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Eero Lehto

PALKANSAAJIEN TUTKIMUSLAITOS LABOUR INSTITUTE FOR ECONOMIC RESEARCH

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INVENTIONS, THE STRUCTURE OF THE MARKET AND OWNERSHIP CHANGES

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Tiivistelmä

Tässä tutkimuksessa tarkastelemme tilannetta, jossa monta keksijäyritystä ja tuotemarkkinayritystä käyvät kauppaa keksinnöillä. Ensin analysoidaan tuotemarkkinayritysten motiiveja investoida omaan T&K:hon sekä keksijäyritysten markkinoille tuloa. Me osoitamme, että julkinen rahoitus, joka helpottaa keksijäyritysten tuloa markkinoille, vähentää osaltaan tuotemarkkinayritysten omaa T&K:ta. Kuitenkin toimialan luonnollisen kasvun myötä, joka ilmenee tuotemarkkinayritysten määrän nousuna, myös itsenäisten keksijäyritysten määrä pyrkii nousemaan, kuten myös tuotemarkkinayritysten keskimääräinen panostus T&K:hon. Tuotemarkkinayritykset eivät luovu omasta T&K:sta, koska ne haluavat säilyttää neuvotteluvoimansa markkinoilla. Myös tuotemarkkinayritysten kyky kohdentaa oma T&K vastaamaan niiden omia tarpeita ylläpitää omaa T&K:ta. Tämä tulos tukee käsitystä, jonka mukaan teknologian markkinoilla ei tapahdu sellaista erikostumista, jossa tuotemarkkinayritykset tyytyvät vain ostajan rooliin.

Tämän tutkimuksen toisessa osassa me kiinnitämme huomion itse kaupan muotoon. Vaihtoehtoina olisi myydä keksintö kiinteän hintaan tai sitten sopia sellaisesta järjestelystä, jossa keksijäyrityksestä tehdään ostavan yrityksen osakkeenomistaja. Jälkimmäinen kaupanteko voitaisiin toteuttaa siten, että yritysosto suoritetaan ostavan yrityksen osakkeilla. Oletamme, että epätäydellinen informaatio ei anna mahdollisuutta tehdä sitovia sopimuksia innovaatioihin ja niiden kaupallistamiseen tähtäävästä toiminnasta. Me oletamme lisäksi, että myynnin kohteena olevasta keksinnöstä saatavat tuotot jakaantuvat ostajan ja myyjän kesken niiden neuvotteluvoiman perusteella. Neuvotteluvoima riippuu muun muassa siitä, kuinka paljon potentiaalisia ostajia ja myyjiä on markkinoilla. Osakekauppa osoittautuu varteenotettavaksi vaihtoehdoksi silloin, kun keksinnön syntymisen jälkeiseen kaupallistamiseen ja keksinnön jatkokehittelyyn tarvitaan myös keksijäyrityksen panostusta. Me osoitamme, että yrityskaupassa, johon liittyy omistusjärjestelyitä, syntyy tarve voimistaa vastapuolen kannustimia lisätä niitä ponnistuksia, jotkasuunnataan keksinnön kaupallistamisen onnistumiseen. Tuotemarkkinayritys on siten keksijäyritystä innokkaampi keksijäyrityksen kannustimia vahvistavaan yrityskauppaan. Me johdamme myös tuloksen, jonka mukaan yleisen hyvinvoinnin kannalta olisi suotavaa, että maksutapaa – kiinteä maksu tai osakekauppa – koskeva päätöksenteko on sillä osapuolella, jonka oma panos kaupallistamisvaiheessa on suhteellisen tehoton nostamaan keksinnön arvoa.

Inventions, the structure of the market and ownership changes

Eero Lehto

13.1.2002

Abstract

We consider situations in which many inventors (sellers) and product market firms (sellers) trade on inventions.We first consider the product market firm's decision to invest in its own R&D. We show that public financing which encourages the inventor's entry reduces the producer's own R&D and thus shifts it toward a more specialized conduct in which the inventions are purchased in the outside market. However, with an increase in the number of product market firms both the number of independent inventors and product market firm's own R&D tend to increase. This shows that the firms do not tend to specialize and give up their own R&D with the natural growth of industries.

In the second section of this study we focus on the form of trading mechanism which either the product market firm or the inventing firm chooses. In the trade considered the number of potential buyers and sellers determines, however, the actual price (and thus each party's shares of the total value of a commercialized invention). The alternative modes of the trading mechanism are either to sell an invention at fixed price or to agree on the arrangement in which the inventor is made a stockholder in the buyer's firm. We assume that in some degree the inventing firm's effort are also required in commercialisation after the trade. Owing to the imperfectness of information, explicit contractual mechanisms are assumed to be excluded. The post-trade commercialization efforts make such an arrangement attractive in which the inventor is encouraged to exert post-trade effort by making the inventor an owner in the product market firm. In the trading mechanism considered there also arises a tendency to enforce the opponent's incentives to exert a post-trade effort. The product market firm would thus be more eager than the inventor to make a payment in the form of its own stocks rather than of pure money. We also show that the decision concerning the mode of agreement (the means of payment) should typically be allocated to that party who is relatively inefficient in raising the total value of an invention in the context of commercialization.

1 Introduction[1]

We consider a market with n such firms who are established in the product market. These producers are the potential buyers of uncommercialized inventions in the market with m specialized inventors.

In the first section we also allow the producers to invest in R&D. We then analyse the inventors' entry into invention activity and the producers' decisions concerning their own R&D. We especially focus on the implication of such policy measures that encourage the inventor's entry. We are interested in how this affects the market structure in terms of the number of those inventors who enter the market, and, on the other hand, in the terms of the amount of the producers' own R&D which determines the number of those producers who buy innovations in the market. We also analyse the implications of the natural growth of the number of producers. The theoretical findings of this section suggest that no such specialization arises very easily in which the producers give up their own R&D and tend to buy all the required knowledge at the market. Some empirical studies have, however, found evidence that this kind of specialization occurs (see Blonigen and Taylor, 2000). In the empirical study based on the Finnish data, following this study, however, we obtained some results which do not support the specialization hypothesis.[2]

In the second section of this study we discuss the case in which the producers are not involved in the invention activity and the number of inventors is given. The parties - the producers and the inventors - trade in inventions.

[1]This paper is a part of a larger project which is ordered and funded by Tekes, the National Technology Agency.

[2]see Lehto and Lehtoranta, 2002.

We assume that the contractual mechanism is excluded, because the financial outcome of an invention is not a verifiable variable and that there does not therefore exist such a measure in which the license agreement of the innovation parties could be fixed. The trading scheme will involve ownership arrangements, or alternatively, the invention is sold at a fixed price. The motive to buy an invention with the firm's own stocks is associated with the incentives to exert effort (or make investments) in the commercialization phase. Like Choi (2001) we assume that commercialization requires both the inventor's and the producer's input. Previous literature has focused on the relationship between cooperation (through licensing, strategic alliances or outright acquisitions) and the incentives to innovate.[3]

In the second section we consider the market in which many sellers and buyers trade in differentiated inventions. The buyers are such firms who have establised their position in the product market, whereas the sellers are specialized in producing inventions which are later commercialized. If the inventor's effort is also required in the post-trade phase, there arises a motive to tie the inventor through ownership arrangements to the production market firm. We assume that in the first phase of the trade the value of an invention - which is for sale - is divided into shares held by the seller and the buyer. These shares are determined according to the number of buyers and sellers in the market. In the second phase the buyer and the seller decide about the form of trade regarding each party's share as given. Then it is decided whether the inventor is given money or the stocks of the production market firm in payment of an invention. The aim of this study is to consider how the form of trade depends on the impact of each party's efforts on the final value of an invention, and, on the other hand, on the party's initial share of trade.

[3]Many authors like Gallini and Winter (1985), and Katz and Shapiro (1986) have previously shown that licensing can affect the firms incentives to innovate. According to the findings of Gans et al. (2000) the innovative start-up firms engage in cooperation (possibly through outright acquisition) with incumbent product market firms, if the innovators have control over the intellectual property rights of their innovations.

2 The producer's own R&D investment

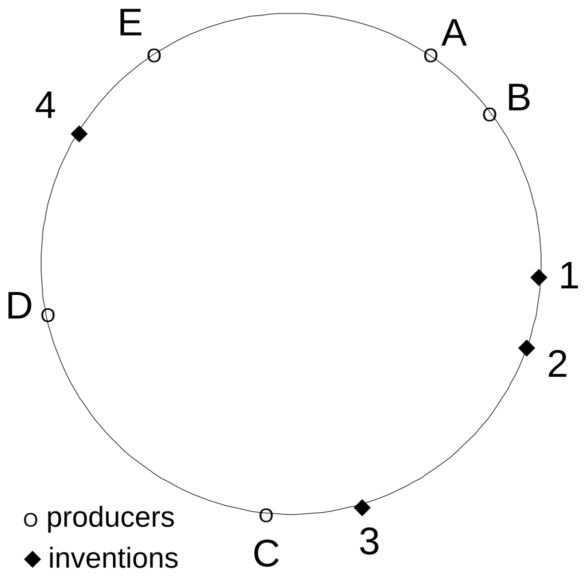
2.1 The total value of an invention and the inventor's share of it

Next we also allow the producers to be active in invention activity. We consider the market of producers and specialized inventors who have no access to the product market. We analyse the determination of a firm's R&D investments. Those producers who have not been successful in their own innovative activity buy innovations in the market.

We assume that the value of a successful invention for a particular producer, denoted h_i, is determined from a producer's location in the circle describing the producer's needs, and, on the other hand, the inventor's location in the same circle describing the purpose of the use of an invention. These locations are drawn from the same distribution. As a result, the producers are symmetric in the sense that, if their locations are the same, then their valuations for all the inventions are identical. But the traded items are not homogenous. This says that if an invention does not suit one producer very well, it may have high value for another producer.

The value of a successful invention for a particular producer thus depends only on matching. This says that the value of an invention describes how well the invention suits a producer. The matching in this sense is described in Figure 1. We suppose that each invention and the need of each producer will be stochastically located on the circle (with a length of two units). The value of an innovation for a producer is inversely and linearly related to the distance between an inventor and a producer. Without the loss of generality we assume that the values follow an uniform distribution. We assume (for the time being) that in their own R&D firms can reach perfect matching. From this it follows that those firms who have successfully created their own innovations do not sell their inventions in the market.

The value of the inventions in the market depends on the number of buyers and sellers. It can be shown that the best allocation resolves when one starts selling inventions sequentially in arbitrary order. Each producer buys at the most only one item. We suppose that the market mechanism then allocates an invention to that producer to whom the value is the highest. Suppose that in the situation described in figures 1 the items are sold in the order 1, 2, 3 and 4. At the high price auction producer A would buy invention



E
A
B
4
1
D
2
producers
inventions
C
3

Figure 1:

1, producer B invention 2, producer C invention 3 and producer E invention 4. Producer D does not manage to buy any invention. If producers A and B later exchanged the inventions in their possession no net benefit would accrue to them. The total value of the allocation thus would not change. The sequential mechanism considered produces, in this sense, efficient allocation. In fact, we have assumed that the bidders have no incentives to misrepresent their types and in this way depress prices strategically. Owing to the differentiation of traded items, it is difficult to sell the inventions through regular auction without a sequential order[4].

The sequential trading mechanism considered can also mean sequential auctions. The mechanism, in fact, leads to the Nash equilibrium. The implementation of the sequential procedure may require an appropriate institutional framework which supports the mechanism. Assuming simultaneous bidding, the analytical tractability of the trading mechanism of our model is hampered by the fact that the buyers value each invention differently. The situation considered cannot be modelled even as an asymmetric auction considered by Maskin and Riley (2000).[5] The results obtained in modelling double auctions in which multiple buyers and sellers trade on homogeneous items shows that quite soon the increase in the number of players brings about efficient allocation[6]. These results hint that even in the simultaneous bidding of differentiated items efficient allocation could be obtained quite fast when the number of players increases.

In the described mechanism the innovations are thus sold one by one in ranking order. Then the value of the first item to be sold for n buyers is determined according to k^{th} order statistics and is of size $\frac{n}{n+1}$ when the value

[4]The double auction with many sellers and buyers submitting bids and offers simultaneously, analysed by Wilson (1985) and Rustichini et al. (1994), assumes homogenous items.

[5]Maskin and Riley analysed an auction mechanism in which the buyers' beliefs are asymmetric. They assumed two buyers - a strong one and a weak one - whose beliefs are drawn from different distributions. The distribution of the strong buyer's valuation first order stochastically dominates that of the weak buyer. The latter assumption is not valid in the situation considered in our study.

[6]Rusticini et al. (1994) showed that in the so-called k-double auction of multiple sellers and buyers an already fairly small number of sellers and buyers leads to price-taking behaviour which guarantees efficient allocation. This result supplements the earlier results of Satterthwite and Williams (1989), who considered a double auction in which only the buyers were assumed to bid below their reservation values.

of each invention for a buyer follows uniform distribution [7]. The value of the next innovation to be sold for $n-1$ producers is of size $\frac{n-1}{n}$. Following this pattern, we obtain for the total value of all m items

$$\sum_{i=0}^{m-1}(\frac{n-i}{n-i+1}). \tag{1}$$

Let V_n denote the expected value of an invention for an average producer before the locations come true. For those producers who do not manage to buy any invention the value is zero. Then V_n is

$$V_n = \frac{1}{n}\sum_{i=0}^{m-1}\frac{n-i}{n-i+1} \tag{2}$$

in a mechanism with n producers (buyers) and m inventors (sellers). It is self-evident that an additional inventor will add V_n. In the mechanism with $n+1$ producers the expected value for a producer is then

$$V_{n+1} = \frac{1}{n+1}\sum_{i=0}^{m-1}\frac{n+1-i}{n-i+2}. \tag{3}$$

Comparing V_n with V_{n+1} it can be shown that $V_n > V_{n+1}$. The expected value for a producer will decrease, because the likelihood of leaving without an invention increases. When the number of sellers increases, the average matching improves and the value of the total trade increases, and so does the expected value for an average producer.

In the market with n producers and m inventors the expected value for an inventor is

$$W_m = \frac{1}{m}\sum_{i=0}^{m-1}\frac{n-i}{n-i+1}. \tag{4}$$

From expression (4) it is seen directly that an additional producer will increase the inventor's expected value. Then $mW = nV$, which shows that that the expected value of purchases equates the expected value of sales.

[7]Suppose the uniform distribution. When there is one auctioneer and n bidders the seller's expected profit is $\frac{n-1}{n+1}$ and the bidders' aggregate profit is $\frac{1}{n+1}$. The sum of these two is thus $\frac{n}{n+1}$.

From expression (4) we also obtain an expected value for an inventor in the market of n producers and $m+1$ inventors. This value is

$$W_{m+1} = \frac{1}{m+1} \sum_{i=0}^{m} \frac{n-i}{n-i+1}. \tag{5}$$

Comparing (4) with (5) we obtain the finding that $W_m > W_{m+1}$, which says that an increase in the number of inventors will decrease their expected value.

We have above derived a consistent estimate for the value of the total trade for an average producer and the average inventor.

In the mechanism considered the invention is, in any case, sold at the price which is expected to equate or exceed the buyer's personal valuation of the invention. If the price equates the value, the buyer's expected share of the invention's total value, in our model, becomes zero. In an auction with one seller and n bidders, the price of the invention tends to approach the buyer's personal valuation when the number of bidders becomes larger. In the sequence of auctions considered, the number of buyers decreases when the trading goes on. The number of sellers determines the number of auctions. In all, the bigger the number of buyers is in relation to the number of sellers, the larger the share the seller is expected to obtain. Let α denote the inventor's share of the expected value of the trade. We then assume that $\alpha(n+1,m) > \alpha(n+1,m)$ and $\alpha(n,m+1) < \alpha(n,m)$. It must also be noticed that the central finding of this study does not require that α is endogeneous in the assumed way. The same implications are derived even if α is assumed to be constant.

In fact, in the trading mechanism considered the price of an invention and consequently the buyers' and sellers' shares of the invention's value are determined similarly as in double auctions of homogeneous items. In double auctions the uniform price clears the market so that all those items are sold whose value for the bidders exceeds the respective value for the seller (see Satterthwaite and Williams, 1989). The more buyers there are in relation to sellers, the narrower is the expected gap between the market price and a buyer's own valuation of an invention (to be sold). This says that the buyers' actual and expected share can be assumed to decrease in the number of bidders.

2.2 The model

Let the number of all producers (product market firms) be N. This number is fixed and we do not consider the entry into the product market. We consider a market where those who have had no success in R&D buy inventions from those inventors who have decided to enter the invention market and who have been successful in their innovative activity.

The time structure of decision making in the case considered is the following:

t_1: Inventors and producers decide to enter the innovation market by investing in R&D and making a fixed entry investment.

t_2: The results of R&D effort is resolved either as a success or as a failure. Those producers who fail in their own R&D go to the innovation market.

t_3: The invention is sold to a producer in the market of many buyers and sellers. The number of producers and sellers determines the buyers' share of the value of the item.

We focus on the decision-making in phase t_1. Then the decisions are made in terms of the expected number of all entering inventors (M), the expected number of those inventors who have been successful (m) and in terms of the expected number of those producers who have had no success (n).

Let E denote the producer's own R&D and p, as a continuous function of E, the probability that a producer is successful so that he actually produces an innvation which suits his needs.Then we obtain for the expected number of those producers who enter the innovation market as buyers the equation $n = N(1 - p(E))$. It is noteworthy that this equation defines n as a real number.

The average producer's expected profit in the model characterized has the presentation

$$\pi^E = p(E)\widehat{R} - E - K_E + (1 - p(E))(1 - \alpha)V, \tag{6}$$

where p is the probability of success and E is the producer's R&D investment and $(1 - \alpha)V$ is the producer's expected share of the trade. We assume that $p'(E) > 0$ and $p''(E) < 0$ when $E > 0$. $\widehat{R}$ denotes the gross profits in the case where the producer succeeds in its own R&D. K_E represents the fixed investment required for entry into the innovation activity. Acording to the previous discussion V can be written in the form $V(n,m)$. Then $V(n,m)$ decreases in n and increases in m.

The inventor is assumed to make a fixed inventment of size K_e when he enters the invention market. The inventor's expected profits are, in the case considered,

$$\pi^e = q(e)\alpha W - e - K_e, \tag{7}$$

where e is the inventor's R&D investments and $q(e)$ is the probability for the success in the inventor's R&D activity. In addition, we assume that $q(e)$ is continuous function of e and that $q'(e) > 0$ and $q''(e) < 0$ when $e > 0$. Above W is the invention's expected value for an inventor, which as a function of n and m can be written as $W(n,m)$. Equation (7) also governs the entry of those inventors who enter the invention market and invest in R&D. Number M , the expected number of entering inventors, is then also a real number. Of these M inventors m are expected to be so successful that they can offer their inventions at the innovation market. This lets us express m as a function of M and e so that $m = M(1 - q(e))$. Here too m is a real number. Treating m and n as real numbers lets us describe the impact of n and m on the expected values V and W, and on the expected share α, using partial derivatives. Then the following holds:

$$\begin{aligned}
\frac{\partial \alpha_i^j}{\partial n} &> 0, \frac{\partial \alpha_i^j}{\partial m} < 0. \\
\frac{\partial V}{\partial n} &< 0, \frac{\partial V}{\partial m} > 0. \\
\frac{\partial W}{\partial n} &> 0, \frac{\partial W}{\partial m} < 0.
\end{aligned}$$

The producer sets his R&D investments at the level $E^* = \arg\max_E \pi^E$, given n and m. The first order conditions

$$\frac{\partial \pi^E}{\partial E} = p'(E^*)(\widehat{R} - (1 - \alpha(n,m))V(n,m)) - 1 = 0 \tag{8}$$

defines $E^* \equiv \arg\max_E \pi^E$. Taking into account the fact that $n = N(1 - p(E))$, we can, however, express E as a function of n and N so that $\frac{\partial E}{\partial n} =$

$-\frac{1}{Np'(E^*)}$ and $\frac{\partial E}{\partial N} = \frac{1-p(E)}{Np'(E)}$. This allows us to replace E in (8) by an implicit function $E(n, N)$. Condition (8) then defines n, which corresponds to E^*.

The inventor's R&D in optimum is resolved by maximizing (7) with respect to e, which gives for the first order conditions

$$\frac{\partial \pi^e}{\partial e} = q'(e)\alpha W - 1 = 0. \tag{9}$$

Let $e^* = \arg\max_e \pi^e$ defined by (9). The entry-condition which determines the number of inventors is then

$$\pi^e = q(e^*)\alpha W - e^* - K_e = 0. \tag{10}$$

We assume that π^e is concave with respect to e also in the case in which m is replaced by $M(1 - q(e))$.

2.3 The results

Let us look closer at how the structure of the market - in terms of the number of buyers and sellers in the innovation market - reacts when the financial support to inventors is increased or when the number of product market firms increases.

In the model considered entry condition (10) defines M when $m = M(1-q(e))$. Let $m(M, e)$ denote those values of m which satisfy $m = M(1 - q(e))$. Then $\frac{\partial m}{\partial M} = 1 - q(e) > 0$ and $\frac{\partial m}{\partial e} = -Mq'(e) < 0$. The first order condition (9), conversely, defines e^*. Inserting $m(M, e)$ into (9) let us express e as a function $e(M, n)$ so that

$$\frac{\partial e}{\partial M} = -\frac{q'(e)(1 - q(e)[\alpha \frac{\partial W}{\partial m} + \frac{\partial \alpha}{\partial m} W]}{B} < 0 \tag{11}$$

and

$$\frac{\partial e}{\partial n} = -\frac{q'(e)[\alpha \frac{\partial W}{\partial n} + \frac{\partial \alpha}{\partial n} W]}{B} > 0, \tag{12}$$

where

$$B = q''(e)\alpha W - q'(e)^2 M[\alpha \frac{\partial W}{\partial m} + \frac{\partial \alpha}{\partial m} W] < 0. \tag{13}$$

by the assumptions of the model. The result (13) guarantees that the model has an innerpoint solution for the producer's effort.

Expressing E, m and e as implicit functions in the forms $E(n, N)$, $m(M, e(M, n))$ and $e(M, n)$ condition (8) can be represented in terms of M and n with the slope

$$\frac{dn}{dM} = -\frac{p'(E^*)[-(1-\alpha)\frac{\partial V}{\partial m} + \frac{\partial \alpha}{\partial m}V](\frac{\partial m}{\partial M} + \frac{\partial m}{\partial e}\frac{\partial e}{\partial M})}{-p''(E^*)(\widehat{R} - (1-\alpha)V)/Np'(E^*) + p'(E^*)[-(1-\alpha)\frac{\partial V}{\partial n} + \frac{\partial \alpha}{\partial n}V] + DP'(E)} > 0. \tag{14}$$

where

$$D = -(1-\alpha)\frac{\partial V}{\partial m}\frac{\partial m}{\partial e}\frac{\partial e}{\partial n} + \frac{\partial \alpha}{\partial m}\frac{\partial m}{\partial e}\frac{\partial e}{\partial n}V > 0.$$

Result (14) shows that an increase in the number of inventors encourages the producer to invest in R&D, because the producers' share of the traded item and the expected value of innovation increases. This results in the fact that the number of those producers who have failed and will enter the innovation market decline.

By inserting $m(M, e(M, n))$ and $e(M, n)$ into equation (10) the entry condition can also be expressed in terms of M and n. The slope $\frac{dn}{dM}$ is then

$$\frac{dn}{dM} = -\frac{[\alpha\frac{\partial W}{\partial m} + \frac{\partial \alpha}{\partial m}W](\frac{\partial m}{\partial M} + \frac{\partial m}{\partial e}\frac{\partial e}{\partial M})}{[\alpha\frac{\partial W}{\partial n} + \frac{\partial \alpha}{\partial n}W] + [\alpha\frac{\partial W}{\partial m} + \frac{\partial \alpha}{\partial m}W]\frac{\partial m}{\partial e}\frac{\partial e}{\partial n}} > 0. \tag{15}$$

In (15) the denominator is positive and the numerator is negative. In Figures 2 and 3 we have characterized how the number of both producers and the potential inventors ($= M$) are determined. Let D_E refer to condition (8). This curvature of this condition in terms of n and m is given in (14). D_E in figures 2 and 3 then denotes the combinations of n and m in which the producer's first-order conditions concerning effort setting are satisfied. Because the number n is determined by the profit-maximizing level of E, the marginal conditions are decisive in the producer's behaviour. The producers also require that $\pi^E(E^*) \geq 0$, but this constraint need not be binding.

The number of inventors is determined from entry condition (10), which is described by curve D_e in Figures 2 and 3. The curvature of D_e is defined by condition (15). The slopes of both D_E and D_e are positive.

In Figure 2 D_e is steeper than D_E and in Figure 3 the situation is reversed. The assumptions of the model do not exclude either of these alternatives.

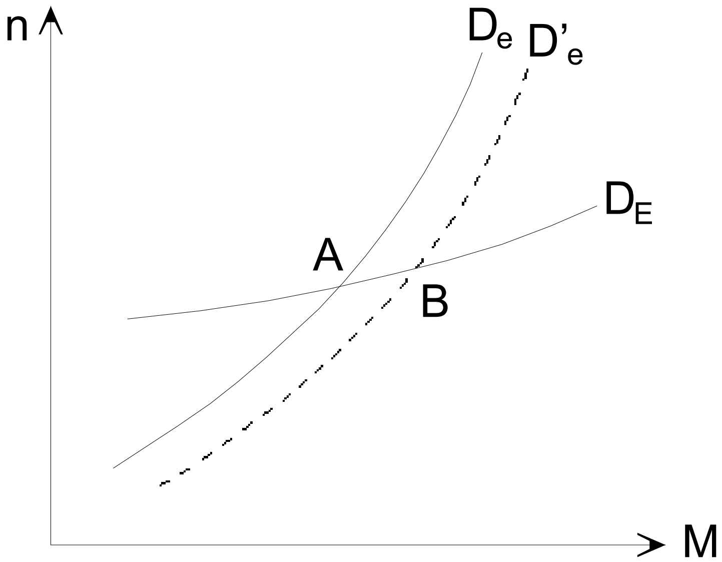


Figure 2:

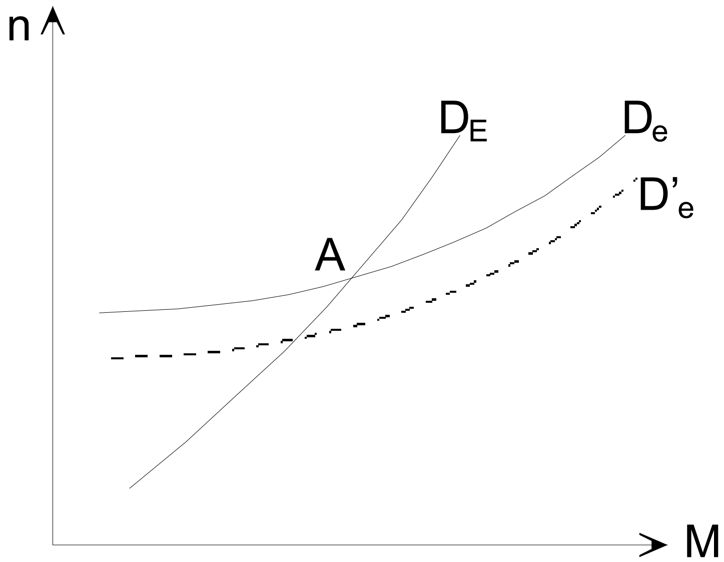


Figure 3:

Let us now consider the consequences of two events. Suppose first that the financial support to the inventors is increased as a consequence of which their entry costs K_e decrease.

Proposition 1 *The decrease in the inventor's entry costs K_e results in an increase in the number of those producers who have not succeeded in their own R&D, and in the number of inventors.*

Proof. From condition (10) it follows directly that this event shifts the inventor's isoprofit curve to a position D_e' in Figure 2. In the new equilibrium (point B) both n and M are at a higher level. In Figure 3 the effect of the decrease in K_e seems to be reversal. But in this situation point A does not describe a stable equilibrium. If the starting point is, however, point A, the decrease in K_e starts a chain reaction which leads both n and M outwards to the right so long as all the producers have given up their own R&D so that $n = N$. In the first place the decrease in K_e increases M again, but the reactions of n and, subsequently, M to this tend to enlarge and not reduce. ■

In the first place (in Figure 2) the entry of inventors is encouraged, which raises M. This strengthens the producers' stand in the innovation market, encouraging them to lower their own R&D and to rest on the outside market.

Corollary 2 *The producer's optimal effort E^* decreases as a result of a decrease in K_e.*

Proof. This follows, because n increases as a result of a decrease in K_e and $\frac{\partial E^*}{\partial n} = -\frac{1}{Np'(E^*)} < 0$. ■

Thus the number of those producers who have not succeeded in their own R&D increase. This result shows that producers are induced to specialize in buying innovations to a certain extent if the entry into purely innovative activities is encouraged, for example, through public R&D financing. The empirical findings of Blonigen and Taylor (2000) indicate that the firms may specialize in buying inventions at the market, which allows them to save in their own R&D.

The effects of an increase in K_e on m, the number of those inventors who are successful, and on the inventor's effort e, remain ambiguous.

Then we discuss a situation in which the number of production market firms ($= N$) increases.

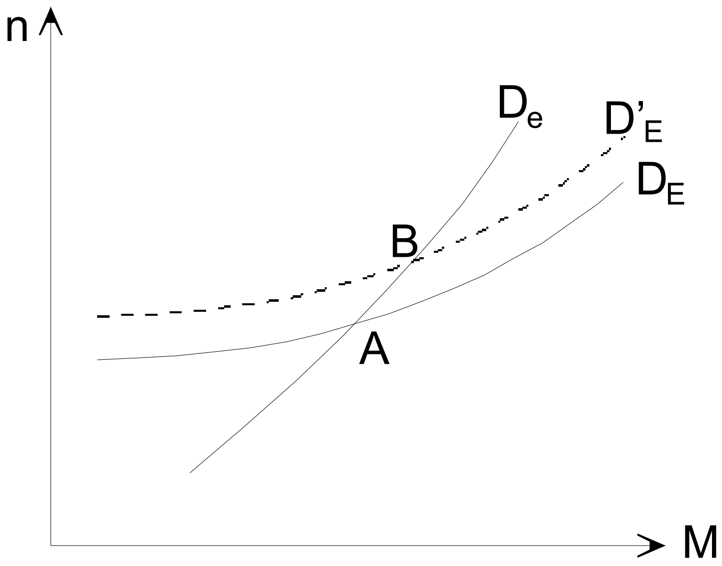


Figure 4:

Proposition 3 *As a consequnence of an increase in N both n and M increase.*

Proof. An increase in N increases the left-hand side of (8). To compensate this, n must also increase (given M). This shifts curve D_E in Figures 4 and 5 upwards. As a consequence, the stable equilibrium in Figure 4 moves upwards to the right. Both n and M have increased. In unstable equilibrium of Figure 5, n and M again increase until $n = N$ ■

Proposition (3) thus shows that when the number of producers increases, it is natural that the number of those firms also increases who have failed in R&D and go to the innovation market. This encourages the inventors to enter the invention market and so their number also increases.

Let us then consider the impact of an increase in N on each producer's own R&D.

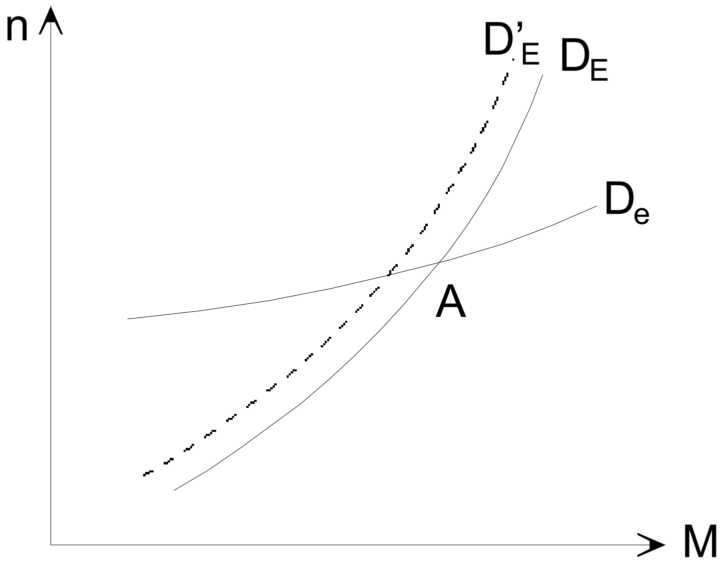


Figure 5:

Corollary 4 *In a stable equilibrium (Figure 4) E^* increases as a result of an increase in N.*

Proof. To evaluate this effect we derive from equation $n - N(1-p(E^*)) = 0$ the derivative

$$\frac{dE^*}{dN} = -\frac{\frac{\partial n}{\partial N} - (1-p(E^*))}{p'(E^*)} \tag{16}$$

when ∂N and dN describes one unit increase in N. The partial derivative above $\frac{\partial n}{\partial N}$ is derived from condition (8) having the expression

$$\frac{\partial n}{\partial N} = -\frac{p''(E^*)(\widehat{R}-(1-\alpha)V)\frac{\partial E^*}{\partial N}}{-p''(E^*)(\widehat{R}-(1-\alpha)V)/Np'(E^*) + p'(E^*)[-(1-\alpha)\frac{\partial V}{\partial n} + \frac{\partial \alpha}{\partial n}V]}, \tag{17}$$

where $\frac{\partial E^*}{\partial N} = \frac{1-p(E^*)}{Np'(E^*)}$. It is clear that in (17) $\frac{\partial n}{\partial N} > 0$. Using expressions (16) and (17), we obtain for $\frac{dE^*}{dN}$ the expression

$$\frac{dE^*}{dN} = -\frac{(1-p(E^*)[-(1-\alpha)\frac{\partial V}{\partial n} + \frac{\partial \alpha}{\partial n}V]}{-p''(E^*)(\widehat{R}-(1-\alpha)V)/Np'(E^*) + p'(E^*)[-(1-\alpha)\frac{\partial V}{\partial n} + \frac{\partial \alpha}{\partial n}V]} > 0$$

■

According to this result the increase in the number of producers also tends to increase each producer's own R&D investments. The producers tend to sustain their bargaining power by holding their R&D investments at a high enough level. The enlargement of the production market, related to globalisation for example, thus does not lead to such specialization in which the producing firms give up their own R&D and lean unilaterally on the innovation market. The theoretical result obtained offers an explanation of just the opposite behaviour to that which is observed by Blonigen and Taylor (2000). The growth of output in a certain industry which also encourages pure innovative activity in this field does not encourage the producers to adopt such a strategy in which inventions are obtained solely by buying them in the market.

In the unstable equilibrium of Figure 5, the numbers n and M, however, increase as long as $n = N$. At this point the producers have given up all their own R&D as a sign of specialization.

3 The commercialization game in the market of many buyers and sellers

3.1 The market and the price mechanism

We consider a situation in which m inventors and n producers enter the same market. All those m inventors who offer their inventions in the market have been successful. The inventors are not establised in the product market. The entry to the product market is assumed to require fixed investments which create sunk costs. This depresses the inventor's own valuation of an invention below the reservation values of all the producers. After the invention is bought it will be commercialized in order to have access to the product market. In the post-trade commercialization phase both the inventor's and the producer's effort may be required.

We assume that the profit stream originating from the invention is not a contractible variable and for this reason all the contracts in which the producer orders a specific invention are excluded. In addition, it is not possible to specify beforehand any such product volume or other criterion which could be the basis for a royalty agreement. In these circumstances it pays the inventor to sell the invention to the highest paying producer. The payment can be a fixed fee or an ownership arrangement in which the inventor obtains the stocks of the product market firm in payment for an invention.

All the players offer and buy inventions in the same market. As in the previous section now also the value of an invention for a producer reflects a fit between the nature of invention and the producer's needs. More specifically, the value of inventor $j's$ invention for a producer i depends on the independently distributed random parameter h_i^j and on the efforts in the commercialization phase.

We further assume that in the market considered the commercialized inventions are close substitutes. Thus, each producer can take advantage of only one invention at a time. This is also a standard assumption in the auction theory. This says that each inventor sells one item and each producer tends to buy one item.

In the mechanism considered the item is sold after it has been successfully invented. Because the inventions are not sold ex post, all the costs related to the invention activity are sunk. Therefore the marginal costs in the production of inventions do not play any role. The seller's own reservation values rather reflect the price at which the invention can utilized when the inventing firm commercializes the invention by itself.

We consider a mechanism where value parameter h_i^j is not a producer's private information. By this assumption there is no generating revelation process and thus the bidder cannot affect the informational rents (and thus the actual shares of the total value) through weakening the seller's incentives to exert post-trade effort[8]. The differentiated nature of h_i^j and the existence of several players who simultaneously bargain over inventions make the invention's price depend on the number of bidders (which is n) and on the number of sellers (which is m). Thus the seller's and the buyer's share of the invention's commercialized value is also contingent on n and m. More specifically, we consider a kind of implicit bargaining in which the increase in the number of producers tends to decrease the producer's share of the traded item and, respectively, to increase the inventor's share. These effects are more or less noticed by those who have also explored the innovation market. Pisano (1990) recognizes that in the innovation market the small number of sellers creates a problem a problem for a buyer. He calls this problem a small-number-bargaining situation. But if we look at this situation from a seller's point of view, a small number of buyers can also be considered to cause a problem. In all, the number of players is here assumed to have the same kind of influence on the sharing as in auctions in which h_i^j is the buyer's private information[9].

We assume that during the bargaining process the mode of the trade is also determined. This says that the total price is divided into a fixed fee component and that component which is paid in the form of the producer's (or merged firm's) stocks. These first-phase decisions are made taking into account those decision rules which fix the post-trade efforts in the second or commercialization phase.

In our setting the mode of agreement between the producer and the inventor may affect the total value of the trade only indirectly through exerted efforts. Because we also abstract from the product market effects, there arise in our model no such direct impacts from the nature of the trade on the

[8]This feature is present in the models which consider the auctioning of incentive schemes (see McAfee and McMillan, 1987 and also Lehto, 2002).

[9]See the previous section of this paper and the efficient allocation in the buyer's bid double auction in Satterthwaite and Williams, 1989.

value of the trade as in the technology transfer models of Gallini and Winter (1985) and Katz and Shapiro (1985).

3.2 The model

We consider a mechanism in which m inventors sell their inventions to n producers. Each producer will buy at most only one invention. The value of inventor's j invention for a producer i depends on the independently distributed random parameter h_i^j, which is not a buyer's private information. Because the value reflects the fit, it is possible that $h_i^j > h_i^k$ and that $h_l^k > h_l^j$ when $j \neq k$ and $i \neq l$. Owing to the differentiated nature of the inventions there also arise such bargains in which not all the rent is going to the party whose number is smaller in the market. According to this, the buyers are assumed to succeed in bargaining a price which may fall short of their personal valuation even if $n > m$.

In whatever case, the inventor's share of the total trade depends on n and m. Let α_i^j be inventor $j's$ share of the total value in the trade with producer i. This share, which is an outcome of bargaining among many producers and inventors, can be expressed as a function $\alpha_i^j(n, m)$ so that $\alpha_i^j(n+1, m) > \alpha_i^j(n, m)$ and $\alpha_i^j(n, m) > \alpha_i^j(n, m+1)$. When the number of producers increase the bargaining power of the inventors decreases, and the increase in the number of inventors has a reversal effect.

The total value of the invention concerned is then assumed to be $R(h_i^j, e_j, E_i)$, where e_j denotes an inventor $j's$ post-trade effort and E_i the producer $i's$ post-trade effort in the commercialization phase. We assume that R is concave in e_j and E_i and separable with respect to e_j and E_i. Each actor can observe only his own efforts, which creates a moral hazard problem. We assume that the value of invention R cannot be observed verifiably and so this variable is not contractible. By various arrangements concerning the ownership of stocks the parties can, however, affect the incentives to exert post-trade effort. The value of an invention is then also different in various ownership structures.

The time order of events is the following:

t_1: m inventors and n producers trade on m inventions. The parties bargain on the invention at this stage. The number of buyers and sellers fixes each party's shares of the traded values. At this phase the party agree on the price of an invention and that party to who has ex-ante bargaining power determines the means of payment. If the payment includes a fixed part it is paid at this stage.

t_2: In the post-trading phase the invention is commercialised. In this phase the producer exerts his own effort and, if necessary, the inventor contributes to the completion of an invention by his own effort.

t_3: The producer's income, generated by a commercialized invention, materializes and the inventor obtains that part of the rent which is based on the stock ownership in the producer's firm.

The sharing is based either on a fixed price contract or on a sharing scheme in which the inventor is made a stockholder in the buyer's firm. Let Q_i represent those incomes of the producing firm which are independent of invention j. Then the present value of the future income of the buyer's firm is $R+Q_i$. The inventor j is then assumed to get the payment for an invention in the form of $q_i^j(R(h_i^j, e_j, E_i)+Q_i)+k_i^j$. He is paid a share q_i^j of the producer $i's$ stock capital. Owing to the nature of the trade $q_i^j \geq 0$. On the other hand, we assume that the inventor is cash-constrained, from which it follows that $k_i^j \geq 0$. This says that the value of the inventor's stocks in the producing firm cannot exceed the value of the invention. The fixed payment will be of size k_i^j. If $q_i^j = 0$, the agreement is purely a fixed price. In any case,

$$q_i^j(R(h_i^j, e_j, E_i) + Q_i) + k_i^j = \alpha_i^j R(h_i^j, e_j, E_i). \tag{18}$$

Equation (18) together with constraint $k_i^j \geq 0$ also implies that $q_i^j \leq \frac{\alpha_i^j R}{R+Q_i}$. If $Q_i = 0$ this constraint transforms into $q_i^j \leq \alpha_i^j$. In the trade concerned, the inventor's profits are

$$\pi_j^e = q_i^j(R(h_i^j, e_j, E_i) + Q_i) + k_i^j - C(e_j), \tag{19}$$

where $C(e_j)$ describes the strictly convex disutility of effort. In the commercialization phase the inventor sets $e_j = e_j^*$ when

$$e_j^* = \arg\max_{e_j} q_i^j(R(h_i^j, e_j, E_i) + Q_i) + k_i^j - C(e_j).$$

The producer $i's$ utility has the expression

$$\pi_i^E = (1 - q_i^j)R(h_i^j, e_j, E_i) - q_i^j Q_i - k_i^j - C(E_i). \tag{20}$$

Here $C(E_i)$ describes the strictly convex disutility of the producer $i's$ effort associated with commercialization. The efforts are then set in the commercialization phase on the level

$$E_i^* = \arg\max_{E_2}(1 - q_i^i)R(h_i^j, e_j, E_i) - q_i^j Q_i - k_i^j - C(E_i).$$

3.3 The choice of a payment scheme

That party who has ex-ante bargaining power is allocated an authority to decide about the rules of the game, in other words, to set the value for the decision parameters q_j and k_j[10]. Similarly as in Grossman and Hart (1986), the allocation of the authority will have a decisive effect on the parties' ex-post decisions by which in our model is meant the decisions to exert effort in the commercialization phase.

When the inventor has ex ante bargaining power he sets $q_i^j = q_i^{jI}$ when

$$q_i^{jI} = \arg\max_{q_i^j} q_i^j(R(h_i^j, e_j^*, E_i^*) + Q_i) + k_i^j - C(e_j^*) \tag{21}$$

subject to the condition

$$k_i^j = (\alpha_i^j - q_i^j)(R(h_i^j, e_j^*, E_i^*) + Q_i) \tag{22}$$

for k_i^j which is derived from equation (18). When the inventor has bargaining power, the inventor sets $q_i^j = q_i^{jI}$, if $0 \leq q_i^{jI} \leq \frac{\alpha_i^j R}{R+Q_i}$, $q_i^{jI} = 0$, if $q_i^{jI} < 0$ or $q_i^j = \frac{\alpha_i^j R}{R+Q_i}$, if $q_i^{jI} > \frac{\alpha_i^j R}{R+Q_i}$.

When the producer has ex-ante bargaining power the decision parameters are set on levels q_i^{jp} and k_i^{jp} so that

$$q_i^{jp} = \arg\max_{q_i^j}(1 - q_i^j)R(h_i^j, e_j^*, E_i^*) - q_i^j Q_i - k_i^j - C(E_i^*), \tag{23}$$

where k_i^j has expression (22). When the producer has bargaining power, the producer sets $q_i^j = q_i^{jp}$, if $0 \leq q_i^{jp} \leq \frac{\alpha_i^j R}{R+Q_i}$, $q_i^{jI} = 0$, if $q_i^{jp} < 0$ or $q_i^j = \frac{\alpha_i^j R}{R+Q_i}$, if $q_i^{jp} > \frac{\alpha_i^j R}{R+Q_i}$.

[10] In this respect our approach is close to that of Aghion and Tirole (1994), who consider incomplete contracting of innovations. According to Aghion and Tirole (1994) that party who has ex-ante bargaining power decides about the ownership of property rights (of any forthcoming innovation) at the first stage of the game.

A specific model with $Q_i = 0$.

To clarify the analysis we specify functions R and $C(e)$ and assume, for the time being, that $Q_i = 0$. It is assumed that

$$C(e_j) = \frac{1}{2}e_j^2$$

$$C(E_i) = \frac{1}{2}E_i^2$$

and that

$$R(h_i^j, e_j, E_i) = Ah_i^j + \sqrt{\beta_e}e_j + \sqrt{\beta_E}E_i.$$

In the specified model

$$e_j^* = q_i^j\sqrt{\beta_e}$$

$$E_i^* = (1 - q_i^j)\sqrt{\beta_E}.$$

An expression

$$q_i^{jI} = \frac{\alpha_i^j(\beta_e - \beta_E)}{\beta_e} \tag{24}$$

is obtained for q_i^{jI} and an expression

$$q_i^{jp} = \frac{(1 - \alpha_i^j)\beta_e + \alpha_i^j\beta_E}{\beta_E} \tag{25}$$

for q_i^{jp}.

Proposition 5 *The producer would like to set a sharing parameter at a higher level than an inventor, and in a neutral case with $\beta_e = \beta_E$, the producer would choose a sharing scheme with $q_i^j = 1$, whereas the inventor would like to follow a fixed-price scheme.*

Proof. Comparing q_i^{jI} from (24) with q_i^{jp} from (25) results in the fact that $q_i^{jp} > q_i^{jI}$. Thus, the producer prefers a scheme with high q_i^j and, respectively, the inventor a scheme with low q_i^j. In addition, when $\beta_e = \beta_E$, $q_i^{jI} = 0$ and $q_i^{jp} = 1$. ■

From proposition (5) it follows that the ownership arrangements are more probable when the producer has ex-ante bargaining power than in a situation in which the inventor has ex-ante bargaining power.

This result also indicates that each party would like to enforce rather a partner's incentives than its own incentives to exert effort. This resembles a kind of free-rider problem in which the fruits of extra efforts are shared but all the costs due to them are carried alone.

It is also remarkable to notice that in the mechanism in which an inventor acts as an auctioneer, the inventor would like to weaken the producer's incentives in order to save in informational rents (see McAfee and McMillan (1987) and also Lehto (2001)). In the setting considered where the party who has bargaining power also regards the actual share α_i^j as given and ignores the partner's disutility of effort, only the motive to strengthen the partner's incentives exists.

3.4 Social efficiency

Social efficiency W is defined to be the producer's and the inventor's consolidated utility

$$W = R(h_i^j, e_j, E_i) - C(e_j) - C(E_i).$$

In the model specified above, the socially efficient effort levels - which maximize W - are $e_j = \beta_e$ and $E_i = \beta_E$. Then

$$W^{fb} = Ah_j + \frac{1}{2}(\beta_e + \beta_E),$$

where W^{fb} denotes socially efficient welfare in the absence of moral hazard.

On the other hand, we may assume that the inventor and the producer set the efforts themselves on the levels e_j^* and E_i^*, and that the social planner decides about q_i^j. When $e_j = e_j^*$ and $E_i = E_i^*$, W can be expressed in the form

$$W(e_j^*, E_i^*) = Ah_j + \frac{1}{2}\beta_E + q_i^j\beta_e - \frac{1}{2}(q_i^j)^2(\beta_e + \beta_E). \tag{26}$$

Denote $q_i^{j*} = \arg\max W(e_j^*, E_i^*)$. In the case considered

$$q_i^{j*} = \frac{\beta_e}{\beta_e + \beta_E}$$

and social welfare - which is denoted by W^* - is, respectively,

$$W^* = Ah_j + \frac{1}{2}\frac{\beta_e^2}{\beta_e + \beta_E} + \frac{1}{2}\beta_E.$$

Owing to the moral hazard which affects W^*, $W^* < W^{fb}$. Let us then consider social welfare in those cases in which either the inventor or the producer decides about the payment scheme. Let W^I denote $W(e_j^*, E_i^*)$ when $q_i^j = q_i^{jI}$ (the case in which the inventor has ex-ante bargaining power) and, respectively, W^p denotes $W(e_j^*, E_i^*)$ when $q_i^j = q_i^{jp}$ (so that the producer has ex ante bargaining power).

Proposition 6 *When $\beta_e > \beta_E$, it is socially efficient that the producer (the inventor) has bargaining power, if $\alpha_i^j < \alpha^c$ ($\alpha_i^j > \alpha^c$) when*

$$(\frac{1}{2} - \alpha_c) + \frac{1}{2}{\alpha_c}^2\frac{(\beta_e^2 - \beta_E^2)}{\beta_e^2} = 0. \tag{27}$$

On the other hand, if $\beta_E > \beta_e$, the producer (the inventor) should have bargaining power if $\alpha_i^j < \alpha^d$ ($\alpha_i^j > \alpha^d$) when

$$\frac{1}{2}\beta_e\beta_E - \frac{1}{2}\beta_e^2(1 - \alpha_d) - \frac{1}{2}\alpha_d\beta_E^2 = 0. \tag{28}$$

Proof. When $\beta_e > \beta_E$, $q_i^{jp} > 1$ so that the producer, having ex-ante bargaining power, sets $q_i^j = 1$, whereas the inventor sets $q_i^j = q_i^{jI}$ when he has the bargaining power. Inserting q_i^{jI} from (24) into (26), we obtain W^I, and, respectively, setting $q_i^j = 1$ into (26), we obtain W^p. $W^p - W^I$ then has expression

$$(\beta_e - \beta_E)(\frac{1}{2} - \alpha_i^j) + \frac{1}{2}\alpha_i^{j2}\frac{(\beta_e^2 - \beta_E^2)}{\beta_e^2}$$

which is positive when α_i^j is below the cut-off value α_c given in (27). When $\beta_E > \beta_e$, $q_i^{jI} < 0$ and the inventor sets $q_i^j = 0$. The producer sets, in this case, $q_i^j = q_i^{jp}$ which is given in expression (25). Using (26), we obtain now for $W^p - W^I$ the expression

$$\frac{(1 - \alpha_i^j)\beta_e + \alpha_i^j\beta_E}{\beta_E} - \frac{1}{2}\frac{[(1 - \alpha_i^j)\beta_e + \alpha_i^j\beta_E]^2}{\beta_E^2}(\beta_e + \beta_E),$$

which is positive insofar as α_i^j is below the cut-off value α_d given in (28). ■

By looking more closely at expression (27), it is seen $\alpha_c \in (\frac{1}{2}, 1)$. Respectively, from (28) it follows that $\alpha_d \in (0, \frac{1}{2})$. This indicates that it would then be socially efficient that bargaining power is allocated to the party who tends to move q_i^j from the extreme values of 0 or 1 closer to the social optimum $\frac{\beta_e}{\beta_e+\beta_E}$. According to this, the producer should have an opportunity to decide when his own share of the profit stream $R(h_i^j, e_j, E_i)$ is large enough. In the reversal case, when the inventor's share rises high enough (above the relevant cut-off values), it is the inventor who should have bargaining power. The relevant cut-off point for share α_i^j is naturally higher when $\beta_e > \beta_E$ compared with the situation in which $\beta_E > \beta_e$. This shows that when the inventor's contribution to the commercialization of the invention is remarkable, the optimal arrangement should encourage the inventor especially to exert post-trade effort. Then the bargaining power is typically allocated to the producer.

It is natural to think that it is the producer who has ex-ante bargaining power to decide about q_i^j when the number of producers is small in relation to the number of inventors. Then α_i^j is also small, and most likely it is really optimal that the producer has bargaining power. If the number of producers increases so that they lose bargaining power, and α_i^j rises well above $\frac{1}{2}$, the inventor may obtain bargaining power. But this arrangement typically is also optimal. It is not, however, difficult to show that in some situations the bargaining power can be allocated to the wrong party. For example, suppose that $\beta_e > \beta_E$ and that $\alpha_i^j \in (\alpha_c, 1)$ so that the producer has bargaining power. In this situation the inventor should, however, decide about q_i^j. The producer would encourage the inventor excessively.

Nonzero Q_j

When the producer's firm has other incomes a merger does not provide for the inventor such powerful incentives to exert effort in the commercialization phase. In a sharing scheme an investor's share

$$q_i^j = \frac{\alpha_i^j R_i}{R_i + Q_i}$$

from which it follows that $\frac{\partial q_i^j}{\partial Qi} < 0$ and that $q_i^j < \alpha_i^j$. This restricts the possibilities to trade on an invention with such a scheme in which the producer's stocks are used as a means of payment.

4 Conclusions

We consider a framework in which, in payment for an invention, an inventing firm receives either cash or stocks of the buyer, who is an established product market firm. Owing to the post-trade efforts which are required in commercialization, both parties' incentives to exert post-trade effort can be affected through the mode of the trade. The inventing firm can then be encouraged to exert effort in the commercialization phase by making it an owner of the product market firm. We show that both parties - the inventing firm and the product market firm - would like to strengthen the opponent's incentives to exert post-trade effort rather than their own incentives. In the situation considered the product market firm would like to use its own stocks as means of payment, whereas the inventor would prefer cash. In the socially efficient outcome the decision-right concerning the means of payment should typically be allocated to that party who is relatively inefficient in augmenting the value of an invention in the context of commercialization.

We also considered the production market firm's decision to invest in own R&D. As concerns the established producers' own R&D, the theoretical results obtained so far in this study do not offer much support for the hypothesis according to which some firms in the innovation market specialize in producing their own R&D and some firms specialize in purchasing required innovations at the market. We show that no specialization occurs in the stable equilibrium characterized. Typically, the number of inventors and also of product market firms' average own R&D increase with the natural growth of industries considered.

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