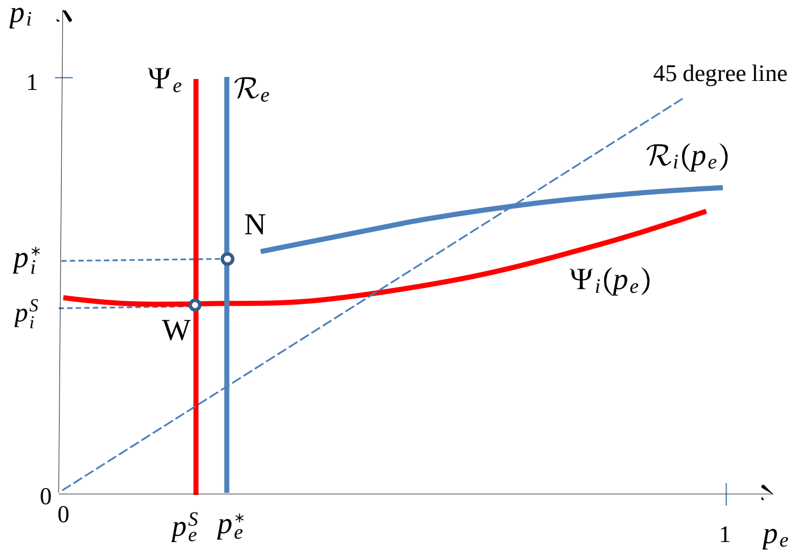

Figure 4.1: The variable cost saving model. The Nash equilibrium is given in point N and the first best solution is given in point S. Parameter values: $\Lambda = a - c = 2, G = 1$.

4.2 The Entrepreneur Always Enters if it Succeeds

In the baseline model, it is assumed that there is only room for the entrepreneur in the market when the incumbent's research project has failed. Now, we examine the case when the entrepreneur always enters the market if it succeeds. The entrepreneur's expected payoff is then given by:

$$\mathrm{E}[\Pi_e] = p_e(1-p_i)[\pi_e^D(p_e) - G] + p_e p_i[\pi_e^D(p_e, p_i) - G] - R_E \tag{4.9}$$

where the corresponding first-order condition is given by:

$$\pi_e^D(p_e^*) - G + p_e^*\pi_e^{D\prime}(p_e^*) + p_i\{\pi_e^D(p_e, p_i) - \pi_e^D(p_e) + p_e[\pi_{e,p_e}^{D\prime}(p_e^*, p_i) - \pi_e^{D\prime}(p_e^*)]\} = 0. \tag{4.10}$$

From (4.10) it follows directly that $\frac{dp_e^*}{dG} < 0$. Note also that:

$$\underset{G \to \pi_e^D(p_e, p_i)}{lim} \mathrm{E}[\Pi_e] = p_e(1-p_i)[\pi_e^D(p_e) - G] - R.$$

So with G approaching $\pi_e^D(p_e, p_i)$, the previous analysis applies. The incumbent's expected payoff is given by:

$$\begin{aligned} \mathrm{E}[\Pi_i] &= p_i(1-p_e)\pi(p_i) + p_e(1-p_i)\pi_i^D(p_e) \\ &\quad + p_i p_e \pi_i^D(p_i, p_e) + (1-p_i)(1-p_e)\bar{\pi} \end{aligned} \tag{4.11}$$

with the first-order condition

$$(1-p_e)\left[\pi(p_i^*)+p_i^*\pi'(p_i^*)-\bar{\pi}\right]+p_e\left[\pi_i^D(p_i,p_e)+p_i\pi_{i,p_i}^{D\prime}(p_i^*,p_e)-\pi_i^D(p_e)\right]=0. \quad (4.12)$$

Note that since $\frac{dp_e^*}{dG}<0$, there must exist an G such that $\lim\limits_{G\to\pi_e^D(p_e,p_i)} p_e^*(G)=0$. But then (4.12) becomes:

$$\pi(p_i^*)+p_i^*\pi'(p_i^*)-\bar{\pi}=0. \quad (4.13)$$

Thus, when the entry costs are sufficiently high, the entrepreneur will choose more risky projects (higher quality) than the incumbent.

4.3 Adding an Entrepreneur

Let us now examine the case with one incumbent and two entrepreneurs, where the entrepreneurs both face entry costs G if they enter the market. Let us retain the assumption that if both entrepreneurs are successful with their R&D projects while the incumbent fails, the triopoly expected profits an entrant would obtain are not sufficient to compensate for the fixed entry cost G. Further assume that entrepreneurs cannot enter if the incumbent is successful and that there is a lottery with equal probability of entry if both entrepreneurs succeed when the incumbent fails.

Then, the expected profit for an entrepreneur (for e.g. entrepreneur 1, e_1) is:

$$\mathrm{E}[\Pi_{e_1}]=(1-\frac{1}{2}p_{e_2})(1-p_i)p_{e_1}[\pi_e^D(p_{e_1})-G]. \quad (4.14)$$

Note that the success probability associated with the optimal project is $p_{e_1}^*=\arg\max_{p_{e_1}}[(1-\frac{1}{2}p_{e_2})(1-p_i)p_{e_1}[\pi_e^D(p_{e_1})-G]$ which is equal to $\overset{*}{p_e}$ where $\overset{*}{p_e}=\arg\max_{p_e}[(1-p_i)p_e[\pi_e^D(p_e)-G]$.

The incumbent's expected profit is:

$$\begin{aligned}\mathrm{E}[\Pi_i] &= p_i(1-p_{e_1})(1-p_{e_2})\pi(p_i)+(1-p_i)\left[p_{e_1}(1-p_{e_2})\pi_i^D(p_{e_1})+p_{e_2}(1-p_{e_1})\pi_i^D(p_{e_2})\right]\\ &\quad +p_i\left[p_{e_1}p_{e_2}+p_{e_1}(1-p_{e_2})+p_{e_2}(1-p_{e_1})\right]\pi(p_i) \\ &\quad +(1-p_i)(1-p_{e_1})(1-p_{e_2})\bar{\pi}.\end{aligned} \quad (4.15)$$

For a sufficiently high entry cost G, both entrepreneurs will choose a project with very high quality, i.e. $lim p_{e_v}^*(G)=0,\ v\in\{1,2\}$. The incumbent's project is then given as $p_i^*=\arg\max_{p_i}E[\Pi_i]=\arg\max_{p_i}[p_i\pi(p_i)+(1-p_i)\bar{\pi}]$, where we once more have $p_i^*>0$. Thus, $p_i^*>p_{e_v}$, and it follows that for a sufficiently large G, the entrepreneurs choose more breakthrough inventions than the incumbent.

4.4 Adding an Incumbent

Let us now add another incumbent, so that the market consists of two incumbents and one entrepreneur. The entrepreneur faces an entry cost G if it enters the market. Let p_{i_j} denote the probability of success corresponding to the research project selected by the incumbent j, $j = 1, 2$. In line with the previous analysis, we will assume that the entrepreneur only enters the market in case it is successful with the chosen research project while both incumbents fail. When this is the case, $\pi_e^T(p_e)$ denotes the entrepreneur's triopoly profit. As before, this (triopoly) profit is independent of the incumbents' probability of success since oligopoly competition only occurs when incumbents' R&D projects have failed. The entrepreneur's expected profit is then given by

$$\mathrm{E}[\Pi_e] = p_e(1 - p_{i_1})(1 - p_{i_2})[\pi_e^T(p_e) - G] - R_F. \tag{4.16}$$

So, if R_F is sufficiently small that the entrepreneur chooses to invest, it will choose an equilibrium value for p_e, p_e^*, implicitly defined by the following first-order condition:

$$\frac{\partial \mathrm{E}[\Pi_e]}{\partial p_e} = \pi_e^T(p_e^*) - G + p_e^* \pi_e^{T\prime}(p_e^*) = 0. \tag{4.17}$$

Now, differentiating the previous first-order condition in p_e and F, it may be concluded that:

$$\frac{dp_e^*}{dF} = \frac{1}{2\pi_e^{T\prime}(p_e^*) + p_e^* \pi_e^{T\prime\prime}(p_e^*)} \tag{4.18}$$

which turns out to be negative since $2\pi_e^{T\prime}(p_e^*) + p_e^* \pi_e^{T\prime\prime}(p_e^*) < 0$ (Assumption A4 holds for $\pi_e^T(p_e^*)$). Hence, the hurdle effect remains when we extend the model to encompass more than one incumbent. Moreover, it remains true that high fixed costs F will force the entrepreneur to choose a very risky strategy, $\underset{G \to \pi_e^T(p_e)}{lim} p_e^*(G) = 0$.

4.5 Commercialization Through Sale

Hitherto, we have assumed that the entrepreneur can only commercialize her invention through entry into the product market. However, an alternative is to sell the invention to the incumbent. If the entrepreneur faces a transaction cost associated with a sale, then the entrepreneurial hurdle effect remains. We can show that in response to an increase in the transaction cost, the entrepreneur chooses an R&D project with a higher probability of success and a lower payoff. Suppose now that if the entrepreneur's research project succeeds, the invention can only be implemented if it is sold to the incumbent firm. In this scenario, the commercialization cost takes the form of a fixed transaction cost $T \geq 0$ that the entrepreneur has to pay in case of sale. If both firms are successful, it is assumed that the incumbent always chooses to implement its own invention and, consequently, the entrepreneur's profit is zero. Hence, the entrepreneur can earn a positive profit if her selected research project is the only one that succeeds, but not otherwise. The firms are assumed to share the surplus created by the invention according to the Nash Bargaining solution, where the incumbent and the entrepreneur have bargaining strengths θ and $1-\theta$, respectively, $\theta \in (0, 1)$. The incumbent's status-quo profit, $\bar{\pi}$, is its outside option in the bargaining. To make the problem interesting, we assume that the profit net of transaction costs is higher than the status-quo profit: $\pi(p_n) - T > \bar{\pi}, n \in \{i, e\}$. The entrepreneur's outside option is zero.

The entrepreneur's expected payoff when playing this game is given by:

$$\mathrm{E}[\Pi_e] = p_e(1 - p_i)(1 - \theta)(\pi(p_e) - T - \bar{\pi}) - R_S. \tag{4.19}$$

If the entrepreneur succeeds and the incumbent fails, the incumbent will acquire the entrepreneur's invention and obtain the profit $\pi(p_e)$ from selling it on the market. The entrepreneur gets a share $(1 - \theta)$ of the surplus created by the invention net of transaction costs and the incumbent's outside option, which is $\pi(p_e) - T - \bar{\pi}$. The entrepreneur pays a fixed R&D cost R_S in order to start a project. Let us define a function $R_S^* \equiv f(p_i, p_e, \pi(p_e), T, \bar{\pi})$, where the subscript S denotes sale, such that for $R_S = R_S^*$, $E[\Pi_e] = 0$. Then, two different regimes might arise in equilibrium. If $R_S \geq R_S^*$, the entrepreneur chooses not to perform any R&D. If instead $R_S < R_S^*$, then it is optimal for the entrepreneur to choose an equilibrium value for p_e, p_e^*, implicitly defined by the following first-order condition:

$$\frac{\partial \mathrm{E}[\Pi_e]}{\partial p_e} = \pi(p_e^*) - T - \bar{\pi} + p_e^* \pi'(p_e^*) = 0, \tag{4.20}$$

where the first three terms capture the direct effect on the expected surplus, $\pi(p_e) - T - \bar{\pi}$, of choosing a project with a different probability of success. The fourth term captures the indirect effect on the expected surplus of choosing a project with a different payoff. Differentiating the entrepreneur's first-order condition in p_e and T, it may be concluded that:

$$\frac{dp_e^*}{dT} = \frac{1}{2\pi'(p_e^*) + p_e^* \pi''(p_e^*)} < 0, \tag{4.21}$$

where $2\pi'(p_e^*) + p_e^* \pi''(p_e^*) < 0$ as a result of Assumption A1. If T increases, the entrepreneur will reduce its equilibrium success probability p_e^*, since this reduces the expected transaction cost $p_e(1 - p_i)(1 - \theta) T$ and, at the same time, increases the payoff $\pi(p_e)$ of its research project if it succeeds. Consequently, our result that the entrepreneur chooses an R&D project with a lower probability of success and a higher payoff if the commercialization (entry) cost increases continues to hold if the entrepreneur commercializes the invention through sale instead of entry.

5 Concluding Remarks

This paper shows that entrepreneurs have incentives to choose projects with high risk and high potential in order to reduce the expected entry costs. This finding is interesting in the light of the recent shift towards more pro-entrepreneurial policies all over the world as revealed in data from the World Bank Doing Business project. The cost of starting a new business declined by more than 6 percent per annum over the period 2003-08 and the decline among OECD countries has been even more dramatic. Our results suggest that this development is likely to lead to more entrepreneurial entry, but to less breakthrough inventions by entrepreneurs. In addition, incumbent firms are likely to respond to this development by (also) choosing R&D projects with a lower risk.

Our analysis points to the fact that the policy maker should take into account that entrepreneurial policies do not only affect the size of entrepreneurial activities but also affect the type of projects chosen by entrepreneurs. In particular, we show that policies designed to reduce entry costs could stimulate entrepreneurship, but also stimulate entrepreneurship that takes too little risk from a social point of view. In a parametric model, we illustrate how entrepreneurship policies might need to be adapted to the specifics of the product market; the policy maker will have an incentive to complement R&D subsidies with a tax on entry in markets characterized by a low degree of product differentiation but may have an incentive to complement the R&D subsidy with a subsidy of entry in product markets with a high degree of product differentiation.

Our theory contributes to an understanding of the entrepreneurship "puzzle" (Åstebro *et al.* 2014), or the stylized fact that entrepreneurship is associated with low average returns but exhibits a large dispersion because most startups fail and only a few are very successful. Behavioral mechanisms such as overconfidence, low risk aversion, and non-pecuniary benefits have been suggested to explain this pattern. In contrast, our explanation is a story of the timing of commercialization costs, where the entrepreneurs' behavior is driven by minimizing high expected entry costs.

Moreover, we believe that this model can be used to better understand the value of the concept innovation diversity. Gilbert (2006) points out that independent researchers develop capabilities that are difficult to replicate within a single organization. It is difficult to model the value of this type of diversity. This paper makes an attempt to formally model innovation diversity showing how independent researchers choose research projects with higher risk profiles than do incumbents. We have also shown that society may prefer firms to undertake more risky R&D and thus, that the diversity of R&D in the form of risk taking entrepreneurial firms can be beneficial to society. In our analysis, we have examined how R&D subsidies affect R&D and welfare. We believe that our model can also be applied to study what is the impact of other types of policies that affect R&D, such as financial and educational policies, innovation diversity and the efficiency of the innovation market.

Our model focuses on the risk in the R&D phase, i.e. the risk of pre-entry failure. However, a large share of the empirical literature on entrepreneurship focuses on the risk associated with the risk of post-entry failure. We can extend our model to also examine such commercialization risk. We could use a setting where the first phase of entry is "small scale", testing a new uncertain business idea – or business project – on a small specific sub-market. If the business idea turns out to work on a small-scale, large scale entry can then be undertaken at a substantially lower risk. Since the (ex post) entry cost associated with large scale entry can be avoided if the small scale entry trial fails, entrepreneurs will also in this setting have an incentive to choose projects with high risk and high potential. Thus, our identified hurdle effect also applies in a setting with risk in the post-entry phase.[17] Examining the interactions between pre-entry research risks and post-entry commercialization risk more in detail seems a fruitful avenue for future research.

Our paper could also be extended to deal with how asymmetries in commercialization costs between incumbents shape R&D project choices. Incumbents may face different entry costs in different new sub-markets. Our set-up would, for instance, predict that incumbents which are closer to a sub-market (geographically, in product space or in the knowledge space) would choose safer projects than incumbent firms at a further distance from that market. In some industries, such as the pharmaceutical industry, there are also positive information spillovers from other research projects, so successes and failures are to some extent shared by all firms in the industry. Incorporating such aspects into the model seems to be an interesting avenue for future research.[18]

[17] Formally, we could assume that the fixed cost R in our model is the net cost of small scale entry, i.e. the cost of small scale entry, σ, say (small) minus the product market profit, π^s, say. Obtaining a sufficiently high product market profit in the sub-market would be a signal that the project could be successfully implemented on a large scale. Typically, in this phase in the commercialization process, the product market profits are low in relation to start-up costs and $R = \sigma - \pi^s > 0$.

[18] For instance, Chiou *et al.* (forthcoming) develop a cumulative innovation model to examine both the roles of success and failure in knowledge accumulation, and test it in the context of the pharmaceutical industry.

Appendix

The Linear Cournot Model with Differentiated Goods

Following Singh and Vives (1984), assume the utility of a consumer to be given by:

$$U(\mathbf{q}, I) = aQ - \frac{1}{2}\left[q_i^2 + 2\gamma q_i q_e + q_e^2\right] + I \tag{5.1}$$

where q_i is the output of the incumbent, q_e is the output of the entrepreneur, $Q = q_e + q_i$ denotes total output, I is a composite good of other goods and a is a constant. The parameter γ measures the substitutability between products. If $\gamma = 0$, each firm has monopolistic power, whereas if $\gamma = 1$, the products are perfect substitutes.

Consumers maximize utility subject to the budget constraint $P_i q_i + P_e q_e + I \leq m$, where m denotes income and the price of the composite good is normalized to one, $P_I = 1$. The first-order condition for good j is $\frac{\partial U}{dq_j} = a - q_j - \gamma q_h - P_j = 0$ for $j \neq h$ which gives the inverse demand for firm j

$$P_j = a - q_j - \gamma q_h, \quad j \neq h \ . \tag{5.2}$$

The product market profit is given by $\pi_j = (P_j - c)q_j$, where c is a constant marginal cost and the first-order condition in (1.1) becomes

$$\frac{\partial \pi_j}{\partial q_j} = P_j - c_j - q_j^* = 0 \tag{5.3}$$

which can be solved for the optimal quantities q^*. With symmetric firms $c_j = c$, defining $\Lambda = a - c$ gives:

$$q_i^M = \frac{\Lambda}{2} \text{ and } q_i^D = q_e^D = \frac{\Lambda}{2+\gamma}. \tag{5.4}$$

Noting that $\frac{\partial \pi_j}{\partial q_j} = 0$ implies $P_j - c_j = q_j^*$, the reduced-form equilibrium profits are then $\bar{\pi}_j^* = \left[q_j^*\right]^2$. From (5.2), prices are $P_i^m = a - q_i^M$ and $P_i^D = P_e^D = a - (1+\gamma)\, q^D$. We then have that the consumer surplus in each market structure is given by

$$\begin{cases} CS^D = CS(\mathbf{q}^D) = aQ^D - \frac{1}{2}\left[\left(q_i^D\right)^2 + 2\gamma q_i^D q_e^D + \left(q_e^D\right)^2\right] - P_i^D q_i^D - P_e^D q_e^D \\ CS^M = CS(q_i^M) = aq_i^M - \frac{1}{2}q_i^M - P_i^M q_i^M. \end{cases} \tag{5.5}$$

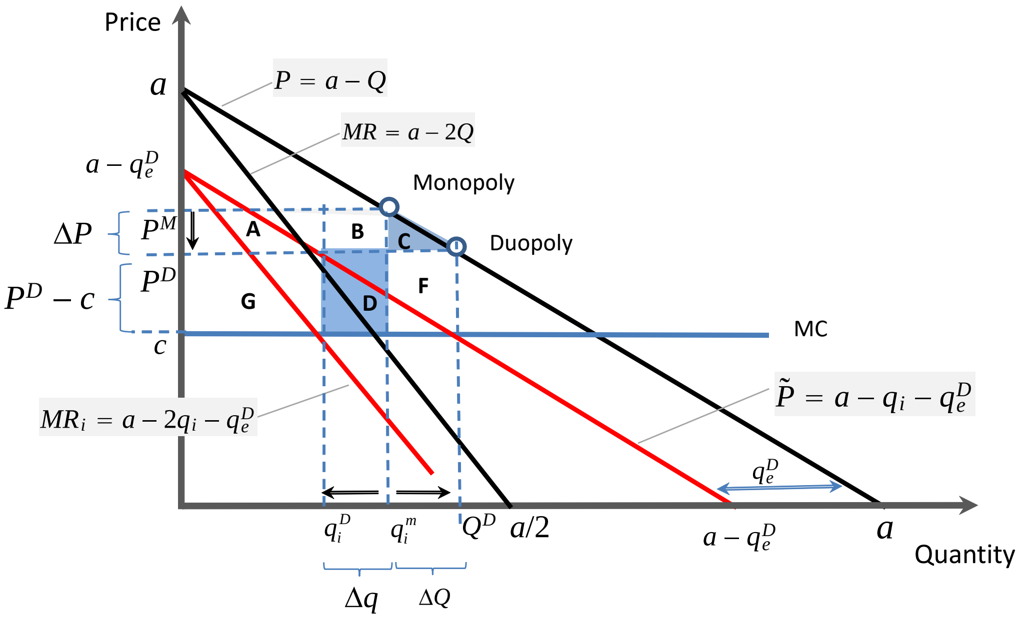

Figure 5.1: The business stealing effect in a Cournot model with homogenous goods is the area D-C.

Homogeneous goods

Let us first examine entry when goods are perfect substitutes, $\gamma = 1$. We have that $CS^M = \frac{1}{2}\left[q_i^M\right]^2$ and $CS^D = \frac{1}{2}\left[Q^D\right]^2$. In addition, some algebra shows that in this **case,** $\bar{\pi}^M - \bar{\pi}^D - \left[CS^D - CS^M\right] = \frac{1}{24}\Lambda^2 > 0$. This gives the following Lemma:

Lemma5In the Linear-Cournot model with homogeneous goods, the business stealing effect is positive, $\pi^M - \pi^D - (CS^D - CS^M) > 0$. As a result, the entrepreneur chooses too safe **a** research project, $p_e^S < p_e^*$, as does the incumbent, $p_i^S < p_i^*$.

This result is illustrated in Figure 5.1. The increase in the consumer surplus from entry $\Delta CS = CS^D - CS^M$ is given as the sum of areas A, B and C. Entry reduces the product market price by $\Delta P = P^M - P^D$, while consumption expands by $\Delta Q = Q^D - q_i^M$, where $Q^D = q_i^D + q_e^D$. Thus, consumers face a lower price on the "old" monopoly consumption q_i^M, corresponding to rectangles A and B. In addition, the consumer surplus also increases since output is higher in duopoly, corresponding to the triangle C.

The loss in profit for the incumbent, $\Delta\pi_i = \bar{\pi}^M - \bar{\pi}^D$, i.e. the entry deterring effect is represented by areas A, B and D. The incumbent faces profit losses since entry by the entrepreneur reduces the incumbent's output by $\Delta q = q_i^M - q_i^D$. The total loss on these units is $(P_i^m - c)\,\Delta q$ and is represented by areas B and D. In addition, the monopolist faces a reduction in price on the (new) duopoly output, leading to a loss of revenues $\Delta P q_i^D$ and shown by area A.

Areas A and B represent a transfer between the monopolist and the consumers, so the business stealing effect must be rectangle D minus triangle C. Note that with homogeneous goods, rectangle D must be larger than triangle C. This follows from the fact that expanding consumption ΔQ adds consumers with a decreasing willingness to pay, while the loss of business from entry for the incumbent, Δq, occurs at a constant price cost margin $P^D - c$. Thus, with homogeneous goods and symmetric firms, the business stealing effect is always positive. From a social planner's point of view, the entrepreneur then chooses R&D projects that are not risky enough. From Proposition 5, both firms take on too little risk.

Differentiated goods

Let us now examine entry with differentiated products, where $\gamma \in (0,1)$. It is instructive to first evaluate the business stealing effect in the limiting case of $\gamma = 0$, i.e. when products are independent and each firm is a monopolist, $q^M = \{q_i^M, q_e^M\}$. Since entry does not imply any output reduction for the incumbent; $\Delta q = 0$, $\pi_i(q^M) = \pi_i(q_i^M)$ and $\Delta\pi_i = \pi_i(q_i^M) - \pi_i(q^M) = 0$. However, aggregate output increases, $\Delta Q = q_e^M > 0$, because of the introduction of a new variety and, as a result, the consumer surplus must increase. To see this, note that $CS(q^M) = CS(q_i^M) + CS(q_e^M)$ so that $\Delta CS = CS(q^M) - CS(q_i^M) = CS(q_e^M)$. Thus, in the limiting case of independent products, the business stealing effect is negative, $\Delta\pi_i - \Delta CS = -CS(q_e^M) < 0$.

Since we have shown that the business stealing effect is positive for the case of homogenous products ($\gamma = 1$) and negative for the case of independent products ($\gamma = 0$) then, by continuity, there must exist a cut-off differentiation such that the business stealing effect turns negative. To see this, first note that the consumer surplus under monopoly is $CS^M = \frac{1}{8}\Lambda^2$, and under duopoly it is $CS^D = \Lambda^2 \frac{\gamma+1}{(\gamma+2)^2}$. Note that $\frac{\partial CS^D}{\partial \gamma} < 0$, which implies that the consumer surplus in a duopoly market is increasing in product differentiation. Then, some algebra shows that

$$\pi^M - \pi^D - (CS^D - CS^M) = \frac{1}{8}\Lambda^2 \frac{3\gamma - 2}{\gamma + 2}. \tag{5.6}$$

From (5.6), we can solve for the level of $\tilde{\gamma}$ such that $(\pi^M - \pi^D) - (CS^D - CS^M) = 0$. Then, we can formulate the following Lemma:

Lemma6In the Linear-Cournot model when goods are sufficiently differentiated, i.e. if $\gamma \in (0, \frac{2}{3})$, the business stealing effect is negative, $\pi^M - \pi^D - (CS^D - CS^M) < 0$, implying that the entrepreneur chooses too risky projects: $p_e^S > p_e^*$, while the incumbent chooses projects with too little risk $p_i^S < p_i^*$.

If the parameter that determines product differentiation, γ, is sufficiently low so that $\gamma \in \left[0, \frac{2}{3}\right)$, the business stealing effect is negative. Consequently, if goods are sufficiently differentiated, the social planner prefers that the entrepreneur takes less risk. This is explained by the fact that as product differentiation increases, the entrepreneur steals less of the incumbent's profits upon entry and, in addition, creates a larger increase in the consumer surplus. Once more, since the incumbent does not internalize the entry effects in terms of the entrepreneur's profit, on the one hand, and on the consumer surplus, on the other, it ends up embarking on projects with too little risk from a social welfare perspective.

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