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Unilateral Spillovers Between East and West and Quality Competition

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Abstract

We model a two-stage duopolistic competition in a vertically differentiated eastern market between the eastern and western firms. In the first stage firms compete in R&D, and in the second stage in prices. Consumers in eastern market are distributed uniformly according to their income, and purchase at most a single unit of the product. The R&D activity improves the quality of the product. There are unilateral spillovers from the western firm which produces the higher quality to the eastern firm which produces the lower quality. The eastern firm can also imitate, to some degree, the western product. We show that if (1) not all consumers have purchased the good initially, (2) the eastern firm has a high rate of absorbing information out of the western firm, (3) the western firm does no learn from the eastern firm, then no firm may have an incentive to deviate unilaterally from the equilibrium in which the eastern firm is the leader an the western firm is the follower. We compare this equilibrium with the one in which only the western firm conducts R&D; the eastern firm increases the quality of its product solely through imitation. We show that under assumptions (1)–(3) listed above and for absorption rate close to 1, the welfare level in the eastern country is higher when the eastern firm imitates only compared to the welfare level in the leader-follower equilibrium.

1. Introduction

The exchange of technological information and know-how may take place on bilateral and reciprocal basis and therefore may cause some industries to be characterized by symmetric spillovers. However, in many cases such as newly created industries or industries in different countries, technological know-how may differ across firms. In such industries asymmetries are likely to be the rule rather than the exception.

The asymmetric spillover approach seems especially useful in modelling R&D competition in East European Countries. In such countries, domestic firms often use old, inefficient technologies compared to western methods of production. Also eastern firms do not have the financial resources to launch R&D [1]. Often in industries characterized by high level of R&D (cars, electronics, drugs etc.), eastern firms produce goods that are of significantly lower quality than imported western goods. The eastern goods are aimed at poor customers whereas western goods are more expensive and usually bought by wealthy customers. Hence, one can observe segmentation of the market – the low quality market served by domestic firms and high quality market served by foreign firms.

The market segmentation according to quality was studied in vertical product differentiation models of oligopoly framework developed by Shaked and Sutton (1982, 1983, 1987), [see also Martin 1993, p.290]. In their model consumers purchase a single unit of the product, the alternative branches of which differ in quality. The defining characteristic of product differentiation is that, if any two varieties of the good are offered at the same price, then all consumers choose the higher quality product. Shaked and Sutton showed that if income differences between consumers are sufficiently high, then in equilibrium more of one variety of the product will be produced. Moreover, the richer the consumers are, the higher the quality they buy.

Contrary to Shaked and Sutton, we assume that qualities are exogenously given, with the higher quality produced by foreign (western) firm and the lower quality produced by domestic (eastern) firm. We assume that initially the qualities are too low, compared with consumers income and the only way to increase the quality is to invest in R&D. Thus, R&D investment improves the quality of the product, rather than decreases costs as it is usually presumed in the R&D literature. We also assume that

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[1] See Schaffer (1991) and (1992) for description of the difficult financial situation of polish enterprises during the transition period.

only eastern firms benefit through spillovers from the R&D activity carried out by western firm, thus we have unilateral spillovers [2]. The existence of unilateral spillovers stems from the initial difference in qualities. The western producers are not interested in absorbing technologies developed in the East since those technologies are already 'old' in the West. On the other hand, eastern firms aim to develop a production of high quality goods to catch up with the bigger part of the market and enjoy higher profits. In the paper we also presume that the eastern firm is able to increase the quality of its product through imitation of the western technology; the degree of imitation is proportional to the difference of qualities. Hence, if the initial quality produced by firm i is q_i and firm i spends r_i on R&D, then the increase of quality is

$$q_i \nearrow q_i + \beta(q_2 - q_1) + \beta r_2 + r_1$$

for eastern firm 1 and

$$q_2 \nearrow q_2 + r_2$$

for western firm 2 (where parameter $0 \leq \beta \leq 1$ is a level of unilateral spillovers from foreign to eastern firm). The term $\beta(q_2 - q_1)$ measures degree of imitation of the western product by the eastern firm [3].

Our approach is closely related to the model presented by De Bondt and Henrique (1995) who analyze the asymmetric spillovers in duopolistic framework. The asymmetric spillovers in their model stem from the fact that one firm has initially lower costs than the other. De Bondt and Henrique model asymmetries in the strategic investment game as differences in initial costs, differences in marginal costs of R&D expenditures, and differences in spillovers.

In the paper we analyze three versions of the model. In the first version both firms make their decisions concerning R&D levels simultaneously. As a result we obtain Nash equilibrium R&D levels.

Second version involves one firm being a Stackelberg leader and another firm a Stackelberg follower in their R&D competition. Then we analyze the announcement game in which both rivals can choose to be a leader or a follower. The intuition suggests that such a game should have a subgame perfect Nash equilibrium with the

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[2] Unilateral spillovers with cost-reducing R&D investment are analyzed in Zigić (1998).

[3] The competition with imitation in a vertically differentiated market was analyzed by Pepall (1997). Pepall assumes that the imitation is costly, with the lower costs of imitation, the higher is product differentiation. Moreover, the follower is able to choose the degree of imitation.

foreign firm as the leader who invest heavily in R&D and increases the quality of its product. In such a equilibrium the domestic firm should benefit from being the follower who imitates the foreign product through spillovers.

Contrary to the intuition, we show that usually the announcement game has not a subgame perfect Nash equilibrium. Only in one case, in which (1) the eastern firm absorbs relatively large spillovers *(β > 1/3)*, and (2) some consumers with the lowest income do not purchase the good initially, the unique subgame perfect Nash equilibrium exists. In this equilibrium both firms enjoy higher profits than in simultaneous move game equilibrium. A leader in this equilibrium is the eastern firm that produces the lower quality good. In the announcement game equilibrium the eastern firm (a leader) invests less in R&D than it would if both rivals were to have chosen their R&D level simultaneously. On the other hand, the western firm (a follower) invests more in R&D than it would if both rivals were to have chosen their R&D level simultaneously. Those results stem from the fact that for large enough spillovers, the eastern firm benefits form the larger R&D level of the foreign firm. Therefore it reduces its own R&D level to free ride on the larger R&D investments of the western firm. The western firm moves second and it is hurt by the eastern firm' R&D level. Consequently, it welcomes the lower effort of the domestic firm and, in response, increases its own efforts.

The announcement game with a choice of leader-follower role is also analyzed by De Bondt and Henrique (1995). They find that a such a game has a unique equilibrium in a case where one firm absorbs large spillovers while the other, at most, is able to receive only small spillovers. The leader in this equilibrium is the firm that absorbs the large spillovers. Other asymmetries in initial costs or efficiency in R&D do not affect this outcome. Our results confirm De Bondt and Henrique finding in this respect that asymmetry in spillovers is crucial in determining a leader and a follower in the announcement game equilibrium. However, we add the additional condition that the leading firm, which produces the product of lower quality and which has high absorption rate, should face a potential increase in demand from consumers who did not purchase the product yet.

The third variation of the model assumes that the eastern firm increases the quality of its product only through imitation, without conducting any R&D. The western firm, knowing the degree of imitation, chooses the R&D level appropriately. Thus, the western firm is a leader who anticipates an increase of quality of the eastern firm. We show that in this equilibrium, the level of R&D investment of the western firm is higher compared to the level chosen in the subgame perfect Nash equilibrium in which the eastern firm is a leader. As a result, the western firm offers the higher

quality product compared to the product offered in the subgame perfect Nash equilibrium of the announcement game. Moreover, the western product is sold for higher price than in announcement game.

The welfare comparisons of the regime in which (1) the eastern firm absorbs relatively large spillovers *($\beta > 1/3$)*, and (2) some consumers with the lowest income do not purchase the good initially, show the following results. If the absorption rate is relatively small (i.e., close to 1/3), then it is more likely that the highest welfare in the eastern country is achieved in simultaneous game equilibrium; the lowest welfare occurs in the situation when the eastern firm imitates the western one. For very high absorption rate (i.e., close to 1), it is more likely that the highest welfare in the eastern country is achieved in the situation when the eastern firm achieves higher quality solely through imitation; the lowest welfare occurs in the simultaneous game equilibrium.

The obtained results show the importance of R&D investments for the eastern firms which produce the goods of the lower quality. Even if the firm is able to absorb the western technology through spillovers and imitations, and there is a room for 'free-riding', it is still crucial from the social point of view that some R&D investments should be conducted. The only case when simple imitation gives the highest welfare results in the eastern country, is the unlikely situation of very high imitation rate.

2. The Model

For the sake of simplicity, assume that there are only two countries 'East' and 'West'. There is only one firm in each country. The eastern (domestic) firm 1 sells only in domestic country 'East' and may conduct R&D. The western (foreign) firm 2 operates in both countries and is supposed to conduct R&D.

Both firm produce a good which can be characterized by different quality. The domestic firm 1 has a constant marginal cost c_1 and produces good of quality q_1. The foreign firm 2 with constant marginal costs c_2 makes a good of quality q_2. We assume that a quality of foreign product is higher then domestic one: $q_2 > q_1$.

All consumers in eastern country are uniformly distributed according to income t on the interval [$\underline{t}$, $\bar{t}$]. Every consumer purchases at most one unit of the good. If consumer with income t does not purchase the good, his utility is t. If consumer with income t purchase the good from the domestic producer for the price p_1, his utility is $q_1 + \alpha_1(t - p_1)$ where $\alpha_1 > 1$. For a consumer who buys the good made by the foreign firm for a price p_2, the utility is $q_2 + \alpha_2(t - p_2)$ where $\alpha_2 > \alpha_1$. Thus, for given qualities

q_1 and prices p_1, the consumer purchases (or not) the product in order to achieve the highest from three utilities:

$$t, \; q_1 + \alpha_1\,(t - p_1), \quad q_2 + \alpha_2(t - p_2).$$

Henceforth, to make the model tractable, we will assume that $\alpha_2 - \alpha_1 = \alpha_1 - 1 = K > 0$, and that marginal costs ci are equal to zero.

The R&D expenditures increase quality of the goods made by the firms. Thus, if firm i spends r_i on R&D then increases of qualities are:

$$q_1 \nearrow q_1 + r_1 + \beta r_2 + \beta(q_2 - q_1), \text{ and } \; q_2 \nearrow q_2 + r_2 \tag{1}$$

where $0 \le \beta \le 1$ is a level of unilateral spillover and imitation from foreign to domestic firm. We will further examine a two-stage game. In the first stage, both firms choose their R&D expenditures r_i, in the second stage the firms compete in prices p_i. We will analyze the game backward, starting from the second stage.

2.1. The Second Stage: Price Competition

As usual in location models, we will look for a "marginal consumer". Consider first the consumer with income t_1 who is indifferent between not purchasing and purchasing from domestic producer. We have

$$t_1 = q_1 + \alpha_1(t_1 - p_1) \tag{2}$$
and

$$t_1 = \frac{1}{K}\,(\alpha_1 p_1 - q_1). \tag{3}$$

Analogously, consider a consumer with income t_2 who is indifferent between purchasing between domestic and foreign product.
We have

$$q_1 + \alpha_1(t_2 - p_1) = q_2 + \alpha_2(t_2 - p_2) \tag{4}$$
and

$$t_2 = \frac{1}{K}(\alpha_2 p_2 - q_2 - \alpha_1 p_1 + q_1). \tag{5}$$

We have to distinguish two situations.

I. When $t_1 > \underline{t}$, consumers with income less than t_1 do not purchase the product at all. Profits of the firm 1 are

$$\Pi_1 = p_1 \, (t_2 - t_1). \tag{6}$$

2. For $t_1 \leq \underline{t}$, all consumers purchase the product. Profits of the firm 1 are

$$\Pi_1 = p_1 \, (t_2 - \underline{t}). \tag{7}$$

In both cases profits of the firm 2 are given by:

$$\Pi_2 = p_2 \, (\bar{t} - t_2). \tag{8}$$

First case: $t1 > \underline{t}$

Consider the first possibility, when $t_1 > \underline{t}$. The first-order conditions for Bertrand-Nash equilibrium are

$$\frac{d\Pi_1}{dp_1} = 0 \quad \text{and} \quad \frac{d\Pi_2}{dp_2} = 0. \tag{9}$$

Solving system of equations (9) we obtain the optimal values of prices:

$$p_1 = \frac{1}{7\alpha_1} \, (3q_1 - q_2 + K\bar{t}), \tag{10}$$

and

$$p_2 = \frac{1}{7\alpha_2} \, (3q_2 - 2q_1 + 4K\bar{t}). \tag{11}$$

Substituting (3), (5), (10) and (11) into the profit functions and using first-order conditions (9) we obtain:

$$\Pi_1 = \frac{2\alpha_1}{K} p_1^2 \quad \text{and} \quad \Pi_2 = \frac{\alpha_2}{K} p_2^2 \,. \tag{12}$$

Hence, in equilibrium, profits are quadratic in prices.

Second case: $t_1 \leq \underline{t}$

For $t_1 \leq \underline{t}$, first-order condition for the domestic firm is

$$\frac{d\Pi_1}{dp_1} = p_1 \frac{dt_2}{dp_1} + t_2 - \underline{t} = \frac{1}{K}(-2\alpha_1 p_1 + \alpha_2 p_2 - q_2 + q_1 - K\underline{t}) = 0. \tag{13}$$

Solving system of equations (13) and $d\Pi_2/dp_2 = 0$ we obtain

$$p_1 = \frac{1}{3\alpha_1}(q_1 - q_2 + K\bar{t} - K\underline{t}), \tag{14}$$

and

$$p_2 = \frac{1}{3\alpha_2}(q_2 - q_1 + 2K\bar{t} - K\underline{t}). \tag{15}$$

Substituting prices (14) and (15) into the profit functions we again obtain that profits are quadratic in prices:

$$\Pi_1 = \frac{\alpha_1}{K} p_1^2 \quad \text{and} \quad \Pi_2 = \frac{\alpha_2}{K} p_2^2. \tag{16}$$

The first stage: competition in R&D

We will study now the competition in R&D expenditures game. We will distinguish two possible scenarios. First, both firms are engaged in R&D and they make their strategic investment decisions independently and simultaneously. Second, both firms are engaged in R&D with the one firm as a leader and the second firm as a follower.

Simultaneous R&D competition

The levels of R&D are chosen to maximize

$$V_i = \Pi_i - \frac{\theta_i}{2} r_i^2, \tag{17}$$

where the cost of R&D to firm i is given by $\frac{\theta_i}{2} r_i^2$. The cost of R&D is assumed to be quadratic, reflecting the existence of diminishing returns to R&D expenditures. The parameter θ_i measures the degree of diminishing returns to R&D expenditures. The

higher θ_i is, the higher is the degree of diminishing returns for firm i.

First case: $t_1 > \underline{t}$

From the first-order condition $dV_1/dr_1 = 0$ we get reaction function of the eastern firm:

$$r_1 = \frac{7\alpha_1 p_1^0 + 3\beta(q_2^0 - q_1^0) + (3\beta - 1)r_2}{\Gamma_1} \, , \tag{18}$$

where p_1^0 is the initial level of prices given by (10) and q_1^0 are initial levels of qualities.

The parameter $\Gamma_1 = \dfrac{49\alpha_1 K}{12}\theta_1 - 3$ is positive by the second-order condition. The slope of the reaction function (18) is

$$\frac{dr_1}{dr_2} = \frac{3\beta - 1}{\Gamma_1} \, , \tag{19}$$

hence, the level of spillover determines whether the domestic firm 1 treats R&D expenditures as strategic substitutes or complements. For small values of β (i.e., $\beta < 1/3$) R&D expenditures are strategic substitutes in the sense that a decrease in the foreign firm R&D expenditures increases the equilibrium choice of the domestic firm (see Fig.1); for large enough values of β (i.e., $\beta > 1/3$), they are strategic complements in the sense that a decrease in the foreign firm R&D expenditures decreases the equilibrium choice of the domestic firm [4] (see Fig. 2).

Analogously, from first-order condition $dV_2/dr_2 = 0$ we obtain reaction function

$$r_2 = \frac{7\alpha_2 p_2^0 - 2r_1}{\Gamma_2} \, , \tag{20}$$

where p_2^0 is the initial level of prices given by (11) and $\Gamma_2 = \dfrac{49\alpha_2}{2K(3 - 2\beta)}\theta_2 - (3 - 2\beta)$. From second-order condition we know that Γ_2 is positive.

The slope of the reaction function (20) is

$$\frac{dr_2}{dr_1} = \frac{-2}{\Gamma_2} < 0, \tag{21}$$

thus, foreign firm 2 always treats R&D expenditure as a strategic substitute.

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[4] For a distinction between conventional substitutes and complements, and strategic substitutes and complements see Bulow, Geanakoplos, and Klemperer (1985).

Solving the system of equations (18), (20) we obtain the equilibrium levels of R&D expenditures:

$$r_1^N = \frac{7}{W_1} \left[\alpha_1 \Gamma_2 p_1^0 + \alpha_2 (1 - 3\beta) p_2^0 \right], \tag{22}$$

and

$$r_2^N = \frac{7}{W_1} \left(\alpha_2 \Gamma_1 p_2^0 - 2\alpha_1 p_1^0 \right), \tag{23}$$

where $W_1 = \Gamma_1 \Gamma_2 + 2(1 - 3\beta) > 0$ [5]. We will denote the levels of profits in this equilibrium by V_i^N.

Second case: $t_i \le \underline{t}$

From the first-order condition $dV_1/dr_1 = 0$ we get reaction function

$$r_1 = \frac{3\alpha_1 p_1^0 - (1 - \beta) r_2}{\Phi_1}, \tag{24}$$

where $\Phi_1 = \dfrac{9K\alpha_1}{2}\theta_1 - 1$ is positive by second-order condition.

Analogously, from condition $dV_2/dr_2 = 0$ we have reaction function

$$r_2 = \frac{3\alpha_2 p_2^0 - r_1}{\Phi_2}, \tag{25}$$

where $\Phi_2 = \dfrac{9K\alpha_2}{2(1 - \beta)}\theta_2 - (1 - \beta)$ is positive by second-order condition.

Note that the slopes of reaction functions (24) and (25) are negative. Hence, both firms always treat R&D expenditures as strategic substitutes.

Solving the system of equations (24)-(25) we obtain the equilibrium levels of R&D expenditures:

$$r_1^N = \frac{3}{W_2} \left[\alpha_1 \Phi_2 p_1^0 - \alpha_2 (1 - \beta) p_2^0 \right], \tag{26}$$

and

$$r_2^N = \frac{3}{W_2} \left(\alpha_2 \Phi_1 p_2^0 - \alpha_1 p_1^0 \right), \tag{27}$$

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[5] The condition $W_1 > 0$ ensures stability of equilibrium, i.e., own effects dominate cross-effects.

where $W_2 = \Phi_1\Phi_2 - (1 - \beta)$ is assumed to be positive.

As before, we will denote the levels of profits in this equilibrium by V_i^N.

Sequential R&D competition

Given the best response functions [equations (22), (23), (26) and (27)], it is possible to compute the sequential announcement equilibria with firm i leading and firm j following The leader maximizes the following:

$$V_i = \Pi_i - \frac{\theta_i}{2} r_i^2 \quad \text{subject to} \quad r_j = r_j(r_i). \quad (28)$$

We will denote the solution to the problem (28) by r_i^L, the corresponding choice for firm j is $r_j^F = r_j(r_i^L)$. The values of profits for problem (28) are denoted by V_i^L and V_j^F.

We are now able to compare the profits of the firms using graphical argumentation. The crucial factors in determining the comparison of simultaneous and sequential moves are slopes of the best response functions. In our analysis we follow Dowrick (1986), see also Gal-Or (1985). We are mostly interested in the circumstances in which both rivals benefit from sequential investment announcements:

Proposition 1. *The leader-follower announcement (with the domestic firm as a leader and the foreign firm as a follower) is mutually beneficial relative to the simultaneous Nash equilibrium (i.e., $V_1^L > V_1^N$ and $V_2^F > V_2^N$) if and only if:*

1. Some consumers do not purchase the product initially, i.e., $t_1 > \underline{t}$ and,

2. The rate of absorption for domestic firm is high enough, i.e., $\beta > 1/3$.

PROOF, see Appendix.

The interesting aspect of proposition 1 is that for existence of subgame perfect Nash equilibrium in the announcement game, it is not enough to the domestic firm have the high absorption rate. There should be also some consumers who did not purchase the good yet. Those consumers are potential clients of the domestic firm. Hence, if the domestic firm increases quality of its product or decreases price, it expands in both directions: firstly, it takes away some relatively wealthy consumers from foreign firm. Secondly it attracts some relatively poor consumers who did not purchase the product before.

Proposition 2. *The leader-follower announcement (with the foreign firm as a leader and a domestic firm as a follower) is:*

1. Always beneficial for the foreign firm relative to the simultaneous Nash equilibrium (i.e., $V_2^L > V_2^N$).

2. Always worse off for the domestic firm relative to the simultaneous Nash equilibrium (i.e., $V_1^F < V_1^N$).

PROOF, see Appendix.

Suppose that both firms announce simultaneously their desired role in the sequence (leader-follower or simultaneous) just before they commit to their R&D activities. If the firms announce the same role, they choose the simultaneous strategies. If different roles are announced, each firm implements the corresponding sequential strategy.

We can see that this announcement game has a unique subgame perfect Nash equilibrium that involves the domestic firm leading and the foreign firm following as described in proposition 1 (i.e., with $\beta > 1/3$ and $\underline{t} > \bar{t}$) . Given that the domestic firm is leading, the foreign firm, which had announced that it would be following, would not retract, since by doing so it would be made worse off (i.e., simultaneous strategy will result in lower profits for the firm). Similarly, the domestic firm, given that the foreign firm is following, cannot improve upon its leadership announcement.

In order to characterize the importance of above results, it is useful to look at some of the implication of sequential moves.

Proposition 3. *Sequential R&D investments that improve profits of both rivals (as described in Prop. 1) are such that:*

1. The western firm (a follower) invests more in R&D and charges a higher price than it would if both firms were to have chosen their R&D level simultaneously, i.e., $r_2^F > r_2^N$ and $p_2^F > p_2^N$;

2. The eastern firm (a leader) invests less in R&D than it would if both firms were to have chosen their R&D level simultaneously, i.e., $r_1^L < r_1^N$;

3. If the absorption rate is high, i.e., close to 1 then it is more likely that the eastern firm (a leader) will charge lower price than it would if both firms were to choose their R&D level simultaneously, i.e., $p_1^L < p_1^N$;

4. If the absorption rate is relatively low, i.e., close to 1/3, then it is more likely that the eastern firm (a leader) will charge higher price than it would if both firms were to choose their R&D level simultaneously, i.e., $p_1^L > p_1^N$.

PROOF, see Appendix.

The intuition behind the proposition 3 is as follows. If domestic firms absorbs sufficiently large spillovers ($\beta > 1/3$) it actually benefits from the larger R&D level of the foreign firm. Therefore it reduces its own R&D to free-ride on larger R&D investments of the foreign firm.

The foreign firm moves second and it is hurt by the domestic firm' R&D level. Consequently, it welcomes the lower effort of the domestic firm and, in response increases its own efforts.

Imitation by the Eastern Firm

Consider now situation in which the eastern firm does not conduct any R&D and increases the quality of its product only by imitating the quality produced by the western firm with the degree of imitation equal to β. In such a situation, the western firm moves first by choosing its R&D level and knowing the degree of imitation β. Hence, the western firm has a first move advantage. In the second stage of the game firms compete in prices. In what follows, we concentrate on the most interesting case in which (1) not all consumers are served, i.e., $t_l > \underline{t}$ and, (2) the absorption rate is high enough, i.e, $\beta > 1/3$.

From the first-order condition $dV_2/dr_2 = 0$ we obtain the optimal level of the R&D expenditures for the western firm:

$$r_2^I = \frac{7\alpha_2 p_2^0}{\Gamma_2}. \tag{29}$$

The comparison of the expenditure levels and prices of western product under different regimes leads to the following result.

Proposition 4. *If the western firm while choosing its R&D level knows that the eastern firm is going only to imitate, without conducting any R&D, then:*

1. The western firm invests more in R&D and charges a higher price than it would if both firms were to choose their R&D level sequentially (as described in Prop. 1), i.e., $r_2^I > r_2^F$ and $p_2^I > p_2^F$.

2. *If the absorption rate is high, i.e., close to 1 then it is more likely that the eastern firm will charge lower price than it would if both firms were to choose their R&D level sequentially (as described in Prop. 1), i.e., $p_1^I < p_1^L$.*

3. *If the absorption rate is relatively low, i.e., close to 1/3 then it is more likely that the eastern firm will charge higher price than it would if both firms were to choose their R&D level sequentially (as described in Prop. 1), i.e., $p_1^I > p_1^L$.*

We can see that the western firm enjoys the highest profits, charges the highest price and invests the most in R&D if it knows that the eastern firm will only imitate the western product. We can say that the western firm has quasi-monopolistic position in the market.

Welfare Analysis

Let us compare the change of welfare in the domestic country under the three regimes described above. The welfare in the domestic country is given by

$$W = \int_{t_1}^{t_2} (t - p_1)dt + \int_{t_2}^{\bar{t}} (t - p_2)dt + V_1 .$$

(30)

After simple manipulations we obtain from (30):

$$W = \frac{\bar{t}^2}{2} - \frac{t_1^2}{2} - \frac{\alpha_2}{K}p_2^2 - \frac{\theta_1}{2}r_1^2 .$$

(31)

When we move along the reaction function (20) from point $(0, r_2^I)$ through point (r_1^L, r_2^L) until the point (r_1^N, r_2^N) (see Fig. 2), then r_1 increases and p_2 decreases (by Prop. 3 and 4). Hence, the last two expressions in the right-hand side of (31) move in opposite directions. By Lemma 1 (see Appendix), for high value of β it is more likely that t_1 will decrease, and for low value of β (close to 1/3) it is more likely that t_1 will increase. Hence, we can say that:

Proposition 5. *The comparison of welfare levels in the eastern country when:*

1. *Some consumers do not purchase the product initially, i.e., $t_1 > \bar{t}$ and,*

2. *The rate of absorption for domestic firm is high enough, i.e., $\beta > 1/3$, shows that:*

(a) *if the value of absorption rate β is relatively high (i.e, close to 1), then it is more likely that the highest level of welfare is achieved when the eastern firm increases its quality only through imitation. In this case the lowest level of welfare is obtained if both firms choose their R&D level simultaneously. In other words:*

$$W^I > W^{LF} > W^N;$$

(b) *if the value of absorption rate β is relatively small (i.e, close to 1/3), then it is more likely that the highest level of welfare is achieved when both firms choose their R&D level simultaneously. In this case the lowest level of welfare is obtained if the eastern firm increases its quality only through imitation. In other words:*

$$W^I < W^{LF} < W^N.$$

The important conclusion from the Prop. 5 is that the lack of R&D expenditures of the eastern firm (equilibrium with imitation only) may lead to the welfare improvement compared to some degree of R&D ('leader-follower' equilibrium, or Nash equilibrium) only when the absorption rate is close to 1. This is rather unlikely situation. Therefore, from the social point of view, it is crucial for the western firm to conduct R&D investments.

3. Conclusions

We model a two-stage competition in a vertically differentiated market between the eastern and western firms in which in the first stage firm compete in R&D activities and in the second stage they compete in prices. Within the context of simple duopoly setting with quadratic payoffs and unilateral spillovers (from the western firm which produces the higher quality to the eastern firm which produces the lower quality), it appears that the intensity of spillovers and the existence of consumers who did not purchase the good, play a crucial role in determining the simultaneous or sequential nature of R&D efforts. If not all consumers purchase the good initially and the domestic firm, that is good at absorbing information out of the foreign firm leads, and the foreign firm which does no learn from the domestic firm at all follows, then no firm may have an incentive to deviate unilaterally.

We also compared the announcement game equilibrium with the equilibrium in which the eastern firm increases the quality solely through imitation. The welfare

comparisons shows that only for absorption rate close enough to 1 we can expect the welfare level in domestic country higher under 'imitation' regime than under 'leader-follower' regime. Thus, it is extremely important for the eastern firm to conduct R&D activity, even if it can imitate the western product.

It is not clear to what extent the obtained results are robust to the other specifications of the model. In general, any changes to the model that affect the signs of cross-derivatives needed to determine the slope of the reaction curves in R&D space will influence the outcome of our results.

In closing we mention some research areas that require further consideration.

The first area centres around the welfare implication of our model. It is not entirely clear which regime produces the highest social welfare level in the domestic country.

The tariff policy in eastern countries tend to protect the domestic producers from the competition of high quality and cheap foreign products. It would be interesting to examine the effects of tariffs imposed on high quality imported products on behaviour of both competitors and on the social welfare level in domestic country. In particular we may ask if there is any optimal tariff policy which maximizes the social welfare in the domestic country.

One can observe big changes of income structure in East European Countries. Generally the average level of income increases but the income inequalities become higher. In terms of our stylized model it would mean that both $\bar{t}$ and $\underline{t}$ increase, but $\bar{t}$ increases more rapidly. The impact of such a change of structure of the income on duopolists behaviour remains to be seen.

Usually the western firms who sell its products in eastern countries also operate on the western markets. This means that western markets are the principal areas of R&D competition for those firms, eastern market playing only a secondary role. We think that the concentration in R&D competition in the western markets can lead to the R&D level which is too high from the point of view of competition in the eastern market. One can ask what are the policy and welfare implications of such an over-investment in R&D in eastern market.

4. Appendix

Proof of Prop. 1–4

We prove Prop. 1–4 for the case $t_1 > \underline{t}$ and $\beta > 1/3$; for the other cases the proof is analogous (see Fig. 1 and 2).

Change of r_1

First-order condition for problem (28) (with $i = 1$) is

$$\frac{dV_1}{dr_1} - 2\frac{dV_1}{dr_2} = 0. \tag{32}$$

We have

$$\frac{dV_1}{dr_2} = \frac{4\alpha_1 p_1}{K}\frac{dp_1}{dr_2} = \frac{4p_1}{7K}(3\beta - 1).$$

Hence, for $\beta > 1/3$, we can rewrite (32) as

$$r_1 = \frac{7\alpha_1 p_1^0 + 3\beta(q_2^0 - q_1^0) + (3\beta - 1)r_2}{\Gamma_1} - A, \tag{33}$$

where A is a positive constant. We see that r_1^L is a solution of the linear system of equations (33)-(20). Note that the only difference between (18) and (33) is the constant A. Since r_1^N is a solution of linear system of equations (18)-(20), we have $r_1^L < r_1^N$.

Change of V_2

If we are moving along the reaction function (20), the differential dV_2 is equal to

$$dV_2 = \frac{\partial V_2}{\partial r_1} = \frac{2\alpha_2 p_2}{K}\frac{\partial p_2}{\partial r_1}\,dr_1 = -\frac{4p_2}{7K}\,dr_1.$$

Hence, V_2 changes in opposite direction to r_1 and $V_2^N < V_2^F < V_2^I$.

Change of p_2

From (11) we know that $\Delta p_2 = 0$ if and only if $(3 - 2\beta)r_2 - 2\beta(q_2^0 - q_1^0) - 2r_1 = 0$, i.e., if $dr_2/dr_1 = 2/(3 - 2\beta) > 0$. All the points (r_1^N, r_2^N), (r_1^L, r_2^L), $(0, r_2^I)$ lie on the

reaction function described by (20) which has negative slope equal to $-2/\Gamma_2$. Since p_2 is higher for higher values of r_2 (while keeping r_1 constant), we have $p_2^I > p_2^F > p_2^N$.

Change of p_1

From (10) we know that $\Delta p_1 = 0$ if and only if $3\beta(q_2^0 - q_1^0) + (3\beta - 1)r_2 + 3r_1 = 0$, i.e., if $dr_2/dr_1 = -3/(3\beta - 1) < 0$. The comparison of the slope of the line $\Delta p_1 = 0$ and the slope of the reaction function (20) in the space (r_1, r_2) shows that the $\Delta p_1 = 0$ line is steeper [flatter] than the reaction function (20) if and only if

$$3\Gamma_2 > [<]2 \, (3\beta - 1). \tag{34}$$

We are not able to say for which values of $\beta \in (1/3, 1)$ the inequality (34) is true. Nevertheless, it is not difficult to check that the expression $\dfrac{3\Gamma_2}{2(3\beta - 1)}$ is increasing with

an increase of β. Therefore, for high values of β (close to 1), it is more likely that the $\Delta p_1 = 0$ line is steeper than the reaction function (20), which means that $p_1^I < p_1^F < p_1^N$. Analogously, for relatively small values of β (close to 1/3), it is more likely that the $\Delta p_1 = 0$ line is flatter than the reaction function (20), which means that $p_1^I > p_1^F > p_1^N$.

Change of t_1

We will now examine the change of t_1 in different equilibria

Lemma 1. *Under the regime described in Prop. 1:*

1. If the value of the absorption rate β is relatively high, i.e., close to 1, then $t_1^I < t_1^F < t_1^N$;

2. When the value of the absorption rate β is relatively small, i.e., close to 1/3, then $t_1^I > t_1^F > t_1^N$.

PROOF

From (2) we know that $\Delta t_1 = \alpha_1 \Delta p_1 - \Delta q_1 = 0$ if and only if $dr_2/dr_1 = -4/(4\beta + 1) < 0$. The comparison of the slope of the line $\Delta t_1 = 0$ and the slope of the reaction function (20) in the space (r_1, r_2) shows that the $\Delta t_1 = 0$ line is steeper [flatter] than the reaction function (20) if and only if

$$4\Gamma_2 > [<]2\ (4\beta - 1). \tag{35}$$

We are not able to say for which values of $\beta \in (1/3, 1)$, the inequality (35) is true.

Nevertheless, it is not difficult to compute that the expression $\dfrac{4\Gamma_2}{2(4\beta - 1)}$ is increasing

with an increase of β. Therefore, for high values of β (close to 1), it is more likely that the $\Delta t_1 = 0$ line is steeper than the reaction function (20), which means that $t_1^I < t_1^F < t_1^N$. Analogously, for relatively small values of β (close to 1/3), it is more likely that the $\Delta t_1 = 0$ line is flatter than the reaction function (20), which means that $t_1^I > t_1^F > t_1^N$.

Figure 1. Reaction functions when (1) $t_1 \leq \underline{t}$ or (2) $t_1 > \underline{t}$ and $\beta < 1/3$
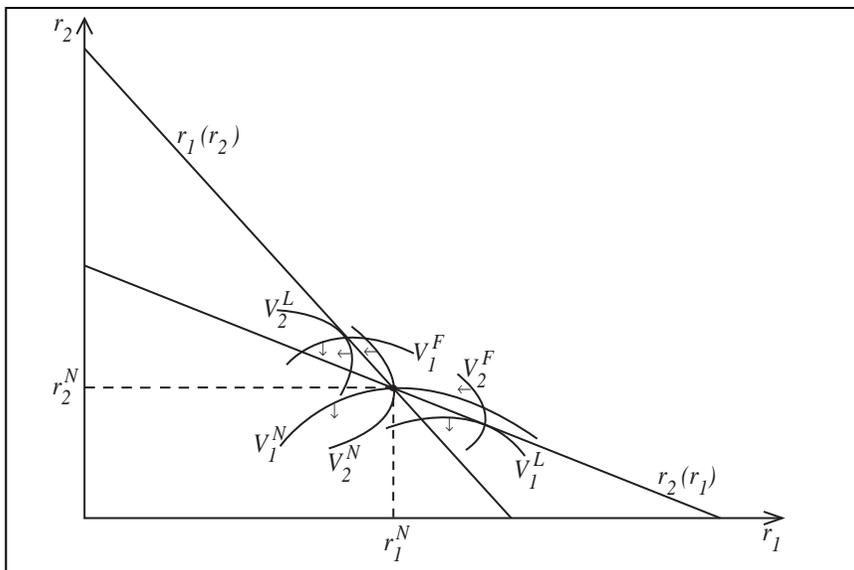
Figure 2. Reaction functions when (1) $t_1 > \underline{t}$ and $\beta > 1/3$
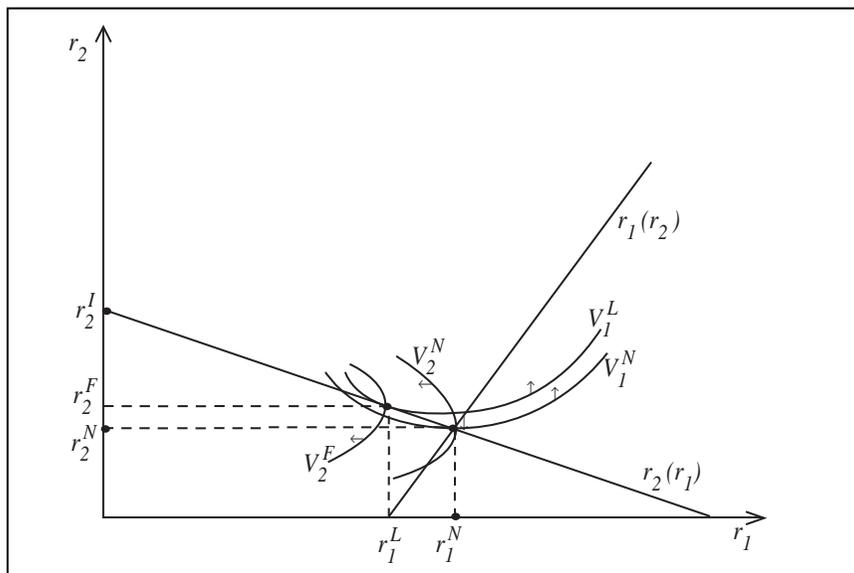
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