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What determines the technology adoption of firms under optimal tax?

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ABSTRACT

Technology adoption in a Cournot duopoly under optimal tax is studied. A benchmark model of laissez-faire economy shows that the chance of adoption increases in market size, a result ubiquitous in the paper. With optimal subsidy, adoption is more likely than in the laissez-faire economy. The chance is even higher if firms make adoption decisions before the government sets the tax rate. Negative externality of the commodity lowers the chance of adoption under optimal tax, but not below that in the laissez-faire economy unless the government moves first and the market is too small. However, if the new technology is clean, the chance of adoption can be significantly improved, even when the externality is only partially remedied. Moreover, a clean technology is more likely adopted than a technology without externality issue when the market is sufficiently large.

1. Introduction

Technology adoption is a crucial part of the understanding of the economics of new technology. The market value of a new technology depends on how widely it is adopted by firms, including domestic and foreign ones, if intellectual property is protected worldwide. While profitability is a fundamental factor, some others have been examined in the literature: Reinganum (1981a,b) shows that technology diffusion occurs with any number of firms even when they are identical and have perfect information. Chen, Yang, Wang, and Wu (2014) and Bagchi and Mukherjee (2014) discuss licensing strategies. DeGraba (1990) considers adoption when price discrimination is present in input market. Brock and Durlauf (2010) examines the social influence on adoption. The timing of adoption differs, as indicated by Milliou and Petrakis (2011), by features of competition and product differentiation. And Choi (1995) and Crowley (2006), among others, incorporate trade policy into the analysis of technology adoption.

The empirical literature of international knowledge spillover via trade, spawned by Coe and Helpman (1995), holds a concept of knowledge that enhances the overall productivity, rather than cost reduction of a single product. Later works in this literature, however, noticed a number of domestic factors that help build the absorptive capabilities (Cincera and van Pottelsberghe (2001)) or, to the contrary, set the absorption barriers. In their theoretic work, Parente and Prescott (1994) establish the result that the monopoly arrangement in a country keeps the inferior technology in use, a prominent example of barrier.

Though far from complete, the above list of studies does not indicate a major role of government except its trade policy. In this paper, we analyze and illustrate how the government's optimal tax policy in a technology-receiving country affects the technology

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adoption of its firms and consequently lowers or lifts its absorption barrier. Quite obviously tax interferes with the decisions of adopting new technology by firms. And if governments are benevolent, then how, *under optimal taxes*, technology adoption differs across countries heterogeneous in relevant dimensions has important implications on international knowledge spillover. Hence, we consider a simple sequential game between duopolistic firms and the government in which the strategy of the former contains two decisions, technology adoption and output, and that of the latter only tax. Since the focus is on the relation between technology adoption and optimal taxes, the adoption decision are assumed to be made simultaneous.

In addition, we explore how such relation changes if other attributes of the new technology or its associated product are taken into account. First we consider a product with negative externalities. There is a large literature of environmental policies, including optimal (pollution) taxes, aimed at externalities. For example, Buchanan (1969) indicates that tax should be lower than marginal external damage in a monopolistic market, Simpson (1995) and Payogo-Theotoky (2003) analyze tax under various price and quantity competitions in a duopoly, and Levin (1985) compares various forms of taxation in controlling pollution in oligopoly. However, none, to the best of our knowledge, has looked at optimal taxes aimed at externalities and technology adoption at the same time.

We then consider the new technology that is also "clean" — in the sense that it reduces the negative externalities. Innovative activity, rather than the adoption of its possible results, towards cleaner technology has recently been the main theme in many studies of environmental policies, for examples, Bradford and Simpson (1996); Montero (2002) and Fisher, Parry, and Pizer (2003). These works, in general, investigate whether and how various policies, including taxes, affect innovative activities. If cleanness of a new technology has a bearing on its adoption under optimal tax, then tax has an influence on the incentive to innovate because adoption is arguably related to the market value of the new technology. As there are usually a lot more users than inventers of new technologies in the world, the inventers have great interests in knowing the determinants of the adoption of their intellectual product by potential users in different countries.

The paper is structured as follows: a benchmark model of adoption with optimal taxation is introduced after introduction, negative externality is discussed in Section 3, the clean technology is studied in Section 4, and the last section concludes.

2. Technology adoption and optimal tax

Consider two firms, $i = 1, 2$, producing a homogenous good given the market inverse demand function $p = A - Q$. They initially produced with the same technology of constant marginal cost $c > 0$ at Cournot equilibrium, where $A > 2c$ is assumed to avoid negative quantity. Then a new technology is invented that brings down the cost to zero. It is available to both firms, but adoption entails a fixed cost of $F > 0$. F could involve capital-embedded investment, cost of license or royalty, or "*barriers to technology adoption*" (Parente & Prescott, 1994). The government intervenes by imposing a commodity (unit) tax t.[1] It is assumed that firms make adoption decisions simultaneously.

Depending on their adoption decisions, their profit functions are

$$\begin{cases} \pi_i^n = (p-t)q_i - F, \text{ if the new technology adopted} \\ \pi_i^o = (p-c-t)q_i, \text{ otherwise}\cdot \end{cases} \tag{1}$$

The output as a result of Cournot competition can therefore be derived as follows.

$$\begin{cases} q^{nn} = \dfrac{A\text{-}t}{3} & ;\text{if both firms adopt} \\ q_n^{no} = \dfrac{A+c\text{-}t}{3}, q_o^{no} = \dfrac{A\text{-}2c\text{-}t}{3} & ;\text{if only one adopts} \\ q^{oo} = \dfrac{A\text{-}c\text{-}t}{3} & ;\text{if neither adopts} \end{cases} . \tag{2}$$

Substituting q into Eq. (1), we obtain the payoff matrix for the adoption game in Table 1, where profits are derived below.

$$\begin{cases} \pi^{nn} = \left(\dfrac{A-t}{3}\right)^2 - F & ;\text{if both firms adopt} \\ \pi_n^{no} = \left(\dfrac{A+c-t}{3}\right)^2 - F, \pi_o^{no} = \left(\dfrac{A-2c-t}{3}\right)^2 & ;\text{if only one adopts}. \\ \pi^{oo} = \left(\dfrac{A-c-t}{3}\right)^2 & ;\text{if neither adopts} \end{cases} \tag{3}$$

The game is symmetric and can be solved by observing that:

$$\pi^{nn} - \pi_o^{no} < \pi_n^{no} - \pi^{oo}. \tag{4}$$

[1] In our model, the tax/subsidy is not directly targeted to the adoption decision. A direct policy towards adoption can be modeled as decreasing or increasing F financed by lump sum tax or subsidy. Unit tax/subsidy is chosen because it can serve a second role of addressing externality later, which is common in discussing environmental policies, at the same time. Besides, a direct policy makes not much sense in one of the scenarios that follows in which firms make adoption decisions first.