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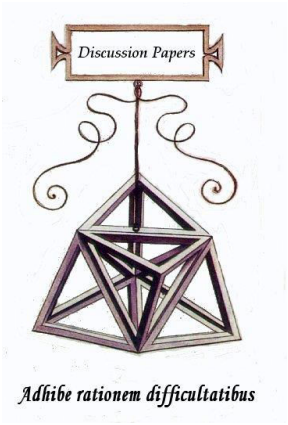

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R&D subsidies in a duopoly market with outsourcing to the rival firm

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Discussion Paper
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R&D subsidies in a duopoly market with outsourcing to the rival firm

Abstract

This paper investigates the effects of a public R&D subsidy policy in a duopoly market of a firm outsourcing input supplies (VS) from its downstream integrated rival (VI). It is shown that a policy setting a R&D subsidy uniform for both downstream competitors has in this market structure relevant effects largely differentiated between competitors. This is because it may significantly modify the relative market shares and profitability of the competing firms. In particular the ultimate effect is to determine R&D investments relatively larger in the VI firm and to shift market shares in favour of the VI firms, with the possible consequence even of a transfer of profits from the VS to the VI firm. Therefore, these findings offer some testable implications and suggest that a subsidy policy in a market with outsourcing to a rival should take also into account of its differential effects on the "competitors".

Keywords: outsourcing, R&D, subsidy policy

JEL: D43, L13, L21

1. Introduction

The study of vertical industries has become increasingly popular over the last decade. Among the various structures which may characterised the vertical relationship, the structure in which the production of key inputs is outsourced to external suppliers is widespread in the modern economy. A relevant case of outsourcing involving many important industries is that in which outsourcing involves retail competitors: for instance, the presence in a duopoly market of a firm outsourcing input supplies from its downstream integrated rival. Such a type of outsourcing characterizes for instance industries such as telecommunications, energy and transportations, where the crucial input represented by access to the network infrastructure is provided by a vertically integrated incumbent to retail competitors (e.g. Bourreau et al., 2011). Popular examples in Italy may be the landline industry (with Telecom as input supplier to the retail competitor such as Wind and Vodafone) and the rail transport industry (with Trenitalia as input supplier[1]- indirectly through RFI, being Trenitalia and RFI subsidiaries of the Ferrovie dello Stato Italiane holding - to the retail competitor, NTV). Therefore, it is natural to observe that this type of outsourcing is particularly present in highly innovative industries. Indeed, they significantly invest in R&D activities to enhance their organisational arrangements and introduce new processes in order to lowering their costs. Theoretical models dealing with a duopoly market with outsourcing to the rival firm have been developed, among others, by Kamien et al. (1989), Spiegel (1993), Baake et al. (1999), Shy and Stenbacka (2003), Van Long (2005), Arya et al. (2008), and Fanti and Scrimitore (2019), where the first five works focus on the effects of nonlinear cost structures while the latter two focus on the strategic decision between price and quantity. Therefore, all of them abstract from the issue of R&D investments as well as R&D subsidies. As to the latter point, we note that in the real world, policies supporting R&D investments are high in the political agenda and R&D subsidies have often been crucial in promoting many technology discoveries (e.g. biotechnology). Facing the increasing importance of sectors, such as those above mentioned, with highly innovative activities, the issue to design an effective technology policy for such sectors through old and new tools is becoming more and more relevant (e.g. Hart 1998).

This paper aims to fill this gap by extending the above mentioned models with R&D investments and, since none of these papers has investigated the potential role of public policy towards R&D, developing a positive analysis of the effects of R&D

[1] However, for the sake of realism, we note that the price for the access to the railway infrastructures paid by NTV (and formally also by Trenitalia) to RFI is regulated by the Transport Authority and is passed in the year 2014 from 13 euro/Km to 8.7 euro/km for each train. However, anectodical evidence shows that also RFI may affect the input price through indirect practices as the following: at the Rimini railway station RFI delayed the renovation of platforms to prevent the arrivals of NTV trains and thus NTV offered 5oo.ooo euros to make the renovation. Therefore, the assumption of a monopolistic choice of the input price by the vertically integrated firm amounts, loosely speaking, to implicitly assume, in a regulated industry, a full (resp. zero) "political" power of such a firm (resp. outsourcing firm).

subsidies on the duopoly market with outsourcing to a rival. Indeed, so far some papers have analyzed the effectiveness of public policy aimed to stimulate business-performed R&D in many different contexts, such as Hinloopen (1997; 2000; 2001) who focuses on the cases of cooperative and non-cooperative R&D with spillover effects, Haaland and Kind (2006) who concentrate on a Economic Union, Liao (2007) who focuses on an international market, Gil-Molto et al. (2010) who deal with a mixed (public/private) market and Michalsen (2012) who concentrates on a vertically related market. However none of them consider the market structure with outsourcing to retail competitors.

We develop a simple model, drawing, essentially, from Arya et al. (2008) and Fanti and Scrimitore (2019), to illustrate formally in a simple and intuitive way within the context of a standard benchmark model the effectiveness of public policy of R&D subsidies. The present paper is, at the best of our knowledge, the first attempt to investigate such a policy in a widespread typology of vertical industry and thus is different from each of these contributions above mentioned in terms its specific objectives, analysis and results. From a broader perspective, our paper belongs to the tradition of public economics dealing with markets and taxation. The paper may also be viewed as a contribution to the wide literature on the role of the public intervention in the Industrial Organization literature.

The remainder of the paper is organised as follows. In Section 2, we present a description of the model and its solution. In Section 3, we analyse its implications as to the R&D subsidy policy. Concluding remarks are contained in Section 4.

2. The model

The market demand in the case of a homogeneous product is given by

$$p(q_i, q_j) = 1 - q_j - q_i \qquad (1).$$

where, as usual, p denotes the product price and q_i and q_j the quantity produced by firm i and j, respectively. Following the baseline model of duopoly competition by Arya et al. (2008), firm 1 is a vertically integrated producer (VI) which is the sole producer of an input that is essential for retail production. This means that firm 2 buys the input by firm 1 (i.e. a vertical separated firm, VS). The latter charges its retail rival firm the unit price z for the input. As usual in the literature on vertical relationships it is assumed that one unit of input is embodied in each unit of output (i.e. perfect vertical complementarity).

Moreover, both firms conduct process R&D that reduces their marginal production cost by an amount x_i, $0 < x_i \leq c_i$, $i=1,2$. We assume[2] that such an activity is perfectly protected against imitation and its cost is given by $x_i = x_i^2$, which entails diminishing

[2] Such assumptions strictly follow D'Aspremont and Jacquemin (1988), which early introduced cost-reducing R&D investments in the basic Cournot duopoly model.

returns to the level of R&D expenditure. Further, firms receive a subsidy to R&D investments, sx_i, where s is the per-unit subsidy.
The profits of firms 1 and 2 when firm i produces retail output q_i, the retail price is p, the input price is z and costs to produce retail output are c_1 and c_2 respectively, are given by:

$$\pi_1 = zq_2 + (1 - q_i - q_j)q_i - (c_1 - x_1)q_1 - x_1^2 + sx_1 \quad (2)$$

$$\pi_2 = (1 - q_1 - q_2)q_2 - (c_2 - x_2)q_2 - x_2^2 + sx_2 - zq_2 \quad (3).$$

Firm 1's profit is given by, as shown to the right of the equality in Eq. (2): 1) a first term representing firm 1's profit from selling the input to firm 2; 2) a second term capturing firm 1's revenue from its retail sales, 3) a third term which is given by its downstream production cost (c_1) net of the reduction due to the R&D investment, x_1, 4) the quadratic cost of R&D, and 5) the R&D subsidy. Firm 2's profit in Eq. (3) derives from its retail sales, its input cost (z), the incremental downstream production cost (c_2) net of the reduction due to the R&D investment, x_2, the quadratic cost of R&D and the R&D subsidy. We assume $c_1 > c_2$, that is the VI firm 1 is less efficient than the rival VS firm 2.[3]
We develop a three-stage game. The timing of the game is as follows. At the first stage, firms choose R&D levels. At the second stage, firm 1 sets the input price it will charge to firm 2. Finally, at the third stage, under Cournot competition, firms 1 and 2 choose their retail output levels simultaneously and independently. This timing implies that the setting of price input is a choice of a shorter period than that of R&D investment.[4] Solving the game by backward induction, standard calculations lead to the following equilibrium outcomes:

$$x_1 = 0.49 - 0.95c_1 + 0.46c_2 + 0.74s \quad (4)$$

$$x_2 = -0.09 + 0.37c_1 - 0.28c_2 + 0.45s \quad (5)$$

$$q_1 = 0.86 - 1.44c_1 + 0.58c_2 + 0.43s \quad (6)$$

$$q_2 = -0.23 + 0.93c_1 - 0.7c_2 - 0.12s \quad (7)$$

$$z = 0.51 - 0.05c_1 - 0.46c_2 + 0.26s \quad (8)$$

$$\pi_1 = 0.35s^2 + (0.38 - 0.53c_1 + 0.15c_2)s + 0.45c_2^2 + (0.3 - 1.19c_1)c_2 + 0.38 - 1.06c_1 + 1.13c_1^2 \quad (9)$$

$$\pi_2 = 0.26s^2 + (0.04 - 0.18c_1 + 0.14c_2)s + 0.41c_2^2 + (0.27 - 1.09c_1)c_2 + 0.04 - 0.36c_1 + 0.73c_1^2 \quad (10).$$

[3] This may be coherent with the idea that the VI firm is the "established" firm, while the VS firm - buying inputs by the "established" firm - is the "younger" firm. In fact, the theory of regulation of entry is usual to assume that the "young" firm has lower costs. By contrast, Arya et al. (2008) assumed $c_1 \leq c_2$; however, this assumption, a part from the problem of its realism, strongly works for a foreclosure of the firm 2 and, in the case of homogeneous product, which is postulated in this paper, we would have only a monopolistic market because the firm 2 would always have to close.
[4] However, although maybe less realistic, in principle also reversed stages (i.e. the length of input price contracts is higher (for instance two years) than the length of the validity of a choice of a R&D subsidy rate (for instance, on yearly basis according to which the Budget Law) may be assumed. This analysis is left for future research.

3. The analysis of a R&D subsidy policy.

There are two stringent conditions regarding the satisfaction of 1) the non-negativity of q_2, such that the non-foreclosure condition ensuring that the duopoly structure is always preserved; and 2) the non-negativity of retail costs after their reduction due to the R&D investments as regards the firm 2, that is, $(c_2 - x_2) \geq 0$. Formally, these conditions are enunciated in the following Lemmas.

Lemma 1. $q_2 \geq 0 \Leftrightarrow c_2 \leq c_{2,1} = -0.07 + 0.29c_1 + 0.35s$.

Lemma 2. $(c_2 - x_2) \geq 0 \Leftrightarrow c_2 \geq c_{2,2} = -0.33 + 1.33c_1 - 0.17s$.

In a nutshell, these conditions require that the marginal production cost of the firm 2, c_2 , is, for a given c_1, neither too high nor too low, that is, it is included in the interval $c_{2,1} \leq c_2 \leq c_{2,2}$. Note that we can see, from the expressions for $c_{2,1}$ and $c_{2,2}$, that the R&D subsidy works for reducing such an interval, and thus also the region of existence of a feasible duopolistic market, favouring the appearance of a monopoly of the VI firm. Preliminarily, we recall the standard results of the basic duopoly model (i.e. without outsourcing) extended with R&D (D'Aspremont and Jacquemin, 1988) in the following remark.

Remark: The R&D subsidy increases R&D investments, output and profits of both firms.

When outsourcing to the rival is introduced, the role played by the R&D subsidy on the R&D investments, output and profits becomes richer than in the D'Aspremont and Jacquemin (1988)'s context, strongly modifying the common wisdom, as shown below.

Lemma 3: The input price is increased by the subsidy rate and reduced by both costs increases.

Proof: $\frac{\partial z}{\partial s} > 0, \frac{\partial z}{\partial c_1} < 0, \frac{\partial z}{\partial c_2} < 0$.

Result 1. The introduction of a R&D subsidy always reduces the firm 2's output.

Proof: $\frac{\partial q_2}{\partial s} < 0$.

Result 2. Profits of the vertical separated firm 2 are reduced by the introduction of a R&D subsidy, and this reductive effect persists until such a subsidy reaches a sufficiently high level, beyond which firm 2's profits becomes increasing with an increasing subsidy (i.e. a U-shaped relationship between firm' 2 profits and R&D

subsidy). Moreover, in any case the positive effects on firm 2's profits is always lower than that on firm 1's profits.

Proof: $\frac{\partial \pi_2}{\partial s} \underset{<}{\overset{>}{-}} 0 \quad \Leftrightarrow s \underset{<}{\overset{>}{-}} s^{\circ} = -0.09 + 0.35c_1 - 0.26c_2$, and $\frac{\partial \pi_1}{\partial s} > \left|\frac{\partial \pi_2}{\partial s}\right|$.

Result 3. When in the absence of the R&D subsidy the R&D investments of the firm 2 are larger than those of the firm 1 (which occurs when the differential cost between the two firms is sufficiently high), if the subsidy sufficiently increases, then this difference may be reversed (and, in any case, an increasing subsidy always increases the R&D investment of firm 1 more than that of firm 2).

Proof: $(x_1 - x_2) \underset{<}{\overset{>}{-}} 0 \quad \Leftrightarrow s \underset{<}{\overset{>}{-}} s^{\circ\circ} = -2 + 4.56c_1 - 2.56c_2$, and $\frac{\partial x_1}{\partial s} > \frac{\partial x_2}{\partial s}$.

Result 4. When in the absence of the R&D subsidy the quantity of the firm 2 is larger than that of the firm 1 (which occurs when the differential cost between the two firms is sufficiently high), if the subsidy sufficiently increases, then this difference may be reversed (and, in any case, an increasing subsidy always increases the quantity of firm 1 while decreases that of firm 2)[5].

Proof: $(q_1 - q_2) \underset{<}{\overset{>}{-}} 0 \quad \Leftrightarrow s \underset{<}{\overset{>}{-}} s^{\circ\circ\circ} = -2 + 4.34c_1 - 2.34c_2$.

Then, it is clear how the R&D subsidy policy affects the relative market shares of firms and their relative profitability: it always transfers market shares from firm 2 to the firm 1 and, at least for sufficiently low levels of subsidy, firm 1's profit increases

[5] Note that, however, the total industry quantity is always increasing with an increasing subsidy (i.e $\frac{\partial q_1}{\partial s} > \left|\frac{\partial q_2}{\partial s}\right|$) and thus the consumer surplus is always enhanced, as expected, by a R&D subsidy policy.

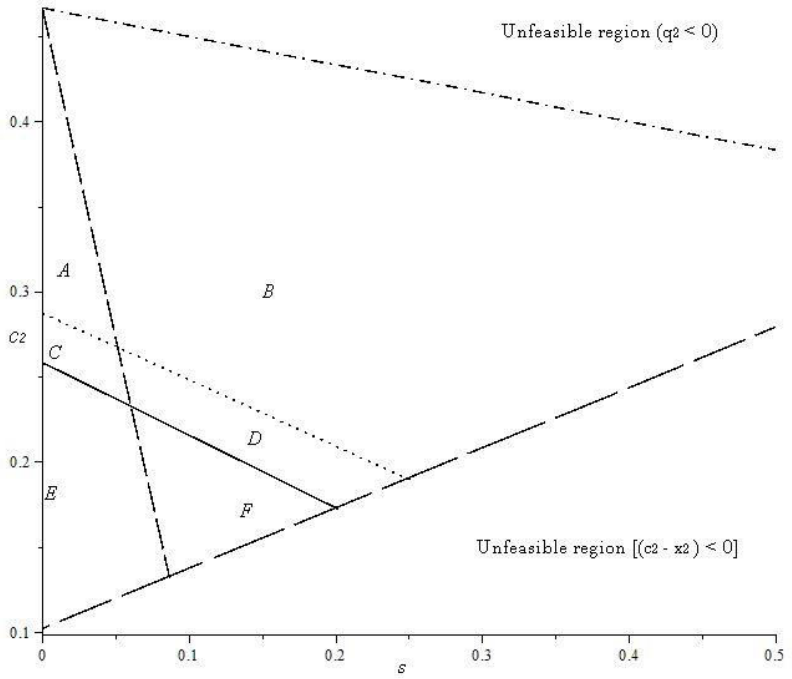

Fig. 1. Curves representing 1) $\frac{\partial \pi_2}{\partial s} = 0$ (dashed line), 2) $(c_2 - x_2) = 0$ (long-dashed line), 3) $(q_2 - q_1) = 0$ (solid line), 4) $(x_2 - x_1) = 0$ (dotted line), 5) $q_2 = 0$ (dashed-dotted line); (c_1=*0.6*).

Legend: the following inequalities hold in these regions: in region A, $\frac{\partial \pi_2}{\partial s} < 0, q_1 > q_2, x_1 > x_2$; in region B, $\frac{\partial \pi_2}{\partial s} > 0, q_1 > q_2, x_1 > x_2$; in region C, $\frac{\partial \pi_2}{\partial s} < 0, q_1 > q_2, x_1 < x_2$; in region D, $\frac{\partial \pi_2}{\partial s} > 0, q_1 > q_2, x_1 < x_2$; in region E, $\frac{\partial \pi_2}{\partial s} < 0, q_1 < q_2, x_1 < x_2$; in region F, $\frac{\partial \pi_2}{\partial s} > 0, q_1 < q_2, x_1 < x_2$.

to the detriment of the firm 2's profit.[6] Figure 1, drawn for a given value of c_1=*0.6*, quantitatively assesses the content of the Results. It is easy to see that the introduction of the subsidy and its increase up to a value of *s=0.30* is able to trigger all the effects enunciated in Results above.

The intuition of these findings is as follows. The presence of a subsidy allows for a higher input price and, through this channel, it reduces the firm 2's quantity. On the other hand, the subsidy also allows for a larger R&D investment of firm 2 with the consequent cost-reduction effect. These counterbalancing forces on quantities and profits originated by the subsidy are ultimately responsible for 1) the non-monotonicity of firm 2's profits with respect to the subsidy; and 2) more in general, a positive effect of the subsidy on the firm 2's profits less than that on the firm'1 profits.

4. Conclusions

[6] By using the Italian rail transport sector for illustrative purposes, we may observe that a R&D subsidy policy would always expand the market share of Trenitalia to detriment of that of Ntv - of course, broadly speaking and under the extreme assumptions of full political power of FS on the decision on the regulated input price and a relatively higher cost-efficiency of Ntv.

In this paper we have studied the effects of a public R&D subsidy policy in a duopoly market of a firm outsourcing input supplies (VS) from its downstream integrated rival (VI), which is a widespread vertical market structure. The main finding of the paper is that, although a uniform subsidy rate with respect to the competing firms is set, a R&D subsidy policy has relevant effects in the presence of outsourcing to the rival, which are different between "competitors". Then, such a policy influences the market structure, in the sense that it may strongly modify the relative market shares and profitability of the competing firms. In particular, the ultimate effect is to determine R&D investments relatively larger in the VI firm and to shift market shares in favour of the VI firms, with the possible consequence even of a transfer of profits from the VS to the VI firm.[7] Therefore, these findings offer some testable implications, and suggest that a subsidy policy in a market with outsourcing to a rival should take also into account of its differential effects on the "competitors".

This paper opens up a number of issues of further research. For example, it may be considered a cooperative R&D choice by rival firms or a creation of a research joint venture between them and a more rich tax/subsidy system[8] with a welfare-maximising Government[9].

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[7] For instance, always referring to the broadly illustrative metaphor of the Italian rail industry, the introduction of a subsidy for promoting the innovation in the retail services uniform for both competitors would have the effects of 1) to promote cost-reducing innovation more in Trenitalia than in Ntv; 2) to increase Trenitalia' profits and reduce Ntv's profits; and 3) to shift market shares towards Trenitalia to the detriment of Ntv.

[8] For instance it would be possible to differentiate the subsidy rates between the VI and the VS firms or introduce a usual tax/subsidy rate on quantities in addition to the R&D subsidy.

[9] Preliminary results with a social welfare maximising Government and a R&D subsidy financed, in the usual simple way, by a lump-sum tax on consumers show that a positive optimal (second-best) R&D subsidy rate always does exist and also the paper's findings are qualitatively confirmed.

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