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STRATEGIC USE OF COSTLY INNOVATION

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Purpose: The aim of this paper is to examine reasons for lagging in innovation of past technological leaders and incentives of entrants to a market to invest more despite smaller market share.
Approach: Examples of banks vs. fintechs and combustion engine carmakers vs. electric carmakers are used as motivation to construct an oligopolistic competition model that demonstrates reasons for giving up development by existing market leaders.
Findings: In the presented model, an impact of costly innovation is non-monotone and hence some incumbents have limited incentives to innovate. Those findings justify why combustion engine carmakers compete with new electric vehicle carmakers in a way less aggressive manner than implied by their market share.
Research limitations: This paper is focused on theoretical framework without extended empirical analysis of existing data. Further research should focus on confronting those findings with data on the banking or automotive sectors.
Practical implications: This paper provides theoretical foundations for analyzing markets with costly innovation and entry by new competitors. It provides a set of cases where competition has to be analyzed separately.
Originality: Existing industrial organization models do not provide economic explanation for actions of industry incumbents faced with innovating entrants that match observed actions in some industries. Such actions are mostly explained by management inaction and not rational economic choices. The presented model provides a novel way to approach this issue which does not contradict rational strategic choices of market incumbents.
Keywords: strategic innovation, competition with innovation, oligopoly.
Category of the paper: Research paper.

1. Introduction

In several industries, established firms operating for several years face competition from new entities that use technology to their advantage. Surprisingly, incumbents often delay their investments in new technologies and later face decreasing market share. Nokia decided not to push investments into large screen touch operated phones (Cord, 2014). Kodak decided not to pursue digital photography (Hess, 2014). Those decisions are often classified as management mistakes and used as examples of strategic errors of management of such companies. Using this 'missed opportunity' line of reasoning implies that large, established companies either did not have a proper understanding of their market or did not analyze strategic prospects of new technologies. The goal of this paper is to demonstrate that incumbents valuing the present stream of income and having a strong market position may decide not to invest, even faced with an aggressive entrant using technology to its advantage.

The structure of the paper is as follows. In the next section, two motivating examples are presented. The literature review on relevant oligopolistic competition models follows. Further discussion of key models of competition with investment or innovation precedes the description of the model, its assumptions and discussion of results. Summary of results and their consequences for future competition and investment strategies closes the paper.

2. Motivating examples

There are several examples of once market dominating firms which ignored some technological change which turned out to be a reason of their later demise. The question posed by this paper is whether such decisions were mistakes or in short term they were rational. Two examples motivating this research are the reaction of European banks to the introduction of PSD II regulation and the slow adoption of electric powertrains by dominating producers of combustion engine-powered cars. The case of PSD II regulation is a leading motivating example used in this research.

2.1. PSD2 directive and competition between banks and fintechs

The financial market in the countries of the European Union is regulated based on national regulations as well as harmonization of EU directives. The regulatory framework should be consistent across the whole EU. The recent financial crisis and the development of new technologies demonstrated how deeply regulations might impact markets in a way not predicted before their implementation. Therefore, all new regulations should be considered in as broad context as it is possible. We should carefully analyze how new regulations will impact strategic choices of existing entities and what strategies new entrants may use. It may be easier to analyze the impact of new regulations from the standpoint of the current market situation, considering only how incumbent companies will act, but this may lead to confusing or wrong implications of new regulations.

Two key European financial regulations, which can substantially change how financial markets operate, are directives PSD2 and MiFID2. The PSD2 directive (BearingPoint, 2016; European Parliament, 2015) regulates how to carry out payments and regulates operations of entities which may, on behalf of the clients of banks, mediate payments. The MIFID2 directive concerns the functioning of the investment market.

There is a consensus among practitioners about the considerable impact of these regulations. However, the economics literature discussion of the impact of PSD2 and MIFID2 on the markets and financial institutions is very limited. The aim of this work is to demonstrate how existing competition models may help us understand the behavior of banks after PSD2 implementation. In the model, incumbent banks have the possibility to invest in technology before competing against potential entrant – fintech company. In the equilibrium, incumbents with lower cost tend to invest more than those with higher costs. Hence, following PSD2 implementation, it is likely that banks that already have cost advantage will strengthen their position in coming years. Banks with lower costs will remain competitive against fintechs, while legacy banks will remain less competitive.

Adopted in October 2015, Payment Services Directive 2 (PSD2) is the development and modification of the PSD directive adopted in 2007. While the PSD directive focused on the harmonization of payment rules in existing electronic systems, PSD2 goes much further.

The aim of PSD2 is to enhance consumer protection, support innovation in the financial sector, and improve the security of payment services in the European Union. Within a period of two years from the adoption of the new regulation, Member States should implement the provisions of the directive to local regulations. The key issues that the revised legislation addresses are changes to the definition of a transaction and how to define it; stricter requirements for proof of identity by payment service providers (PSP); faster handling of payment service complaints; payment initiation services and account information services. From the perspective of consumer protection, key issues are requirements related to validating the customer’s identity, reducing the time to process complaints up to 15 days, limiting the liability of payment service users and requiring a free card exchange in the event of a loss.

But from the perspective of the banking market, other issues are far more important. The most important is the introduction of possibility to initiate payment by a third party and the obligation for banks to make available information about bank accounts to third parties who got the consent of banks’ customers. In the first case, the directive indicates the need to enable the customer to initiate online payments through a third party and define such entities as payment information service providers (PISP). This possibility means that an alternative to payment cards will be provided for online transactions because with the consent of the consumer PISP will be able to initiate payment directly from the bank account. In the second case, the directive introduces the concept of the account information service provider (AISP). With the consent of clients, AISP should have access to information about the consumers’ bank accounts. This information should include not only the basic info but also the history of the account and its status.

In practice, introducing the possibility to initiate payments and provision of access to account information combined with the tightening of security requirements puts an enormous burden of adapting to new regulations on banks and existing payment institutions. Banks must provide the possibility to obtain account information directly from computer banking systems and to initiate certain operations in these systems. This means opening to the external users of systems that now communicate only with banks' own applications provided to their customers. This creates plenty of opportunities for potential illegal activity. Preventing such acts will be the responsibility of banks.

New regulations can open new opportunities to entities broadly identified as fintech companies. In most cases, fintechs are entities that use new technologies to offer products that are either complementary or competitive to related products offered by regulated financial institutions. Typically, such products do not require fintechs to act as regulated entities. The PSD2 directive will enable those companies to offer services related to banking products. An example of such a service can be software that allows access to bank accounts in multiple banks in different countries of the European Union within a single interface. In this case, the provider of the software offers a service to access several accounts and several other services competitive with banks' products. For banks, this scenario implies the risk of loss of continuous and direct contact with their clients.

From a consumer perspective, new regulations can mean easier access to services provided by existing institutions, as well as the possibility of using new innovative services offered in parallel.

2.2. Competition of combustion engine carmakers and electric vehicles producers

Traditional carmakers knew about the possibility of producing electric vehicles for a long time. Early attempts to produce electric cars can be dated as early as 19th century (Patel et al., 2020). Despite this, Tesla gained substantial handicap due to the inaction of other carmakers. Similarly to the previous example, one can argue that the cost of investment in technology change was so high for traditional carmakers that they allowed Tesla and other companies to gain ground on the market.

In such setting, car is a homogeneous good and potential buyers consider purchase based on a total cost of ownership which may be considered lower for electric cars. Therefore, entrants, such as Tesla, can gain substantial market share due to the lack of initiative of traditional carmakers, which are reluctant to invest in new electric powertrains and design of electric vehicles.

3. Literature review

Literature related to this topic can be divided into three main areas: studies focusing on practical issues related to regulatory changes arising, studies on competition between banks, and the texts on the modeling of imperfect competition and strategic innovation.

The literature on regulatory issues is mainly the European Union's documentation (European Parliament, 2015) and comments on the existing regulations indicating several possible scenarios for financial institutions to achieve compliance (BearingPoint, 2016; McKinsey&Co et al., 2018; Cortet et al., 2016). The focus is on how the situation of existing institutions will change with the implementation of new regulation. Some analysts also try to foresee how strategies of financial institutions will change due to changes in regulatory regime (Evry, 2016). Such analysis is based on potential scenarios of market development, and hence can provide us with insight into how existing financial institutions may think about the strategic impact of new regulations.

From the perspective of this paper, much more relevant is the literature on modelling imperfect competition in a broader sense. The key ingredient in presented considerations is how investments impact competition between incumbents and entrants. Interesting perspective provided classic articles on oligopoly and entry barriers – (Milgrom, Roberts, 1982; Dixit, 1980; Salop, 1979; Kreps, Scheinkman, 1983; Schmalensee, 1981). A broader discussion of (Dixit, 1980) and (Kreps, Scheinkman, 1983) is provided later in this paper.

In the case of modelling competition between banks, the existing literature focuses on the challenges posed by the recent financial crisis and liquidity and risk-related issues – (Goddard, Wilson, 2009; Fernandez et al., 2016; Schaeck, Cihak, 2012). Those papers discuss how to model competition between banks looking closely into limitations of banking activity. The key relationship in this part of the literature connects capital and willingness to take the risk. In this setting, competition between financial institutions looks more like competition for resources or providing investors with a preferred risk profile. This approach may not be helpful when we need into account fintechs as bank competitors because risk profile, sources of funding and regulations may be substantially different for those companies.

4. Competition modelling

What distinguishes banks from other financial institutions, such as insurance companies or investment fund companies, is the frequency of contacts with a customer. More importantly, this is usually a client-initiated contact. This allows banks to know their customers better than other financial institutions and offer them new products if they meet the capital requirements and the cost of providing the product is sufficiently low.

The purpose of PSD2 was to create new opportunities for innovative companies. However, AISP services may be interpreted as a possibility to distribute financial products to banks' clients without the necessity to build the costly banking infrastructure. Hence, banks will have to face the possibility of entry of new players that have considerably lower costs.

One can look at the cost of running banking operations from the point of view of two sources of costs. First, banks must acquire enough capital and simultaneously invest in technology to provide banking products efficiently. Second, banks will compete for customers. It is safe to assume that in such settings most of the banking products will be homogenous and therefore banks will compete in prices. This approach may have important consequence for equilibrium in such model. Simple competition in prices (i.e., Bertrand model) in equilibrium leads to cutting prices down to marginal costs level and erasing all economic profits of competing entities (Tirole, 1988). Because banks first acquire capital and invest in technology, we can use insight from other research to simplify this setting without loss of generality.

It is worth noting that looking at competition from the standpoint of setting prices of homogeneous product disregards all considerations about the product differentiation and impact of capital requirements in some industries.

4.1. Kreps-Scheinkman model

Assuming competition in prices while selling homogenous goods leads to an equilibrium where firms cut down prices to the marginal cost level. This prediction is problematic for a variety of homogenous goods. When price competition is preceded by setting up production capacity, the equilibrium no longer falls into the price cutting trap. Kreps & Scheinkman (1983) showed that costly construction of production capacity followed by price competition yields Cournot outcome in the whole game. Hence, despite the price competition and homogeneity of companies' product, they can achieve positive economic profits – higher than profits in the case of perfect competition. Similar results are also presented by (Moreno, Ubeda, 2006).

We can interpret this result in several ways. First, the margin realized by banks in the distribution process is equal to the margin realized in an oligopoly with price competition. In the price competition model, competitors lower the price to an equivalent level of perfect competition. This means that it is not possible to increase the competitiveness of the market for the distribution of banking products. Second, equilibrium in Kreps-Scheinkman model is subgame perfect. Therefore, decisions on the acquisition of capital by banks (i.e., construction of production capacity) will remain unchanged in equilibrium even if the distribution decisions are taken independently of decisions concerning the acquisition of capital. In this case, entry of an additional entity will change the outcome through supplying additional capacity to the market.

Kreps and Scheinkman result allows for simplification of earlier considerations about the competition in the banking services market. A model, where banks acquire capital and invest in technology to compete in prices, can be replaced by a model where banks invest in technology to lower their marginal costs in the competition phase and later compete in quantities (i.e., Cournot model). This setting allows for the easier introduction of the entrant in the model.

4.2. Competition preceded by innovation – Dixit model

The complementary approach was adopted by Dixit in his paper on strategic innovation (Dixit, 1980). The competition is a three-step process – the incumbent chooses how much to invest in minimal production capacity, then the potential entrant decides whether to enter the market and, in the case of entry, companies compete in quantities. In the equilibrium, the company which decides to invest in a production capacity can discourage its competitor from entering a new market by building large production capacities and thus reducing potential profits of the entrant.

In the context of our discussion, the equilibrium in Dixit model can be interpreted as a scenario where banks invest before implementation of PSD2 to discourage potential entrants. This is a reasonable interpretation of Dixit results because investors in all fintech companies pay close attention to the number of consumers acquired by these companies. Further financing depends on the pace of development of these companies.

An interesting aspect of both presented models of competition with prior investment is information carried by earlier investments. In both cases, a firm investing in periods preceding the competition on the market, deliberately influences payoffs in subsequent periods. Investment is a costly signal of a commitment to defend the market position of the incumbent.

Unaddressed remains merging investment in technology followed by the potential entry. The simplest model to address this topic would require costly investment in technology followed by competition. Gaining technological advantage must be sufficiently costly to avoid cases where the marginal cost of improving technology is always lower than the marginal benefit.

5. Model

Two incumbent firms denoted by A and B compete in quantities with one entrant denoted by F. Initial marginal costs are denoted by $c_j \in [0, M]$ for $l \in \{A, B, F\}$. Inverse demand function for their products is $P(Q) = M - Q$.

The game between incumbents and entrant is split into three phases. First, incumbents simultaneously decide how much to invest in technology. Afterward, an entrant company enters the market, and finally all three entities compete in quantities supplied to the market. See figure (Figure 1). Technology investment by each incumbent is observed by the entrant and other incumbents. In such a game, a new company always enters the market. A brief discussion of costly entry is presented later in this section.

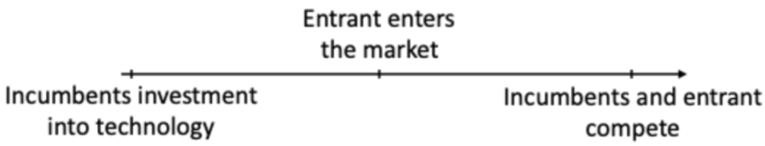

Figure 1. Sequence of actions in the model.

Incumbents capacities are given exogenously. As in (Kreps, Scheinkman, 1983) competition in quantities can be interpreted as the outcome of a capacity building stage followed by a price competition stage and therefore the additional complexity of capacity construction is removed from the model.

Through initial investments in technology, incumbents can lower their marginal costs. Investments' cost is a convex-increasing function such that $t(0) = 0$ and $t'(i) > 0$, $t''(i) > 0$ for $i > 0$. That is, small advances in technology are cheaper than big leaps. Suppose

$$t(i) = Ti^2 \tag{1}$$

for $T > 1$ and $i > 0$ where i denotes investment into incumbents' technology. Therefore, if an incumbent $l \in \{A, B\}$ invests $c(i_l)$ into improvement of its technology, the marginal constant cost is equal to $c_l - i_l$.

Competition between incumbents and entrant can be modelled as a dynamic game between them, where incumbents first choose investment levels and then quantities. The entrant chooses only quantities. Joint supply and inverse demand function determine market price while payoffs of incumbents are equal to profits

$$\Pi_l = (M - q_A - q_B - q_F)q_l - (c_l - i_l)q_l - t(i_l) \text{ for } l \in \{A, B\} \tag{2}$$

and payoff of entrant is equal to

$$\Pi_F = (M - q_A - q_B - q_F)q_F - c_F q_F, \tag{3}$$

where q_l denotes quantity supplied to the market.

5.1. Assumptions

Description of the model contains several assumptions. The assumption about the form of competition on the market that is competing in quantities instead of more intuitive competition in prices, relates to Kreps and Scheinkman model, where prior investment in production capacity makes those two forms of competition give the same Cournot outcome. That is why in the model there is no reference to the formation of incumbents' capacity.

The more important assumption is how incumbents invest in their technologies. Strictly increasing the convex cost of investment is consistent with how difficult significant changes in the legacy infrastructure of incumbents are. Small changes and adjustments are usually easy, despite being costly. Large adjustment leading to relevant cost reduction is costly and risky because they usually involve replacing a substantial part of infrastructure. For the sake of an argument, a specific form of the cost function is used in the model. T parameter allows for changing how steeply cost of new technology grows. It is possible to get most of the presented later results with more general cost functions, but presentation is less convenient analytically. Furthermore, notice that there is a need to control for boundary conditions while looking for optimal investment level. Optimal investments may lead to costs going below zero.

Entry in the basic model is costless. This assumption simplifies the analysis but also is consistent with the behavior of new technology companies. Pressure from investors and willingness to test new solutions on the financial markets often make new companies enter already crowded markets to test their technology.

5.2. Solution concept

The most applicable solution concept for dynamic games as the one presented earlier is subgame perfect Nash equilibrium. Backward induction, in this case, implies that we have to solve for the equilibrium in the quantity competition stage with investment levels given. The results for the final stage of the game can be used to determine optimal investment levels.

Using backward induction to find subgame perfect Nash equilibrium may give only one of the potential solutions. With quantity competition in the last stage, that cannot be the case. To account for similar scenarios, it is necessary to analyze the possibility of costly entry into the market. That is how entry deterrence is modelled in Dixit model.

6. Results and discussion

6.1. Equilibrium without entrant

Given profit functions of incumbents

$$\Pi_l = (M - q_A - q_B)q_l - (c_l - i_l)q_l - t(i_l) \text{ for } l \in \{A, B\} \tag{4}$$

the first order conditions in the last stage game equilibrium are

$$\frac{\partial \Pi_l}{\partial q_l} = 0 \text{ for all } l. \tag{5}$$

Second order conditions for a local maximum are trivially satisfied and therefore, using the convention of denoting by $-l$ the other incumbent and solving for q_l, we have

$$q_l = \frac{(c_{-l} - i_{-l}) - 2(c_l - i_l) + M}{3}. \tag{6}$$

It implies that equilibrium profits of each incumbent are equal to

$$\Pi_l = \frac{(2(c_l - i_l) - (c_{-l} - i_{-l}) - M)^2}{9}. \tag{7}$$

First order conditions in the first stage are

$$\frac{\partial \Pi_l}{\partial i_l} = 0 \text{ for all } l. \tag{8}$$

Second order condition for local maximum is satisfied. Therefore, substituting $t(i) = Ti^2$, in interior solution where $0 \leq i_l \leq c_l$ we get equilibrium investment levels of investments

$$i_l = \frac{2(3Tc_{-l} - 6Tc_l + 2c_l + 3MT - 2M)}{(3T-2)(9T-2)} \tag{9}$$

and equilibrium profits equal to

$$\Pi_l = \frac{9T^2(3Tc_{-l} - 6Tc_l + 2c_l + 3MT - 2M)^2}{(3T-2)^2(9T-2)^2} \text{ for } 0 \leq i_l \leq c_l. \tag{10}$$

Observe that condition $0 \leq i_l \leq c_l$ needs to be satisfied. Because $c_l \in [0, M]$ boundary solutions are either 0 or c_l. Solving for boundary conditions, we get

$$I_l^L = \frac{2(3Tc_{-l} + 3MT - 2M)}{3T(9T-4)} \text{ and } I_l^H = \frac{3Tc_{-l} + 3MT - 2M}{2(3T-1)}. \tag{11}$$

For $0 \leq c_l \leq I_l^L$ the company will invest as much as c_l in equilibrium. For $I_l^H \leq c_l \leq M$ company will invest nothing in equilibrium. Therefore, we can split possible values of c_l into three intervals, presented in figure (Figure 2). Notice that

$$\frac{\partial I_l^L}{\partial c_{-l}} > 0 \text{ and } \frac{\partial I_l^H}{\partial c_{-l}} > 0. \tag{12}$$

and hence the interval of where interior solutions are possible moves closer to M as c_{-l} increases.

Figure 2. Split of possible values of c_l into intervals.

We can also notice that

$$\frac{\partial I_l^L}{\partial T} < 0 \text{ and } \frac{\partial I_l^H}{\partial T} > 0. \tag{13}$$

where the first inequality holds for sufficiently large c_{-l}.

With this split of potential investment levels, one can notice that in equilibrium, investment levels are non-monotone. Given an analytical representation of equilibrium investment levels:

$$i_l = \begin{cases} c_l & \text{for } 0 \leq c_l \leq I_l^L, \\ \dfrac{2(3Tc_{-l} - 6Tc_l + 2c_l + 3MT - 2M)}{(3T-2)(9T-2)} & \text{in interior solution, i.e. } c_l \in [I_l^L, I_l^H], \\ 0 & \text{for } I_l^H \leq c_l \leq M. \end{cases} \tag{14}$$

Lower and upper bounds of the region, where investments have an interior solution, depending on the cost's levels of the other company. Moreover, for the assumed shape of the technology investment function, the boundaries of an interior solutions region are linear functions of c_{-l}. Graphical representation of the region where exist interior solutions for optimal investment level of one firm is depicted by gray area in figure (Figure 3a). In the region on the left side, firm investment results in zero marginal cost in the competition phase. In the region on the right side, a firm does not invest at all.

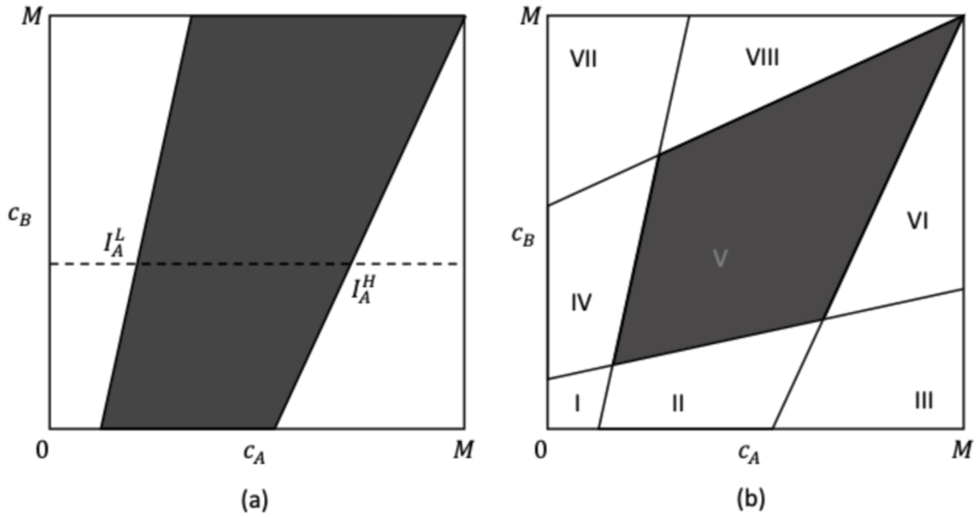

Figure 3. Types of equilibria with no entrant.

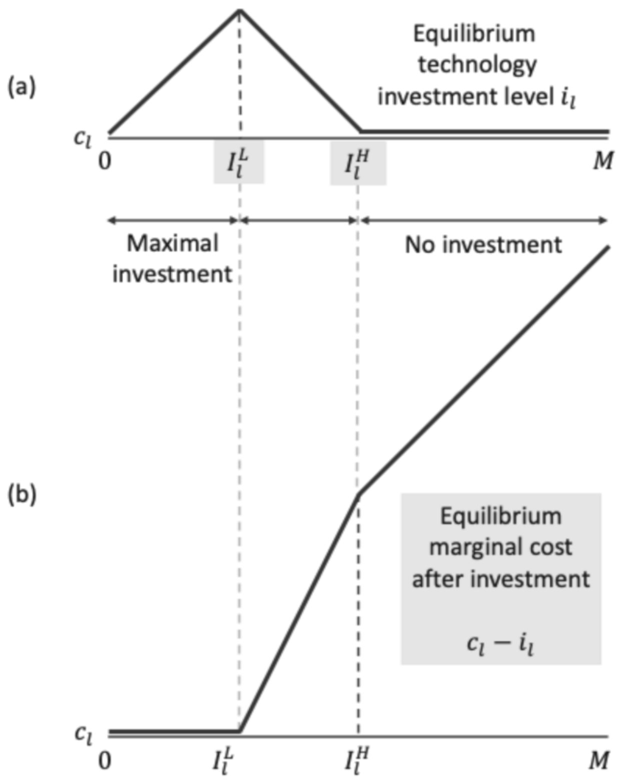

Figure 4. Equilibrium technology investments and resulting costs with no entrant.

Putting together this result for both firms, we get eight regions presented in figure (Figure 3b). Only in the region marked V both firms' investment levels are in $(0, c_l)$. In other regions, investment levels can be classified in the way described in the table (**Błąd! Nie można odnaleźć źródła odwołania.**

Table 1.
Equilibrium strategies of incumbents ordered by sets depicted in figure (Figure 3)

VII Incumbent A invests to reduce marginal cost to 0, while incumbent B does not invest.	VIII Investment of incumbent A does not reduce its cost to 0 and Incumbent B does not invest.	
IV Only A will invest to reduce marginal cost to 0. Investment of incumbent B does not reduce its cost to 0.	V Both incumbents invest and their resulting marginal cost is larger than 0.	VI Investment of incumbent B does not reduce its cost to 0 and incumbent A does not invest.
I Both companies invest to reduce marginal cost to 0.	II Only B will invest to reduce marginal cost to 0. Investment of incumbent A does not reduce its cost to 0.	III Incumbent B invests to reduce marginal cost to 0, while incumbent A does not invest.

Source: Own elaboration.

All considerations above rely on the shape of optimal technology investment in equilibrium and resulting cost levels, which are presented in figure (Figure 3).

Notice that in the equilibrium, incumbents with lower marginal costs invest more than incumbents with higher initial costs. The source of this surprising result lies in the difference between the marginal cost and benefit of technology investment. On one hand, investing in technology increases profitability, but the cost of investment is regulated by parameter T or more generally steepness of function $t(\cdot)$. By choosing the quadratic technology function, we matched it with the profit function. This simplifies analysis of the model but generally the same results can be obtained with sufficiently quickly increasing convex functions.

As T increases cost of implementing a new technology changes. In particular, it becomes more costly to achieve technology advance as T grows. Notice also that we can rewrite the equations for I_l^L and I_l^H in the following way:

$$I_l^L = \frac{2(3Tc_{-l} + 3MT - 2M)}{3T(9T-4)} = \underbrace{\frac{6T}{3T(9T-4)}}_{\substack{\partial\cdot/\partial T<0 \\ T>1}} c_{-l} + \underbrace{\frac{6MT-4M}{3T(9T-4)}}_{\substack{\partial\cdot/\partial T<0 \\ T>1.052}} \tag{15}$$

and

$$I_l^H = \frac{3Tc_{-l} + 3MT - 2M}{2(3T-1)} = \underbrace{\frac{3T}{2(3T-1)}}_{\partial\cdot/\partial T<0} c_{-l} + \underbrace{\frac{3MT-2M}{2(3T-1)}}_{\partial\cdot/\partial T>0}. \tag{16}$$

That implies that as T goes up the boundaries of the gray region in figure (Figure 3a) become steeper and move further away from each other.

6.2. Equilibrium with entrant

Given profit functions of incumbents $l \in \{A, B\}$ and entrant F

$$\Pi_l = (M - q_A - q_B - q_F)q_l - (c_l - i_l)q_l - t(i_l) \text{ for } l \in \{A, B\} \tag{17}$$

$$\Pi_F = (M - q_A - q_B - q_F)q_l - c_F q_F \tag{18}$$

the first order conditions in the last stage game equilibrium are

$$\frac{\partial \Pi_j}{\partial q_j} = 0 \text{ for all } j \in \{A, B, F\}. \tag{19}$$

Following the same reasoning as in the previous section, those first order conditions result in:

$$q_l = \frac{c_F + (c_{-l} - i_{-l}) - 3(c_l - i_l) + M}{4} \text{ for } l \in \{A, B\}, \tag{20}$$

$$q_F = \frac{(c_A - i_A) + (c_B - i_B) - 3c_F + M}{4}. \tag{21}$$

The resulting equilibrium interior investment levels are

$$i_l = \begin{cases} c_l \text{ for } c_l < I_l^L \\ \frac{3}{2}\left(\frac{c_F - 2c_l + M}{8T - 3} + \frac{4T(c_{-l} - c_l)}{(4T - 3)(8T - 3)}\right) \text{ for } c_l \in [I_l^L, I_l^H] \\ 0 \text{ for } c_l < I_l^H \end{cases} \tag{22}$$

for

$$I_l^L = \frac{3}{4T}\frac{(c_F + M)(4T - 3) + 4Tc_{-l}}{16T - 9} \text{ and } I_l^H = \frac{(c_F + M)(4T - 3) + 4Tc_{-l}}{6(2T - 1)}. \tag{23}$$

Notice that the existence of an entrant changes an equilibrium structure. It is possible that in the equilibrium no incumbent invests in new technology. Hence, there exists a new scenario where no entrant decides to invest in a new technology. Entrant that certainly enters the market leaves less space on the market for incumbent companies. Therefore, sometimes additional spending on a new technology would not improve the strategic position of incumbents. A new split of equilibrium actions of incumbents is presented in figure (Figure 5).

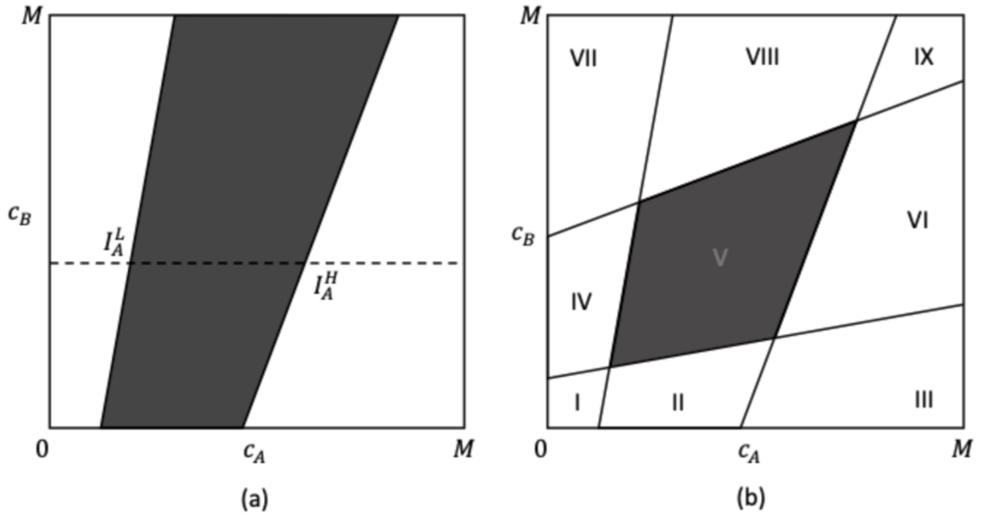

Figure 5. Types of equilibria with entrant.

Depending on each incumbent, there exists a set of interior solutions where companies lower their initial costs to some non-zero level. The shape of i_l remains identical to the one presented in figure (Figure 4).

6.3. Comparative statics

Basic comparative statics of equilibrium investment levels for $c_l \in [I_l^L, I_l^H]$ are straightforward

$$\frac{\partial i_l}{\partial c_l} < 0, \frac{\partial i_l}{\partial c_{-l}} > 0, \text{ and } \frac{\partial i_l}{\partial c_F} > 0. \tag{24}$$

The other key comparative statics in the presented model is how investment levels of incumbents change in equilibrium depending on the cost structure of the entrant. It is straightforward to show that

$$\frac{\partial I_l^L}{\partial c_F} = \frac{3}{4T}\frac{4T-3}{16T-9} > 0 \text{ and } \frac{\partial I_l^H}{\partial c_F} = \frac{4T-3}{6(2T-1)} > 0. \tag{25}$$

Moreover, we have also $\partial I_l^H/\partial c_F > \partial I_l^L/\partial c_F$. That implies that when an entrant has higher initial costs compared to incumbents, the size of the region where companies invest in cost reduction is bigger. Entrant with relatively low initial costs will not be met with strong initial investments by incumbents.

This observation is interesting because it explains why entrants in areas where entry does not require substantial initial costs meet no competition from existing incumbents. The costs of investments in existing infrastructure do not justify spending. Incumbents prefer to hold on to the market share they have without overspending. This is obviously a consequence of the assumed investment cost function. We can expect that a market will behave similarly in equilibrium if we have convex and sufficiently quickly increasing costs. The convexity assumption in this case is in line with what we observe in spending of corporations on their IT infrastructure (Christensen, 1997).

6.4. Identical incumbents

So far, the analysis focused on the case of incumbents that have different marginal costs and, therefore, in an equilibrium they choose different investment levels. For the sake of simplicity, prior to analyzing costly entry, it is worthwhile to turn to the case of identical incumbents. The existence of identical incumbents in the analyzed model implies $c_A = c_B$ and the existence of symmetric equilibrium where both incumbents make the same investments into technological improvement of their marginal cost.

Notice that in the model without entrant, symmetric incumbents always invest in technology improvement. Area V in Figure 3.b denotes equilibria investment levels that reduce initial marginal cost. Area I in Figure 3.b denotes equilibria where investments of both competitors reduce initial costs down to zero. It is straightforward to derive the levels of I^L and I^H in case of no entrant: $[2M/9T, M]$. The steps are as follows: (1) find equilibrium quantities, given initial cost and investment; (2) find equilibrium investments using first order conditions on total profits of both incumbents; (3) verify for what range of investments you have them in $[0, c]$ where c denotes initial marginal costs. It is worth noting that in the symmetric case you have identical initial marginal cost and hence to find I^L and I^H it is not enough to plug c to formulas for asymmetric case – you must solve equations for I^L and I^H under condition that $c_A = c_B$. When incumbent's marginal costs fall into this region both firms invest into lowering their marginal cost in the investment phase but do not manage to lower it down to zero in equilibrium.

One can repeat the same line of reasoning in the case of an entrant with marginal cost c_F. In such case the interval where incumbents less than their initial marginal cost but more than zero is $[3(c_F + M)/16T, (c_F + M)/2]$. See figure (Figure 6).

Surprisingly, it implies that incumbents always invest more only when entrant has sufficiently small costs. To prove it is enough to consider two cases $c_F \in [0, 5/27M]$ and $c_F \in (5/27M, M]$. Notice that in the first case I^L on the lower left graph in figure (Figure 6) will be larger than I^L on the lower right graph in Figure 6 and therefore, all values of i_l will be larger in the case of no entrant.

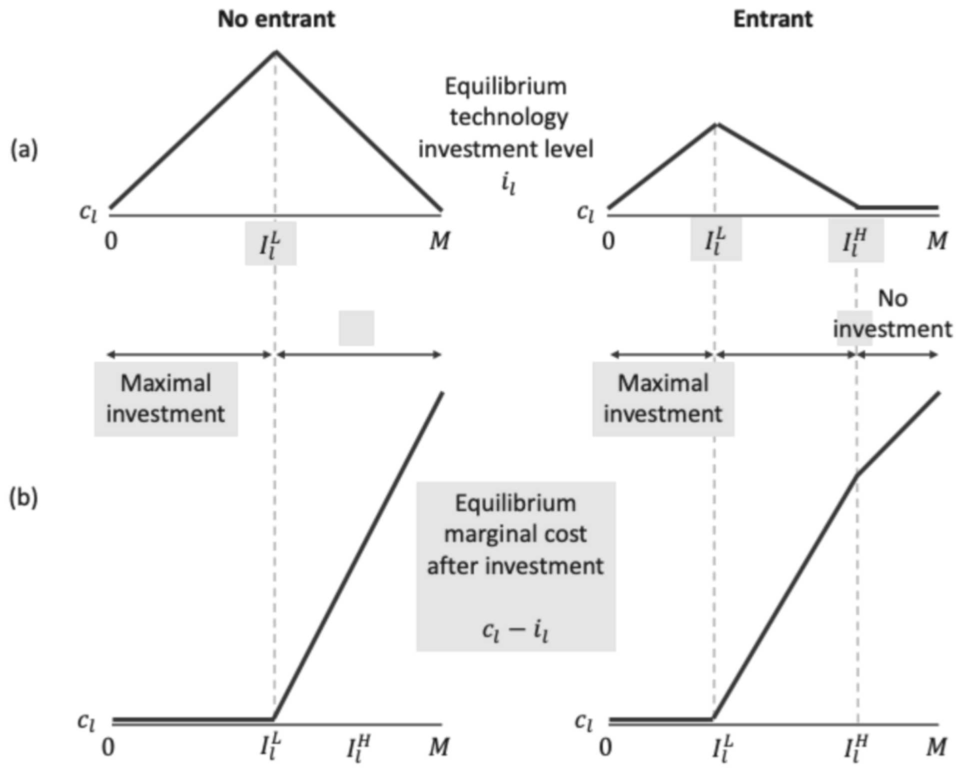

Figure 6. Equilibrium investment levels and resulting costs in the case of identical incumbents.

6.5. Costly entry with identical incumbents

In his paper, Dixit demonstrated that prior investments my deter entrants. The key for such a result is the possibility to commit. If the incumbent on the market cannot commit to fighting the entrant, then in most cases it will accommodate entry as more profitable than engaging in strong competition that will hurt all companies present on the market. On the other hand, when incumbent can commit to being tough in case of entry, it is possible to deter entry whatsoever.

So far, entrant in the model only made choice during the competition phase. Suppose the sequence of moves allows for an entrant to decide whether to enter the market. The sequence of actions in this case is presented in figure (Figure 7). Obviously, in the absence of other costs, in the framework presented in the previous section, the entrant would always enter. Thus, there is an additional cost that needs to be added. Hence, a rational entrant will decide to enter the market if and only if its profit will be higher than zero.

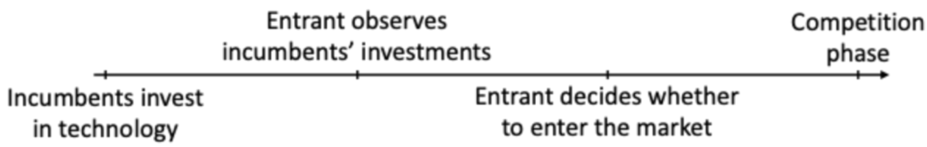

Figure 7. Sequence of decisions in case when an entrant can decide whether to enter the market.

Intuitively, the larger cost of entry, the smaller will be region IX in figure (Figure 5). Without developing an analytical solution to the equilibrium problem, we can conclude that results will have the same structure as before. The additional cost of entry will deter the entrant in some cases. An entrant with a sufficiently high cost will not enter the market.

7. Conclusions

The model presented in this paper provides insight why it is possible that rational incumbents do not innovate enough to keep up with an innovative entrant to the market. Despite the simplicity of the model, its subgame perfect equilibrium turns out to be quite complex. The main result is that smaller or less advanced incumbents my benefit more from innovating. Therefore, they are able to keep up with innovative entrants. The main limitation of the presented approach is the complexity of equilibrium. Considering a larger number of incumbents and a more general approach to cost of innovation may lead to the necessity of numerical modelling instead of clean analytical solutions.

There are three clear extensions of the presented model that are worth investigating. The first extension is using other technology cost functions to study the impact of assumptions of the presented model. Some results we can expect from making the technology cost function steeper are the same comparative statics we got with changes in T. More complex technology cost functions may considerably impact analytical part of the model and make solutions to some problems impossible to represent in a meaningful closed form.

Another extension is allowing for several periods of innovation. In such a model it is possible to observe how technology spending evolves. In multi-period setting, it should also be possible to verify how companies minimize total cost of innovation and how the trade-off between current profits and future innovation benefits work.

The third set of extensions is to add randomness to effects of innovation to see how randomness impacts earlier results.

The PSD2 directive substantially changes the way money on bank accounts may be used in the future. At the same time, most of the consumers are unaware of the changes that are coming to the financial sector. Some banks invest in technologies to safeguard themselves from regulatory regime changes.

Consulting companies published several reports on the possible outcome of PSD2 implementation (McKinsey&Co et al., 2018). The most far-reaching scenario, which will be the very rapid expansion of fintech, will prevent banks from distributing large-scale banking products themselves. A prerequisite for this market development scenario is that banks will make entry easy. This implies making interfaces that connect banking systems with fintech IT solutions widely and easily available. This implies substantial investments of banks that will not improve their competitive position. Following the presented model, we can see that inside every bank, investment money will be split between funds for fulfilling regulatory obligations and investing into own bank's technology to effectively compete with fintech entrants.

An alternative scenario presented by the consulting firms is the situation where banks will fulfil regulatory obligations but do nothing to encourage fintech to use their systems and possibly limit access to their systems. The PSD2 introduces the obligation to allow access to the systems but at the same time imposes security and confidentiality constraints on banks. This gives them the ability to restrict access by creating non-friendly interfaces or extremely advanced security requirements. In this case, banks will take a strategic decision on the availability of information systems, guided by the possible scale of action and the efficiency. In this case, additional spending on information technology may be limited if it will not hurt banks' market position.

Those two scenarios essentially imply that smaller banks will have to compete with fintechs head-to-head to stay profitable. This finding is consistent with the presented model. Some institutions will not participate in the technological race because it would be far too costly. Others must match fintechs in their agility and willingness to innovate.

We do not yet know what the outcome will be stemming from the PSD2. However, today we can already observe actions of banks. It is particularly interesting looking from the point of past investments in technology. Most of the banks in developed markets invested in technology before the end of the last century. After implementing big core banking systems, new features were built on top of existing infrastructure. On the other hand, several banks in less developed markets, like those of CEE, invested in new core banking systems several years later. That gives those institutions instant cost advantage and the possibility to easily add new technologies to their existing systems. This path is clearly visible in payment technologies used across Europe. It is far easier to use advanced payment methods in CEE countries. The outcome of PSD2 is yet to be seen, but we can see that not all banks will use the same strategic options competing with new entrants to the financial services market.

Directives PSD2 and MiFID2 will substantially change the foundations of the financial markets in the coming years. However, to understand the possible impact of the new regulations, you need to go beyond typical models of banking services market. Better tools to understand the possible implications of upcoming changes are the models of imperfect competition from industrial organization literature. It is crucial for this approach to observe the decisions of market participants from the perspective of their strategic behavior.

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