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UNILATERAL SPILLOVERS
AND THE NORTH-SOUTH QUALITY COMPETITION

Abstract. The important feature of competition between developed (northern) and less developed (southern) countries is vertical product differentiation where firms’ quality choices represent strategic decisions. In this paper we model a two-stage duopolistic competition in a southern country. In the first stage, firms compete in research and development, and in the second stage – in prices. There are unilateral spillovers from the firm from developed country to the firm from less developed country. The southern firm can also imitate, to some degree, the northern firm. We show that if (1) not all consumers have purchased the good initially, (2) the southern firm has a high rate of absorbing information out of the northern firm, then no firm may have an incentive to deviate unilaterally from the equilibrium in which the southern firm is the leader and the northern firm is the follower. We compare this equilibrium with the one in which only the northern firm conducts research and development; the southern firm may increase the quality of its product solely through imitation. We show that under assumptions (1) and (2) and for absorption rate close to 1, the welfare level in the southern country is higher when the southern firm imitates only compared to the welfare level in the leader-follower equilibrium.

Key words: north-south competition, product imitation, vertical product differentiation.

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 modeling research and development (R&D) competition in less developed or southern countries (later denoted by LDCs). In such countries, domestic firms often use old, inefficient technologies compared to developed methods of production. Also firms from LCDs do not have the financial resources to launch R&D. Often in industries characterized by high level of R&D (cars, electronics, drugs, etc.), LDC firms
produce goods that are of significantly lower quality than imported goods from northern, developed countries (later denoted by DCs). Typically goods produced in less developed countries are aimed at poor customers whereas goods made in developed countries 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.

There exists significant empirical evidence presenting persistent vertical product differentiation in trade between DCs and LDCs. P.D. Clark and D.I. Stanley (1999) show that intra-industry trade between developing countries and the US is characterized by different product qualities they offer in the same market. The same pattern holds (or used to hold) in the trade between Eastern European Countries and the EU. In particular, C. Aturupane et al. (1999) found that vertically differentiated intra-industry trade between the EU and Eastern Europe accounts for 80 to 90 percent of the total intra-industry trade (see also S. Van Berkum (1999) and M.E. Schaffer (1991)).

The market segmentation according to quality was developed in vertical product differentiation models of oligopoly framework developed by A. Shaked and J. Sutton (1982, 1983 and 1987). 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, DC firm and the lower quality produced by domestic, LDC 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 only LDC firms benefit through spillovers from the R&D activity carried out by the DC firm, thus we have unilateral spillovers\(^1\). The existence of unilateral spillovers stems from the initial difference in qualities. Producers from developed countries are not interested in absorbing technologies developed in less developed countries since those technologies are already considered obsolete in developed countries. On the other hand, LDC firms aim to develop a production of high quality goods to catch up with the bigger part of the market and enjoy higher profits.

\(^1\) Unilateral spillovers with cost-reducing R&D investment are analyzed by K. Zigić (1998) in the context of intellectual property rights.
In the paper we also presume that the LDC firm is able to increase the quality of its product through imitation of the developed 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

$$q_i \rightarrow q_i + \beta(q_2 - q_i) + \beta r_i + r_i,$$

for LDC firm 1 and

$$q_2 \rightarrow q_2 + r_2,$$

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

Our approach is closely related to the model presented by De J. Bondt and I. Henriques (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 Henriques 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 foreign firm as the leader who invests heavily in R&D and increases the quality of its product. In such 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 LDC firm absorbs relatively large spillovers ($\beta > \frac{1}{2}$), 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 LDC firm that produces the lower quality product. In the announcement game equilibrium the LDC firm (a leader) invests less in R&D than it would if both rivals were to have

\[2\] The competition with imitation in a vertically differentiated market was analyzed by L. 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.
chosen their R&D level simultaneously. On the other hand, the DC 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 LDC firm benefits from 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 DC firm. The DC firm moves second and it is hurt by the LDC firm’s 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 J. De Bondt and I. Henriques (1995) (see also M. Reisinger (2004) and D. Petropoulou (2007)). They find that 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 Henriques 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 LDC firm increases the quality of its product only through imitation, without conducting any R&D. The DC firm, knowing the degree of imitation, chooses the R&D level appropriately. Thus, the DC firm is a leader who anticipates an increase of quality of the LDC firm. We show that in this equilibrium, the level of R&D investment of the DC firm is higher compared to the level chosen in the subgame perfect Nash equilibrium in which the LDC firm is a leader. As a result, the DC firm offers the higher quality product compared to the product offered in the subgame perfect Nash equilibrium of the announcement game. Moreover, the product of the DC firm is sold for higher price than in announcement game.

The welfare comparisons of the regime in which (1) the LDC firm absorbs relatively large spillovers ($\beta > \frac{1}{3}$), 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 $\frac{1}{3}$), then it is more likely that the highest welfare in the LDC is achieved in simultaneous game equilibrium; the lowest welfare occurs in the situation when the LDC firm imitates the DC firm. For very high absorption rate (i.e., close to 1), it is more likely that the highest welfare in the less developed country is achieved in the situation when the LDC 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 LDC firms which produce the goods of the lower quality. Even if the firm is able to absorb the
developed 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 less developed 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: less developed country and developed country with one firm in each country. The LDC (domestic) firm 1 sells only in domestic less developed country and may conduct R&D. The DC (foreign) firm 2 operates in both countries and is supposed to conduct R&D.

Both firms 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 than domestic one: $q_2 > q_1$.

All consumers in domestic, less developed country are uniformly distributed according to income $t$ on the interval $[L, T]$. 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 $t$ purchases 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 $q_i$ and prices $p_i$, the consumer purchases (or not) the product in order to achieve the highest from three utilities:

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

Henceforth, to make the model tractable, we will assume that

$$\alpha_2 - \alpha_1 = \alpha_1 - 1 = K > 0,$$

and that marginal costs $c_i$ 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:

$$q_i \rightarrow q_i + r_i + \beta r_2 + \beta (q_2 - q_i), \quad \text{and} \quad q_i \rightarrow q_2 + r_2,$$

where $0 \leq \beta \leq 1$ 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

$$t_1 = q_1 + \alpha_1(t_1 - p_1)$$

(2)

and

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

(3)

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

$$q_i + \alpha_i(t_2 - p_i) = q_2 + \alpha_2(t_2 - p_2)$$

(4)

and

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

(5)

We have to distinguish two situations.

1. When $t_l > t$, consumers with income less than $t_l$ do not purchase the product at all. Profits of the firm 1 are

$$\Pi_1 = p_1(t_2 - t_1).$$

(6)

2. For $t_l \leq t$, all consumers purchase the product. Profits of the firm 1 are

$$\Pi_1 = p_1(t_2 - t).$$

(7)

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

$$\Pi_2 = p_2(T - t_2).$$

(8)

**First case: $t_l > t$.**

Consider the first possibility, when $t_l > t$. The first-order conditions for Bertrand-Nash equilibrium are

$$\frac{d\Pi_1}{dp_1} = 0 \quad \text{and} \quad \frac{d\Pi_2}{dp_2} = 0.$$
Solving system of equations (9) we obtain the optimal values of prices:

\[ p_1 = \frac{1}{7\alpha_1} (3q_1 - q_2 + KT), \]  

(10)

and

\[ p_2 = \frac{1}{7\alpha_2} (3q_2 - 2q_1 + 4KT). \]  

(11)

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

\[ \Pi_1 = \frac{2\alpha_1}{K} p_1^2 \quad \text{and} \quad \Pi_2 = \frac{\alpha_2}{K} p_2^2. \]  

(12)

Hence, in equilibrium, profits are quadratic in prices.

**Second case: \( t_1 \leq t \).**

For \( t_1 \leq t \), first-order condition for the domestic firm is

\[ \frac{d\Pi_i}{dp_1} = p_i \frac{dt_2}{dp_1} + t_2 - t = \frac{1}{K} \left( -2\alpha_1 p_1 + \alpha_2 p_2 - q_2 + q_1 - KT \right) = 0. \]  

(13)

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

\[ p_1 = \frac{1}{3\alpha_1} (q_1 - q_2 + KT - 2KT), \]  

(14)

and

\[ p_2 = \frac{1}{3\alpha_2} (q_2 - q_1 + 2KT - KT). \]  

(15)

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

\[ \Pi_1 = \frac{\alpha_1}{K} p_1^2 \quad \text{and} \quad \Pi_2 = \frac{\alpha_2}{K} p_2^2. \]  

(16)

**2.2. 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.
2.2.1. Simultaneous R&D competition

The levels of R&D are chosen to maximize

\[ V_i = \Pi_i - \frac{\theta_i}{2} r_i^2, \]  

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 \( \theta_i \) measures the degree of diminishing returns to R&D expenditures. The higher \( \theta_i \) is, the higher is the degree of diminishing returns for firm \( i \).

**First case: \( t_1 > t \).**

From the first-order condition \( dV_i/dr_1 = 0 \) we get reaction function of the LDC firm:

\[ r_1 = \frac{7\alpha_i p_i^0 + 3\beta (q_2^0 - q_1^0) + (3\beta - 1) r_2}{\Gamma_1}, \]  

where \( p_i^0 \) is the initial level of prices given by (10) and \( q_i^0 \) are initial levels of qualities. The parameter

\[ \Gamma_1 = \frac{49 \alpha_i K}{12} - \theta_i - 3 \]

is positive by the second-order condition.

The slope of the reaction function (18) is

\[ \frac{dr_1}{dr_2} = \frac{3 \beta - 1}{\Gamma_1}, \]  

hence, the level of spillover determines whether the domestic firm 1 treats R&D expenditures as strategic substitutes or complements. For small values of \( \beta \) (i.e., \( \beta < \frac{1}{3} \)) 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 \( \beta \) (i.e., \( \beta > \frac{1}{3} \)), 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\(^3\) (see Fig. 1).

\(^3\) For a distinction between conventional substitutes and complements, and strategic substitutes and complements see (J.I. Bulow, J. Geanakoplos, P. Klemperer (1985)).
Analogously, from first-order condition \( dV_2/dr_2 = 0 \) we obtain reaction function

\[
    r_2 = \frac{7\alpha_2 p_2^0 - 2r_1}{\Gamma_2},
\]

where \( p_2^0 \) is the initial level of prices given by (11) and

\[
    \Gamma_2 = \frac{49\alpha_2}{2K(3 - 2\beta)} \theta_2 - (3 - 2\beta).
\]

From second-order condition we know that \( \Gamma_2 \) is positive.

The slope of the reaction function (20) is

\[
    \frac{dr_2}{dr_1} = \frac{-2}{\Gamma_2} < 0,
\]

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

\[ W_1 = \Gamma_1 \Gamma_2 + 2(1 - 3\beta) > 0 \quad ^4. \]

We will denote the levels of profits in this equilibrium by \( V_i^N \).

**Second case:** \( t_1 \leq t \).

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 \( \Phi_1 = \frac{9K\alpha_1}{2} \theta_1 - 1 \) 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 \( \Phi_2 = \frac{9K\alpha_2}{2(1 - \beta)} \theta_2 - (1 - \beta) \) 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

\[^4\text{The condition } W_1 > 0 \text{ ensures stability of equilibrium, i.e., own effects dominate cross-effects.}\]
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\[ r_2^N = \frac{3}{W_2} \left( \alpha_2 \Phi_1 p_1^0 - \alpha_2 \Phi_2 p_2^0 \right), \]  
(27)

where \( W_2 = \Phi_1 \Phi_2 - (1 - \beta) \) is assumed to be positive, assuring that the equilibrium is stable.

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

2.2.2. 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:

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

We will denote the solution to the problem (28) by \( r_j^F \), the corresponding choice for firm \( j \) is

\[ r_j^F = r_j\left(r_i^L\right). \]

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 S. Dowrick (1986), see also E. 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., \( V_i^L > V_i^N \) and \( V_j^F > V_j^N \)) if and only if

1) some consumers do not purchase the product initially, i.e., \( t_i > T \) and,
2) the rate of absorption for domestic firm is high enough, i.e., \( \beta > \frac{1}{2} \).

Proof, see Appendix.

The interesting aspect of proposition 1 is that for the 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., \( V^L_2 > V^N_1 \)),
2) always worse off for the domestic firm relative to the simultaneous Nash equilibrium (i.e., \( V^F_1 < V^N_1 \)).

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 \( \beta > \frac{1}{2} \) and \( t_1 > T \)). 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 the 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 DC 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., \( r^F_2 > r^N_2 \) and \( p^F_2 > p^N_2 \);
2) the LDC 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., \( r^L_1 < r^N_1 \);
3) if the absorption rate is high, i.e., close to 1, then it is more likely that the LDC firm (a leader) will charge lower price than it would if both firms were to choose their R&D level simultaneously, i.e., \( p^L_1 < p^N_1 \);
4) if the absorption rate is relatively low, i.e., close to \( \frac{1}{2} \), then it is more likely that the LDC firm (a leader) will charge higher price than it would if both firms were to choose their R&D level simultaneously, i.e., \( p^L_1 > p^N_1 \).

Proof: see Appendix.

The intuition behind the Proposition 3 is as follows. If domestic firm absorbs sufficiently large spillovers (\( \beta > \frac{1}{2} \)) 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’s R&D level. Consequently, it welcomes the lower effort of the domestic firm and, in response, increases its own efforts.

2.3. Imitation by the firm from less developed country

Consider now situation in which the LDC firm does not conduct any R&D and increases the quality of its product only by imitating the quality produced by the DC firm with the degree of imitation equal to $\beta$. In such a situation, the DC firm moves first by choosing its R&D level and knowing the degree of imitation $\beta$. Hence, the DC 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., $t_1 > t$, and (2) the absorption rate is high enough, i.e., $\beta > \frac{1}{2}$.

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

$$ r_2^* = \frac{7\alpha_2 p_0^g}{\Gamma_2}. \quad (29) $$

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

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

1) the DC 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., $r_2^F > r_2^F$ 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 LDC 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., $p_1^1 < p_1^F$;

3) if the absorption rate is relatively low, i.e., close to $\frac{1}{2}$, then it is more likely that the LDC 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., $p_1^I > p_1^F$.

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

3. 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
After simple manipulations we obtain from (30):

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

(30)

When we move along the reaction function (20) from point \((\theta, r_2^1)\) through point \((r_1^L, r_2^F)\) 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.

$$W = \frac{T^2}{2} - \frac{t_1^2}{2} - \frac{\alpha_2}{K} p_2^2 - \frac{\theta}{2} r_1^2.$$  

(31)

By Lemma 1 (see Appendix), for high value of \(\beta\) it is more likely that \(t_1\) will decrease, and for low value of \(\beta\) (close to \(\omega\)) it is more likely that \(t_1\) will increase. Hence, we can say that

**Proposition 5.** The comparison of welfare levels in the less developed country when

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., $\beta > \frac{1}{5}$, shows that

a) if the value of absorption rate $\beta$ is relatively high (i.e., close to 1), then it is more likely that the highest level of welfare is achieved when the LDC 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 $\beta$ is relatively small (i.e., close to $\frac{1}{5}$), 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 LDC firm increases its quality only through imitation. In other words:

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

The important conclusion from Proposition 5 is that the lack of R&D expenditures of the LDC 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 DC firm to conduct R&D investments.

4. Conclusions

We model a two-stage competition in a vertically differentiated market between the LDC and DC 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 DC firm which produces the higher quality to the LDC 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 (1) not all consumers purchase the good initially, (2) the domestic firm, that is good at absorbing information out of the foreign firm is the leader, and (3) the foreign firm which does no learn from the domestic firm at all is the follower, then no firm may have an incentive to deviate unilaterally.

We also compared the announcement game equilibrium with the equilibrium in which the LDC firm increases the quality solely through imitation. The welfare comparison shows that only for absorption rate close enough to one, 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 LDC firm to conduct R&D activity, even if it can imitate the DC firm.

In closing we mention some research areas that require further consideration.
The tariff policy in less developed countries tends 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 behavior 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 assuming different type.

Recently one can observe significant changes of income structure in some less developed 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 $T$ and $t$ increase, but $T$ increases more rapidly. The impact of such a change of structure of the income on duopolists behavior remains to be seen.

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

**Literature**


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5 The trade policy in the context of vertical product differentiation competition between DCs and LDs was analyzed by E. Kovac, K. Zigić (2007) (see also M. Kunin, K. Zigić (2004)). The authors assumed different type of the utility functions as compared to our paper. Moreover, the DC firm is always a leader in the sequential game. They show that it is always optimal for the LDC country to impose a tariff for foreign product. In this case the choice of qualities may lead to the LDC firm choosing higher quality.


Appendix

Proof of Propositions 1-4.
We prove Propositions 1-4 for the case \( t_1 > t_2 \) and \( \beta > \omega_2 \); for the other cases the proof is analogous (see Figs. 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 \( \beta > \omega_2 \), we can rewrite (32) as

\[
\frac{r_1}{\Gamma_1} = \frac{7\alpha_1 p_1^0 + 3\beta (q_2^0 - q_1^0) + (3\beta - 1)r_2}{4p_1} - A,
\tag{33}
\]

where \( A \) is a positive constant. We see that \( r_1^L \) is a solution of the linear system of equations (20)-(30). 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

\[
dV_2 = \frac{\partial V_2}{\partial r_1} = \frac{2\alpha_2 p_2}{K} \frac{dp_2}{dr_1} = \frac{4p_2}{7K} dr_1.
\]

Hence, \( V_2 \) changes in opposite direction to \( r_1 \) and \( V_2^N < V_2^E < V_2^L \).

Change of \( p_2 \)
From (11) we know that \( \Delta p_1 = 0 \) 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 \((r_1^N, r_2^N), (r_1^L, r_2^L), (0, r_2^L)\) 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

\( p_2^L > p_2^E > p_2^N \).
Unilateral spillovers and the north-south quality competition

Change of $p_i$

From (10) we know that $\Delta p_i = 0$ 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 $\Delta p_i = 0$ and the slope of the reaction function (20) in the space $(r_1, r_2)$ shows that the $\Delta p_i = 0$ line is steeper [flatter] than the reaction function (20) if and only if

$$3\Gamma_2 > [-]2(3\beta - 1).$$

(34)

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

$$\frac{3\Gamma_2}{2(3\beta - 1)}$$

is increasing with an increase of $\beta$. Therefore, for high values of $\beta$ (close to 1), it is more likely that the $\Delta p_i = 0$ line is steeper than the reaction function (20), which means that $p_i^{P} < p_i^{F} < p_i^{N}$. Analogously, for relatively small values of $\beta$ (close to $\frac{1}{2}$), it is more likely that the $\Delta p_i = 0$ line is flatter than the reaction function (20), which means that $p_i^{I} > p_i^{F} > p_i^{N}$.

Change of $t_i$

We will now examine the change of $t_i$ in different equilibria.

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

1) if the value of the absorption rate $\beta$ is relatively high, i.e., close to 1, then $t_i^{I} < t_i^{P} < t_i^{N};$

2) when the value of the absorption rate $\beta$ is relatively small, i.e., close to $\frac{1}{2}$, then $t_i^{I} > t_i^{P} > t_i^{N}$.

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

$$4\Gamma_2 > [-]2(4\beta - 1).$$

(35)

We are not able to say for which values of $\beta \in (\frac{1}{2}, 1)$ the inequality (35) is true. Nevertheless, it is not difficult to compute that the expression
\[ \frac{4\Gamma_2}{2(4\beta - 1)} \]

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