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Technology adoption in a differentiated duopoly: Cournot versus Bertrand

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A R T I C L E I N F O

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A B S T R A C T

This paper shows that the cost as well as the effectiveness of technology has a differential impact on technology adoption under two alternative modes of competition. If the cost of the technology is high, Bertrand competition provides a stronger incentive to adopt technology than Cournot competition unless the effectiveness of the technology is very low. On the contrary, if the cost of the technology is low, Cournot competition fares better than Bertrand competition in terms of technology adoption by firms. This demonstrates that the commonly subscribed assumption of 'positive primary outputs' restricts (inflates) the scope of higher degree of technology adoption under Bertrand (Cournot) competition. Moreover, in contrast to standard welfare ranking, it shows that Cournot competition leads to higher social welfare than Bertrand competition under certain situations.

1. Introduction

This paper analyses the incentives to adopt cost-reducing technology by firms in a horizontally differentiated industry under two alternative categories of product market competition, Cournot and Bertrand. When the cost of production is endogenously determined, whether Bertrand competition or Cournot competition provides the stronger incentive for technology adoption is an essential concern. Our framework allows us to address the question of how the cost of the technology as well as its effectiveness affects this comparison in a more general setting that does not rely on the commonly subscribed assumption of 'positive primary outputs'—'both firms sell positive outputs even if prices are set at respective marginal costs'.[1]

Whether higher or lower intensity of product market competition provides greater incentive to adopt cost-reducing technology is of perennial interest. A large literature, dating at least as far back as Schumpeter (1943), emphasizes the role of the intensity of competition on innovation. Schumpeter (1943) argues that, since the possibility to realize returns from technological advancement is higher in concentrated markets, market concentration stimulates innovation. In contrast, Arrow (1962) shows, comparing a perfectly competitive industry with a monopoly, that the gain from adopting cost-reducing technology is higher under a competitive environment. This indicates that a more competitive environment provides a higher incentive to innovate. Recently, attention has turned to the comparison of two oligopolistic industries. A number of recent studies, considering different scenarios, compare firms' incentives to introduce cost-reducing technologies under alternative modes of product market competition. This helps us to understand a variety of issues: the role of the nature of product differentiation (Bester and Petrakis, 1993; Bonnano and Haworth, 1998), speed of technological

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[1] This assumption is crucial for ranking of the equilibrium outputs and profits under the two categories of competition (Zanchettin, 2006; Amir and Jin, 2001).

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progress (Aghion et al., 19997), conflict between static and dynamic efficiency (Delbono and Denicolo, 1990), impact of competition intensity (Boone, 2001), incentives in mixed oligopoly (Lin and Ogawa, 2005), etc. While characterizing equilibrium outcomes, these studies subscribe to the assumption of 'positive primary outputs' and thus restrict the parameter space, which is likely to distort the equilibrium outcomes. Also, to the best of our knowledge, existing studies do not analyse the impact of the cost of technology on technology adoption decision explicitly. This paper attempts to fill these gaps.

We consider a two-stage non-cooperative game between two firms. Initially, both firms have symmetric cost functions. In the first stage, each firm simultaneously and independently decides whether to adopt a cost-reducing technology, by incurring some given cost, or not. In the second stage, firms engage either in Cournot competition or in Bertrand competition. The analysis shows that, if the cost of the technology is high, Bertrand competition provides a stronger incentive to adopt technology than Cournot competition unless the cost-reducing effect of the technology is very low: an 'Arrow-like' result. On the contrary, if the cost of the technology is low, Cournot competition fares better than Bertrand competition in terms of technology adoption by firms: a 'Schumpeter-type' result. The intuition behind our result is as follows. Following technology adoption, Bertrand competition not only leads to lower prices (price effect), but also results in a lower market share of the non-adopting firm (selection effect) than Cournot competition. While the price effect generates more disincentive to adopt technology under Bertrand competition than under Cournot competition, the selection effect works in the opposite direction. When only one firm adopts the cost-reducing technology, the selection effect dominates the price effect, and the net effect is higher under Bertrand competition than under Cournot competition unless the cost-reducing effect of the technology is very low. On the other hand, if both firms adopt the technology, the selection effect vanishes and the gain from technology adoption becomes higher under Cournot competition than that under Bertrand competition. Needless to say, a firm's gain from technology adoption is higher when only that firm adopts the technology. Therefore, when the cost of the technology is low, in equilibrium, both firms adopt the technology under Cournot competition whereas under Bertrand competition only one firm adopts the technology.

This paper also shows that the scope for superior outcomes in terms of technology adoption under Bertrand (Cournot) competition is lower (higher) for lower level of effectiveness of the technology. If the cost-reducing effect of the technology is very low, the equilibrium technology adoption is never better under Bertrand competition than that under Cournot competition. This implies that the assumption of positive primary outputs is likely to restrict the scope of technology adoption under Bertrand competition and bolster that under Cournot competition.

Comparison of social welfare under the two modes of product market competition reveals that, when technology adoption is higher under Cournot competition than that under Bertrand competition, Cournot competition may lead to higher social welfare than Bertrand competition. This result is in sharp contrast to the standard social welfare ranking of the two modes of competition.

The rest of the paper proceeds as follows. The next section presents the model and characterizes Bertrand and Cournot equilibria. Section 3 presents the comparison of equilibrium outcomes under alternative modes of competition. Section 4 concludes.

2. The model

Let us consider an economy with an oligopolistic sector, consisting of two firms, firm 1 and firm 2, that produce a differentiated good and a competitive numeraire sector. Initially, the marginal costs of production of firm 1 and firm 2 are equal to $\bar{c}$. That is, we start with a situation in which there is no asymmetry in terms of cost of production between firm 1 and firm 2.

Now, before undertaking production decisions, firms can adopt the new technology by incurring an exogenously determined fixed cost r (>0) to reduce the marginal cost of production. If a firm adopts the technology, its marginal cost of production reduces to $\underline{c}$ ($0 < \underline{c} < \bar{c} = \underline{c} + x$), whereas the non-adopting firm's marginal cost remains at $\bar{c}$. That is, the cost-reducing effect (effectiveness) of the technology is $x = \bar{c} - \underline{c}$. Needless to say, such a type of discrete choice of technology is observed in many real-life situations and has received some attention in the literature recently (see, for example, Elberfeld and Nti (2004), Jensen (1992), Lahiri and Ratnasiri (2007), Khan and Ravikumar (2002), and Leung and Tse (2001), to name a few).[2]

We consider that, if there is positive demand for both goods, the direct demand function is $q_i = \frac{1}{1-\gamma^2}[(1-\gamma)a - p_i + \gamma p_j]$, ($a > \bar{c}$; $i, j = 1, 2$; $i \neq j$), where q_i (p_i) is the quantity (price) of the product of firm i and γ ($0 < \gamma < 1$) is the product differentiation parameter.[3] The corresponding inverse demand function is $p_i = a - q_i - \gamma q_j$ ($i, j = 1, 2$; $i \neq j$). However, if the prices are such that $q_j \leq 0$, the demand for good i is $q_i = a - p_i$, as in Zanchettin (2006).

[2] Considering a dynamic framework, Lahiri and Ratnasiri (2007), Khan and Ravikumar (2002), Leung and Tse (2001) examine technology adoption and its impact on macroeconomic variables. Elberfeld and Nti (2004) and Jensen (1992) analyse technology adoption by firms under uncertain environment considering Cournot competition in the product market. We abstract away, for simplicity, from possible uncertainty about the cost-reducing effect of new technology.

[3] The underlying utility function of the representative consumer is $U = aq_1 + aq_2 - \frac{1}{2}(q_1^2 + q_2^2 + 2\gamma q_1 q_2) + m$, where m is the quantity of the numeraire good.