DISCUSSION PAPER SERIES

No. 9397

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INDUSTRIAL ORGANIZATION

Centre for Economic Policy Research

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ISSN 0265-8003

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Discussion Paper No. 9397
March 2013

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CEPR Discussion Paper No. 9397

March 2013

ABSTRACT

Screening-Based Competition*

We apply a reduced form representation of product market competition, facilitating an explicit characterization of the equilibrium investments in consumer-specific screening. The effects of market structure on screening incentives depend on the microstructure of the imperfect screening technology and on the characteristics of the pool of consumers. We conduct a welfare analysis, which reveals that the microstructure of the screening technology and the characteristics of the pool of consumers determine whether there are private incentives for overinvestment or underinvestment in screening. Furthermore, we show that the introduction of screening competition amplifies market failures associated with screening investments.

JEL Classification: D43 and L15
Keywords: imperfect competition and imperfect screening

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*We are grateful for valuable comments from Topi Miettinen.

Submitted 09 March 2013

1. Introduction

The implementation of any system of price discrimination requires the ability to separate different consumer types. Consumer-specific screening is a central mechanism to facilitate such separation. This holds true not only in banking and insurance, where evaluations of consumer-specific creditworthiness and riskiness, respectively, belong to the core activities, but equally well in many service industries where the implementation of customer value-based management[1] requires the ability to acquire consumer-specific information.

In this study we apply a reduced form representation of product market competition in order to design a duopoly model, which facilitates an explicit characterization of the equilibrium investments in consumer-specific screening. We show that the effects of market structure on screening incentives depend on the microstructure of the imperfect screening technology and on the characteristics of the pool of consumers. We find that competition typically has an ambiguous effect on investments in screening. More specifically, we establish that the introduction of competition reduces the total investments in screening, if the screening benefits serve the purpose of identifying profitable customers (i.e. the elimination of type-I errors). On the contrary, the introduction of competition promotes total investments in screening, if the screening benefits are realized in the form of eliminating unprofitable customers (i.e. the elimination of type-II errors). We also explore the effects of screening collaboration and demonstrate that the effects thereof are highly dependent on how the collaboration is organized.

We conduct a welfare analysis, which reveals that the microstructure of the screening technology and the characteristics of the pool of consumers determine whether there are private incentives for overinvestment or underinvestment in screening. We find that the private incentives to invest in screening always fall short of the social ones if the screening benefits serve the purpose of identifying profitable customers. Conversely, the private incentives to invest in screening always exceed the social ones if the screening benefits are realized in the form of eliminating unprofitable customers. Furthermore, we show that the introduction of screening competition amplifies market failures associated with screening

[1] See, for example, Subramanian, Raju and Zhang (2008).

investments. More precisely, the introduction of screening competition amplifies the underinvestment problem associated with the identification of profitable customers (screening focusing on type-I errors), whereas it amplifies the overinvestment problem associated with the detection of unprofitable consumers (screening focusing on type-II errors).

An extensive literature in banking has theoretically analyzed the effects of credit market competition on screening investments. Broecker (1990) is a seminal contribution exploring how lending market competition affect screening investments under circumstances where the banks evaluate loan applicants based on imperfect creditworthiness tests with exogenous precision. Conditional on the creditworthiness tests the banks subsequently compete with respect to lending rates. Broecker (1990) identifies a winner's curse problem with the feature that an increased number of competitors, each conducting independent creditworthiness tests of given precision, decreases the average quality of the funded projects. By applying a common value auction approach with exogenous signals Riordan (1993) establishes a winner's curse problem of a similar type. According to Riordan, intensified lending market competition tends to damage market performance. Our study is distinguished from these contributions by the fact that we endogenize the screening investments and that we distinguish between type-I and type-II errors resulting from imperfect screening.[2]

Gehrig (1998) shows that loan profitability promotes the screening incentives and that intensified loan market competition may reduce or enhance investments in loan-specific screening, which means that intensified competition leads to quality degradation or improvement of the banks' loan portfolios, depending on the properties of the screening technology and underlying project pool. Hauswald and Marquez (2006) focus on the strategic role of information acquisition in a specific model of localized lending competition with the feature that borrower-specific information improves the ability to exploit captive market segments, and thereby benefit from product differentiation. Within that framework they demonstrate that intensified competition implies reduced screening investments, and thereby deteriorated loan quality and less efficient credit allocation. In comparison with

[2] In the sequel we will find it convenient to label type-I errors as α -errors and type-II errors as β -errors correspondingly.

Gehrig (1998) or Hauswald and Marquez (2006) we get a richer characterization of the relationship between market structure and screening investments as we explicitly separate between α - screening and β -screening. Moreover, we add a welfare analysis.

Banerjee (2005) endogenizes information acquisition by allowing banks to select between borrower tests with two different degrees of precision. He further distinguishes between the ability of the screening technology to "screen in productive borrowers" (α - screening) and "screen out unproductive borrowers" (β - screening).[3] Within such a framework Banerjee (2005) establishes that the two types of screening have different effects on the screening incentives and that these two types of screening imply qualitatively different information externalities between competing lenders. Our model differs from Banerjee along many dimensions. 1. We apply a very different screening technology with a continuum of feasible investment levels. Our model therefore facilitates an explicit closed-form characterization of a symmetric investment equilibrium. 2. Our model exhibits how the effects of introducing screening competition depend not only on the nature of the screening technology, but also on the pool characteristics associated with the consumers. 3. We conduct a welfare analysis, which makes it possible for us to characterize the welfare implications of introducing screening competition. 4. We focus on a reduced form representation of profits, meaning that the results apply to a large spectrum of industries.

A few studies have analyzed screening-based competition within the framework of general models, which are not restricted to the banking industry. Hoppe and Lehman-Grube (2008) explore the effects of customer-specific tests with exogenous precision on the intensity of price competition in a differentiated industry. They focus on a duopoly model where customers are either profitable or not. In particular, they argue that the probability that a captive customer, classified as profitable by only one competitor, is profitable is lower than that of a non-captive customer, who has passed the tests of both competitors. Hoppe and Lehman-Grube (2008) find that sufficiently differentiated information partitions eliminate price-undercutting, and may therefore support a price equilibrium in pure strategies.

[3] Also Kanniainen and Stenbacka (1998) introduce α - and β - screening in a lending monopoly in order to explore how the proportion of creditworthy borrowers affect the screening incentives. However, they do not analyze screening-based competition nor the welfare effects thereof.

Esteves (2013) explores a model with consumers differentiated by their brand preference. Firms observe imprecise exogenous signals of consumer brand preferences, and these signals facilitate for firms to differentiate their pricing between loyal customers and consumers who can be induced to switch. She shows that in equilibrium firms charge higher prices to loyal customers. Furthermore, she demonstrates that the price charged to loyal customers has an inverted U-shape relationship with the information precision. Further, the industry profits and total welfare fall monotonically as price discrimination is based on increasingly more accurate information, but consumer surplus increases from improved signal accuracy. In this respect, price discrimination increases the distributional conflict between firms and consumers as firms have access to more precise information.

Our study proceeds as follows. Section 2 introduces the model of screening investments. Section 3 characterizes the duopolistic equilibrium with respect to screening investments. Section 4 explores the effects of market structure on screening investments. Section 5 discusses the consequences of cooperative screening investments. Section 6 conducts a welfare analysis and explores the welfare implications of introducing screening competition. Finally, section 7 presents some concluding comments.

2. Screening Investments: The Model

Consider a duopolistic industry with firms denoted A and B. The firms face consumers of two types: good (*g*) and bad (*b*). The proportion of type-g consumers is λ. It is profitable for the firms to serve g-type consumers, whereas the type-b consumers are unprofitable. Thus, the firms have incentives to apply a screening technology in order to identify the profitable consumers.

We assume the screening technology to be costly and imperfect. This imperfection is manifested in the probabilities that consumers are misclassified. More precisely, there is a probability of an α-error (type-I error) whereby a truly good consumer is classified to be bad. Likewise there is a probability of a β-error (type-II error) capturing the event that a truly bad consumer is classified to be good. The firms can control the magnitude of these classification errors by investments in screening. Formally, conditional on an investment x in screening the firm receives a signal, either good (G) or bad (B), regarding consumer types according to the conditional probabilities

$$P(B|g,x) = 1 - \alpha(x); \qquad P(G|g,x) = \alpha(x)$$

$$P(G|b,x) = \beta(x) \; ; \qquad P(B|b,x) = 1 - \beta(x) \; .$$

The classification errors are functions of the investment (x) in screening: $\alpha(x)$ is increasing and concave, whereas $\beta(x)$ is decreasing and convex. The costs of conducting a screening investment x is determined by a continuous, strictly increasing and strictly convex function $c(x)$ satisfying that $c(0) = 0$, $c'(0) = 0$ and $c'(x) \to \infty$, as $x \to \infty$. With these assumptions there will typically exist an optimal investment.

We assume that product market competition takes place conditional on the outcomes of screening. Firms have access to no additional information regarding individual consumers than the signal received from the screening and knowledge about the proportion of good types in the population[4]. In particular, firms have access to no customer history, meaning that the firms compete for unattached consumers.

Following the pioneering work of Broecker (1990), we formally assume that consumers perceived to be bad (B) are ex ante unprofitable to serve. This means that the firm will not serve a consumer classified as B, no matter how the rival has classified such a consumer. Consumers classified as good (G) are ex ante profitable irrespectively of whether they are classified as good (G) or bad (B) by the rival.

We apply reduced form representations to capture product market competition. Formally, we let $\pi_k^i(G,G)$ denote the equilibrium profit to firm *i* ($i = A, B$) from a consumer, who is truly of type *k* ($k = g, b$), and who has been classified to be of type G by the firm itself (the first argument) as well as by the rival (the second argument). Analogously, $\pi_k^i(G,B)$ denotes the equilibrium profit to firm *i* from a consumer, who is truly of type *k*, and who has been classified

[4] It should be emphasized that we introduce no structure whereby a firm would be able to observe the rival's classification of a consumers. Thus, potential re-evaluations conditional on the rival's classification are outside the scope of our model. We return to this issue in the discussion after Assumption 1

to be of type G by the firm itself, but classified as type B by its rival. The reduced forms capture the equilibrium profits in the product market conditional on the information available to the competing firms, i.e. the classifications made by these firms. It should be emphasized that the firms cannot make their product market decisions contingent on the true type of the consumer. Throughout our analysis we will focus on symmetric firms, meaning that we can drop the firm-specific indices.

Our analysis of screening-based competition does not explicitly model the decisions in the product market – a feature distinguishing our approach from the existing relevant literature. For that reason it does not really matter whether the product market is characterized by an equilibrium in pure strategies or mixed strategies[5]. With a focus on price competition in the product market a class of important contributions has clarified whether there is an equilibrium in mixed or pure strategies (for example, the lending market analysis of Broecker (1990), von Thadden (2004) and Banerjee (2005), or the more general analysis of Hoppe and Lehman-Grube (2008)). Our reduced form representation of the product market has the advantage that it facilitates for us to concentrate exclusively on analyzing the investments in screening without paying detailed attention to the precise consequences for a particular mode of competition in the product market.

Assumption 1 *Conditional on the signals received the equilibrium profits in the product market satisfy properties (A1) – (A4) below:*

(A1) $\delta_g = \pi_g(G,B) \quad > \quad 0,$

(A2) $\delta_b = \pi_b(G,B) \quad \leq \quad 0,$

(A3) $\Delta_g = \pi_g(G,B) - \pi_g(G,G) \quad > \quad 0,$

(A4) $\Delta_b = \pi_b(G,B) - \pi_b(G,G) \quad > \quad 0.$

Assumptions (A1) – (A4) imply that consumers perceived to be bad (B) are ex ante unprofitable

[5] Of course, with a mixed strategy equilibrium we focus on the expected value of the associated equilibrium profits.

to serve. This means that the firm will not serve a consumer classified as B, no matter how the rival has classified such a consumer[6]. Consumers classified as good (G) are ex ante profitable irrespectively of whether they are classified as good (G) or bad (B) by the rival. $\pi_g(G,G)$ is the profit on a truly good consumer if this consumer is classified as G by both competing firms. This is the profit outcome when both firms make competing offers to the consumers classified to be profitable by both firms. Such a consumer can be characterized as "non-captive". $\pi_g(G,B)$ is the profit on a truly good consumer if this consumer is classified as G by the firm itself , but as B by the rival. Such a consumer can be characterized as "captive".

According to (A3) we assume that $\Delta_g > 0$. Such an assumption captures the intuitive idea that the firm can make a higher profit on a consumer for whom there is no competition. Clearly, if the firms exchange information regarding the classifications the firm could sustain monopoly profits associated with those consumers it has classified as G, while at the same time these consumers have been classified as B by the rival. With information exchange there would be duopoly competition for those classified as G by both firms. However, it should be emphasized that we make no assumption as to whether firms engage in information exchange or not. With no information exchange the firm has to make its product market decision with no knowledge about the rival's classification of a particular consumer. In such a configuration assumption (A3) can be interpreted to mean that in a symmetric equilibrium the firm wins all its "captive" consumers, but only half of the "non-captive" consumers. Based on an analogous argument we also assume $\Delta_b > 0$. Overall, Δ_g (Δ_b) is inversely related to the intensity of competition for good risks (bad risks) in the product market.

Assume that firm *i* ($i = A, B$) has invested x_i in screening and that both firms have access to identical screening technologies characterized by the functions $\alpha(x_i)$ and $\beta(x_i)$ described above. Under such circumstances the number of consumers classified as G by both firms is given by

$$\Gamma(G,G|x_A, x_B) = \lambda\,\alpha(x_A)\,\alpha(x_B) \quad + \quad (1-\lambda)\,\beta(x_A)\,\beta(x_B)\,.$$

[6] In this respect our assumptions coincide with those made by Broecker (1990) and Banerjee (2005).

The first term captures the number of truly good (type-g) consumers classified to be good (G) by both firms. The second term denotes the number of truly bad (type-b) consumers, who have been misclassified by both firms. The probability that a consumer classified as (G,G) is truly g:

$$\tau^{GG} = \tau(g|G,G) \quad = \quad \frac{\lambda\, \alpha(x_A)\alpha(x_B)}{\lambda\, \alpha(x_A)\alpha(x_B) \quad + \quad (1-\lambda)\, \beta(x_A)\beta(x_B)} \ .$$

Conditional on the screening investments the number of consumers classified as G by firm A and as B by firm B is given by

$$\Gamma_A(G,B|x_A,x_B) = \lambda\, \alpha(x_A)(1-\alpha(x_B)) \quad + \quad (1-\lambda)\, \beta(x_A)(1-\beta(x_B)) \, .$$

The first term captures the number of truly good (type-g) consumers classified to be good (G) by firm A, but bad (B) by firm B. The second term expresses the number of truly bad (type-b) consumers, who have been misclassified to be good (G) by firm A, but correctly classified to be bad (B) by firm B. The posterior probability that a consumer classified as (G,B) is truly of type g:

$$\tau_A^{GB} = \tau_A(g|G,B) \quad = \quad \frac{\lambda\, \alpha(x_A)(1-\alpha(x_B))}{\lambda\, \alpha(x_A)(1-\alpha(x_B)) \quad + \quad (1-\lambda)\, \beta(x_A)(1-\beta(x_B))} \, .$$

3. Duopolistic Screening Investments

In this section we analyze non-cooperative competition with respect to the screening investments. Firm A's investment in screening is determined in order to solve the following optimization problem:

$$\max_{x_A} \pi_A(x_A,x_B) = \quad \Gamma_A(G,G|x_A,x_B)\left[\tau_A^{GG}\, \pi_g(G,G) + (1-\tau_A^{GG})\, \pi_b(G,G)\right] \quad +$$

$$\Gamma_A(G,B|x_A,x_B)\left[\tau_A^{GB}\, \pi_g(G,B) + (1-\tau_A^{GB})\, \pi_b(G,B)\right] \quad - \quad c(x_A)\, . \qquad (1)$$

Firm B faces a completely analogous optimization problem.

The equilibrium investments in screening are given as the solution to the system of equations

$$\lambda\,\alpha_A'(x_A)\left[\delta_g - \alpha_B(x_B)\Delta_g\right] + (1-\lambda)\,\beta_A'(x_A)\left[\delta_b - \beta_B(x_B)\Delta_b\right] - c'(x_A) \;=\; 0, \quad (2)$$

$$\lambda\,\alpha_B'(x_B)\left[\delta_g - \alpha_A(x_A)\Delta_g\right] + (1-\lambda)\,\beta_B'(x_B)\left[\delta_b - \beta_A(x_A)\Delta_b\right] - c'(x_B) \;=\; 0. \quad (3)$$

In order to facilitate explicit solution of this system of equations we introduce the following assumptions regarding the screening technology.

Assumption 2 *The classification errors associated with the screening technology are characterized by the following functions*

$\alpha_i(x_i) = \lambda + a\,x_i$ *with* $a \geq 0$*, and* $\beta_i(x_i) = (1-\lambda) + b\,x_i$ *with* $b \leq 0$ *(*$i = A, B$*).*

This screening technology is characterized by the feature that the composition of the pool of consumers affects the classification errors. In particular, it captures the intuitive idea that $\alpha_i(0) = \lambda$ and $\beta_i(0) = (1-\lambda)$ meaning that the probabilities of misclassification coincide with the pool proportions of the two types of consumers with no investments in screening.

Assumption 3 *The costs associated with screening are characterized by the function* $c(x) = \dfrac{K}{2}x^2$*, where K is sufficiently large to satisfy* $K > K_0$ *with* K_0 *defined by*

$$K_0 = \max\left\{\frac{a}{1-\lambda}\left(\lambda\,a\,\pi_g^M(G) + (1-\lambda)\,b\,\pi_b^M(G)\right), \frac{-b}{1-\lambda}\left(\lambda\,a\,\pi_g^M(G) + (1-\lambda)\,b\,\pi_b^M(G)\right)\right\}.$$

By applying Assumptions 2 and 3 when solving the system of equations (2) and (3) we can characterize the equilibrium with respect to screening investments according to

Result *1* *The equilibrium with competing screening investments is given by*

$$x^* = \frac{\lambda\,a\,(\delta_g - \lambda\,\Delta_g) \;+\; (1-\lambda)\,b\,(\delta_b - (1-\lambda)\,\Delta_b)}{K + \lambda\,a^2\,\Delta_g + (1-\lambda)\,b^2\,\Delta_b}\quad. \quad (4)$$

For the formal proof of Result 1 we refer to the Appendix.

It should be emphasized that the equilibrium investment in Result 1 is always positive, because it holds true that $a(\delta_g - \lambda \Delta_g) \geq 0$ and $b(\delta_b - (1-\lambda)\Delta_b) \geq 0$. As for comparative statics properties it can directly be seen that $\frac{\partial x^*}{\partial K} < 0$ meaning that higher investment costs reduces screening investments. Furthermore, we can infer that $\frac{\partial x^*}{\partial \Delta_g} < 0$, from which we can conclude that intensified competition for good risks promotes screening investments. However, the effect of intensified competition for bad risks is not identical, because it holds true that $\frac{\partial x^*}{\partial \Delta_b} > 0$ unless λ is sufficiently close to 1, whereas $\frac{\partial x^*}{\partial \Delta_b} < 0$ if the population of consumers has a sufficiently high proportion of bad consumers. Consequently, the effect of intensified product market competition on the screening investments is strongly linked to whether these investments predominantly reduce classification errors with respect to good or bad risks.

In the screening equilibrium (4) there is a strong complementarity between the proportion of profitable consumers (λ) and the productivity of the screening technology to identify profitable consumers (a). More precisely, the productivity of the screening technology to identify profitable consumers (a) is immaterial for the screening equilibrium if there are no profitable consumers ($\lambda = 0$) and vice versa. Likewise, the productivity of the screening technology to detect unprofitable consumers (b) is immaterial for the screening equilibrium if all consumers are profitable ($\lambda = 1$) and vice versa.

4. The Effects of Market Structure on Screening Investments

In this section we explore the effect of market structure on screening investments. For that purpose we compare the optimal screening investment in a monopoly with the screening equilibrium in a duopoly.

Consider a monopoly operating with a screening technology identical to the one presented in the previous section. Such a monopoly classifies $\Gamma(G|x) = \lambda\,\alpha(x) + (1-\lambda)\,\beta(x)$ consumers to be profitable. The probability that a consumer classified to be good is truly profitable is

$\tau^{G} = \tau(g|G,x) = \dfrac{\lambda\,\alpha(x)}{\lambda\,\alpha(x) + (1-\lambda)\,\beta(x)}$. Further, let the monopoly profit from a truly good consumer, classified as good, be $\pi_g^M(G)$, whereas that associated with a bad type is $\pi_b^M(G)$. It must clearly hold true that $\delta_g \le \pi_g^M(G)$ and $\delta_b \le \pi_b^M(G)$.

The optimal screening investment by a monopolist is given as the solution to the following optimization problem

$$\max_x \pi(x) = \Gamma(G|x)\left[\tau^G \pi_g^M(G) + (1-\tau^G)\pi_b^M(G)\right]. \tag{5}$$

The optimal screening investment by the monopolist is given by

$$x^M = \frac{\lambda\,a\,\pi_g^M(G) + (1-\lambda)\,b\,\pi_b^M(G)}{K}. \tag{6}$$

We can directly draw the conclusion that $x^M > x^*$ meaning that the monopolist invests more in screening than a firm subject to duopolistic competition. Furthermore, Assumption 3 guarantees that $\alpha(x^M) < 1$ and $\beta(x^M) > 0$.

But, what is the effect of market structure on total industry investment in screening? By comparing the screening investments in duopoly with that of a monopoly we find from (4) and (6) that

$2x^* > x^M$ if and only if

$$2K\left[\lambda\,a(\delta_g - \lambda\,\Delta_g) + (1-\lambda)\,b(\delta_b - (1-\lambda)\,\Delta_b)\right] >$$

$$\left[K + \lambda\,a^2\,\Delta_g + (1-\lambda)\,b^2\,\Delta_b\right]\left[\lambda\,a\,\pi_g^M(G) + (1-\lambda)\,b\,\pi_b^M(G)\right]. \tag{7}$$

Based on a detailed investigation of condition (7) we can draw the following conclusion regarding the effects of market structure on screening.

<u>Result 2</u> *The introduction of screening competition*

(i) *decreases industry investments in screening compared with a monopoly if these screening activities focus on the reduction of α - errors (type-I errors);*

(ii) *increases industry investments in screening compared with a monopoly if these screening activities focus on the reduction of β - errors (type-II errors).*

For the formal proof of Result 2 we refer to the Appendix.

Results 2 (i) and (ii) reveal that the effects of market structure on screening incentives depend on the microstructure of the screening technology. If the screening benefits serve the purpose of identifying profitable customers the introduction of competition reduces the screening incentives, leading to reduced investments in screening on the industry level. On the contrary, if the screening benefits are realized in the form of eliminating unprofitable customers the introduction of competition promotes total screening investments.

Result 2, according to which the effects of introducing screening competition depend on the nature of the screening technology, suggests that the relationship between market structure and screening incentives may plausibly be industry-specific. In credit markets operating with debt contracts the main purpose of bank screening is to identify bad borrowers, thereby focusing on the reduction of β - errors. Accepting such a perspective on lending markets, Result 2 (ii) leads us to support the hypothesis that the introduction of screening-based competition in lending markets would increase industry investments in screening. Likewise, to the extent that consumer-specific screening in insurance industries serve the primary purpose of reducing bad risks (risks for accidents etc.), the insurance industry would tend to exhibit a similar relationship between market structure and screening incentives. Venture capital financing is an example of an industry with the feature that the primary role of screening is to identify highly profitable projects. Thus, the venture capital industry would fall well into the category of industries for which Result 2 (i) apply, i.e. the introduction of competition reduces the screening investments. More generally, all service industries where screening serves the purpose of identifying consumer relationships offering valuable options for future business expansion have the feature that the introduction of competition reduces the screening investments.

According to Result 2 the microstructure of the screening technology determines the effects of market structure on screening incentives. It should nevertheless be emphasized that condition (7) exhibits a strong complementarity between the proportion of profitable consumers (λ) (the proportion of unprofitable consumers ($1-\lambda$)) and the productivity of the screening technology to identify profitable consumers (a) (to detect unprofitable consumers (b)). For that reason condition (7) could equally well be exploited to draw conclusions about how the pool of consumers determines the effects of market structure on screening incentives. Based on arguments analogous to those applied when deriving Result 2 we can formulate

Result 3 *The introduction of screening competition*

(i) *decreases industry investments in screening compared with a monopoly if the proportion of profitable consumers is sufficiently high;*

(ii) *increases industry investments in screening compared with a monopoly if the proportion of profitable consumers is sufficiently low.*

5. Cooperative Screening Investments

So far we have focused on non-cooperative screening decisions. In this section we will direct our attention towards an analysis of cooperative screening decisions. Such an analysis seems relevant in many industries. For example, in the insurance industry the European Commission has for a long time maintained a policy with a block exemption from the general bans on restrictive business practices. This block exemption regulation[7] applies to, for example, the exchange of “statistical information for the calculation of risks and the creation of insurance pools” (see, Jansen and Stenbacka (2011)). The growing activities of database marketing companies, like the Acxiom Corporation, provide another real-world example justifying why it is important to explore cooperative screening decisions[8]. The database marketing companies collect and sell data about many aspects of individual consumers to firms, often competitors in the product market. The database marketing companies serve as a screening intermediary selling customer-specific information to interested firms, but to the extent that competing firms in the product market acquire this information, the effect seems fairly equivalent to a particular form for the organization of cooperative screening investments.

In our study focusing on a duopolistic industry we distinguish between two types of screening collaboration.

Decentralized Screening Collaboration: The investments of both firms affect the precision of the consumer test. However, each firm decides non-cooperatively how much to invest.

Centralized Screening Collaboration: The investments of both firms affect the precision of the consumer test. In addition, the investments are coordinated so as to maximize industry profits.

This distinction between centralized and decentralized screening collaboration follows closely the distinction between RJV competition and RJV cartels made by Kamien, Muller and Zang (1992) in their analysis of research joint ventures (RJVs) .[9]

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[7] Strictly speaking, the block exemption regulation focuses on the exchange of information regarding risks facing the whole population rather than customer-specific risks, but it might be hard to acquire information regarding the risk facing the whole population without customer-specific screening. Thus, from the perspective of information acquisition this block exemption regulation seems to generate some type of cooperative investment incentives.

[8] For contemporary illustrations of the debate about database marketing companies, see New York Times 16 June 2012, 21 June 2012 or 10 October 2012.

[9] See also the general literature focusing on the organization of research (e.g. Gehrig, 2004).

5.1 Decentralized Screening Collaboration

With decentralized collaboration the precision of a customer test is determined by the total investments of the firms. Furthermore, an increase in the rival's investment promotes screening precision in an equally efficient way as an increase in the firm's own investment.

Let $x = x_A + x_B$ denote the sum the screening investments made by firms A and B. With decentralized collaboration the firm A's screening investment is determined by the following optimization problem

$$\max_{x_A} \pi_A(x_A, x_B) = \lambda \alpha_A(x)\alpha_B(x)\pi_g(G,G) + (1-\lambda)\beta_A(x)\beta_B(x)\pi_b(G,G) +$$

$$\lambda \alpha_A(x)(1-\alpha_B(x))\pi_g(G,B) + (1-\lambda)\beta_A(x)(1-\beta_B(x))\pi_b(G,B) - c(x_A). \qquad (8)$$

Firm B faces an analogous optimization problem.

With this type of screening collaboration the equilibrium investments are given as the solution to the system of equations

$$\lambda \alpha_A'(x)\left[\delta_g - (\alpha_A(x)+\alpha_B(x))\Delta_g\right] + (1-\lambda)\beta_A'(x)\left[\delta_b - (\beta_A(x)+\beta_B(x))\Delta_b\right] - c'(x_A) = 0$$

$$\lambda \alpha_B'(x)\left[\delta_g - (\alpha_A(x)+\alpha_B(x))\Delta_g\right] + (1-\lambda)\beta_B'(x)\left[\delta_b - (\beta_A(x)+\beta_B(x))\Delta_b\right] - c'(x_B) = 0.$$

With the linear screening technology, specified in Assumption 2, and with quadratic costs, specified in Assumption 3, we can explicitly calculate the investment equilibrium. In the Appendix we show that equilibrium with decentralized screening investments is given by

$$\hat{x} = \frac{\lambda a(\delta_g - 2\lambda\Delta_g) + (1-\lambda)b(\delta_b - 2(1-\lambda)\Delta_b)}{K + 4(\lambda a^2 \Delta_g + (1-\lambda)b^2 \Delta_b)}. \qquad (9)$$

Based on a direct comparison of (9) with (4) we can draw the following conclusion.

<u>**Result 4**</u> *With decentralized screening collaboration the firms invest less than with non-cooperative screening ($\hat{x} < x^*$).*

Result 4 captures the economic intuition that decentralized screening collaboration suffers from structural free riding problems, which explain why investments are lower than with non-cooperative screening. This result is in line with the finding of Kamien, Muller and Zang (1992), according to which the R&D investments are lower in RJV competition than with non-cooperative R&D competition.

5.2 Centralized Screening Collaboration

We now assume that the screening investment is determined in a centralized way in order to maximize industry profits. For that purpose we let y denote the associated investment per firm. The investment per firm is determined in order to maximize

$$\max_y \; \pi_A(y,y) = \lambda\,\alpha_A(2y)\,\alpha_B(2y)\,\pi_g(G,G) \;+\; (1-\lambda)\,\beta_A(2y)\,\beta_B(2y)\,\pi_b(G,G) \;+$$

$$\lambda\,\alpha_A(2y)(1-\alpha_B(2y))\,\pi_g(G,B) \;+\; (1-\lambda)\,\beta_A(2y)(1-\beta_B(2y))\,\pi_b(G,B) \;-\; c(y)\,. \quad (10)$$

With the linear screening technology and with quadratic costs, specified in Assumptions 2 and 3, respectively, as in the previous sections it is straightforward to calculate that the optimal investment is given by

$$\tilde{x} = \frac{\lambda\, a\,(\delta_g - 2\lambda\Delta_g) + (1-\lambda)\, b\,(\delta_b - 2(1-\lambda)\Delta_b)}{\frac{K}{2} + 4(\lambda\, a^2\,\Delta_g + (1-\lambda)\, b^2\,\Delta_b)}\,. \quad (11)$$

Comparing the investments under decentralized, given by (9), and centralized screening collaboration, given by (11), we can directly draw the following conclusion.

Result 5 *Centralized screening collaboration leads to higher investments than decentralized screening collaboration (* $\tilde{x} > \hat{x}$ *).*

From Result 5 we can conclude that the organization of screening collaboration is decisively important for the screening incentives. This conclusion is in line with the insights from Kamien, Muller and Zang (1992) regarding the organization of R&D. Similarly, Gehrig, Regibeau and Rocket (2000) establish that the specific aggregation rule for private signals will affect the overall performance in a non-strategic context.

The comparison of the investments under centralized screening collaboration with those associated with non-cooperative screening is fairly tedious. It seems fairly clear from a comparison between (4) and (11) that $\tilde{x} > x^*$ when K is sufficiently large. However, there seems to be parameter combinations such that this relationship could be reversed if K is not too large. More precisely, $\tilde{x} > x^*$ if and only if $K > \max\{K_0, K_1\}$, where K_0 is given in Assumption 3 and K_1 is defined by

$$K_1 = \frac{2\left(\lambda a^2 \Delta_g + (1-\lambda) b^2 \Delta_b\right)\left(4\lambda a(\delta_g - \lambda \Delta_g) + 4(1-\lambda) b(\delta_b - (1-\lambda)\Delta_b) + \lambda^2 a \Delta_g + (1-\lambda)^2 b\Delta_b\right)}{\lambda a(\delta_g - \lambda \Delta_g) + (1-\lambda) b(\delta_b - (1-\lambda)\Delta_b) - 2(\lambda^2 a \Delta_g + (1-\lambda)^2 b\Delta_b)}.$$

For parameter combinations with $K < K_1$ it would hold true that $\tilde{x} < x^*$.

Finally, it should be emphasized that we have established that the organization of screening collaboration is highly important for the screening incentives under particular circumstances. In general, screening collaboration could also be expected to affect the independence of the classifications tests or the costs of conducting these tests. It is a good topic for future research to more systematically explore the effects of screening collaboration on investments under alternative specifications of how collaboration affects the consumer-specific tests.

6. Socially Optimal Screening Investments

In this section we characterize the socially optimal screening investments under the assumption that the consumers are screened by an institution operating with social objectives. To that amount we let $W_g(G)$ ($W_b(G)$) denote the total welfare generated from supplying a consumer, who is truly of type g (b) and who is classified to be good in light of the screening. We make the following assumption.

Assumption 4 *The relationship between the social value and the profit generated by a consumer classified to be good satisfies properties (A5) and (A6) below:*

(A5) $$0 < \pi_g^M(G) \leq W_g(G) \, ,$$

(A6) $$\pi_b^M(G) \leq W_b(G) \leq 0 \, .$$

A truly good consumer, classified to be good, generates a profit for a monopoly firm. Property (A5) means that the monopoly is unable to capture all the surplus from such a consumer (unless $\pi_g^M(G) = W_g(G)$). Property (A6) focuses on a truly bad consumer classified to be good. It induces a loss on the firm to serve such a consumer. According to (A6) a truly bad consumer captures some surplus from being served by the monopolist (unless $\pi_b^M(G) = W_b(G)$).

Under the circumstances presented we can characterize the socially optimal screening investment in a straightforward way. The socially optimal screening investment is given as the solution to the following optimization problem

$$\max_x \quad \lambda\,\alpha(x) W_g(G) + (1-\lambda)\,\beta(x) W_b(G) - c(x) \; .$$

The sufficient and necessary first-order condition for a socially optimal screening investment is given by

$$\lambda\,\alpha'(x)\, W_g(G) \; + \; (1-\lambda)\,\beta'(x) W_b(G) \; - \; c'(x) \; = \; 0 \, . \qquad (12)$$

With the linear screening technology, specified in Assumption 2, and with quadratic costs, specified in Assumption 3, we find that the socially optimal screening investment is given by

$$x^S = \frac{\lambda\, a W_g(G) + (1-\lambda)\, b W_b(G)}{K} \quad . \qquad (13)$$

For the particular configuration with $\pi_g^M(G) = W_g(G)$ and $\pi_b^M(G) = W_b(G)$ a comparison of (13) with (6) reveals that the socially optimal investment coincides with that associated with a monopoly. Of course, this is a trivial result as it focuses on the configuration where the social value of serving a customer classified to be good always coincides with the value which can be captured by a monopolist. Let us therefore focus on the configuration where either $\pi_g^M(G) < W_g(G)$ or $\pi_b^M(G) < W_b(G)$ (or both) so that there is a genuine conflict of interest between monopoly profits and social value. Under such circumstances it holds true that

$$x^S > x^M \quad \text{if and only if} \quad \lambda\, a\left(W_g(G) - \pi_g^M(G)\right) \; > \; (1-\lambda)\, b\left(\pi_b^M(G) - W_b(G)\right). \qquad (14)$$

We can formulate this finding according to

Result 6 *The private monopolist engages in underinvestment in screening if and only if the difference in the marginal social return and the marginal private return from identifying truly good consumers exceeds the difference in the marginal private return and the marginal social return associated with the detection of truly bad consumers.*

From (14) we can draw interesting conclusions regarding the relationship between the private and social incentives for investment in screening. If the screening benefits serve the purpose of identifying valuable customers ($b \to 0$) the private incentives to invest in screening always fall short of the social ones. Conversely, if the screening benefits are realized in the form of eliminating unwanted customers ($a \to 0$) profit maximization yields excessive incentives for screening. Overall, (14) reveals that the microstructure of the screening technology determines whether there are private incentives for overinvestment or underinvestment in screening.

It should be emphasized that condition (14) exhibits a strong complementarity between the proportion of profitable consumers (λ) (the proportion of unprofitable consumers ($1-\lambda$)) and the productivity of the screening technology to identify profitable consumers (a) (to detect unprofitable consumers (b)). This feature we also observed in Section 4. Within the framework of the present welfare evaluation we can conclude that the pool of consumers importantly determines whether the private screening investments exceed or fall short of the social optimum. In this respect we find that the private screening investments are too low compared to the social optimum if the proportion of valuable consumers is sufficiently high. And, conversely, the private screening investments exceed the social optimum if the proportion of valuable consumers is sufficiently low.

Combination of (7) and (14) facilitates very interesting conclusions regarding the welfare effects of the introduction of screening competition. Let us first consider the case where the screening benefits serve primarily the purpose of identifying valuable customers ($b \to 0$). From (14) we know that the private monopoly engages in underinvestment compared with the social optimum. In addition, according to (7), under the very same conditions the introduction of screening competition reduces the screening investments even further. Thus, the introduction of screening competition amplifies the underinvestment problem associated with the identification of valuable customers (screening focusing on α - errors).

Let us next consider β-screening with the purpose of detecting bad consumers. According to (14) the private monopoly then engages in excessive screening investments compared with the social optimum. And, in light of (7), the introduction of screening competition stimulates the screening investments even further under these circumstances. Consequently, the introduction of screening competition amplifies the overinvestment problem associated with the detection of unprofitable consumers (screening focusing on β - errors).

We can summarize these findings according to

Result 7 *The introduction of screening competition amplifies market failures associated with screening investments. More precisely, the introduction of screening competition amplifies*

- *(i)* *the underinvestment problem associated with the identification of profitable customers (screening focusing on α - errors);*

(ii) *the overinvestment problem associated with the detection of unprofitable consumers (screening focusing on β - errors).*

7. Concluding Comments

This study has presented an explicit characterization of the effects of market structure on screening investments. We have demonstrated that these effects depend on the microstructure of the imperfect screening technology and on the characteristics of the pool of consumers. In particular, we have established that the introduction of competition reduces the total investments in screening, if the screening benefits serve the purpose of identifying profitable customers, whereas the introduction of competition promotes total investments in screening, if the screening benefits are realized in the form of eliminating unprofitable customers. We have also conducted a welfare analysis, revealing that the introduction of screening competition amplifies market failures associated with screening investments. More precisely, the introduction of screening competition amplifies the underinvestment problem associated with the identification of profitable customers, whereas it amplifies the overinvestment problem associated with the detection of unprofitable consumers.

Our model incorporated a number of simplifying assumptions in order to facilitate an explicit characterization of the screening investments. This characterization is greatly enhanced by the application of the reduced form representation of product market competition. While such an approach facilitates a transparent characterization of a number of important welfare properties, it might be insufficient for conclusions regarding the potential distributional conflicts between consumers and firms introduced by screening-based competition. In order to address potential distributional conflicts between consumers and firms the model must specify an explicit mode of competition in the product market.

Our analysis of screening-based competition has focused on a highly symmetric configuration: firms endowed with identical screening technologies compete in a product market with no asymmetries of any kind. Nevertheless we present a structure which is sufficiently rich to generate ambiguous effects of competition on screening investments.

Since the model lends itself to generalizations so as to capture interesting dimensions of asymmetry between firms a fascinating topic for future research is the analysis of asymmetric equilibria with some firms specializing in screening and others concentrating on the remaining market. What are the conditions for asymmetric screening to occur in equilibrium and what is the minimal amount of screening required by the low-intensity firms in such an equilibrium?

Appendix

Proof of Result 1: Based on Assumptions 2 and 3 the system of equations (2) and (3) can be expressed according to

$$\lambda a\left[\delta_g - (\lambda + a x_B)\Delta_g\right] + (1-\lambda) b\left[\delta_b - ((1-\lambda) + b x_B)\Delta_b\right] = K x_A \,, \tag{A1}$$

$$\lambda a\left[\delta_g - (\lambda + a x_A)\Delta_g\right] + (1-\lambda) b\left[\delta_b - ((1-\lambda) + b x_A)\Delta_b\right] = K x_B \,, \tag{A2}$$

respectively. Substitution of x_B from (A2) into (A1) yields

$$x_A\left(K - \frac{G^2}{K}\right) \;=\; H\left(1 - \frac{G}{K}\right),$$

where $G = \lambda a^2 \Delta_g + (1-\lambda) b^2 \Delta_b$ and $H = \lambda a(\delta_g - \lambda\Delta_g) + (1-\lambda) b(\delta_b - (1-\lambda)\Delta_b)$. Solution of this equation yields

$$x_A \;=\; \frac{H}{K+G} \,,$$

from which the conclusion drawn in Result 1 follows. **QED**

Proof of Result 2: We first consider the limiting case where $b \to 0$. Under such circumstances the condition (7) can be expressed as

$$2a\lambda K(\delta_g - \lambda\Delta_g) \;>\; (K + \lambda a^2 \Delta_g)\lambda a \pi_g^M(G),$$

which is equivalent to

$$2K\pi_g(G,G) + 2K(1-\lambda)\Delta_g \quad > \quad K\pi_g^M(G) + \lambda a^2\Delta_g\,\pi_g^M(G) + 2K(1-\lambda)\Delta_g \,.$$

But, the latter inequality cannot hold true, since it violates the condition that $2\pi_g(G,G) < \pi_g^M(G)$. Consequently, it must hold true that $2x^* < x^M$ in the limiting case with $b \to 0$, i.e. when the screening focuses on the reduction of α-errors.

We next focus on the limiting case where $a \to 0$. In this case condition (7) can be simplified to

$$2b(1-\lambda)K(\delta_b - (1-\lambda)\Delta_b) \quad > \quad (K + (1-\lambda)b^2\Delta_b)(1-\lambda)b\,\pi_b^M(G)\,,$$

which is equivalent to

$$2Kb\,\pi_b(G,G) + 2Kb\lambda\Delta_b \quad > \quad Kb\,\pi_b^M(G) + (1-\lambda)b^3\Delta_b\,\pi_b^M(G) + 2Kb\lambda\Delta_b \,.$$

The latter inequality holds true because $2\pi_b(G,G) < \pi_b^M(G) \leq 0$ and $b \leq 0$. Thus, we can conclude that $2x^* > x^M$ in the limiting case with $a \to 0$, i.e. when the screening focuses on the reduction of β-errors. **QED**

The equilibrium with decentralized screening investments (9): Based on Assumptions 2 and 3 the system of first-order conditions associated with the optimization problem (8) for firm A and the analogous problem for firm B can be written according to

$$\lambda a\left[\delta_g - (2\lambda + a(x_A + x_B))\Delta_g\right] + (1-\lambda)b\left[\delta_b - (2(1-\lambda) + 2b(x_A + x_B))\Delta_b\right] = Kx_A\,, \qquad \text{(A3)}$$

$$\lambda a\left[\delta_g - (2\lambda + a(x_A + x_B))\Delta_g\right] + (1-\lambda)b\left[\delta_b - (2(1-\lambda) + 2b(x_A + x_B))\Delta_b\right] = Kx_B\,. \qquad \text{(A4)}$$

Solving (A4) with respect to x_B and substituting into (A3) yields

$$x_A = x_B = \hat{x} = \frac{\lambda a(\delta_g - 2\lambda\Delta_g) + (1-\lambda)b(\delta_b - 2(1-\lambda)\Delta_b)}{K + 4(\lambda a^2\Delta_g + (1-\lambda)b^2\Delta_b)}\,.$$

QED

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