The Welfare Implications of Non-Patentable Financial Innovations

Enrique Schroth
Helios Herrerah

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Helios Herrera

ITAM, Centro de Investigacion Economica

Enrique Schroth\textsuperscript{2}

HEC - University of Lausanne and FAME

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\textsuperscript{2}Corresponding author: Ecole des HEC, Université de Lausanne. BFSH 1, 1015 Lausanne, Switzerland. Email: enrique.schroth@hec.unil.ch. Tel.: +41 21 692 3352. Fax: +41 21 692 3435.
Abstract

Investment Banks invest in R&D to design innovative securities even when imitation is possible, i.e., when innovations cannot be patented. We show how a financial institution can profit from the development of financial products even if they are unpatentable. For certain types of financial products innovating investment banks have an information advantage over imitators. This information advantage makes them better competitors and market leaders. The mere possibility of costless imitation drives innovators’ profits down, but still keeps them positive.

The absence of patents allows part of the surplus generated by the innovation to be allocated to investors. The extent of surplus sharing depends on the degree of asymmetry in the information owned by imitators and innovators and on the total number of innovators. The larger this asymmetry, the higher the innovator’s profits and the lower the investor’s surplus. With more than one innovator all the surplus goes to investors. (JEL: G24, L12, K20).

Keywords: Financial innovation, imperfect imitation, patents.
1 Introduction

Unlike other product innovations, a striking feature of new financial securities is that they cannot be patented, as documented by Tufano[9]. Industrial Organization Theory has shown that in the absence of a patent firms will not pay the R&D cost to develop a certain product if imitators can copy the product, free-riding on the development stage. Despite the absence of patents, innovation in financial securities has been a permanent phenomenon in financial markets. This shows that the financial sector is capable of evolving without them. The important question of how this can happen remains to be addressed.

Some types of financial innovations differ crucially from other more general forms of non-financial innovations, such as a new pharmaceutical. The latter can be imitated perfectly once it starts to be distributed (its formula is observed and can be duplicated immediately), and therefore patent protection is crucial to make the investment in its development profitable for a pharmaceutical company by foreclosing fierce competition from imitators that free-ride on the development cost. For innovative structured finance products, such as some variations of Credit Derivative or Collateralized Debt Obligations, the story is different. The required disclosure of their benchmark contracts (terms-sheet) or the mere observation of the traded product do not reveal the underlying hedging mechanisms and the money making schemes that are concealed behind it. As a J.P. Morgan Credit Derivatives Trader puts it:

"Everybody can see the laid-out contract but what I am very careful not to disclose are the positions in my

1Since the resolution of the “State Street Case” (State Street Bank vs Signature Financial Group) in January 1999, financial formulas and methods have become patentable. See Lerner for a description of recent patenting awards in finance. Financial securities, however, are unpantentable by their very nature: by the time a patent can be awarded (at least one year) the design would most likely have been imitated already and the market inefficiency the innovation was exploiting would be erased.

2See Tirole [8, Ch. 10] for a survey of models that analyze incentives to create new technologival innovations.

3According to a survey by Levin et al. [6], Pharmaceuticals, Medical Appliances Organic Chemicals and Steel Mill products are industries that rely fully on patents. All other industries rely significantly on them. The securities industry seems to be the only one that by its nature does not and cannot rely on patents at all.
book. With this information you could track down the logic and see where I make money. Without it you could not price correctly the product, break down the risks involved, and understand what the components are. New ideas are not easily imitated: the developing process is a set of complex skills that are not easy to acquire”. (Andrei Paracivescu, JP Morgan).

This means that there is a fundamental difference between these financial innovations and non-financial ones: some new financial products, by their nature, cannot be imitated perfectly in the short run.

In this paper we show that a Financial Institution can profit from the development of some innovative financial products such as private securities. As noted, these are completely unpatentable, unlike non-financial innovations and are, therefore, potentially imitable by competitors. Since the money making scheme behind the new product is not fully observable and understandable, the imitation will be imperfect. The innovator, in other words, will enjoy a first-mover advantage that will make the patent inessential for the profitability of the endeavor. 4

Constructing a general theory of profitable innovation in financial markets may be too ambitious given the large array of financial products that have been introduced, and the different characteristics of the innovators involved. 5 However, our argument best applies to a variety of new private securities created by IBs in the last two decades. Representative examples are debt capital market highly structured products such as variations of Collateralized Debt Obligations (CDOs), CMOs, and the many variations of these.

In this paper, an information first-mover advantage will make unpatentable financial innovation profitable. As we will see, this advantage will make the innovator a better competitor than imitators and allow him to price his product above marginal cost in equilibrium. The main purpose of the model

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4 See Herrera and Schroth [4] for a model where the first-mover advantage consists of an information asymmetry generated endogenously in the period before imitation.

5 In many cases the incentive to innovate is the image value for an IB of being recognized as a lead innovator.
is to analyze the welfare implications that arise from the creation of new securities. We analyze how the surplus created by the innovation is shared between innovators, imitators and investors. More important, the absence of a patent may benefit investors. We show how the mere presence of imitation, although imperfect, limits the profitability of the innovation and allows the investors to get a share of the surplus generated by the innovation. If the latter could be patented, the surplus would go entirely to the innovator at the expense of investors.

The paper is divided into two main parts. In the first part we consider those innovations for which the event that two different IBs that invested in R&D discover the exact same new security occurs with zero probability. In this case, for any given innovation there will only be one innovator. In the second part of the paper we consider those innovations which can possibly be independently developed by all IBs at the same time. These will be called “obvious” innovations.\(^6\)

In the next section we briefly review some related literature. Then, we model what we understand by an innovative security. In the fourth section we describe investors’ behavior and how securities are priced depending on the identity of the IB, i.e., the knowledge that investors have on the quality of information owned by each issuer. The next two sections deal with the case of one innovator: Section 5 characterizes the equilibria of the Bertrand Game and Section 6 discusses the welfare distributive implications: how surplus is shared between IBs and Investors in equilibrium.

In the remaining sections we deal with “obvious” innovations: in Section 7 we introduce the innovation game. We will show how the One Innovator Case mentioned above will arise as a particular equilibrium of a two-stage game: in the first stage the decision whether to innovate or not is made, and in the second, price competition takes place after the new security is issued and imitated. We proceed by solving for the equilibria at each stage of the game by backwards induction and pin down the equilibrium payoffs for all the second stage subgames. In Section 8 we establish the propositions

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\(^6\)These innovations are new security designs waiting to emerge as a consequence of changes in the economic or legal environments. Thus, all IBs that invest in R&D will eventually discover the same security.
that characterize all the pure and mixed strategy equilibria. We determine the equilibrium number of innovators for all of them. Finally, in Section 9 we describe how the total surplus of the innovation is distributed across innovators, imitators and investors depending on the equilibrium selected. The final section summarizes our results and discusses their relevance briefly.

2 Related Literature

Most of the literature on Financial Innovation has directed its attention towards explaining what new securities are and what creates a demand for new security designs. Although these studies identify possible reasons for the enduring demand for innovation in these markets, the reason for and the effect of the lack of patents for financial products have hardly been addressed by the literature.

Tufano [9] has illustrated empirically some features of this process but has not analyzed why the patent is not needed. The most important fact is that innovators end up being market leaders for the securities they introduced. Allen and Gale [1, Ch. 3] explain this market shares fact using a simple model in which the innovating IB is the Stackelberg leader of the imitating IBs. Thus, the innovator has the ability to pre-empt imitators and ends up with a larger market share during the imitation phase. This makes R&D expenditures profitable when patents cannot be obtained. But, as they point out, their analysis treats the security as any other commodity with a given downward sloping demand function. In our model, IBs will compete in prices rather than quantities. Indeed, price competition is more appropriate than quantity competition for the study of competitive banks.7

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7In asset markets, where demand will exhibit a large elasticity, issuers will undercut each other in prices rather than compete in quantities à la Cournot.
3 Information and Product Design

In this model, we consider an innovative security to be a new financial product sold to investors that exploits a recently discovered market inefficiency. For instance, this technology can consist of a new way of pooling correlated cash flows of different types of existing securities, selling portions to investors after matching cash flows of similar risk rating or an improved way to hedge a partially uncovered risk. Any kind of new security creation involves some knowledge about the state of the world. The more refined this knowledge is, the better security an IB will make. As we show later, we keep the main intuition simple by dealing with risk-neutral investors. In this sense, by better security we mean a security with higher expected return.

The central idea is that imitation cannot be perfect. Even though the absence of patent protection allows imitators to duplicate the idea of the new security without paying the R&D cost, the mere R&D experience gives the innovators an information advantage. Innovators will have a finer partition of the states of the world space relevant for the creation of the new security. This will allow them, in general, to create a product with higher expected value:

\[ E[\varphi_{In}] > E[\varphi_{Im}] \]  \hspace{1cm} (1)

This can be enhanced by a learning process, but it goes beyond the scope of this paper. Next, we formalize this information asymmetry problem and its consequence for the design implementation.

3.1 Information Structure

In this model we assume that there are two different levels of knowledge on the distribution of the state of the world. The state of the world is \( z \in \mathcal{Z} = \{1, 2, ..., N\} \). Innovators and imitators both have the same prior distribution \((\gamma_1, \gamma_2, ..., \gamma_N)\) defined over \( \mathcal{Z} \). However, innovators have further private information
which is not revealed to imitators. This information can be described by a totally informative signal
\( j \in \{1, ..., M\} \) that selects an element of a given partition \( \{Z_1, Z_2, ..., Z_M\} \) of \( Z \). The signal \( j \) reveals
that \( z \in Z_j \subset Z^8 \).

We will illustrate the basic idea with a simple example and leave the general result to the appendix.

### 3.1.1 A simple example

Suppose there are two states of the world, \( z = 1, 2 \). The imitator has no information on the true
realization but has a probability distribution on \( z \). The innovator, on the other hand, has perfect
knowledge on the actual state. Given this knowledge, IBs will choose \( a \) to maximize a function \( \varphi(a, z) \)
which is conditional on the state \( z \). In this model, \( a \) is a real variable defined in a compact set that
summarizes the inner characteristic of the security given by its design. \( \varphi(.) \) is a real valued continuous
function of \( a \) that represents the returns of the new security.

**Innovator’s problem** After observing \( z = 1 \) or \( z = 2 \), the innovator chooses \( a \) to maximize \( \varphi(a, z) \).

Let the solution to this problem be given by \( a^{In} = a(z) \), and for each state let \( \varphi_{In}(z) = \varphi(a^{In}, z) \) be
the maximized value for the security’s return function.

**Imitator’s problem** Since the imitator does not observe \( z \) he uses his beliefs on the true state to
solve the following problem:

\[
\text{choose } a \text{ to maximize } \gamma_1 \varphi(a, 1) + \gamma_2 \varphi(a, 2),
\]

where naturally \( \gamma_1 + \gamma_2 = 1 \).

In this case, the choice of \( a \) is not contingent on the actual state. Let \( a^{In} \) be the solution to this

\(^8\text{In Herrera and Schroth [4] we generate this signal endogenously and show how this information asymmetry guarantees condition (1).} \)
problem, and $\varphi_{\text{Im}}(z) = \varphi(a_{\text{Im}}, z)$ be the return on each state.

**Proposition 1** $\forall z$, $\varphi_{\text{In}}(z) \geq \varphi_{\text{Im}}(z)$.

**Proof.** If $z = 1$, for every $a_{\text{Im}}$, $\varphi_{\text{In}}(1) = \max_a \varphi(a, 1) \geq \varphi(a_{\text{Im}}, 1) = \varphi_{\text{Im}}(1)$. Likewise, for $z = 2$. $\blacksquare$

The intuition is that the innovator knows the objective whereas the imitator knows it only up to a probability distribution. The innovator can always make the same choice as the imitator, and generically, given his finer knowledge he can do better and will obtain a higher return (the inequality will be strict). For this simple case, we have shown this way that the innovator’s security first order stochastically dominates its imitation. This is a stronger result than the simple expected value dominance. It guarantees that given relative prices, even risk-averse investors will only choose to hold one type of security and not diversify across innovative securities and their imitations. This is true however only if the innovator has complete knowledge of the state $z$. In the appendix we explore a more general case, where only the weaker result $E[\varphi_{\text{In}}] > E[\varphi_{\text{Im}}]$ is obtained.

### 4 Investor’s and Banks Objectives

#### 4.1 Demand for Financial Products

We assume that there is a fixed number $\bar{q}$ of identical investors, each one endowed with a unit of cash for investment in a portfolio of assets. These investors have access to a new type of securities issued by both, imitators and innovators, which pay one-period given returns of $\varphi_{\text{Im}}$ and $\varphi_{\text{In}}$, and trade at prices $P_{\text{Im}}$ and $P_{\text{In}}$, respectively. These prices are set by the issuers, in our case the investment banks, and taken as given by investors.

Investors choose their portfolio $(h_{\text{Im}}, h_{\text{In}}) \geq 0$ to maximize the expected returns:

$$E[h_{\text{In}}\varphi_{\text{In}} + h_{\text{Im}}\varphi_{\text{Im}}],$$  \hspace{1cm} (P1)
subject to the resource constraint

\[ 1 = P_{In}h_{In} + P_{Im}h_{Im}. \]  
(3)

It is important to stress that the implicit assumption of risk-neutrality is not a crucial but just a simplifying assumption. The underlying crucial assumption here is the perfect substitutability among new securities issued by different IBs. As long as this is true, there is no need even for a risk-averse investor to diversify across several IBs securities. One security will guarantee that utility is maximized. Risk-neutrality serves only the purpose of simplifying investors’ demand. So we restrict the analysis to comparison of expected returns only and leave aside volatility considerations. These volatility considerations can be accounted for by extending the model.

Since the optimization problem (P1) is linear, we will have a corner solution. Investors will only demand a positive amount of the security which maximizes their net return, and demand zero of the other. The condition for an investor to hold only securities issued by the innovator is:

\[ (h_{In}, h_{Im}) = \left( \frac{1}{P_{In}}, 0 \right) \text{ iff } E(\varphi_{In}) - \frac{P_{In}}{P_{In}} \geq \frac{E(\varphi_{Im}) - P_{Im}}{P_{Im}}, \]  
(4)

and similarly for the imitators’ security. In other words, investors will go for the best deal the market offers to them. Note that, how we defined the information structure, \( E(\varphi_{In}) \) does not depend on the particular innovator: any innovator will issue exactly the same security as the other innovators, and the same if true of imitators.

We must stress a point relevant for the next section. The expected returns are an inherent characteristic of the security while the corresponding prices are determined by the issuers so as to maximize their profits. Typically, in financial markets, the demand for the preferred asset will be perfectly elastic.
and its price will depend on its inner characteristics (volatility, dividend or payoff stream).\(^9\)

### 4.2 Investment Banks

There is a fixed number \(I\) of IBs in the economy. The profits of the \(i\)-th IB are:

\[
\pi_i = (P_i - C) q_i,
\]

where \(q_i\) is the quantity of the security sold to investors by the \(i\)-th bank, \(P_i\) is its price, and \(C\) the operating cost for each unit of the security, which is the same for all IBs. The results of this paper do not change if we assume that the innovator’s advantage translates into lower operating costs for managing the new financial product, rather than higher expected returns of the latter.\(^10\)

IBs try to sell their newly issued security to investors by choosing its price \(P_i\). For any given expected return of a new security, the IB that charges the lowest price obtains the entire market. To make sure that this actually happens we assume that IBs have no constraint on their issuing capacity, i.e., they are effectively Bertrand competitors. Having said this, we assume, as is usually done in Bertrand models that, whenever the lowest price is charged by more than one IB the demand is shared evenly among them.

### 5 The One Innovator Case

Suppose only one of the \(I\) IBs has incurred an R&D sunk cost \(K_i\) in order to design a new security. Therefore, he will be the innovator (In) for this particular innovation, while the remaining \(I - 1\) IBs

\(^9\)Of course, demand will be horizontal until it reaches the full capacity investors are willing to hold, \(\pi\), then it drops to zero.

\(^10\)We have assumed that the innovator’s informational advantage is reflected in a higher expected value for his product: \(E(\varphi_{In}) > E(\varphi_{Im})\). Alternatively, we could have proceeded by assuming that the advantage was reflected in a lower marginal cost, i.e., \(C_{In} < C_{Im}\), that would allow the innovator to have a higher margin. Lower operating costs can be the result of smaller accounting losses due to lower chances of making mistakes in the pricing or in the engineering choices of the product.
will be imitators (Im) and will try to free-ride on this unprotected discovery.\textsuperscript{11}

In this scenario, the innovator will enjoy a monopolistic advantage over all the \((I - 1)\) imitators. Taking the logarithm of the inequality (1), this advantage will be summarized by the inequality:

\[
\varepsilon(\varphi_{In}) > \varepsilon(\varphi_{Im}),
\]

where \(\varepsilon(\varphi_i) \equiv \ln E(\varphi_i)\). Also, taking the logarithms of the demand inequality 4 we have:

\[
\varepsilon(\varphi_{In}) - p_{In} > \varepsilon(\varphi_{Im}) - p_{Im},
\]

where \(p_i \equiv \ln P_i\).

All IBs compete in prices a la Bertrand to maximize their profit, \(\pi\). Since Ins and Ims are selling products that are different they will, in general, be charging different prices. In this Bertrand game \(p_{Im}\) is the imitators’ strategy, i.e., the price he charges for his security. Likewise, \(p_{In}\) is the innovator’s strategy.

Let us now analyze the best responses. Taking the value of \(p_{Im}\) as given, the In will choose \(p_{In}\) depending on that value. This will be the highest price that still secures to the In all the investor demand \(\bar{q}\) and a positive profit. That is:

\[
p_{In} = \varepsilon(\varphi_{In}) - [\varepsilon(\varphi_{Im}) - p_{Im}] \equiv \Delta \varphi + p_{Im}.
\]

\(p_{In}\) is the price that makes consumers indifferent between purchasing the innovator’s security or the imitators’s security. Imitators’ best response given any \(p_{In}\) is to lower \(p_{Im}\) to try to capture some market share. This process of mutual price undercutting comes to a halt at marginal cost pricing:

\textsuperscript{11}The case of one innovator can be thought of as the case which innovations are “rare”, i.e., the probability that there will be two IBs that have invested in R&D and end up developing exactly the same security is zero.
\( p_{\text{Im}} = c \equiv \ln C \), that is, when Ims’ profits shrink to zero. So, this Nash Equilibrium strategy profile is:

\[
p_{\text{In}} = \Delta \varphi + c \quad \text{and} \quad p_{\text{Im}} = c.
\]

5.0.1 Equilibria with Weakly Dominated Strategies

There are other equilibria, in which Ims price below their marginal costs: \( p_{\text{Im}} < c \). This happens as long as it is still profitable for the In to get all the market by lowering \( p_{\text{In}} \), leaving zero profits for the Ims. The interpretation of the Ims strategy in this equilibria is as follows: Ims are sure not to get any market share; if they were, they would incur losses. The Ims can decide to charge less than marginal cost since they will make zero profits anyway. More specifically, Ims will be indifferent to price in the following interval:

\[
c - \Delta \varphi < p_{\text{Im}} \leq c
\]

This is the interval that guarantees that \( p_{\text{In}} - c > 0 \), i.e., positive profits for the In. The equilibria will be then characterized by:

\[
p_{\text{In}} = \Delta \varphi + p_{\text{Im}}
\]

\[
c - \Delta \varphi < p_{\text{Im}} \leq c.
\]

Note that for Ims, charging a price below marginal cost is weakly dominated by pricing at marginal cost: \( p_{\text{Im}} = c \).
5.0.2 Equilibrium Selection

Among all the equilibria described, we will select the unique weakly undominated equilibrium, the one given by the strategy profile (9). Note that $p_{\text{Im}} > c$ weakly dominates the equilibrium strategy $p_{\text{Im}} = c$, however it is never an equilibrium strategy. The equilibrium we select is the only one that is weakly undominated, even though the Ims strategy is weakly dominated by all the other equilibrium strategies.\textsuperscript{12}

The In’s advantage has made it a stronger competitor and has guaranteed all the investors’ demand $\bar{q}$. The corresponding profits are:

\[
\pi^{\text{In}} = \left[ \frac{E(\varphi_{\text{In}})}{E(\varphi_{\text{Im}})} - 1 \right] C\bar{q} \equiv \hat{\pi}^{\text{In}} \quad \text{and} \\
\pi^{\text{Im}} = 0.
\]

6 Welfare Distribution for the Case of One Innovator

Investors’ surplus generated by the innovation is given by the difference between the maximum price they are willing to pay for the new security minus the price they are actually charged, multiplied by the quantity of the security purchased. Assuming that investors can always keep cash in their portfolio, the price of any security cannot exceed its expected value:

\[ E(\varphi_i) \geq P_i. \]

If this were not the case for the most profitable security, the net returns for that security (and any other) would be less than one. Hence, investors would rather hold cash that yields a unit return.

\textsuperscript{12}In a discrete strategy space this corresponding equilibrium will, in fact, use weakly undominated strategies.
The investors’ surplus derived from buying security $i$ is defined by:

$$S \equiv [E(\varphi_i) - P_i]q_i,$$

(11)

where $E(\varphi_i)$ is the maximum price that investors are willing to pay for that security. Further, we assume that $E(\varphi_{Im}) > C$ so that there exist a price sufficiently low such that:

$$E(\varphi_{Im}) - P_{Im} \geq 0 \quad \text{and} \quad P_{Im} - C > 0.$$

The first inequality states that investors will find the Ims’ new security more profitable than cash. The second inequality states that at the price $P_{Im}$ the issue is profitable for the Ims.

In the Bertrand Equilibrium (9), only the innovator’s security is sold at a price given by:

$$P_{In} = \exp(\Delta \varphi + c) = \frac{E(\varphi_{In})}{E(\varphi_{Im})}C.$$

(12)

Thus, the investors’ surplus in this equilibrium is:

$$S = E(\varphi_{In})[1 - \frac{C}{E(\varphi_{Im})}]q_i.$$

(13)

### 6.1 Surplus Sharing

The total surplus generated by an innovation is defined by:

$$W \equiv S + (\pi - K),$$

(14)
where $\pi - K$ is the aggregate firms’ profits (given in (5)) net of the total costs of R & D.\footnote{We have now assumed that R&D costs are homogeneous across IBs. Introducing heterogeneity costs would not alter the main qualitative results, e.g., the equilibria and the welfare implications remain unchanged.}

In this scenario we see that the surplus generated by the discovery is shared between investors and the In. We would like to emphasize that this sharing is merely due to the presence of imitators. Suppose that imitation was impossible and there were no imitators in the market. Then, the innovator would charge the highest possible price investors were willing to pay, $P_{In} = E(\varphi_{In})$. This would leave no surplus to the investors, i.e., there would be no surplus sharing:

$$S = 0,$$

and

$$\pi - K = [E(\varphi_{In}) - C] \bar{q} - K = W. \quad (15)$$

This hypothetical situation is depicted in the first panel of Figure 1.\footnote{In this picture we have omitted the innovator’s sunk cost $K$ since, at this stage, it does not have any bearing on the results.} This case could correspond to a case with patents, if patenting a new financial design was possible. The fact that patenting is impossible will restrain the innovator’s monopoly power and thus transfer some of the surplus to the investors. This happens thanks to the possibility of imitation. Even though imitators do not supply the security in equilibrium, their mere presence guarantees that $P_{In} < E(\varphi_{In})$: investors surplus is positive (as given by (13)) and the innovator’s is reduced to: $\tilde{\pi}_{In} - K$ (as given by (10)). The aggregate surplus, though, is the same for the case with or without imitation. Panel 2 of Figure 1 illustrates this situation.

6.2 Discussion

The share, $S$, of the total surplus, $W$, that goes to investors depends crucially on the imitation side, namely on $E(\varphi_{Im})$. The fact that other IBs can create, by simple imitation, a security that investors
are willing to buy at a price higher than the marginal cost, $C$, of issuing it, guarantees that consumers will benefit from this new technology. The possibility of free imitation is what cuts down the profits of the innovator.\footnote{This result is in the spirit of Baumol, Panzar and Willig’s [2] argument for contestable markets. In their theory, a monopolist cannot price above marginal cost due to the possibility of free entry. Our result is not as extreme as theirs because the innovator is still pricing above the operating cost $C$ and making profits. What is very similar is that imitators sell nothing in equilibrium and the mere threat of entry is enough to drive prices down from the monopoly level.}

The more imperfect the imitation, i.e., the larger the wedge between $E(\varphi_{In})$ and $E(\varphi_{Im})$, the higher the innovator’s profits. Conversely, the more precise imitation is, the lower the innovator’s profits and the larger the share of the total innovation surplus that goes to the investors.

From a welfare point of view, it is possible to rationalize the decision of a regulator, e.g., the USPTO, to refuse a patent for a new security design. If the regulator is concerned about investor’s welfare, by denying patent protection he allows investors to capture some of the surplus. Furthermore, surplus is transferred directly from the innovator to investors without changing aggregate welfare.\footnote{There are no deadweight losses in this analysis since the demand curve is perfectly elastic.}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Surplus Sharing with One Innovator}
\end{figure}
7 The Innovation Game

We now turn to the analysis of innovations that are “obvious” to all the IBs and thus, all of them simultaneously face the decision whether to pursue their development. We describe the following innovation game. We have players denoted by $i = 1, 2, ..., I$, which represent $I$ IBs. The game can be summarized in two subsequent stages.

- In the first stage players face a binary choice: to innovate or not. If they choose to innovate, they will henceforth be called Ins. They will discover a new security with probability one, incurring the sunk R&D cost $K_i > 0$. If not, they will be called Ims. They will imitate Ins’ security incurring no development cost.

- In the second stage all IBs choose a price, $P_i$ for their security. Ims can implement the new design without paying the cost $K_i$ but with a lower expected return ($E[\varphi_{In}] > E[\varphi_{Im}]$, imperfect imitation). All IBs, Ims and Ins alike, engage in price competition while trying to capture investors demand given by the schedule (4).

The payoffs of the game are $\pi_i - K_i$, where $\pi_i$ is given by (5), and are obtained by an analysis similar to the one in Section 4. To be more general, we can assume entry cost heterogeneity: for a given innovation, IBs do not necessarily face the same development costs, $K_i$. This cost will depend on the innovation at stake, i.e., the IB with lower $K_i$ would be the one that has the best infrastructure in place to develop that particular innovation.\footnote{By infrastructure we mean human resources, software systems, client base, etc.}

In this game we will look for Subgame Perfect Equilibria only. For this purpose we proceed by backwards induction.

\footnote{By infrastructure we mean human resources, software systems, client base, etc.}
8 Subgame Perfect Nash Equilibria

8.1 Second Stage Competition

In this section we describe and solve for the equilibria of the second stage subgames. Let $I_{Im}$ and $I_{In}$ be the number of Ins and Ins at the second stage of the game. Then $I_{Im} + I_{In} = I$, and these numbers are determined in the previous stage. We will analyze separately three scenarios. One In: $I_{In} = 1$, more than one In: $I_{In} > 1$ and no innovation $I_{In} = 0$. These three scenarios encompass all the possible second stage subgames.

8.1.1 The Case of One Innovator

This case has already been analyzed in Section 4. We selected the unique Nash Equilibrium which was weakly undominated within the set of Nash Equilibria.

In order to make innovation profitable it would have to be the case that:

$$\hat{\pi}^{In} - K_i > 0 \quad \forall i = 1, 2, ..., I;$$  \hspace{1cm} (16)

where $\hat{\pi}^{In}$ is given by (10).\(^{18}\) In other words, the one innovator has to be able to recoup the sunk R&D investment with the second period profits obtained by selling his new financial product. Thus, what makes a new security design profitable is how imperfect its imitation is relative to its development cost. We argue that for new securities being created this is true in general. This leaves open the possibility that some innovations are not undertaken because imitation is too good.\(^{19}\)

\(^{18}\)One interpretation of this can be that only $I$ IBs have the infrastructure in place to potentially profit from this particular innovation.

\(^{19}\)Of course, reputation issues are at stake. On the one hand, there is an intrinsic value from being recognized as a cutting edge innovator in these markets. This may prompt innovators to even bear a pecuniary loss from tough competition. On the other hand, the innovator is bearing all the risk in case the innovation is not successful, i.e., that it will not be marketed, representing a pecuniary loss and no increase in reputation.
8.1.2 The Case of More than One Innovator

**Proposition 2** In any second stage subgame in which the number of Ins is larger than one, Ins price their securities at marginal cost in equilibrium and make zero profit.

**Proof.** Standard Bertrand competition among identical Ins will drive their price to marginal cost:

\[ P_{In,i} = C. \]

The total investor's demand, \( \bar{q} \), will be shared equally by the Ins. In any event, all Ins and Ims will make zero profit in the second stage. That is

\[ \pi_i = 0 \quad \forall i = 1, 2, ..., I. \]  \( (17) \)

8.1.3 The Case of no Innovation

No further subgame starts at the information set where there is no innovation. The payoffs are at this node are:

\[ \pi^{im} = 0. \]  \( (18) \)

8.2 First Stage Innovation Decision

In the stage of the innovation decision every IB, \( i \), faces the binary choice: Innovate and pay \( K_i \) or do not and imitate.

\[ \text{In equilibrium, any Im will charge any price so that } p_{im,j} \geq C - \Delta \phi. \text{ This is not relevant to our discussion.} \]

\[ \text{All IBs are potential Ins, but there is nothing to imitate.} \]
For each one of the possible scenarios above, the next proposition builds on the second stage equilibrium profits $\pi^I$ and $\pi^I$ (given by (10), (18), and (17)):

\[
\begin{align*}
\pi^I &= \begin{cases} 
\pi^I_{\text{Im}} & \text{for One Innovator,} \\
0 & \text{for more than One Innovator}
\end{cases}, \\
\pi^I &= 0 \text{ always.}
\end{align*}
\]

We characterize the set of pure strategy equilibria using the following proposition.

**Proposition 3** This game has $I$ pure strategy equilibria in which one IB innovates and the rest imitate.

**Proof.** The player that innovates is making positive profits, $\pi^I_{\text{Im}} - K_i$, and will make zero by deviating; the players that imitate are making zero profits and will make $-K_i < 0$ by deviating. ■

No other pure strategy equilibria exist. More than one innovator is inconsistent with equilibrium since innovators would make $-K_i$ and find it optimal to deviate to make zero profit instead. No innovation is not an equilibrium since for any IB it is optimal to deviate and make positive profits rather than no profits. Since we have $I$ players, we have then only $I$ pure strategy Nash equilibria.

This game has multiple equilibria but we can identify a focal point. For a given innovation the IB with the lowest R&D cost, $K_i$, could be the one selected as the innovator. This is intuitive: the bank with the best infrastructure already in place would be the developer. Notice that this is also the most efficient outcome.

To summarize, we can see how any pure strategy equilibria of this game yield exactly the same outcome as that in Section 4. Even though the innovation at stake is now assumed to be expected or obvious, i.e., all IBs have the choice of becoming the only one IB will choose to do so in equilibrium. So, the One Innovator outcome seems to be a natural one for any kind of innovation. Besides, the
welfare analysis of Section 4 applies to these pure strategy outcomes.

For all the pure strategy outcomes, the regulator’s reason for not allowing patents is strengthened: there is still the incentive to innovate without patents since the non-profitable and inefficient outcomes (the more than one innovator or the no innovation outcomes) are not equilibria.\textsuperscript{22} Thus, in the pure strategy context, the patent is not only unnecessary for financial innovation but precludes imitation and surplus sharing with investors.

8.2.2 Mixed Strategy Equilibria

The innovation game has mixed strategy equilibria. To keep the analysis from being too burdensome, we will consider only the symmetric game where R&D costs are identical across IBs, i.e., $K_i = K$ $i = 1, 2, ..., I$. Nonetheless, the main qualitative results obtained below will also hold with R&D cost heterogeneity.

The symmetric game has a natural symmetric outcome. Let $\alpha$ be the probability of innovating.

**Proposition 4** There is a unique symmetric mixed strategy equilibrium:

$$\alpha = 1 - \left[ \frac{K}{\bar{\alpha}} \right]^{\frac{1}{r-1}}$$  \hspace{1cm} (20)

**Proof.** We look for a symmetric mixed strategy profile, $\alpha$, that makes every player indifferent between innovating and not. Since the profit of not innovating is zero, we must have:

$$E[\pi^{In}] = \left( \bar{\pi}^{In} - K \right) [1 - \alpha]^{I-1} - K \left[ 1 - (1 - \alpha)^{I-1} \right] = 0,$$

\textsuperscript{22}We will show below that non-profitable and inefficient outcomes can arise from mixed strategy equilibria ex-post. However, mixed strategies are unlikely to be implemented in investment banking: it is debatable that IBs would, in any real financial decision context, randomize over the choice between innovating or not. To be indifferent between these choices is highly unlikely because there are so many factors involved in such an investment decision.
which yields the desired result. ■

Since $\frac{\pi}{I} - K > 0$, the above ratio is strictly between zero and one and therefore so is $\alpha$, given that $J \geq 2$. In other words, we have a strictly mixed strategy equilibrium.

We will now generalize the result: all the possible equilibria of the symmetric version of the game can be characterized and summarized in the following propositions.

**Proposition 5** For $I \geq 2$, we have mixed strategy equilibria where $J (\leq I)$ IBs mix with:

$$\alpha(J) = 1 - \left[ \frac{K}{\frac{\pi}{I}n} \right]^\frac{1}{J-1},$$

and the rest do not innovate.

**Proof.** See appendix. ■

The previous equilibria we found are just particular cases of the above. Note that for $J = I$ we re-obtain the unique symmetric mixed strategy equilibrium (shown in (20)). And, as $J \to 1$, by taking the limit of the above expression we get $\alpha = 1$. So we are back to the pure strategy equilibrium, i.e., the One Innovator case.

**Proposition 6** No other equilibria exist.

**Proof.** See appendix. ■

## 9 Welfare Analysis for the Innovation Game

### 9.1 Pure Strategies Case

We will now analyze the welfare implications of all the equilibria, as summarized in Proposition 5. Bear in mind that mixed strategies equilibrium outcomes can have more than one IB innovating ex-post. In
More than one innovator

Figure 2: Surplus Sharing with more than One Innovator

the general case, total surplus (14) becomes:

\[ W \equiv S + \sum_{i=1}^{I_{in}} (\pi_i^{ln} - K_i). \]  

(21)

where, as usual, investors’ surplus is \( S \), the aggregate innovators’ profits \( \sum_{i=1}^{I_{in}} \pi_i^{ln} \), and the total costs of R & D are \( \sum_{i=1}^{I_{in}} K_i \). Note that, by (19):

\[ \sum_{i=1}^{I_{in}} \pi_i^{ln} = \begin{cases} \hat{\pi}_i^{ln} & \text{for One Innovator} \\ 0 & \text{for more than One Innovator} \end{cases}. \]  

(22)

When more than one IB innovate, they make zero profit. The entire surplus created by the innovation is then transferred to investors who obtain \( [E(\varphi_{In}) - C] \tilde{q} \) (see Figure 2).
To summarize:

\[
S = \begin{cases} 
0 & \text{for no Innovation,} \\
E(\varphi_{In}) \left[ 1 - \frac{C}{E(\varphi_{In})} \right] \bar{q} & \text{for One Innovator,} \\
[E(\varphi_{In}) - C] \bar{q} & \text{for more than One Innovator}
\end{cases}
\]  

(23)

where the middle case comes from (13). Failure to innovate, of course, creates no investor’s surplus.

Given the definition (21) of total surplus \( W \) and using (10), we have:

\[
W = \begin{cases} 
0 & \text{for no Innovation,} \\
[E(\varphi_{In}) - C] \bar{q} - K & \text{for One Innovator,} \\
[E(\varphi_{In}) - C] \bar{q} - \mathcal{I}_{In} K & \text{for} \mathcal{I}_{In} > 1 \text{ Innovators}
\end{cases}
\]  

(24)

9.2 Mixed Strategies Case

Ex-ante, any number of innovators could be an outcome in the mixed strategy equilibrium. The number of IBs not choosing \( \alpha = 0 \) will determine a distribution of the random number of innovators \( \mathcal{I}_{In} \) over \( \{1, 2, ..., I\} \). For the symmetric case, this distribution implies the following probabilities:

\[
\begin{align*}
\Pr(\mathcal{I}_{In} = 0) & = (1 - \alpha)^J, \\
\Pr(\mathcal{I}_{In} = 1) & = J \alpha (1 - \alpha)^{J-1}, \\
\Pr(\mathcal{I}_{In} \geq 2) & = 1 - [1 - \alpha]^J - J \alpha (1 - \alpha)^{J-1}.
\end{align*}
\]  

(25)

Let us focus on the symmetric equilibrium of this game. In our notation, fix \( J = I \) so that all IBs are randomizing over the choice to innovate or not, with the probability of the playing the former being \( \alpha = 1 - \left[ \frac{K}{\bar{q}} \right]^{\frac{1}{J-1}} \).
First, notice that the One Innovator outcome occurs with probability:

\[
\frac{KI}{\pi^I} \left[ 1 - \left( \frac{K}{\pi^I} \right)^L \right]^{I-1}. 
\]

In this case the surplus is allocated exactly like in the pure strategy equilibrium case: it is maximized on aggregate. Second, with probability \( \frac{K}{\pi^I} \) no innovation occurs. This is a very inefficient outcome since no surplus whatsoever is generated.

In this mixed strategy scenario, the higher the \( \Pr(I_n \geq 2) \) the higher the expected surplus of investors. Further, we can verify by differentiating (25) that \( \Pr(I_n \geq 2) \) is increasing in \( \alpha \). From equation (20) we can see that, ceteris paribus, \( \alpha \) can be increased by a reduction in the cost \( K \), the R&D cost IBs must pay to innovate, which is fixed exogenously. Hence, only a subsidy to R&D can ease the cost-burden the IBs face if they want to innovate and make them choose to do so in equilibrium with a higher probability \( \alpha \) at the benefit of investors.

### 9.3 Efficiency Analysis

The total welfare introduced by an innovation will be maximized when the aggregate R&D costs are minimized, i.e., in the One Innovator outcome. In this case there are no inefficiencies since only one agent, the innovator, pays the sunk cost of R&D. More innovators benefit investors: two innovators are sufficient to give the maximum surplus to investors. Any outcome with more than two innovators is Pareto Dominated by the two innovator outcome: \( S \) is the same for both cases but at least one innovator is strictly worse off because it is now making \(-K_i < 0\) profits. The No Innovation outcome is Pareto Dominated by the One Innovator Case: \( S \) becomes positive and one IB makes \( \bar{\pi}^{In} - K_i > 0 \). Thus, the only two Pareto Undominated outcomes are the ones with one and two innovators. The former has higher total welfare \( W \), but the latter has a higher investor surplus \( S \).

For the innovation surplus to be created it suffices that one IB pays the sunk cost. Hence, each
additional innovator after the first one introduces a deadweight loss. The total deadweight loss increases linearly in the number of innovators while the total gains remain constant.

10 Summary

We have shown that in the outcome of an innovation game, at least one IB will find it profitable to pay the costs of R&D despite the absence of patent protection. Even in the case of pure strategies, we find equilibria where one IB innovates. What drives this result is the fact that imitation is imperfect, i.e., that imitators have a less refined information set on the true state of nature.

Innovations are profitable ex-post for IBs only in the pure strategy equilibrium scenario. In this case, free but imperfect imitation limits the monopoly power of the innovator to the benefit of consumers.

In the mixed strategy scenario inefficiencies may arise: no innovation can occur with positive probability. In any mixed equilibrium, all IBs make zero expected profits and consumers obtain a positive expected surplus.

We have also shed some light on why patents are not allowed for innovative financial products. If the first-mover obtains better knowledge of the state of the world, the innovator has an advantage over imitators despite the revelation of his design. So, grant of a patent gives monopoly power to the patent holder without offsetting benefit. In fact, innovation can still be profitable with imperfect imitation. Further, the patent precludes investors from sharing any of the surplus.
References


11 Appendix

Proposition 7 $E[\varphi_{In}] > E[\varphi_{Im}]$.

Proof. Let us define the problem first.

For any signal $j$ the innovator chooses $a$ to maximize:

$$
\sum_{i \in Z_j} \Gamma_i \varphi(a, i),
$$

(27)

where $\Gamma_i = \frac{\gamma_i}{\sum_{k \in Z_j} \gamma_k} \forall i \in Z_j$. Now, let the solution to the problem be given by $a^{In} = a(j)$ and let:

$$
\varphi_{In}(j) \equiv \sum_{i \in Z_j} \Gamma_i \varphi(a^{In}, i) \equiv E[\varphi(a^{In}, z) | z \in Z_j],
$$

be the maximized value of 27.

The Imitators choose $a$ to maximize:

$$
\sum_{i \in Z} \gamma_i \varphi(a, i),
$$

In this case, the optimal choice $a^{Im}$ is independent from the state, since the latter is unobserved by Imitators. Let:

$$
\varphi_{Im}(j) \equiv \sum_{i \in Z_j} \Gamma_i \varphi(a^{Im}, i) \equiv E[\varphi(a^{Im}, z) | z \in Z_j]
$$

be the returns for each element $j$ of the partition. □

Claim 8 $\forall j, \varphi_{In}(j) \geq \varphi_{Im}(j)$.

Proof. WLOG assume $z \in Z_j$, for every $a^{Im} \varphi_{In}(j) = \max_a \{\sum_{i \in Z_j} \Gamma_i \varphi(a, i)\} \geq \sum_{i \in Z_j} \Gamma_i \varphi(a^{Im}, i) = \varphi_{Im}(j)$. □

The intuition is that the innovator is maximizing the right objective, whereas the imitator does not know the right objective and will optimize to the best of his knowledge. This means that in general the
inequality will be strict. We have shown this way that the innovator’s security dominates in expectation the imitators’ one.

**Proposition 9** For \( I \geq 2 \) we have mixed strategy equilibria of the form: \( \alpha_i = \alpha, \ i = 1, 2, ..., J \) and \( \alpha_i = 0, \ i = J + 1, ..., I \).

**Proof.** This proof shows a characterization for all the equilibria of this game.

Suppose we have \( I \geq 2 \) IB and \( J \leq I \) of them innovate with a probability \( \alpha \in (0, 1) \), while \( I - J \) do not innovate. Without loss of generality pick the following strategy profile: \( \alpha_i = \alpha \forall i = 1, 2, ..., J \) and \( \alpha_j = 0 \) for \( j = J + 1, ..., I \). Take any player of the \( J \) IBs that plays the strictly mixed strategy. It will be indifferent between innovating or not. As we have seen in the previous section, the profit from not innovating is zero, since innovators take over all the market. Profits from innovating are given by \( \hat{\pi}^{In} - K > 0 \) if no other IB innovates, and by \(-K\) if at least another IB innovates. Associating the respective probabilities to these two mutually exclusive events we can evaluate the expected profits from innovating:

\[
E[\pi^{In}] = \hat{\pi}^{In} \left[ 1 - \alpha \right]^{J-1} - C \left[ 1 - (1 - \alpha)^{J-1} \right].
\]

\( E[\pi^{In}] = 0 \) is the indifference condition for the first \( J \) players that are mixing, which yields:

\[
(1 - \alpha)^{J-1} = \frac{K}{\hat{\pi}^{In}}.
\]

This condition will determine the value of \( \alpha \), which will be a function of \( J \):

\[
\alpha (J) = 1 - \left[ \frac{K}{\hat{\pi}^{In}} \right]^{\frac{1}{J-1}}. \tag{28}
\]
Given the indifference condition for the first $J$ players, the last $I - J$ players will face the inequality:

$$(1 - \alpha)^J < \frac{K}{\pi^{In}}$$

which tells that they are strictly better off by not innovating, i.e., by choosing $\alpha_i = 0 \quad i = J + 1, \ldots, I$.

Note that for every $J = 1, \ldots, I$ we will have an equilibrium of this type.

As we noticed before the pure and the symmetric outcomes of this game are included in the set of equilibria described in the previous proposition.

**Proposition 10** No other equilibria exist.

The proof of this Proposition is given by the following three lemmas.

**Lemma 11** There are no asymmetric totally mixed strategy equilibria in this game.

**Proof.** Suppose a totally mixed strategy profile $(\alpha_1, \alpha_2, \ldots, \alpha_I)$ is an equilibrium, with $\alpha_i$s not all equal. Then every player must be indifferent, i.e.: $E[\pi^{In}] = 0$. That is, considering player $j$ for instance:

$$\frac{\pi^{In}}{\pi^{In}} \prod_{i \neq j} (1 - \alpha_i) = K \left[ 1 - \prod_{i \neq j} (1 - \alpha_i) \right]$$

which yields the following indifference condition:

$$\prod_{i \neq j} (1 - \alpha_i) = \frac{K}{\pi^{In}}.$$

The RHS is constant, whereas the LHS depends on $j$ because the $\alpha_i$s are not all equal. Hence the above equality cannot hold simultaneously for two players with different $\alpha_i$s. So for any totally mixed strategy profile, not all players can be made indifferent and the equilibrium will not survive.

**Lemma 12** No other equilibria exist with a different support other than the two point support: $\{0, \alpha\}$.  

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Proof. Any equilibria where agents can choose different probabilities: $\alpha_i \in \{0, \alpha, \alpha', \alpha'', \ldots\}$ for $i = 1, 2, \ldots, I$, will be ruled out by the same argument of the previous lemma, that is, no asymmetric totally mixed equilibria exist. This relies on the fact that the players are identical and that in order to mix you must be indifferent to the strategy profile you face. □

Lemma 13 No partially mixed equilibria exist with $\alpha_i = 1$ for some $i$.

Proof. If one player innovates for sure then all other players will strictly prefer not to innovate. So we are back to the initial pure equilibrium. □