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Liquidation value of productive assets and product differentiation*

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Abstract

This study examines the choice of individual companies to adapt productive assets (PAs) to specific production. To soften competition, companies may modify their assets to increase product differentiation. However, this decision alters the liquidation value of the assets in the case of bankruptcy for the presence of redeployment costs (larger for specialized assets) faced by potential buyers. We determine the equilibrium level of specialization of PAs, pointing to a novel trade-off between product market differentiation and the resale value of PAs. We find that industry entry and redeployment costs, together with the number of potential bidders in the second-hand market of PAs are important factors in explaining the degree of product differentiation.

Keywords: Asset Specificity; Horizontal Differentiation; Bankruptcy; Second-hand market of productive assets.

JEL Codes: G32, G33, L11

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1 Introduction

The decision to invest in specialization of the real assets used in production is affected not only by the value of the assets when the company is healthy, but also by the liquidation value when they are sold following a bankruptcy. When the company is healthy, investing in asset specialization creates a competitive advantage for the firm (e.g., softening product market competition). However, when the company goes bankrupt, the resale value of PAs depends on how the assets designed to suit a specific production may be of use to other potential users. Specialization of productive assets (PAs) is an important factor shaping a firm's competitive environment; it may change the physical characteristics of the final product and, thus, the degree of substitution between products. One notable example is offered by the US railroad industry in the past century (see Benmelech, 2009). The distance between two tracks (i.e., gauge) across the United States was set at different lengths for historical reasons. Railroad companies had to adapt their rolling stocks (locomotives, passenger coaches, etc.) to a particular gauge. Competition among companies was naturally softened since it was impossible to use the same rolling stock in a state where the measure of the gauge was different.

However, the liquidation value of specialized PAs may be affected by the presence of redeployment costs. In the railroad example, when a company was liquidated due to bankruptcy, it had to sell its rolling stocks on the secondary market. The value of the locomotives was lower if the train was not ready to travel on tracks with a different gauge. The wheels of the rolling stock had to be adapted to a specific gauge to travel in a different state. Buyers in the secondary market incurred redeployment costs to be able to reuse the acquired locomotives in a different state than that of the seller.

Another example is the car industry. Since the 1970s, this industry has been characterized by specific investments in assets (Dyer, 1996) and highly differentiated products (Goldberg, 1995). Cars are assembled products, and each specific investment that can be made on the production and assembling process of the different components (engines, wheels, air conditioning system, etc.) can change the final characteristics of the vehicle sold in the market. To enhance the quality of the matching between the different inputs to be assembled, the equipment (i.e., PAs) to produce each component must be adapted through specific investments that cannot be recovered if the two companies involved in the transaction of the component fail.

In summary, a company may adapt its PAs to a specific production for historical reasons, as in the case of the US railroad industry or on purpose, as in the case of the car industry, and this brings differentiation in the quality of its products with respect to those of the rivals. Investing in asset specificity enhances product differentiation and softens product market competition but decreases the possibility that a specific PA can be redeployed by alternative users without sacrificing its value (Williamson, 1991). This is relevant when bankruptcy is possible since the liquidation value of an asset in the secondary market is affected by the costs associated with its redeployment by the potential buyer. In this case, the degree of asset specificity is the main determinant of the resale value.

This study investigates the link between the choice of specialization of PAs and product differentiation when companies might go bankrupt. We develop a theoretical model in which two firms compete *á la* Cournot. Each firm faces an indirect demand function that depends on the choice of PAs specificity. The greater the degree of specificity chosen by the two firms, the greater the differentiation in the product market. Then, we add a positive idiosyncratic probability of failure. In the case of failure, the PAs of the failed company are sold in the secondary market, which is a first-price auction in which healthy incumbents and outsiders (new firms willing to enter the industry) may participate. The degree of liquidity in the secondary market is affected by the number of outsiders willing to acquire PAs. While healthy incumbents face redeployment costs when acquiring PAs, outsiders face only an entry cost. The balance between entry and redeployment costs determines who acquires the PAs and thus their resale values. Our model provides the determinants of the resale value of PAs. A lower expected revenue from liquidation affects the ex-ante investment in asset specificity by incumbents in the first place and this leads to a lower level of product differentiation. Lastly, since the expected consumer surplus is increasing in the level of product differentiation, the equilibrium level of asset specificity chosen by incumbents at equilibrium is always sub-optimal. We point to the absence of a liquid second-hand market of PAs as a limit to reach the first best for consumers.

This work adds a novel contribution to the literature by linking the ex-ante choice of asset specificity to the liquidation value of PAs. In this way, it is possible to relate the choice of specialization of PAs to the product market environment in which firms compete: First, we focus on the choice of asset specificity on product market competition, and then on the effect of product market competition on firms' ex-ante investment in asset specificity.

The rest of the paper is organized as follows: in section 2 we review the relevant literature. Section 3 describes the setup, i.e. the product market structure and the secondary market for productive assets; in section 4.3 we analyze the ex-ante choice of asset specificity; after a discussion of the results we relax some assumptions of the model in section 6. In section 5 we derive the optimal level of asset specificity from the social welfare point of view; section 7 concludes the paper. All proofs are in Appendix.

2 Related literature

Our study is based on the literature on productive asset specificity and its role in influencing and shaping the competitive environment in which firms interact. Asset specificity refers to the ability to redeploy an asset with the least sacrifice in terms of productivity (Williamson, 1988, 1991). Our starting point is the classical trade-off concerning asset specificity; highly specialized assets are valuable from the incumbents' viewpoint but have a low liquidation value because their redeployability is low. Therefore, the liquidation prices of specialized PAs are often below their fair value in their best alternative use (Shleifer and Vishny, 1992).

The liquidation value of a PA is determined in the secondary market, in which the degree of specificity and the number of potential buyers affect its final price. A higher degree of asset specificity implies a lower liquidation value, as potential buyers face costs when redeploying the asset. Moreover, highly specific assets will have fewer potential buyers in the secondary market (Shleifer and Vishny, 1992; Benmelech and Bergman, 2008, 2011; Kim and Kung, 2017). Kim and Kung (2017) demonstrate that incumbents active in industries with more redeployable assets experience higher recovery rates and are more active in secondary markets and asset sales.

In general, when a firm is in liquidation, incumbents in the same industry have the advantage in bidding for the PAs on sale (Shleifer and Vishny, 1992). However, there may be outsiders who are willing to enter the market by acquiring these PAs (e.g. see Louri, 2001; Lee and Lieberman, 2010; Cerasi et al., 2017 and 2019). Therefore, asset specificity plays a key role for incumbents also through the secondary market (Boccaletti, 2020). In our study, when a firm chooses a degree of asset specificity, it affects the outcome of the secondary market by facilitating or deterring entry. Our study is also close to the literature on investment and entry deterrence, in which the commitment to a specific level of investment allows incumbent firms to alter the post-entry payoff to the disadvantage of potential entrants (e.g., see Dixit, 1980).

The role of asset specialization has been extensively analyzed in the literature on the boundaries of the firm and, more specifically, on vertical integration (e.g., Klein et al., 1978 ; Riordan and Williamson, 1985; Joskow, 1988; Whyte, 1994). More recently, Erkal (2007) links asset specificity to product differentiation but within vertical relationships; in their case, suppliers may produce specialized inputs for downstream firms, which may demand specific inputs to increase product differentiation. In our study, although asset specificity is a way to boost product differentiation, it is analyzed in relation to the secondary market without any contractual aspect in the supply chain. Another body of literature focuses on the relationship between asset-specific investments and firms' financing conditions. While most of this literature takes the degree of asset specificity as given, Marquez and Yavuz (2013) develop a model in which asset specificity is endogenous and impacts a firm's financing condition. They demonstrate that, on the one hand, specialization erodes the PAs liquidation value, while it improves a firm's productivity and hence its ability to pay back investors on the other.

The airline industry is one of the best examples in which we find the interaction between productive asset specificity, product differentiation, and the resale value of assets in liquidation.

A first selection of research investigates the interaction between productive asset specificity and liquidation values. For instance, Benmelech and Bergman (2008, 2011) and Gavazza (2010) examine the resale value of aircrafts when airline companies pledge them as collateral in their loan agreements. Since airlines tend to use a low number of aircraft, potential buyers in the secondary market are firms already operating with similar models. The specificity of an aircraft (in this case, its popularity) affects its liquidation value in the secondary market. They all focus on the impact of the expected liquidation value of the fleet on an airline company's financial condition. In our study, companies are self-financed, and thus we ignore the effect of asset specialization on access to external finance, although we also investigate the relationship between productive asset specificity and product differentiation.

A second set of studies take the airline industry as a case to analyze the relationship between product differentiation and entry deterrence. For instance, airport presence is an aspect of product differentiation, since hub-and-spoke networks allow airlines to transport a larger number of passengers to different ultimate destinations and to offer more frequent flights (e.g., see Berry, 1990). Aguirregabiria and Ho (2010) reveal that hub-and-spoke networks can be an effective strategy for deterring new entry by competitors. Bet (2021) provides evidence that incumbents adjust their departure times in response to the threat of entry and set departure time more evenly spaced around the clock; in this way they achieve a greater product differentiation and block potential entrants. In contrast to these studies, where product differentiation reduces new entries, in our study, greater product differentiation facilitates entry by outsiders, since new entrants do not face any redeployment cost when using second-hand productive assets.

3 The model

In this section, we describe the key features of our model. We introduce the players, that is, firms and consumers. Then, we investigate the market outcome and relocation of PAs when incumbents may be hit by a negative shock that leads to bankruptcy.

We consider a standard Cournot model with two incumbent firms and large number of potential entrants (outsiders) in the industry.

Firms. Each incumbent (female, she) owns a productive asset to supply a good. Incumbents produce at the same marginal cost c and face a fixed cost I to build their initial productive capacity. Between the payment of the initial fixed cost and production, each firm may be hit by an idiosyncratic negative shock, *iid* across firms: each incumbent may be *healthy*, with probability $p \in [0, 1]$ or *distressed*, with a complementary probability $1 - p$. In the first case, the incumbent firm is productive, whereas in the latter, its profits are zero. There is a large number of outsiders (male, he) ready to enter the industry; entrants have to pay a fixed entry cost $e > 0$. These entrants may operate, provided that they succeed in acquiring a productive asset in the secondary market from any of the two incumbents.

Consumers. The preferences of a representative consumer are given by the following utility function:

$$U(x_i, x_j, v) = a(x_i + x_j) - \frac{1}{2}(x_i^2 + x_j^2) - (1 - v)x_i x_j \tag{1}$$

where x_i, x_j are the quantities supplied by the two firms in the market (incumbents or outsiders) and v is the degree of product differentiation. Notice that the utility is increasing in v, implying that consumers like variety. Differentiating (1) with respect to x_i yields the demand function:

$$P_i = a - x_i - (1 - v)x_j$$

which encompasses different cases with one single parameter:

- when $v = 0$, goods are perfect substitutes: any change in price will affect both demands by the same amount $\frac{\partial P_i}{\partial x_i} = \frac{\partial P_i}{\partial x_j} = -1$ for any i or $j = 1, 2$;
- when $v = 1$, firms are local monopolists: changing the price of a firm will not affect the quantity demanded of the other good;
- finally, for $0 < v < 1$, the goods are horizontally differentiated and $\frac{\partial P_i}{\partial x_i} \neq \frac{\partial P_i}{\partial x_j}$.

In the model the degree of product differentiation v is affected by the choice of specificity of the asset used to produce the good on sale. Since the level of asset specificity is endogenous and it affects the variety, we have to be specific about the timing of the events.

The timing is the following:

t=0 each incumbent firm i may affect v by choosing the degree of its PA specificity at an increasing cost (we will be more specific in section 4.3);

t=1 incumbents may be hit by a negative shock;

t=2 in the secondary market PAs are traded and relocated from distressed incumbents either to healthy incumbents or to outsiders;

t=3 all firms with a PA in place produce, consumers buy and firms earn profits.

The solution concept is sub-game perfect equilibrium.

4 Equilibrium analysis

In this section we solve for the equilibrium quantities and the relocation of the assets in the second-hand market. In stage $t = 2$ and $t = 3$ the degree of product differentiation is taken as given; in section 4.3 we solve for its equilibrium level.

4.1 Product market structure

The game is solved by backward induction. Hence we begin with the analysis of the structure of the product market.

At stage $t = 3$ there might be two possible industrial structures:

- **Cournot**: two active firms competing in the product market, either two healthy incumbents, or one healthy incumbent competing with the outsider who has acquired the asset from the other incumbent in distress, or two outsiders who have acquired one asset each from the two incumbents in distress. Denoting by x^C, P^C and Π^C respectively the level of output, the price and individual firms' profits at the symmetric Cournot equilibrium, we have:

  Lemma 1 $x^C = \frac{a-c}{3-v}$; $P^C = \frac{a-c}{3-v} + c$; $\Pi^C = \left(\frac{a-c}{3-v}\right)^2 = (x^C)^2$

- **Monopoly**: one of the two incumbents who becomes a single monopolist in the product market produces using the two assets, when only one incumbent is healthy and acquires the asset from the other incumbent in distress. Denoting by x^M, P^M and Π^M respectively the level of output per asset, the price and the overall profits for the two assets at the monopoly, we have:

  Lemma 2 $x^M = \frac{a-c}{2(2-v)}$; $P^M = \frac{a-c}{2} + c$; $\Pi^M = \frac{(a-c)^2}{2(2-v)} = 2(2-v)(x^M)^2$

With respect to Cournot, in the monopoly case, as usual, the level of output per asset is lower, while the price is higher.

4.2 The secondary market of productive assets

Moving backward one stage, at $t = 2$, we analyze the allocation of productive assets in the secondary market. The secondary market is a first price auction and takes place when at least one of the two incumbents is in distress and sells its productive asset to the best bidder. When only one incumbent is in distress, the other healthy incumbent participates in the auction for the PA together with outsiders willing to enter the market. When instead both incumbents are in distress, only outsiders are bidding for the two assets. We assume that the secondary market for PAs is liquid, i.e. that the number of outsiders is so large that the probability of one outsider acquiring both productive assets is close to zero[1].

As anticipated in the previous section, an outsider who has acquired the productive asset in the secondary market, has to pay a fixed entry cost $e > 0$ in order to be able to serve the market.

[1] This assumption simplifies computations without affecting the results.

Conversely, an incumbent who acquires the productive asset from the rival, has to incur a redeployment cost before re-using the asset in its production. Note that outsiders face only entry costs without any redeployment costs, since they were not producing in that market before, hence they have not to adapt their previous production technology[2].

The cost of redeploying the productive asset $d(v)$ is a function of the distance v between the two original assets:

Assumption 1 $d'(v) \geq 0 \ \forall v \quad$ *and* $\quad d(0) = 0.$

Redeployment costs are always increasing in v: if variety is large (i.e. PAs are very specific), the cost to adapt the asset to a different production technology is high; if instead PAs are standard (i.e. low v), the cost to re-use an asset to produce similar goods is small.

Accordingly to the structure of the model, we may have two possible scenarios: (i) two incumbents are in distress and two assets are on sale in the secondary market; or (ii) only one incumbent is in distress and one asset is on sale.

Scenario (i): two assets on sale.
In this case only outsiders are able to bid for the two assets on sale. Since the number of outsiders is so large that the probability that one is assigned the asset is close to zero, then two outsiders enter the market by bidding their maximum willingness to pay which is the Cournot profit net of the entry cost. Hence, the resale price in the auction is their maximum willingness to pay:

$$\omega^O(v) \equiv \Pi^C(v) - e \tag{2}$$

Under this scenario, the two assets are allocated to two outsiders entering the market and competing à la Cournot.

Scenario (ii): one single asset on sale.
Two possible type of bidders compete for the single asset:

- one of the numerous outsiders, with maximum willingness to pay for the asset $\omega^O(v)$. If an outsider acquires the asset he will compete with the healthy incumbent. The alternative is to remain outside the market gaining zero profits.
- the healthy incumbent who has maximum willingness to pay for the asset:

$$\omega^I(v) \equiv \Pi^M(v) - \Pi^C(v) - d(v) \tag{3}$$

[2]This assumption will be discussed in section 5

When acquiring the second asset, she will earn the monopoly profit Π^M but has to face a re-deployment cost $d(v)$; while if she does not buy the asset, at $t = 2$ will compete with an outsider in the market, thus earning the Cournot profit Π^C (her outside option).

The following Proposition defines who is the winner of the auction in the case of a single asset on sale:

Proposition 1 *Let* $G(v) \equiv \omega^I(v) - \omega^O(v)$*, when* $d(1) \geq e$*, there* $\exists\, \tilde{v} \in [0, 1]$ *such that*

- *if* $v < \tilde{v}$*, then* $G(v) > 0$*;*
- *if* $v \geq \tilde{v}$*, then* $G(v) \leq 0$*.*

Notice that Proposition 1 does not depend on a specific function of redeployment cost, but only on Assumption 1. In order to find a closed form solution and be able to plot the equations of the model, we specify redeployment costs according to the following function: $d(v) = Dv^2$, where $D \geq 0$. In our analysis, an increase in redeployment cost is represented by an increase in D.

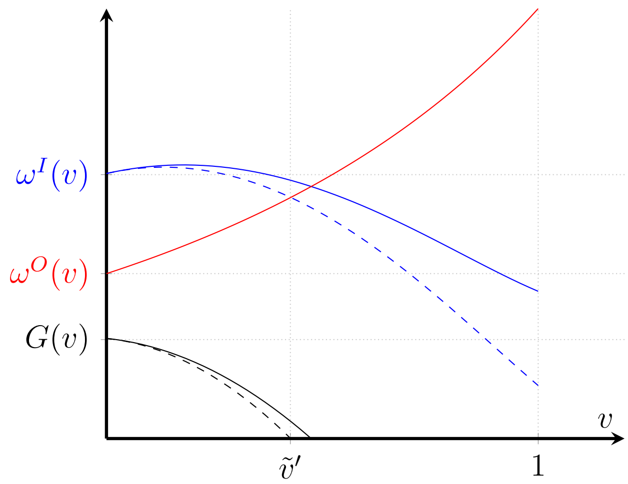
Proposition 1 implicitly defines a threshold level of variety, $\tilde{v}$, such that $G(\tilde{v}) = 0$, namely:

$$\Pi^M(v) - \Pi^C(v) - d(v) = \Pi^C(v) - e \tag{4}$$

Since $G(v)$ depends on the mark-up ($b \equiv a - c$) the entry cost (e) and the redeployment cost (D), we can rewrite $\tilde{v}$ as a function of those parameters: $\tilde{v} \equiv \tilde{v}(b, e, D)$. Notice that this threshold does not depend on the probability of being healthy, p. From equation 4 it is possible to show that $\tilde{v}$ is increasing in the mark-up b and in the entry cost e, while it is decreasing in the redeployment cost D.

Figure 1 is a graphical representation of Proposition 1: the curve $G(v)$ (in black) represents the difference between the maximum willingness to pay for the PAs of the incumbents, $\omega^I(v)$ (in blue) and of the outsiders, $\omega^O(v)$ (in red). When the entry cost does not exceed the threshold $d(1)$, there exists a $\tilde{v} \in (0, 1)$ that splits into two regions the highest maximum willingness to pay for the asset and therefore who wins the auction.

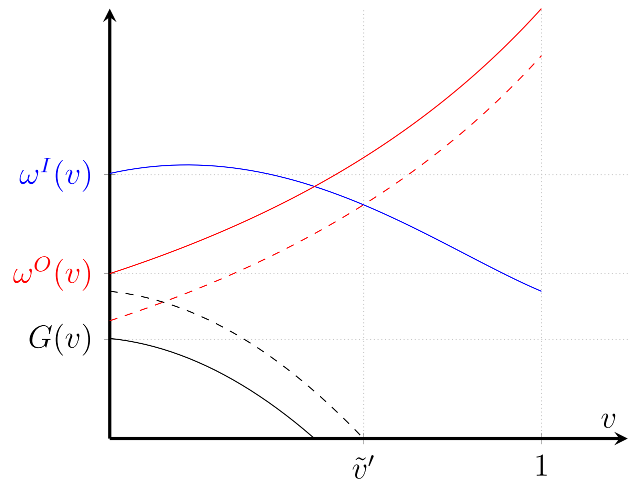
Figure 1: Maximum willingness to pay of the bidders



The reward from gaining access to the additional asset by the healthy incumbent is decreasing in v: the revenue for an incumbent to gain access to a second asset decreases as the degree of product differentiation increases (when $v \to 1$) since the profit of a duopolist becomes equal to that of a monopolist for $v = 1$. On the other hand the redeployment cost increases with v. Overall the advantage of the healthy incumbent over the outsider diminishes as v increases, up to the point where outsider's willingness to pay dominates. Hence, for $v < \tilde{v}$, the incumbent's maximum willingness to pay is greater than that of the outsiders, while the opposite is true for $v \geq \tilde{v}$.

The threshold $\tilde{v}$ depends on redeployment and entry costs. When redeployment costs increase, the threshold $\tilde{v}$ decreases: in this case, the healthy incumbent finds it too costly to redeploy the specific PA and this facilitates entry by outsiders (see the two dashed lines in Figure 1). Similarly when outsiders have to recover a greater entry cost e they will bid less, increasing the chances that the incumbent will outbid them, thus $\tilde{v}$ increases. (see Figure 2)

Figure 2: Increase in the entry cost e



We are now able to conclude that the equilibrium resale value of the productive asset, irrespective of who is the acquirer, is always:

$$\max\left\{\Pi^C(v) - e, 0\right\} \tag{5}$$

for any degree of product differentiation v. When both incumbents are in distress, only outsiders can bid for the two assets on sale. Given that there are numerous outsiders they will bid up to $\omega^O(v)$ to acquire each asset. Given the small probability that the auction allocates the two assets to the same outsider, they end up paying their maximum willingness to pay. When only one incumbent is in distress, the asset goes to the user who has the highest willingness to pay. Assume that outsiders have a higher maximum willingness to pay compared to the healthy incumbent ($v \geq \tilde{v}$): in this case competition among outsiders will drive their bid up to their maximum willingness to pay, which is given by (2). When instead the healthy incumbent has the highest maximum willingness to pay ($v < \tilde{v}$), given by (3), she will outbid by ϵ the outsider and gain the asset. Assuming that ϵ is close to zero, the resale value of the asset is again (2).

It is immediate to conclude that the resale value of the productive asset is always increasing in v, since Cournot profit is increasing in the variety.

Finally, given the outcome of the secondary market, we can derive the expected profit of an incumbent firm according to which of the two cases occur:

- case (a) when $v < \tilde{v}$:

$$E_{t=0}[\Pi(v)]^a = p^2\Pi^C(v) + p(1-p)[\Pi^M(v) - d(v)] + (1-p)^2[\Pi^C(v) - e] - I \tag{6}$$

When $v < \tilde{v}$ the expected profit in (6) can be written in its extensive form, omitting the v to simplify the notation, as:

$$E_{t=0}[\Pi]^a = p^2\Pi^C + p(1-p)[\Pi^M - d - (\Pi^C - e)] + (1-p)p[\Pi^C - e] + (1-p)^2[\Pi^C - e] - I$$

When both incumbents are healthy (probability p^2), they compete in a duopoly and earn Cournot profits; when our incumbent is healthy, while the rival is in distress (probability $p(1-p)$) the healthy one (since here we look at $v < \tilde{v}$) outbids outsiders by paying the asset $[\Pi^C - e]$ and earning monopoly profit net of the redeployment cost; when our incumbent is in distress, while the rival is not (probability $(1-p)p$), she sells the asset to the rival who outbids outsiders and pays $[\Pi^C - e]$ for the asset; finally when both incumbents are in distress (probability $(1-p)^2$) the asset on sale is sold at the resale price $[\Pi^C - e]$ due to the competition between numerous outsiders in the auction.

- case (b) when $v \geq \tilde{v}$:

$$E_{t=0}[\Pi(v)]^b = \Pi^C(v) - (1-p)e - I \tag{7}$$

where I is the initial investment to set productive capacity. When $v \geq \tilde{v}$ the expected profit in (7) can be rewritten as:

$$E_{t=0}[\Pi]^b = p^2\Pi^C + p(1-p)\Pi^C + (1-p)p[\Pi^C - e] + (1-p)^2[\Pi^C - e] - I$$

The difference in the two profits is given by what happens in case our incumbent is healthy while the rival is in distress (probability $p(1-p)$): while in the previous case our incumbent was in the position to win the auction, here is not. Hence one of the numerous outsiders will outbid her and earns the asset. Our healthy incumbent will have to face competition by an entrant and thus will earn Cournot profit Π^C instead of becoming the sole monopolist in the market producing with two assets.

We can summarize the result in the following Corollary:

Corollary 1 *The profits in the two cases can be written according to the following expression:*

$$\Pi^C + p(1-p)\max\{G(v), 0\} - (1-p)e - I$$

where $G(v) \equiv \omega^I(v) - \omega^O(v)$: if $v < \tilde{v}$ the profit collapses to case (a), while if $v \geq \tilde{v}$ to case (b). The difference between the profits in the two cases is then:

$$E_{t=0}[\Pi(v)]^a - E_{t=0}[\Pi(v)]^b = p(1-p)G(v)$$

Hence when $v < \tilde{v}$ the profit in case (a) is larger, while the opposite holds for $v \geq \tilde{v}$.

When there is a low degree of differentiation, the incumbents have a greater reservation value for the asset and they over-bid outsiders; the opposite when the degree of differentiation is large, since the redeployment costs are too large for the incumbents to be able to win the asset in the auction.

The difference between the two cases is given by the shape of the industry structure at $t = 2$ when one single asset is on sale: if the variety is low, it is the healthy incumbent who acquires the rival's asset and becomes monopolist, while if the variety is large, given the higher cost to reuse the asset for the healthy incumbent, the auction is won by one of the outsiders who enters the market and competes in a duopoly with the healthy incumbent.

4.3 Choice of asset specificity

We now move back one stage, at $t = 0$, and solve for the choice of asset specificity. We will see that this choice will lead to an endogenous level of liquidity in the secondary market. If the level of asset specificity chosen is high, outsiders will be attracted, since the resale value of the asset becomes too high for incumbents to be willing to acquire and re-use them due to redeployment costs. If instead the degree of asset specificity chosen is low, then incumbents outbid outsiders in the secondary markets and succeed in acquiring the assets of a distressed rival.

The outcome in terms of product market competition is somewhat paradoxical: on the one hand, when asset specificity is low, competition in the product market is tougher because products are not differentiated. However, this more likely leads to the transfer of the productive asset to an incumbent who therefore gains market power. The structure of the product market collapses to a monopoly. On the other hand, when asset specificity is high, competition among incumbents will be softer, outsiders will outbid incumbents in the secondary market, and the structure of the market will be more competitive.[3]

Each incumbent might soften competition in the product market by investing in asset specificity to increase product differentiation. The variety is endogenously determined by each incumbent's decision, where the overall level of variety $v(\lambda_i, \lambda_j) \in [0, 1]$ depends upon the level of specialization of the two incumbents λ_k for $k = i, j$. We make the following assumptions on v:

Assumption 1: (a) $v(0, 0) = 0$; (b) $\frac{\partial v}{\partial \lambda_k} > 0$ and $\lim_{\lambda_k \to \infty} v = 1$ for any $k = \{i, j\}$.

Assumption 1(a) implies that in the absence of investment in asset specificity the product is homogeneous. Assumption 1(b) implies that the variety is strictly increasing in λ and that the upper limit of the variety v is 1. In the rest of the paper we assume a specific form in which individual

[3]Notice that this result is in line with the literature on endogenous entry (see Sutton, 1991). In a competitive market, outsiders are not willing to enter, expecting to gain zero profits. However, with a non-negative probability of bankruptcy, the industry may even become a monopoly.

investments map into variety:

$$v(\lambda_i, \lambda_j) = 1 - \frac{1}{1 + \lambda_i + \lambda_j} \tag{8}$$

Notice that in this case $\frac{\partial v}{\partial \lambda_k} = (1 - v)^2$, hence whoever invests in specificity increases the variety in the market. We assume that the cost of investing in specialization is $\frac{\lambda^2}{2}$: incumbents are faced with a free-riding problem, since investing in asset specificity is costly, but it benefits both incumbents in the market.

The choice of asset specificity affects either product differentiation and the value of the asset in the secondary market. A higher level of asset specificity implies greater profits when the firm is healthy, but also higher redeployment costs reducing the willingness to pay for the asset on sale by an incumbent when the firm is in distress.

Now we analyze the choice of asset specificity. Each incumbent will choose the level of asset specificity as a best reply to the investment of the rival, as incumbents set their choice simultaneously and without any coordination.

Proposition 2 *At the symmetric SPE:*

- *case (a): when $v^a < \tilde{v}$, since $G(v^a) > 0$, the choice of variety v^a is the solution to:*

$$\left[\Pi^C(v^a)' + p(1-p)G'(v^a)\right](1 - v^a)^2 - \lambda_i^a = 0 \tag{9}$$

- *case (b): when instead $v^b \geq \tilde{v}$, since $G(v^b) < 0$, the choice of variety v^b is the solution to:*

$$\left[\Pi^C(v^b)'\right](1 - v^b)^2 - \lambda_i^b = 0 \tag{10}$$

It is easy to rank the equilibrium investment in asset specificity λ in the two cases (9) and (10).

Corollary 2 *At the equilibrium the investment in asset specificity (λ) is increasing in the degree of liquidity of the secondary market for productive assets, i.e. $\lambda^b > \lambda^a$. Since the variety v is increasing in the equilibrium level of asset specificity we have that:*

$$v^a \leq v^b.$$

The more liquid is the secondary market, that is, the more attractive is the secondary market for outsiders and the greater the degree of variety in the product market.

As it is evident from Proposition 2, also, not all parameters affect the two equilibrium levels of variety in the same way, more specifically while $v^a \equiv v^a(b, p, D)$, $v^b \equiv v^b(b)$.

The probability of success of the project p affects only v^a and not v^b. From equation 9, it is possible to show that the effect of p on v^a can be either positive or negative, depending on the value of p: when $p < 0.5$, then v^a is decreasing in p, while when $p > 0.5$, then v^a is increasing in p.

As for the probability of success, the redeployment cost D affects only v^a and not v^b. Since D positively affects the cost of redeployment and negatively $G(v)$ (namely, $\frac{\partial G(v)}{\partial D} < 0$), then v^a is decreasing in D.

Unlike p and D, the mark-up b affects both v^a and v^b since it directly and positively affects both competitive and monopoly profits. Therefore, since an increase in the mark-up will always boosts firms profits, hence both v^a and v^b are increasing in b.

Dependently upon the value of the parameters b, D, p and e, it is possible to have multiplicity of equilibria. This case might happen when it is possible to find a solution for both case (a) and case (b) of Proposition 2.

5 Welfare analysis

In this section we compare the solution in the SPE with the optimal investment in asset specificity from the point of view of consumers and of the social planner.

Consumer surplus. The consumer surplus is defined as the utility of a specific bundle of quantities $\{x_i(v), x_j(v)\}$ net of the expenditure to acquire it, that is

$$S \equiv U\left(x_i(v), x_j(v), v\right) - P_i\left(x_i(v), x_j(v), v\right) \times x_i(v) - P_j\left(x_i(v), x_j(v), v\right) \times x_j(v)$$

The expected consumer surplus at $t = 0$ (where we omit v for simplicity) is then:

$$E_{t=0}(S) = E_{t=0}U(x_i, x_j, v) - E_{t=0}(P_i x_i) - E_{t=0}(P_j x_j)$$

Since we focus on the symmetric equilibrium ($x_i = x_j = x$), we can rewrite the expected consumer surplus as follows:

$$E_{t=0}(S) = 2aE_{t=0}(x) - 2E_{t=0}[P(x)x] - (2 - v)E_{t=0}(x^2)$$

The expected consumer surplus can be finally simplified as

$$E_{t=0}(S) = (2 - v)E_{t=0}x(v)^2. \tag{11}$$

We can state the following result for the choice of the level of variety in terms of the expected consumer surplus:

Proposition 3 *For any set of parameters, the expected consumer surplus is always increasing in v.*

Since consumers like a greater variety, even though this implies higher prices, they would like the two companies to invest more in asset specificity.

Total Welfare. Let's now discuss the asset specificity that maximizes the total welfare. The social planner chooses the variety that maximizes the expected consumer surplus together with the overall expected industry profits, in other words:

$$E_{t=0}(W) = E_{t=0}(S) + E_{t=0}(\Pi_i) + E_{t=0}(\Pi_j) \tag{12}$$

Defining λ^* the solution of the social planner's problem, we can state the following result:

Proposition 4 *For any set of parameters, the degree of asset specificity chosen by the social planner is always higher than that in SPE, i.e. $\lambda_k^* \geq \lambda_k^b > \lambda_k^a$ for any $k = i, j$.*

There are two reasons why the social planner chooses a larger variety compared to the equilibrium values chosen by the two companies at the equilibrium: i) consumers appreciate the variety and ii) the social planner is able to overcome the free-riding problem in the investment in asset specificity and achieves thus overall a greater variety.

6 Extensions

In this section we discuss two possible extensions of our analysis.

6.1 Variable entry costs

So far we have assumed that entry costs are constant and equal to e. However, it might be that not only redeployment costs but also entry costs depend on the variety in the targeted market. For instance, in market with greater product differentiation, entry costs may be increasing in the degree of product differentiation as the entrant has to match the level of advertising or brand reputation of the incumbent.

Therefore we may assume that entry costs have a form similar to that of redeployment costs:

$$e(v) = Ev^2$$

where E is the per unit entry cost similar to D in the case of redeployment costs. This assumption affects the differences in willingness to pay between incumbents and outsiders, that is $G(v)$, and as a consequence, the expected profits after taking into account the outcome of the secondary market for PAs.

In what follows we study the relation between D and E, and its effect on $G(v)$.

Proposition 5 *If $E \geq D$, then $G(v) \geq 0$ and incumbents always outbid outsiders.*

Given proposition 5, to have new entry by outsiders through the secondary market, we need to assume that $E < D$. To have a liquid secondary market, i.e. a market attracting several outsiders, we need to assume that $e(v) < d(v) \quad \forall v \in (0,1)$, that is entry costs must be lower than redeployment costs for any v. In this case the analysis and the results are unchanged.

6.2 Illiquid second-hand market

We now discuss the case with only one outsider willing to enter the market, capturing a lack of liquidity in the secondary market for PAs. In this case although all the analysis of the secondary market goes through as in the previous case, the resale price and the expected profits of the incumbent firms will change.

We can show that the expected profit for each incumbent is given by the following Proposition.

Proposition 6 *At t=0, each incumbent firm's expected profit is:*

$$E_{t=0}[\Pi(v)] = p^2\Pi^C(v) + p(1-p)[\Pi^M(v) - d(v)] - I \tag{13}$$

for any degree of variety v.

While a liquid secondary market with numerous outsiders, was providing always a positive price for the PAs equal to the Cournot profit, irrespective of who is producing (incumbent or outsider), in the case of an illiquid secondary market, the assets may be worth zero, when there are no buyers ready to use the asset. This implies that the expected profits are smaller than in the Cournot case.

Each incumbent will choose the level of asset specificity, by maximizing the expected profit

$$E_{t=0}[\Pi(v)] = p^2\Pi^C(v) + p(1-p)[\Pi^M(v) - d(v)] - I - \frac{\lambda_i^2}{2}$$

while taking into account the reaction of the rival.

It is easy to show that the problem is:

$$\max_{\lambda_i} E_{t=0}[\Pi(v)] = \Pi^C(v) + p(1-p)G(v) - (1-p)^2\Pi^C(v) + p(1-p)e - I - \frac{\lambda_i^2}{2}$$

The choice of asset specificity at the SPE is implicitly given by the following condition:

$$\left[\Pi^C(v)' + p(1-p)G'(v) - (1-p)^2\Pi^C(v)'\right](1-v)^2 - \lambda_i = 0 \tag{14}$$

When both incumbents choose the same level of asset specificity (i.e. $\lambda_i = \lambda_j = \hat{\lambda}$), the overall amount of variety is $\hat{v} = \frac{2\hat{\lambda}}{1+2\hat{\lambda}}$. Plugging the derivatives of the profits from Lemma 1 and 2 and the specific form of the redeployment cost $d(v) = Dv^2$ into (14), we have that:

$$\left\{p^2\frac{2b^2}{(3-\hat{v})^3} + p(1-p)\left[\frac{b^2}{2(2-\hat{v})^2} - 2D\hat{v}\right]\right\}(1-\hat{v})^2 - \frac{\hat{v}}{2(1-\hat{v})} = 0$$

It is possible to show that $\hat{v}$ increases with b and p, while $\hat{v}$ decreases if D increases.

Finally, it is easy to show that $\hat{v}$ is lower than v^a: from the FOC in (14) it is easy to see that the LHS is smaller than the LHS of (9) as $\Pi^C(v)' > 0$. Hence the variety in case of an illiquid second-hand market is lower than the smaller variety in either case of a liquid second-hand market.

7 Conclusions

In a model where two firms compete in quantities and face a positive idiosyncratic probability of distress, we examine the incentives of the incumbents to differentiate their products. Each incumbent can adapt its PA to achieve greater differentiation from the rival's product. In the case of distress, the incumbent has to liquidate the asset on the second-hand market, where the buyers may be either a healthy rival or one of the numerous outsiders willing to enter the industry. The resale value of the asset depends on the outcome in the second-hand market, which is a first-price auction. The investment in asset specificity by each incumbent depends upon the expected value, which is the average between the profit in the case the incumbent is healthy and the resale value in the case of distress. Given that investing in asset specificity increases the variety in the market, thus softening market competition for both rivals, but involves a private cost for the incumbent who invests, the level of variety in the non-cooperative equilibrium is sub-optimal compared to the optimal welfare level. We derive the endogenous level of the resale value together with its determinants, namely the probability of distress, the entry cost for the outsiders, and the redeployment cost when acquiring the asset of the rival in distress. The model can feature multiple equilibria since the resale value is affected by how much the second-hand market is attractive for outsiders willing to enter the industry.

This study has some limitations in terms of keeping the analysis simple. The first limitation concerns the assumption that the probability of bankruptcy is exogenous. For instance, one can assume that the manager of the incumbent firm may affect the probability of success by choosing a level of effort at a private cost, thus adding a moral hazard problem. This may give rise to an interesting extension of the model, whereby the liquidity of the secondary market will affect not only the choice of the variety, but also the probability of bankruptcy. Another limitation derives from the absence of asymmetric information. In this framework, the return for a lender when financing the investment in asset specificity is equal to that of a self-financing incumbent firm. Therefore, the level of variety is not affected by the mode of financing. It would be interesting to add some friction in the model to observe how the choice of asset specificity is affected when the incumbent's ability to access credit is limited.

In the present version, we assume that the specific investment boosts the revenues of the incumbent firms. One could also consider a model in which the individual investment reduces the marginal cost, for instance, in the case of $R\&D$, and this in turn affects product market competition. This may have interesting implications for the incentives to innovate when considering that the recovery value from the sale of PAs when innovators fail may be affected by their initial investment.

We leave all these possible avenues for future research.

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Appendix A - Proofs

Proofs of Lemma 1 and 2

It is enough to solve for the Cournot Nash equilibrium and the monopoly solution. ■

Proof of Proposition 1

$G(v)$ is the difference between the reservation value of incumbents $\omega^I(v)$ and outsiders $\omega^O(v)$, that is:

$$G(v) \equiv \Pi^M(v) - 2\Pi^C(v) - d(v) + e$$

Substituting the definitions of profits from Lemma 1 and 2 and of redeployability costs $d(v) = Dv^2$ we derive that:

$$G(v) = \frac{b^2}{4-2v} - \frac{2b^2}{(3-v)^2} - Dv^2 + e = \frac{b^2(1-v)^2}{2(2-v)(3-v)^2} - Dv^2 + e \tag{15}$$

When $v = 0$ we have that $G(0) = \frac{b^2}{36} + e > 0$, while when $G(1) = e - D < 0$. Given that $G(v)' < 0$, there exists an internal value $\tilde{v}$ such that $G(\tilde{v}) = 0$ if and only if $D \geq e$. ■

Proof of Proposition 2

From Corollary 1 we derive the incumbent's expected profit, after considering the outcome of the secondary market, net of the cost of investing and of the cost of setting the capacity:

$$\max_{\lambda_i} E_{t=0}[\Pi(v)] = \Pi^C(v) + p(1-p)\max\{G(v), 0\} - (1-p)e - I - \frac{\lambda_i^2}{2}$$

where $v(\lambda_i, \lambda_j)$ is defined in (8). Solving for the best replies for λ_i and λ_j, we derive the result. ■

Proof of Corollary 2

Given that the RHS of the FOCs in (9) and (10) is the same, we can focus on the first term within brackets. It is easy to see that, given that $G(v)' < 0$, we have an obvious ranking, namely that the RHS of equation (9) is smaller than the RHS of (10). ■

Proof of Proposition 3

We have to compute the expected consumer surplus in (11). With probability p^2 and $(1-p)^2$ the equilibrium quantities are those of the Cournot case $x^C(v)$ from Lemma 1. We have to distinguish instead between the two cases when one of the two incumbents is in distress, namely what happens with probability $2p(1-p)$:

- when $v < \tilde{v}$ the healthy incumbent acquires the asset of the other distressed incumbent and becomes the monopolist: in this case the quantity is $x^M(v)$ from Lemma 2. The expected surplus is then:

$$E_{t=0}(S) = (2-v)\left\{[p^2 + (1-p)^2]x^C(v)^2 + 2p(1-p)x^M(v)^2\right\}$$

$$= (2-v)[p^2 + (1-p)^2]\Pi^C(v) + p(1-p)\Pi^M(v)$$

  Taking the derivative w.r.t. v we derive:

$$\frac{\partial E_{t=0}(S)}{\partial v} = [p^2 + (1-p)^2][(2-v)\Pi^C(v)' - \Pi^C(v)] + p(1-p)\Pi^M(v)'$$

  substituting the equilibrium profits from Lemma 1 and 2, we derive the following expression:

$$\frac{\partial E_{t=0}(S)}{\partial v} = [p^2 + (1-p)^2]\frac{b^2(1-v)}{(3-v)^3} + p(1-p)\frac{b^2}{2(2-v)^2}$$

  We can now compute the derivative w.r.t. λ_k recalling that $\frac{\partial v}{\partial \lambda_k} = (1-v)^2$:

$$\frac{\partial E_{t=0}(S)}{\partial \lambda_k} = b^2(1-v)^2\left\{[p^2 + (1-p)^2]\frac{(1-v)}{(3-v)^3} + p(1-p)\frac{1}{2(2-v)^2}\right\} \geq 0 \qquad (16)$$

- when $v \geq \tilde{v}$ it is one of the outsiders to acquire the asset of the distressed incumbent and to compete with the healthy incumbent: in this case the equilibrium quantity is always $x^C(v)$. The expected surplus is then:

$$E_{t=0}(S) = (2-v)x^C(v)^2 = (2-v)\Pi^C(v)$$

  Taking the derivative w.r.t. v and substituting the equilibrium quantity from Lemma 1, we have:

$$\frac{\partial E_{t=0}(S)}{\partial v} = [(2-v)\Pi^C(v)' - \Pi^C(v)] = b^2\frac{(1-v)}{(3-v)^3}$$

  We can now compute the derivative w.r.t. λ_k recalling that $\frac{\partial v}{\partial \lambda_k} = (1-v)^2$:

$$\frac{\partial E_{t=0}(S)}{\partial \lambda_k} = b^2(1-v)^2\frac{(1-v)}{(3-v)^3} \geq 0 \qquad (17)$$

  Therefore the expected consumer surplus is increasing in λ_k for any $k = 1, 2$. ■

Proof of Proposition 4

The objective of the social planner is to find the λ that maximizes the total welfare in (12). Again we have to distinguish between the two cases:

- when $v < \tilde{v}$ the sum of the two profits at the symmetric equilibrium is;

$$E_{t=0}(\Pi_i + \Pi_j) = 2\Pi^C(v) + 2p(1-p)G(v) - 2p(1-p)e - 2I - \frac{\lambda_i^2}{2} - \frac{\lambda_j^2}{2}$$

  Taking the derivative w.r.t. λ_i

$$\frac{\partial E_{t=0}(\Pi_i + \Pi_j)}{\partial v} \times \frac{\partial v}{\partial \lambda_i} = \left[2\Pi^C(v)' + 2p(1-p)G(v)'\right](1-v)^2 - \lambda_i = 0$$

  We have therefore:

$$\frac{\partial E_{t=0}(W)}{\partial \lambda_i} = \frac{\partial E_{t=0}(S)}{\partial \lambda_i} + \left[2\Pi^C(v)' + 2p(1-p)G(v)'\right](1-v)^2 - \lambda_i = 0 \tag{18}$$

  The first term is positive as we know from equation (16). The second term can be decomposed into two terms:

$$\left[\Pi^C(v)' + p(1-p)G(v)'\right](1-v)^2 + \left\{\left[\Pi^C(v)' + p(1-p)G(v)'\right](1-v)^2 - \lambda_i\right\}$$

  The second term is the FOC in (9), therefore is zero. The first term is positive, being the positive term of the FOC in (9). Define λ^* the solution to the FOC in (18), we can conclude that $\lambda^* > \lambda^a$.

- when $v \geq \tilde{v}$ the sum of the two profits at the symmetric equilibrium is;

$$E_{t=0}(\Pi_i + \Pi_j) = 2\Pi^C(v) - 2p(1-p)e - 2I - \frac{\lambda_i^2}{2} - \frac{\lambda_j^2}{2} \tag{19}$$

  Taking the derivative w.r.t. λ_i

$$\frac{\partial E_{t=0}(\Pi_i + \Pi_j)}{\partial \lambda_i} = 2\Pi^C(v)'(1-v)^2 - \lambda_i = 0$$

  We have therefore:

$$\frac{\partial E_{t=0}(W)}{\partial \lambda_i} = \frac{\partial E_{t=0}(S)}{\partial \lambda_i} + 2\Pi^C(v)'(1-v)^2 - \lambda_i = 0 \tag{20}$$

  The first term is positive as we know from equation (17). The second term can be decomposed into two terms:

$$\Pi^C(v)'(1-v)^2 + \left\{\Pi^C(v)'(1-v)^2 - \lambda_i\right\}$$

The second term is the FOC in (10), therefore is zero. The first term is positive, being the positive term of the FOC in (10). Define λ^{**} the solution to the FOC in (20), we can conclude that $\lambda^{**} > \lambda^a$.

In both cases the level of asset specificity chosen by the social planner is larger compared to that in the SPE. ■

Proof of Proposition 5

$\Pi^M(v) - \Pi^C(v) - Dv^2 \geq \Pi^C(v) - Ev^2$ implies that $\Pi^M(v) - 2\Pi^C(v) \geq (D-E)v^2$. The LHS is always greater than zero if $v < 1$ and equal to zero at $v = 1$. Since $G'(v) < 0$ and $G(v) = 0$ if and only if $E = D$ and $v = 1$, it implies that the willingness to pay of incumbents is always greater than that of outsiders. ■

Proof of Proposition 6

When both incumbents are healthy (probability p^2), they compete in a duopoly and earn Cournot profits; when both incumbents are in distress (probability $(1-p)^2$) the asset on sale is sold at the smallest price $\epsilon \to 0$ which is the price that the outsider will bid to acquire each of the two assets on sale, given that he is the sole potential user of the asset.■