



R&D versus output subsidies in mixed markets[☆]

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ABSTRACT

We analyse the relative welfare effects of an R&D and an output subsidy in a mixed duopoly. We show that an R&D subsidy is beneficial for society as a whole, and socially superior to an output subsidy, when spillovers are sufficiently high. Otherwise, an output subsidy is socially superior.

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1. Introduction

Public firms are present in several industries such as banking and insurance, gasoline distribution, radio, television, automobile and steel, health-care and energy (Anderson et al., 1997). As recognised by White (1996), among others, in mixed markets – where public firms coexist with private ones – there are two production-related inefficiencies: the output level is sub-optimal, and the distribution of production costs across firms is not efficient. To address these two market failures, the use of output subsidies has been proposed, and the so-called “irrelevance result” has been generated (White, 1996; Pal and White, 1998; Poyago-Theotoky, 2001). This is an important finding suggesting that privatisation does not alter welfare, as long as the regulator can subsidise output.¹

Though plentiful, the mixed market literature often ignores that public firms are key players in R&D-intensive industries such as health-care, energy and bio-agriculture (e.g. Godø et al., 2003). As well as empirically relevant, the study of R&D activity in mixed markets is becoming increasingly popular from a theoretical perspective (e.g. see Poyago-Theotoky, 1998; Ishibashi and Matsumura, 2006; Tomaru, 2007; Heywood and Ye, 2009; Cato, 2011). Only Gil-Moltó et al. (2011), however, investigate the role of R&D subsidies as a policy instrument in a mixed duopoly with cost-reducing R&D.² In that context, the authors suggest that “an R&D subsidy may partly serve the same purpose as an output subsidy” (p. 235), since an R&D subsidy can tackle inefficiencies related to output in addition to the ones regarding R&D. This is an interesting finding but it also raises the question of whether the two subsidy schemes imply the same (or similar) welfare effects.

In this paper, we show that an R&D subsidy is socially superior to an output subsidy only in specific circumstances: when technological spillovers are sufficiently high. The reason for this finding is as follows. When spillovers are high, the gains from an R&D subsidy are relatively large. This is because each firm receives a beneficial cost spillover from its rival. Thus, the cost savings under an

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¹ Fjell and Heywood (2004) provide related work showing that the irrelevance result breaks down, if the public firm acts as a Stackelberg leader after privatisation.

² Investments in cost-cutting are particularly important in the health-care and energy sectors (Gil-Moltó et al., 2011).

R&D subsidy, which are substantial, can compensate for the wasteful cost asymmetry associated with the public firm's higher output relative to the private firm. If, however, spillovers are low, then an output subsidy is socially superior to an R&D subsidy. This result indicates that there may be a welfare-related reason to favour one subsidy scheme over the other.

2. Model

Our model follows Gil-Moltó et al. (2011) though we depart from this study by considering the role of output subsidies and compare them with R&D subsidies.

Consider a simple market setting consisting of a public and a private firm denoted by the subscripts 0 and 1, respectively. We assume that firms face identical costs functions and marginal costs are increasing.³ Moreover, firms invest in R&D to look for process innovations. As well as its own R&D, a firm can benefit from its competitor's R&D via spillovers of intensity δ , with $\delta \in [0, 1]$. Firm i 's cost function is given by

$$C_i(q_i, x_i, x_j) = (\bar{c} - x_i - \delta x_j)q_i + q_i^2, \quad i \neq j, i, j \in \{0, 1\}, \quad (1)$$

where $X_i \equiv x_i + \delta x_j$ is firm i 's 'effective' R&D level, which represents the total reduction in firm i 's marginal cost due to R&D. The cost of investment is quadratic, reflecting diminishing returns to R&D expenditure: $\Gamma(x_i) = \gamma x_i^2$, $\gamma \geq 1$. For simplicity, we normalise γ to 1, which ensures nonnegativity of all equilibrium variables.⁴ If s_x is the R&D subsidy rate, then each firm receives $S_x(x_i) = s_x x_i$,⁵ while $S_q(q_i) = s_q q_i$, if s_q is the output subsidy rate. Assume that the inverse demand function is $p = a - Q$, where p is price and Q is total output. Each firm's profit is

$$\pi_i = p(Q)q_i - C_i(q_i, x_i, x_j) - \Gamma(x_i) + S_k(k_i), \quad i \neq j, i, j \in \{0, 1\}, k = x, q. \quad (2)$$

The private firm maximises profit, while the public firm maximises social welfare defined as the sum of consumer surplus (CS) and producer surplus (PS) net of subsidies (S)

$$SW = \underbrace{\frac{Q^2}{2}}_{CS} + \underbrace{(\pi_i + \pi_j)}_{PS} - \underbrace{s_k(k_i + k_j)}_S. \quad (3)$$

Note that subsidies cancel out when aggregating. The timing in the model is as follows. In stage one, the regulator commits to the level of an R&D or output subsidy so as to maximise welfare. In stage two, firms choose simultaneously their R&D investments. In stage three, firms compete in the product market by setting quantities. The game is solved by backward induction to obtain its subgame-perfect equilibrium.

3. Result

To understand the social optimality of each form of subsidy, we need to consider the increase in social welfare brought about by each subsidy. The change in social welfare can be split into three components: $\Delta SW_k = \Delta CS_k + \Delta PS_k - \Delta S_k$, $k = x, q$. To fix ideas, consider first the change in CS due to an R&D subsidy. This is given by

$$\Delta CS_x = CS|_{s=s_x} - CS|_{s=0} \quad (4)$$

where $CS|_{s=s_x}$ denotes CS under the (optimal) R&D subsidy; and $CS|_{s=0}$ denotes CS when no subsidy is provided. Using the subgame-perfect equilibrium solutions in Appendix, it is no surprise that $\Delta CS_x > 0$: the use of an optimal R&D subsidy increases CS. Similarly, we observe that CS rises under an optimal output subsidy: i.e. $\Delta CS_q = CS|_{s=s_q} - CS|_{s=0} > 0$.

An R&D subsidy yields greater CS than an output subsidy if

$$\begin{aligned} \Delta CS_x - \Delta CS_q &> 0 \\ CS|_{s=s_x} - CS|_{s=s_q} &> 0 \\ \delta &> \delta_{cs} \end{aligned} \quad (5)$$

where $\delta_{cs} \approx 0.83$. Condition (5) suggests that, on CS grounds, the use of an R&D subsidy outperforms an output subsidy, but only if spillovers are sufficiently high. The intuition is as follows. In the absence of subsidies, results are consistent with Gil-Moltó et al. (2011): the public firm produces more output than the private firm; also, even though the public firm undertakes more R&D, it still operates at a higher marginal cost than the private firm. Thus, the distribution of production costs across firms is not efficient. As noted by White (1996), using an output subsidy, *ceteris paribus*, has the effect of redistributing output from the higher-marginal-cost public firm to the lower-marginal-cost private firm. The resulting increase in the private firm's output works toward lowering total industry costs. The lower industry costs tend to increase total output, which *ceteris paribus* increases CS. Importantly, when δ is low, the total cost savings under an R&D subsidy are small relative to an output subsidy. This is because each firm receives only a limited beneficial cost spillover from its rival; therefore, the cost savings under an R&D subsidy which are small cannot offset the excess costs associated with asymmetric outputs. As δ rises, however, the level of total effective R&D increases. The resulting (overall) cost savings under an R&D subsidy become relatively large: they can now offset the excess costs associated with asymmetric outputs. As a result, an R&D subsidy becomes better than an output subsidy in terms of CS when spillovers are sufficiently high, as condition (5) suggests.⁶

We can conduct a similar analysis for PS. Once again, we confirm that PS rises both with an R&D and an output subsidy. In line with CS, we find that the increases in PS are more pronounced under an R&D subsidy, if spillovers are sufficiently high

$$\begin{aligned} \Delta PS_x - \Delta PS_q &> 0 \\ PS|_{s=s_x} - PS|_{s=s_q} &> 0 \\ \delta &> \delta_{ps} \end{aligned} \quad (6)$$

where $\delta_{ps} \approx 0.87$. This outcome can be explained by considering the two components of PS, the public and the private firm's profit. Using the subgame-perfect equilibrium solutions in Gil-Moltó et al. (2011) and Appendix, it is fairly straightforward to show that the private firm's profit is always higher under an output subsidy than under an R&D subsidy: i.e. $\pi_1|_{s=s_q} > \pi_1|_{s=s_x}$. Intuitively, the private firm cares only about its own profit. Thus, an output subsidy which redistributes output from the public to the private firm, implies that the private firm enjoys an increase in its market share. The public firm, on the contrary, maximises welfare rather than its own profit. This means that the public firm internalises the positive effect of the R&D subsidy both on private profit and consumer surplus. Therefore, the public firm undertakes more R&D than its

³ The assumption of diminishing returns to scale used by other authors rules out the case where the public firm prices at marginal cost and, thus, drives the private firm out of the market.

⁴ We discuss the implications of relaxing this assumption at the end.

⁵ We have checked that the main result (Proposition 1) is robust to the provision of subsidies toward R&D expenditure. The relevant proof is available from the authors on request.

⁶ We have checked that CS increases 'faster' with an R&D subsidy than with an output subsidy, as long as δ is sufficiently high; that is, $\frac{\partial}{\partial \delta} (CS|_{s=s_x} - CS|_{s=s_q}) > 0$ if $\delta > 0.33$. Thus, having started with a lower level of CS under an R&D subsidy, CS eventually becomes higher under an R&D subsidy.

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