Economic Modelling 36 (2014) 484–494

Contents lists available at ScienceDirect

Economic Modelling

journal homepage: www.elsevier.com/locate/ecmod

Firm's objective function and product and process R&D☆

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ARTICLE INFO

Article history:
Accepted 29 August 2013

JEL classification:
O33
O32
L20

Keywords:
General objective function
Process R&D
Product R&D
R&D subsidies

ABSTRACT

Firms undertake different kinds of R&D activities. They do *product R&D* (R&D aimed at improving the quality of existing products, and creating new products). They also do *process R&D* (R&D aimed at lowering the cost of making existing and new products). Moreover, firms often do both product and process R&D simultaneously. As far as the objective of firms is concerned, this need not be limited to profit-maximization only. Rather, firms may have a broader objective, where they care about profits as well as consumer surplus. This paper studies effects of a firm having a *general objective function* (that takes into consideration both profits and consumer surplus) on its product and process R&D choices, and corresponding implications.

I consider product and process R&D choices of firms in an infinite horizon set-up with discrete time. Firms in my framework can simultaneously do both product and process R&D in every period, face a discrete-choice model of consumer demand with vertical product differentiation, and maximize a discounted, weighted sum of their profits and consumer surplus over the infinite time horizon.

I show how process and product R&D differ from each other in my framework, and the role of a firm's objective function in this regard. I compare process and product R&D choices across firms that differ in their objective function, and illustrate effects of providing *general R&D subsidies* (subsidies given for any R&D, regardless of whether it is product or process R&D) to firms. I also characterize how in my framework, the choice of process R&D in total R&D — *R&D composition* — by an individual firm varies over time, and how process and product R&D choices, process and product R&D productivity, and the choice of R&D composition vary across firms that differ in size but are otherwise similar.

1. Introduction

R&D choices by firms are of vital importance, not just to individual firms themselves, but to economies and nations as a whole (Greenhalgh and Rogers, 2010; Vives, 2008). This, together with the often-held notion that R&D choices by private firms differ significantly from corresponding socially optimal choices, has in fact over the years led governments all over the world, in both developed as well as developing nations, to engage in various efforts to promote R&D activities (Bloom et al., 2002; Hall and Maffioli, 2008; Hall and Reenen, 2000; Klette et al., 2000; Mansfield, 1986; Özcelik and Taymaz, 2008; Whalley and Zhou, 2007).

Studies regarding R&D have typically looked at choices of overall R&D levels by profit-maximizing firms. However, as discussed in greater detail below, it is increasingly being recognized that firms (a) undertake different kinds of R&D activities, and (b) may have a broader objective than profit-maximization alone.

Within R&D, firms undertake different kinds of R&D activities. Firms do *product R&D*, defined as R&D aimed at trying to improve the quality of existing products, and creating new products. Firms also do *process R&D*, defined as R&D aimed at improving existing processes, and creating new processes so as to lower the cost of making existing and new products. Further, firms typically do both product and process R&D simultaneously (Capon et al., 1992; Landau and Rosenberg, 1992), and do so in an incremental fashion and on a continuing basis rather than in a one-off manner (Bayus, 1995; Kline and Rosenberg, 1986).

It is also increasingly being recognized that firms need not have only profit-maximization, or alternatively welfare-maximization as their objective. Rather, firms may have an objective broader than that of only profit-maximization, where they care, at least to some extent, about consumer surplus as well as profits, without necessarily being welfare-maximizing. This broader objective may be due to one or more, fairly commonly observed factors like (a) the implementation by firms, investor-owned or otherwise, of the concept of "stakeholder society" (Ghosh and Mitra, 2012; Tirole, 2001; Willner, 2012), (b) partial government ownership of firms (Matsumura, 1998), and (c) firms having organizational forms other than that of investor-owned firms, such as various kinds of non-profits and cooperatives, and the corresponding allocation of residual control rights in an environment with incomplete contracts (Glaeser and Shleifer, 2001; Hansmann, 1996; Hart and Moore, 1996; Hart et al., 1997; Herbst and Prüfer, 2011;

☆ I thank the participants at the 2010 Royal Economic Society Meetings, the Editor Stephen George Hall, and in particular two referees for their helpful comments and suggestions. The usual disclaimer applies.

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http://dx.doi.org/10.1016/j.econmod.2013.08.041

Levin and Tadelis, 2005). Further, there are increasing trends of (i) the concept of corporate social responsibility (hereafter CSR) becoming both popular among consumers as well as a mainstream business activity (Berger et al., 2007; Besley and Ghatak, 2007; Kitzmueller and Shimshack, 2012; Kopel and Brand, 2012), and (ii) privatization, usually partial, of state-owned enterprises around the world (Chen et al., 2009; Megginson, 2005; Wang and Chen, 2011). These two trends suggest that the number of firms that care not just about profits but also, though perhaps not necessarily to the same extent, about consumer surplus is only likely to increase, and that too perhaps rapidly, in the coming years.[2] The objective function is also unlikely to be the same across all such firms owing to differences in (a) the extent to which they care about various stakeholders and what the stakeholders care about, (b) the extent of government control, and/or (c) their organizational form.

Given these observations, it seems imperative that we try to understand effects of a firm having a *general objective function* — i.e., an objective function that takes into consideration, though not necessarily to the same extent, both profits and consumer surplus — on its process and product R&D choices over time, and corresponding policy implications. To the best of my knowledge, there are two separate strands of theoretical literature that come closest in this regard, but neither study both the aspects of firm behavior discussed above together. One is the growing theoretical literature on issues related to simultaneous process and product R&D choices by firms (Athey and Schmutzler, 1995; Bandyopadhyay and Acharyya, 2004; Chenavaz, 2011; Cohen and Klepper, 1996a; Eswaran and Gallini, 1996; Klepper, 1996; Lambertini and Mantovani, 2009; Lambertini and Orsini, 2000, 2003, 2004; Lin and Saggi, 2002, 2004; Mantovani, 2006; Plehn-Dujowich, 2009; Rosenkranz, 2003; Saha, 2007).[3] This literature however has only considered the case of profit-maximizing firms, and in some cases (Eswaran and Gallini, 1996; Lambertini and Orsini, 2000, 2003; Lin and Saggi, 2002; Rosenkranz, 2003) corresponding welfare implications. There is another body of theoretical work that has considered issues related to R&D choices by firms with objective functions different from that of only profit-maximization (Bühler and Wey, 2010; Cato, 2008a,b; Delbono and Denicolo, 1993; Gil-Moltó et al., 2011; Goel and Haruna, 2007; Heywood and Ye, 2009; Ishibashi and Matsumura, 2006; Kesavayuth and Zikos, 2013; Lambertini, 1998; Luo, 2013; Nishimori and Ogawa, 2002; Poyago-Theotoky, 1998). This second literature however has considered one-off choices regarding in most cases only process innovations, or in some cases only product innovations.

In this paper, I study product and process R&D choices by firms and corresponding implications in an infinite horizon set-up with discrete time, where firms (a) can do both product and process R&D simultaneously over time, and (b) have a general objective function consisting of a discounted sum over time of profits and a non-negative weight times consumer surplus with the weight attached to consumer surplus capturing the extent to which firms care about consumers' well-being. I find that

(i) Returns to process R&D for a firm are independent of its objective function, while returns to product R&D depend on a weighted sum of the marginal buyer's willingness to pay (hereafter WTP) and the average WTP of buyers for quality improvements with the weights depending on the firm's objective function;
(ii) Among firms that differ in the extent to which they care about consumers' well-being but are otherwise the same, (a) the amount of process R&D undertaken is the same, while (b) as far as product R&D is concerned, a firm that attaches a greater weight to consumer surplus does more of product R&D than a firm that attaches a lower weight, and moreover this difference increases over time;
(iii) If an R&D subsidy is provided to a firm regardless of whether it undertakes process or product R&D, then such a policy leads to an increase in both the amount of process and product R&D undertaken by the firm; however, in proportional terms the amount of increase is the same for both kinds of R&D, and thus, such a policy is ineffective if the aim is to change the proportions of total R&D effort devoted by the firm to process and product R&D;
(iv) An individual firm has a tendency to do *relatively more of process R&D* (i.e., between process and product R&D, devote a greater fraction of its total R&D effort to process R&D) over time; and
(v) Among firms that differ in size but have the same objective function and are also the same in all other respects, a larger firm (a) does more of but has a lower productivity for both process and product R&D, and also (b) does relatively more of process R&D, than a smaller firm.

The rest of the paper is as follows. Section 2 lays down the basic framework. Section 3 presents the analysis. Section 4 concludes. All proofs are in Appendix A.

2. The model and preliminaries

2.1. The basic model

I consider the case of a single firm that sells a non-durable product in an infinite horizon set-up. In my framework, time is discrete, and there are infinitely many time periods denoted by t, where $t = 0, 1, 2, \ldots$. The firm is (a) alone in the market for the product, (b) unaffected by choices or actions of any other firm,[4] and (c) characterized by two parameters, namely q, and c (these, as well as the objective function of the firm are described in detail later). There is a numeraire good, and price of and utility from the product, costs, revenues, and expenditures are all measured in terms of this numeraire good.

The demand for the firm's product is as follows. I assume that in each period, the firm faces an exogenously given mass of potential buyers. This mass of potential buyers is the same in all periods, and is normalized to be 1. I model consumer preferences using a discrete-choice model of consumer demand with vertical product differentiation (Maskin and Riley, 1984; Mussa and Rosen, 1978). In my framework, the parameter q stands for the quality of the product sold by the firm. All potential buyers, and the firm agree on the value of q. Each potential buyer has a finite, non-negative preference parameter θ, where $\theta \in [\theta_1, \theta_2]$. Also, in each period, every potential buyer buys either a single unit or none of the product. The net utility to a buyer with preference parameter θ from buying one unit of the product of quality q from the firm at price P is $\theta q - P$. The parameter θ thus represents the WTP of a buyer for each unit of product quality. The value of θ differs across buyers. I assume that in each period, the value of θ across all potential buyers is uniformly distributed over $[\theta_1, \theta_2]$. A buyer's purchasing decision regarding the product in any period does not affect his/her utility or choice set in any way in subsequent periods. Also, each potential buyer has a reservation utility of 0 in every period. Hence, in any period, a potential buyer buys one unit of the product from the firm if the resultant net utility from doing so is non-negative. The firm faces no potential threat of entry, and cannot discriminate between various potential buyers.

[2] Note that the number and contribution of firms, both now and previously, with an objective function broader than that of profit-maximization alone is not insignificant to begin with, and moreover this is true in R&D-intensive sectors as well (Anderson et al., 1997; Bartlett et al., 1992; Bühler and Wey, 2010; Case, 2005; Gil-Moltó et al., 2011; Godø et al., 2003; Goering, 2008b; Hansmann, 1996; Heisey et al., 2005; Kopel and Marini, 2012; Marini and Zevi, 2011; Nilsson, 2001; Oehmke, 2002; Ohnishi, 2011).

[3] Some of these studies have considered one-off product and process R&D choices by firms, while others have considered product and process R&D choices by firms over time.

[4] Such a set-up would for example be consistent with an industry having identical and independent submarkets where there is at most one firm in each submarket (Bresnahan et al., 1997; Sutton, 1998).