

Economics
Discussion Paper Series
EDP-1414

R&D Spillovers on a Salop Circle

Fabio Lamantia

Mario Pezzino

August 2014

Economics
School of Social Sciences
The University of Manchester
Manchester M13 9PL

R&D spillovers on a Salop circle

Fabio Lamantia*

Department of Economics, Statistics and Finance
University of Calabria (Italy)
fabio.lamantia@unical.it

Mario Pezzino

School of Social Sciences
University of Manchester
mario.pezzino@manchester.ac.uk

Abstract

The paper describes quality/price equilibrium and welfare effects of R&D spillovers when firms are located around the circumference of a Salop (1979) circle and the extent of the spillover may depend on the geographic proximity between firms. In particular, in contrast to previous related contributions that studied the relationship between spatial competition and quality provision, we show that an increase in competition (i.e. additional entry on the circle) may have a positive effect on the provision of quality and firms' profits. We also extend the model allowing a multinational enterprise, MNE, to locate at the centre of the circle. In this scenario it is important to understand the interplay of local R&D spillovers with spillovers that propagate from and to the centre.

Keywords: Endogenous spillovers; Quality-enhancing R&D; Salop Circle

JEL classification: L13; D43; R10; O30

1 Introduction

We study a model that provides insights to markets where firms' entry/location decisions may affect the extent of R&D spillovers and may define the way competition affects consumers and efficiency. For example AstraZeneca, a pharmaceutical giant historically based in the North West of England, has recently announced¹ plans of a £330m investment to relocate global headquarters to Cambridge. The choice has been motivated by the intention of exploiting the

*Corresponding author. Tel.: +39-0984-492253; fax: +39-0984-492421.

¹See <http://www.bbc.co.uk/news/uk-england-21833207>.

existence of a *bioscience hotspot* in Cambridge². It is not clear however what the effects of the relocation will be in terms of the quality of the innovation process, study of new compounds and social welfare.

The paper contributes to two strands of literature; one that studies relationship between quality provision and competition, and one that studies the effects of the existence of R&D spillovers in international markets where multinational enterprises, MNEs, decide to decentralize their R&D activities.

The first question (related to the first strand of literature) that we try to answer is whether an increase in firms' density and competition has a positive effect on the provision of quality and in turn social welfare in the presence of R&D spillovers increasing in the geographic proximity among firms. The economic literature offers already a number of contributions³ that consider spatial competition in prices and quality. Two papers in particular are closely related to ours.

Assuming linear utility functions and cost separability between quality and output Economides (1993) shows that an increase in the number of firms competing on a Salop circle has a negative effect of quality provision. Intuitively an increase in the number of competitors has a negative effect on demands and prices and in turn on quality provision. Interestingly Brekke et al. (2010) extended Economides (1993) framework to include income effects (i.e. the possibility that consumers' utility may be concave in the numeraire good) and cost substitutability between output and quality production. The authors show that with a sufficiently high degree of cost substitutability in production an increase in the number of firms would lower individual firms' demands (this is standard) but, for a sufficient degree of cost substitutability, this translates into lower costs for quality and therefore higher investments⁴.

In our paper we provide another argument in favour of a positive relationship between competition and quality provision. In the presence of R&D spillovers that depend on firms' geographic proximity, quality may increase with spatial competition even if income effects in utility and cost substitutability in production were not assumed.

Specifically in this paper we study the effects that R&D spillovers may have on an oligopolistic market represented by a Salop (1979) circle. The model is a natural extension of the Hotelling (1929) duopoly described in Piga and

²The company will locate in a biomedical campus and will share facilities with other industry key players, including academic research centres, clinics and other commercial organisations such as GlaxoSmithKline (the largest pharmaceutical company in UK). This means that the two largest producers in UK will share the same location. See <http://cambridge-biomedical.com/about-the-campus-2/occupiers/>

³See for example Ma and Burgess (1993) and Gravelle (1999). In both papers transportation costs are a measure of competition and a negative relationship is found between quality and competition. Lower transportation costs produce lower prices and in turn lower investments in quality. Other contributions (with a particular focus on the provision of secondary health care) consider quality investments in models of spatial competition with regulated prices. Quality is the only competitive instrument in the hands of firms and not surprisingly a positive relationship between competition and quality is found. See for example Calem and Rizzo (1995), Brekke et al. (2006), (2007).

⁴The result is further strengthened if decreasing marginal utility of income is assumed.

Poyago-Theotoky (2005), PPT from now on, where R&D spillovers (of the nature described in Kamien et al. (1992)) are favoured by geographic proximity.

In our model the profitability of firms and consequently their strategic conduct in terms of R&D investments and prices strongly depend on the number of firms active in the market and the extent of the spillover. The additional entry of a competitor has standard effects, such as an increase of the competitive pressure in the market (connected to the well-known business stealing effect), a positive effect on consumer surplus due to the average reduction in transportation costs and a negative effect on quality investments (as reported in Economides (1993)). However our model introduces another effect of entry, i.e. the increase in the degree of R&D spillovers due to the increase in proximity and the consequent effects on average quality. We show that an increase in competitive pressure (measured by the number of firms on the circle) has a negative effect on individual R&D investments. However, for sufficiently strong density-dependent spillovers, entry may translate into an increase in the aggregate quality effectively provided to consumers. These two results (i.e. lower individual investments and higher quality experienced by consumers) produce that interesting result that profits may increase if competition increases. We also show that the equilibrium R&D investment of firms may be socially insufficient.

The second question that we try to answer is related to the literature that studies the geographic dispersion of MNEs in the presence of R&D spillovers. In many industries (think for example of global players in software and broadcasting industries such as Microsoft and Sky) local firms face competition from a global competitor. While the local firms tend to be horizontally differentiated in the eyes of consumers (in the sense that consumers tend to have preferred brands), a global competitor owns a brand that all consumers may value in the same way. In other words the product/service of the global firm, even if it may be vertically superior to the local alternatives, it is not a neighboring competitor in the product space to any particular local firm, but to all firms simultaneously. We allow a firm to locate at the centre of the circle and simultaneously compete against all other firms located on the circumference. This scenario would describe the effects that a global competitor would produce on an oligopolistic market with R&D spillovers.

Our model contributes to the growing literature that, moving in part away from traditional motives of MNEs' decentralization such as demand (better knowing the preferences of local customers) and supply (better employ local skills) oriented reasons, sees in geographic dispersion a source of knowledge for MNEs. In other words, choosing to decentralize R&D to subsidiaries, MNEs can acquire knowledge from local competitors thanks to existence of R&D spillovers. Of course, spillovers may play in both directions (from and to the local firms), effectively playing an important role in the definition of MNEs' boundaries (see Petit and Sanna-Randaccio (2000) and Sanna-Randaccio and Veugelers (2007)) and their internationalization strategies (e.g. the choice between exports, FDI and licensing) (see Ethier and Markusen (1996), Siotis (1999) and Fosfuri (2000)). The contributions in this literature often consider a two-country two-firm models, under a non-address approach framework. The model that we

present in this paper contributes to this literature in three ways. First we employ the address approach, where each firm on the circle competes directly with only two neighbouring firms. Second, thanks to symmetry provided by the Salop (1979) set up, we can study oligopolistic competition between one MNE firm and n local firms, that compete strategically in R&D and prices for the local market. Finally, we consider the realistic possibility of the existence of local R&D spillovers, i.e. knowledge leakage between (neighbouring) local competitors on the circle and we study how such spillovers may affect the relationship between competition and quality provision. We show that in the extended scenario with a MNE competition can again have a positive effect on quality, both at the centre and on the circumference and, eventually, on social welfare.

The remainder of the paper is organized as follows. In section two we describe the basic model and derive the equilibrium when firms located on a Salop circle experience R&D spillovers produced by the investments of the neighboring competitors. In section three we extend the model allowing a firm to locate at the centre of the circle. Section four concludes.

2 The model

The market is represented by a circle of length equal to one. A unit mass of consumers demanding inelastically one unit of a homogeneous good is uniformly distributed around the circumference of the circle, along which $n \geq 3$ identical firms are symmetrically located. The utility of a generic consumer buying from firm $i \in \{1, 2, \dots, n\}$ is given by

$$U_i(x) = v + Q_i - p_i - tx \quad (1)$$

where $v > 0$ is consumers' reservation price (assumed to be sufficiently large to guarantee full market coverage in equilibrium); Q_i is a measure of the quality of good i , which coincides with firm's i total innovation technology (specified below); p_i is the price of good i ; $t > 0$ is the transportation cost parameter and $x \geq 0$ represents the distance between the consumer and firm i 's location.

The profits of the generic firm i are:

$$\Pi_i = p_i D_i - \gamma \frac{q_i^2}{2} \quad (2)$$

where D_i is the demand of firm i , q_i represents the investment in R&D of firm i and γ is a measure of the firm's inefficiency to innovate. Firm i 's demand is:

$$D_i = \frac{1}{n} + \left(\frac{2(Q_i - p_i) - (Q_{i-1} - p_{i-1}) - (Q_{i+1} - p_{i+1})}{2t} \right) \quad (3)$$

where subscripts $i - 1$ and $i + 1$ are assigned to values, respectively, of the counterclockwise and clockwise neighbor of firm i .⁵

⁵As customary in these models, demand D_i is obtained by summing the demand in the arc between firms $i - 1$ and i with the demand in the arc between i and $i + 1$. For instance

The innovation technology to firm i , inclusive of the spillover externalities, is given by:

$$Q_i = q_i + \beta g(n) (q_{i-1} + q_{i+1}) \quad (4)$$

where $\beta \in [0, 1]$ represents the R&D spillover parameter and the sequence of positive real numbers $g(n)$ models how R&D spillovers fade with the distance between firms. It is natural to assume that $g(n)$ is increasing in n (i.e. the lower the distance, the higher the spillover⁶), with $\sup g(n) = 1$. We are considering the simple case in which the innovative effort of a firm is reinforced by the R&D investments of the neighboring firms. Thus, the extent of the spillovers depends on the β parameter (related for example to the particular market and product provided) and (similar to PPT) to the distance between two neighboring firms.

The entry of an additional firm in the market reduces the distance between firms and creates two effects. On one hand, it increases the competitive pressure (it is easier for consumers to switch to another provider) in the market and, on the other, increases the extent of R&D spillovers.

Let us assume that firms target own profit maximization and choose simultaneously and non-cooperatively R&D investments and prices. Let us restrict our attention to the parameter subset $S \equiv \{(t, \gamma, n, \beta) \in \mathbb{R}^4 \text{ s.t. } 2t\gamma > 4(1 - g(n)\beta)\}$. Parameters belonging to S ensure that Second Order Conditions for profit maximization and non-undercutting condition (i.e. no firm will find profitable to increase R&D investment and lower price to the point of undercutting the neighboring rivals) are satisfied.

The unique symmetric ($p_i = p^*$, $q_i = q^*$, $i \in \{1, 2, \dots, n\}$) equilibrium is:

$$\begin{aligned} q^* &= \frac{1 - \beta g(n)}{n\gamma} \\ p^* &= \frac{t}{n} \end{aligned} \quad (5)$$

with innovation technology to each firm $Q = \frac{1 + \beta g(n)[1 - 2\beta g(n)]}{n\gamma}$.

In equilibrium profits are given by:

$$\begin{aligned} \Pi &= \frac{p}{n} - \gamma \frac{q^2}{2} \\ &= \frac{t}{n^2} - \frac{(1 - \beta g(n))^2}{2n^2\gamma} \end{aligned}$$

the latter is obtained by considering the utility of a consumer who is indifferent between buying from firm i or firm $i + 1$. This consumer is located at \bar{x}_{i+1} , which solves the equation $v + Q_i - p_i - t\bar{x}_{i+1} = v + Q_{i+1} - p_{i+1} - t(\frac{1}{n} - \bar{x}_{i+1})$. Therefore \bar{x}_{i+1} , (firm's i demand from the "left" side) is given by $\bar{x}_{i+1} = \frac{1}{2n} + \left(\frac{(Q_i - p_i) - (Q_{i+1} - p_{i+1})}{2t} \right)$.

⁶ A simple particular specification might be for example $g(n) = (1 - \frac{1}{n})$.

Social welfare is given by the sum of producers' surplus ($n\Pi$) and consumers' surplus⁷ ($2n \int_0^{1/2n} (v - p + Q - tx)dx$).

$$\begin{aligned} W &= n\Pi + 2n \int_0^{1/2n} (v - p + Q - tx)dx = \\ &= v + Q - \frac{t}{4n} - n\gamma \frac{q^2}{2} = \\ &= v - \frac{t}{4n} + \frac{(1 - \beta g(n))(1 + 5\beta g(n))}{2n\gamma} \end{aligned}$$

Propositions 1-3 provide our first set of results.

Proposition 1 *In equilibrium an increase in n has a negative effect on prices and individual firm R&D investment, q (i.e. $\frac{dq}{dn} < 0$). Effective quality perceived by consumers may however increase (i.e. $\frac{dQ}{dn} > 0$ if $g' > \frac{(1-\beta g(n))^2}{\beta(1-4\beta g(n))}$). The effect of an increase in n on welfare depends on the sign and strength of $\frac{dQ}{dn}$. In particular $\frac{dW}{dn} > 0$ if $t\gamma > (8 - 10\beta g(n)) + \beta(g(n) - ng')$. Finally, profits may increase in n (i.e. $\frac{d\Pi}{dn} > 0$) if $t\gamma < \frac{(1-\beta g(n))^2 + n\beta g'(1-\beta g(n))}{2}$.*

If an additional firm enters the market, prices and market shares decrease (*business stealing effect*). The increase in n has however an additional effect compared to the standard Salop model without R&D: since firms are more closely located, the extent of R&D spillovers increases. This has a negative effect on firms' willingness to invest in R&D, i.e. q decreases and, if the extent of the spillover strongly increases with n (high g'), interestingly in aggregate this may also translate into higher profits (due to lower costs) and an increase of the aggregate quality perceived by consumers. The effect of an increase in n on welfare is ambiguous. Additional entry has both a (double) positive effect on welfare (i.e. it decreases aggregate transportation costs and, due to R&D spillovers, firms spend less in innovation) and a potentially negative effect (i.e. lower quality provided to consumers). Consequently the nature of the spillover propagation plays a key role. If the spillover effect is sufficiently large to ensure that aggregate quality does not decrease and the increase in proximity has a sufficiently strong effect on the spillover ($g'(n)$ sufficiently large), competition may have a positive effect on welfare, especially if firms are inefficient, i.e. high γ .

Without the existence of income effects or cost substitutability in quality and quantity, we have shown that standard results in previous literature can be reversed if the strength of R&D spillovers depends on firms' density in the market.

⁷In the symmetric equilibrium firms share equally the market, each firm covers a $\frac{1}{n}$ portion of the circle. The endpoints of the interval of integration represent half (say the portion of the right side) the market share of a generic firm, for example the one located at 0.

Proposition 2 *In equilibrium an increase in t has no effect on quality, a positive effect on prices and profits and a negative effect on welfare.*

The fact that more competitive pressure represented by a decrease in transportation cost t may have a negative effect on prices and profits is clearly not surprising and in line with the findings in Economides (1993).

Proposition 3 *In equilibrium an increase in the spillover parameter β has a positive effect on profits and a negative effect on q and Q . When spillovers are small, an increase in spillovers may have a positive effect on social welfare (that is $\frac{dW}{d\beta} > 0$ if $\beta g(n) < 2/5$).*

If β increases, firms have a lower incentive to invest in R&D and the savings in costs have a positive effect on profits. These savings of course translate into lower quality for consumers and eventually, for sufficiently high spillovers, into lower social welfare.

3 Spillovers from a global competitor

In this section we consider competition between a MNE (i.e. a brand that all consumers may value in the same way) and horizontally differentiated local firms. The product/service of the MNE, even if it may be vertically superior to the local alternatives, it is not a neighboring competitor in the product space to any particular local firm, but to *all* local firms simultaneously.

A way to introduce this type of global Vs local competition in the Salop framework is to assume that the global competitor, say firm c , locates at the centre⁸ of the circle and all consumers have to incur the same (regardless of their location on the circle) transportation cost $\delta \geq 0$ to buy from c . We want to study how the decision of a MNE to enter a market with a subsidiary able to exploit knowledge spillovers due to proximity with local competitors may affect competition and quality provision. Indeed in such a scenario R&D spillovers do not propagate only among local firms (as we discussed in Section 2), but may also originate from the MNE to spread equally to the local competitors; in addition, entering the local market, the MNE may absorb in part the knowledge of the local competitors.

Suppose that the R&D spillovers propagate in the following way:

$$Q_i = q_i + \beta_1 \left(1 - \frac{1}{n}\right) + \beta_2 q_c \quad (6)$$

$$Q_c = q_c + \beta_3 \sum_{i=1}^n q_i \quad (7)$$

⁸Madden and Pezzino (2011) study the Salop model with competition from the centre. Their focus however is the study of firms' long run entry decisions and the social desirability of global competition. Our objective here is instead to consider R&D competition and the effects of spillovers in a Salop model with centre.

where Q_i is the quality of firm i , q_i is the individual investment in R&D of firm i , $i = 1, \dots, n$, q_c is the R&D investment of the central firm. $\beta_1, \beta_2, \beta_3 \in (0, 1)$ are the R&D spillover parameters. β_1 is the parameter that describes spillovers among local firms. Similar to the analysis of Section 2, we assume that local spillovers also depend on the proximity of firms according to the expression⁹ $(1 - \frac{1}{n})$. β_2 and β_3 are the parameters that represent respectively the R&D spillover from the centre to the periphery and vice versa. The way spillovers propagate in (6) seems natural for many markets. When a MNE enters a market with a subsidiary, all local firms are in direct competition for consumers with the global firm. This competitive interaction between the local firms and the MNE may be a source of the R&D spillovers described in (6). The MNE can exploit knowledge spillovers from the local firms, that in turn experience local R&D spillovers with the neighboring competitors. At the same time, however, since the MNE has entered the local market, the local firms can also take advantage of knowledge leaks from the MNE¹⁰. To simplify the analysis and make the model tractable we assume that $t = 1$ and $\beta_2, \beta_3 \in \{0, \beta_1\}$.¹¹

Consumers located further away from two neighboring firms on the circle may consider to buy from the central firm. If all the $n + 1$ firms have a positive market share, then the demands are given by

$$\begin{aligned} D_c &= 1 - 2nx \\ D_i &= 2x \end{aligned} \tag{8}$$

where $x = \frac{p_c - p_i + Q_i - Q_c + \delta}{t}$ is the location of the marginal consumer indifferent to buy from firm i on the circumference or firm c . In what follows we shall restrict our attention to parameter subset¹² that allow both types of firms to be active in equilibrium¹³, i.e. $x \in (0, \frac{1}{2n})$, equilibrium prices, quantities and profits are strictly positive and no firm has the incentive to deviate undercutting the rivals.

The profit function of the local firms is still given by (2). The central firm targets the maximization of¹⁴:

⁹The extension of the model that we are describing here is significantly more complex compared to the case without a central firm. Choosing to focus on the case $(1 - \frac{1}{n})$ ensures tractability, unfortunately at the expense of generality.

¹⁰Of course, the MNE may also have the option to keep R&D activities in the HQ. However in this paper we are considering the case in which competitive interaction (and proximity) are the two key ingredients that allow technological spillovers, for example, due to reverse engineering or imitation. In this sense, simply exporting to the foreign country the MNE may not able to avoid spillovers to local firms (i.e. $\beta_2 > 0$).

¹¹In our framework β_1 can be interpreted as the degree of patent protection in a particular country.

¹²In the Appendix we describe in detail the conditions that produce the parameter space.

¹³See Madden and Pezzino (2011) for the description of scenarios where the condition is not satisfied.

¹⁴The fact that the MNE and the local firms access the same technology, i.e. the same quality-dependent cost function, simplifies the analysis and allows us to focus our attention to the role played by R&D spillovers in equilibrium.

$$\Pi_c = p_c D_c - \frac{q_c^2}{2} \quad (9)$$

Similar to the case considered in Section 2, let us consider the game in which the $n + 1$ firms simultaneously set their investments in R&D and choose prices. The equilibrium with R&D decentralization is:

$$q^{**} = \frac{(-1 + \beta_3)(t + 2n(-(-1 + \beta_2)^2 + \delta))}{n(2 - 3t - 2\beta_3 + 2n((-1 + \beta_2)^2 - \beta_3 + \beta_3^2)) - 4(-1 + n)(-1 + \beta_3)\beta_1}$$

$$q_c^{**} = \frac{2(1 - \beta_2)(2(-1 + \beta_3)\beta_1 - n(t + (-1 + \beta_3)(1 + 2\beta_1)) + n^2((-1 + \beta_3)\beta_3 + \delta))}{2n(2 - 3t - 2\beta_3 + 2n((-1 + \beta_2)^2 - \beta_3 + \beta_3^2)) - 8(-1 + n)(-1 + \beta_3)\beta_1} \quad (10a)$$

$$p^{**} = \frac{-t(t + 2n(-(-1 + \beta_2)^2 + \delta))}{2n(2 - 3t - 2\beta_3 + 2n((-1 + \beta_2)^2 - \beta_3 + \beta_3^2)) - 8(-1 + n)(-1 + \beta_3)\beta_1}$$

$$p_c^{**} = \frac{t(2(-1 + \beta_3)\beta_1 - n(t + (-1 + \beta_3)(1 + 2\beta_1)) + n^2((-1 + \beta_3)\beta_3 + \delta))}{n[n(2 - 3t - 2\beta_3 + 2n((-1 + \beta_2)^2 - \beta_3 + \beta_3^2)) - 4(-1 + n)(-1 + \beta_3)\beta_1]} \quad (10b)$$

where $q_i = q^{**}$, $p_i = p^{**}$, $i = 1, \dots, n$.

Before providing the main results of this section, let us define the social welfare function and a measure of the average quality in the market. The welfare function with an active central firm in a symmetric equilibrium is given by the sum of producers' surplus ($n(pD - \frac{q^2}{2}) + p_c D_c - \frac{q_c^2}{2}$) and consumers' surplus of those who buy from the local firms ($2n \int_0^{D/2} (v + Q - p - tx) dx$) and those who buy from the central firm ($D_c \times (v + Q_c - p_c - \delta)$):

$$W = v + (Q_c - \delta) D_c + Q n D - n \frac{q^2}{2} - \frac{q_c^2}{2} - t n \left(\frac{D}{2} \right)^2$$

where $D_i = D$, $i = 1, \dots, n$, and $D_c = 1 - n D$ are firms' market shares in equilibrium. Average quality is given by

$$AQ = Q n D + Q_c D_c$$

Proposition 4 - 6 describe the effect of an increase in competition.

Proposition 4 *In equilibrium an increase in n has always a negative effect on the individual investment in R&D of the local firms, $\frac{dq^{**}}{dn} < 0$. The effect on MNE's investment and all qualities is ambiguous, $\frac{dq_c^{**}}{dn} \leq 0$, $\frac{dQ^{**}}{dn} \leq 0$, $\frac{dQ_c^{**}}{dn} \leq 0$.*

Proposition 5 *In equilibrium an increase in n has a negative effect on the profits of all firms in the market.*

Proposition 6 *An increase in n has an ambiguous effect on social welfare.*

The decision of the MNE to enter the market effectively creates two additional sources of knowledge spillovers. Fiercer competition induces local firms to reduce their investment in R&D (this is standard and intuitive), but the local spillovers may be enough to ensure that in aggregate quality provided by the local firms may increase. In contrast to the case reported in Proposition 1, the reduction in quality-dependent costs is not enough now to guarantee an increase in the profits of the local firms. Due to an increase in n , the MNE faces lower quality investments from local firms. However, thanks to the existence of spillovers, even if firms may decide to invest less in R&D, quality in equilibrium may increase, reducing profitability for all firms. In aggregate the effect of an increase in competition may be positive. Consumer surplus may increase (due to higher qualities) and more than offset the decrease in profits, with positive effects on welfare.

Proposition 7 *In equilibrium an increase in the local spillover parameter β_1 has a negative effect on the individual investment of all firms in the market. The quality and profits of the local firms increase with β_1 , whereas the quality and profits of the MNE decrease. Welfare effects are ambiguous.*

Proposition 8 *In equilibrium an increase in β_2 has a positive (negative) effect on the quality investment of the local (MNE) firms. The quality of local firms may increase, but the quality of MNE decreases, and so does average quality in the market. Profits of the local firms increase, but the effect of MNE's profits is ambiguous. In aggregate the negative effect on quality prevails and welfare decreases with β_2 . The effect of an increase in β_3 are mostly ambiguous and depend on the specific values of the parameters.*

Similar to the results in Proposition 3, an increase in the local R&D spillover parameter¹⁵ has a negative effect on local firms' investment in quality that, saving in costs, may earn higher profits. Nonetheless, in contrast to the results reported in Section 2, now local quality *increases*. Not surprisingly, an increase in β_1 puts the local firms at a competitive advantage and, *ceteris paribus*, the MNE reacts lowering quality and earning lower profits. The increase in β_1 has an ambiguous effect on welfare. In particular, since the reduction in central investment in quality may have a negative effect on average quality. The decrease in average quality (accompanied by lower profits for MNE) may have in turn a negative effect on welfare. Interestingly, if the ability of the local firms to extract knowledge from the MNE increases (i.e. higher β_2), the local economy tends to be worse off. Local firms, clearly, are better off, but at the same time consumers are provided with lower quality and in aggregate social welfare decreases. This result seems to produce a very important caveat to a standard line of reasoning in favour of globalization and competition from multinational enterprises. Even if local firms indeed gain from global competition, it is essential to understand whether the whole economy (and in particular consumers) can benefit from competition from a global competitor.

¹⁵Notice that we are calculating the effects on the equilibrium expressions of an increase in β_1 , evaluated at $\beta_1 = \beta_2 = \beta_3 = \beta$.

Proposition 9 *In equilibrium an increase in δ has a positive (negative) effect on the individual investment of the local (central) firms. The profits of the local firms increase with δ , whereas the quality and profits of the MNE decrease. The effects on the quality of the local firms and social welfare are respectively ambiguous and negative.*

Parameter δ is a measure of the mismatch between consumers' preferences and the characteristics of the good provided by the MNE. It can be interpreted also as local consumers' attitude towards a multinational, global brand. For a given $t > 0$, δ can be interpreted also as measure of vertical differentiation between global and local brands. In particular notice that if $\delta \rightarrow 0$, then the MNE is producing a vertically superior good compared to the local alternatives. An increase in δ clearly puts the MNE at a competitive disadvantage. It is not surprising then that local firms react to an increase in δ increasing quality investments and earn higher profits. The MNE instead reacts lowering quality investments. The aggregate effect on quality provided by local firms is however ambiguous and it depends on the interplay between local and global spillovers. Average quality and social welfare decrease unambiguously with δ . An interesting consequence of this result is that some campaigns against multinational brands¹⁶ may produce negative effects for consumers (i.e. lower quality) and local welfare.

The propositions above describe how the profits of the MNE change with the parameters of the model. If the MNE is entering the market incurring, as it would be realistic, fixed costs (e.g. setting up factories and labs, hiring new staff, security, etc.) it is then worth to investigate what factors may favor entry of a global firm. We have seen that a more competitive market is a less profitable environment for the MNE, in particular if local firms are able to exploit spillovers among each other (higher β_1 together with higher proximity). Not surprisingly, a market where consumers experience a significant mismatch with the MNE's product, i.e. high δ , is less profitable for the MNE.

4 Conclusions

We studied quality/price competition in an oligopolistic market represented by a Salop circle with R&D spillovers. In particular we considered the existence of spillovers that depend on the density of firms active in the market. We showed that an increase in the degree of competition (i.e. an increase in the number of firms) may have ambiguous effects in the terms of quality provided and social welfare. The existence and particular nature of R&D spillovers, increasing in the number of firms active in a market, play an important role in the way firms react

¹⁶Consider for example the recent "You must confess" campaign in China. See <http://www.forbes.com/sites/gordonchang/2013/08/25/you-must-confess-chinas-red-campaign-against-multinationals/>

Recently Microsoft and Apple are also under scrutiny in China due to allegations of the products being a threat to privacy and national security. See <http://www.bbc.com/news/technology-28292378>

to an increase in competition. Interestingly, it may be possible that an increase in competition can indeed produce an increase in quality provided (in contrast to Economides (1993)), profits (in contrast to standard economic intuition) and welfare (in contrast to the standard Salop (1979) model).

In addition we extended the model in order to study the role played by R&D spillovers in a market where a MNE competes with n local firms. We showed that the positive relationship between competition and quality survives also in this scenario, even if firms are not better off now if competition becomes fiercer. Whether a MNE may find profitable to enter a market where R&D spillovers are possible depends on the degree of local competition. In particular, we observed that a more competitive market may prevent a MNE to enter the local market.

The model provides interesting paths for further research. It would be worthwhile to study the out-of-equilibrium adjustment of price/quality choice over time, both under full best reply and gradient-like dynamics (see for example Bischi and Naimzada (2000) and Bischi and Lamantia (2002)). In addition, it would be interesting to study the endogenous formation of R&D networks, for example allowing firms on the circle to create connections (i.e. joint ventures) with competitors other than the neighbors.

Acknowledgements. *The authors are grateful to Francesca Sanna-Randaccio and Vitor Ribeiro and the participants to the 2014 Oligo Workshop, Rome, for helpful comments on a previous version of the paper. The authors gratefully acknowledge support from ISCH COST Action IS1104. Mario Pezzino is also grateful for support from NIHR support from grant RMOFS 2012/07 and ICER (<http://www.icer.it>).*

References

Gian Italo Bischi and Fabio Lamantia. "Nonlinear Duopoly Games with Positive Cost Externalities due to Spillover Effects", *Chaos, Solitons & Fractals*, 13, 805-822, 2002.

Gian Italo Bischi and Ahmad Naimzada. "Global Analysis of a Duopoly Game with Bounded Rationality", ed. Filar J.A. et al., 2000.

Kurt R. Brekke, Robert Nuscheler, and Odd Rune Straume. "Quality and location choices under price regulation.", *Journal of Economics & Management Strategy*, 15(1), 207–227, 2006.

Kurt R. Brekke, Robert Nuscheler, and Odd Rune Straume. "Gatekeeping in health care.", *Journal of Health Economics*, 26(1), 149–170, 2007.

Kurt R. Brekke, Luigi Siciliani, and Odd Rune Straume. "Price and quality in spatial competition.", *Regional Science and Urban Economics*, 40(6), 471–480, 2010.

Paul S. Calem and John A. Rizzo. "Competition and specialization in the hospital industry: An application of Hotelling's location model", *Southern Economic Journal*, 61(4), 1182–1198, 1995.

Nicholas Economides. "Quality variations in the circular model of variety-differentiated products", *Regional Science and Urban Economics*, 23(2), 235–257, 1993.

- Wilfred J. Ethier and James R. Markusen. "Multinational firms, technology diffusion and trade", *Journal of International Economics*, 41(1-2), 1-28, 1996.
- Andrea Fosfuri. "Patent protection, imitation and mode of technology transfer", *International Journal of Industrial Organization*, 18(7), 1129-1149, 2000.
- Hugh Gravelle. "Capitation contracts: access and quality", *Journal of Health Economics*, 18(3), 315-340, 1999.
- Harold Hotelling. "Stability in competition" *The Economic Journal*, 39:41-57, 1929.
- Morton I Kamien, Eitan Muller, and Israel Zang. "Research joint ventures and R&D cartels", *American Economic Review*, 82(5), 1293-306, 1992.
- Ching to Ma and James Burgess. "Quality competition, welfare, and regulation", *Journal of Economics*, 58(2), 153-173, 1993.
- Paul Madden and Mario Pezzino . "Oligopoly on a Salop circle with centre", *The B.E. Journal of Economic Analysis & Policy*, 11(1), 1-30, 2011.
- Maria-Luisa Petit and Francesca Sanna-Randaccio. "Endogenous R&D and foreign direct investment in international oligopolies", *International Journal of Industrial Organization*, 18(2), 339-367, 2000.
- Claudio Piga and Joanna Poyago-Theotoky. "Endogenous R&D spillovers and locational choice", *Regional Science and Urban Economics*, 35(2), 127-139, 2005.
- Steven C. Salop. "Monopolistic competition with outside goods", *Bell Journal of Economics*, 10(1), 141-156, 1979.
- Francesca Sanna-Randaccio and Reinhilde Veugelers. "Multinational knowledge spillovers with decentralised R&D: a game-theoretic approach", *Journal of International Business Studies*, 38(1), 47-63, 2007.
- Georges Siotis. "Foreign Direct Investment Strategies and Firms' Capabilities", *Journal of Economics & Management Strategy*, 8(2), 251-270, 1999.

Appendix

In this Appendix we briefly describe the subset of parameters that ensures the sufficient conditions for the existence of the equilibrium described in Section 3 are met.

The second order conditions, Socs, for the simultaneous maximization of the profits of the local and central firms are:

$$t > (1 - \beta_2)^2$$

for the local firms and

$$\frac{t}{n} > (1 - \beta_3)^2$$

for the MNE.

In order to produce an equilibrium as described in Section 3 where all $n + 1$ firms serve a strictly positive portion of the market, we need that (i) the location of the marginal consumer, $x = \frac{p_c - p_i + Q_i - Q_c + \delta}{t}$, to be $x \in (0, 1/2n)$ in equilibrium and (ii) the NASH requirements that no firm has the incentive to offer a quality so high (or price so low) to undercut the rivals. A sufficient

condition to ensure that no local firm find feasible to undercut the rivals is to assume that there is a technological limit to the individual quality that a local firm can provide. Let us assume that the quality of a local firm is $q_i \in [0, \bar{q}]$. Let us assume in addition that

$$\bar{q} \leq \hat{q} \equiv \frac{1}{1 - \beta_2} \left[t \left(\frac{1}{n} - x \right) + (1 - \beta_3) q_c + q (\beta_2 (n - 1) - 2\beta_1) - p_c - \delta \right]$$

evaluated at $p = p^{**}, q = q^{**}, p = p_c^{**}, q = q_c^{**}$. \hat{q} is the lowest (we are imposing $p_i = 0$) level of quality investment that a generic local firm i , $i = 1, \dots, n$, has to incur in order to undercut the MNE and compete directly, Salop (1979)'s style, with the neighboring local rivals. Of course, if firm i wanted to consider deviation undercutting the local rivals, then it would have to provide a level of investment higher than \hat{q} . We are assuming that this will not be possible. The subset of parameters that guarantees the satisfactions of the Socs, non-negative prices, profits and quality investments and $x \in (0, 1/2n)$ in equilibrium is

$$\begin{aligned} S &\equiv \{t, \beta_1, \beta_2, \beta_3, \delta, n\} \\ \text{such that } t &= 1; \beta_2 = \beta_3 = \beta_1 \\ &\text{and} \\ (1 - \beta_1)^2 - \frac{1}{2n} &< \delta < \frac{1}{2n} + n - 2\beta_1 + \beta_1^2 + \frac{n - 2 - 3n^2 + 2(1 + n)\beta_1}{3n + 4(1 - \beta_1)\beta_1} \\ n &< \frac{1}{(1 - \beta_1)^2} \\ &\text{and either} \\ n &> \frac{1}{2(1 - \beta_1)^2} \text{ and } 1 > \beta_1 > 1 - \frac{1}{\sqrt{6}} \\ &\text{or} \\ n &> 3 \text{ and } 1 - \frac{1}{\sqrt{3}} > \beta_1 \geq 1 - \frac{1}{\sqrt{6}} \\ &\text{or} \\ \frac{1}{2(1 - \beta_1)^2} &\geq n > 3 \text{ and } 1 - \frac{1}{\sqrt{3}} > \beta_1 \geq 1 - \frac{1}{\sqrt{6}} \end{aligned}$$

If parameters belong to S , then $\bar{q} > q^{**}$. In addition it can be shown that the MNE finds unprofitable to deviate and offer a quality so high to monopolize the whole market.