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# Effects of patent protection on economic growth and welfare in a two-R & D-sector economy☆

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ABSTRACT

This paper examines the effects of patent protection in a growth model, where final goods firms and intermediate goods firms engage in R&D. The results show that: (i) strengthening patent protection is likely to increase the technology level of the final goods sector relative to the intermediate goods sector in most cases; (ii) if R&D productivity in the final goods sector is lower than that in the intermediate goods sector, the relationship between patent protection and economic growth is an inverted-U shape; and (iii) an increase in R&D productivity in the intermediate goods sector can reduce the welfare-maximizing level of patent protection.

## 1. Introduction

According to Park (2008), patent protection has strengthened in many countries. Patent policy is an important tool used by policy-makers to stimulate innovation and economic growth. A number of studies have investigated the effects of patent protection on economic growth and welfare using growth models where firms engage in R&D activities in either the final or the intermediate goods sectors (i.e., the models assume there is only one R&D sector).[1] However, in practice, both final and intermediate goods firms engage in R&D activities, and all inventions in both final and intermediate goods sectors are protected by patent policy. For example, in the computer industry, computer makers (final goods firms) invest in R&D activities that improve designs and their production processes, and firms that manufacture computer parts such as CPUs and storage devices (intermediate goods firms) also invest in R&D activities that improve their productivities and the performances of components. The purpose of this paper is to investigate the effects of patent protection on economic growth and welfare in a growth model where firms engage in R&D activities in both the final and the intermediate goods sectors (i.e., there are two R&D sectors, and the relationship between the sectors in which firms invest in R&D is vertical).[2]

The paper constructs a quality-ladder model where firms in both the final and intermediate goods sectors engage in R&D activities. The paper finds that, in most cases, strengthening patent protection is likely to lead to final-goods-biased technical change. Strengthening patent protection increases the technology level of the final goods sector relative to the intermediate goods sector.[3] By examining the effect of patent protection on economic growth, the paper shows that there is an inverted-U relationship between patent protection and economic growth[4] if R&D productivity in the intermediate goods sector is larger than that in the final goods sector. The paper also shows that an increase in R&D productivity in the intermediate goods sector can reduce the welfare-maximizing level of patent protection.

This study relates to some important existing studies. In particular, Goh and Olivier (2002) and Chu (2011) address similar issues. However, Goh and Olivier's (2002) model is a variety-expansion type R&D-based growth model, in which the variety of both the final and intermediate goods sectors is expanding. Furthermore, Chu's (2011) model is a quality-ladder model where there are two final goods sectors in which firms engage in R&D; thus, the relationship between the sectors in which firms invest in R&D is horizontal.

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[1] Since the seminal paper by Judd (1985), many studies in the literature on patent protection and growth assume that firms engage in R&D activities in either the final or the intermediate goods sectors. For example, see the early studies by Li (2001); Iwaisako and Futagami (2003); Kwan and Lai (2003), and O'Donoghue and Zweimuller (2004).

[2] Some studies present two-R&D-sector models in the form of expanding variety of new product and quality improvement of these products. For example, see Li (2000).

[3] In terms of the directed technical change (Acemoglu, 1998), the present paper relates to the literature on patent protection and directed technical change. For example, see Chu, Cozzi, Furukawa (2015).

[4] Some studies explain the inverted-U relationship between patent protection and economic growth (or innovation) using different models. For example, see Furukawa (2007, 2010); Horii and Iwaisako (2007); Akiyama and Furukawa (2009); Chu, Cozzi, Galli (2012, 2014); Gangopadhyay and Mondal (2012); Iwaisako and Futagami (2013), and Niwa (2016).

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The remainder of the paper is organized as follows. Section 2 describes the model. Section 3 derives the market equilibrium path of this model. Section 4 analyzes the effects of patent protection. Section 5 considers the extension. Concluding remarks are given in the final section.

## 2. The model

The present paper constructs a closed economy model, with a unit continuum of differentiated final goods and of differentiated intermediate goods. Each final good is produced from a unit continuum of intermediate goods. Each intermediate good is produced using labor. In the final and intermediate goods sectors, the productivity of these goods improves as a result of R&D activities, following Grossman and Helpman's (1991) quality ladder model, and there exists incomplete patent breadth, as in Li (2001). This study assumes that the levels of patent protection are the same across the two sectors.[5]

### 2.1. Households

The economy has a unit continuum of identical households. The representative household maximizes its lifetime utility as follows:

$$U = \int_0^\infty e^{-\rho t} \ln u_t dt, \tag{1}$$

subject to the budget constraint:

$$\dot{A}_t = r_t A_t + w_t L - E_t, \tag{2}$$

where $\rho$ is the subjective discount rate, $A_t$ denotes the value of assets held by households, $r_t$ is the rate of return, and $E_t$ represents expenditure at time $t$. Each household in elastically supplies $L$ units of labor to earn the wage $w_t$. $u_t$ represents instantaneous utility given by:

$$u_t = \exp\left(\int_0^1 \ln x_t(i) di\right), \tag{3}$$

where $x_t(i)$ is the consumption level of the differentiated final good $i$, indexed by $i \in [0, 1]$. From the static utility maximization, the demand for $x_t(i)$ is:

$$x_t(i) = \frac{E_t}{p_{x,t}(i)}, \tag{4}$$

where $p_{x,t}(i)$ is the price of $x_t(i)$. As a result of the dynamic optimization, the familiar Euler equation is obtained as follows:

$$\frac{\dot{E}_t}{E_t} = r_t - \rho. \tag{5}$$

### 2.2. Final goods

There is a unit continuum of differentiated final goods, indexed by $i \in [0, 1]$. Each final good $i$ is temporarily produced by a current monopolistic leader who succeeded with the latest innovation until the arrival of the next innovation, and is produced from a unit continuum of differentiated intermediate goods, indexed by $z \in [0, 1]$. The production function for the leader of final good $i$ is:

$$x_t(i) = \lambda^{N_{x,t}(i)} \exp\left(\int_0^1 \ln y_t(i, z) dz\right). \tag{6}$$

$y_t(i, z)$ is the intermediate good $z$, which is used for the production of $x_t(i)$ at time $t$. The parameter $\lambda > 1$ is the exogenous invention size of each productivity improvement. $N_{x,t}(i)$ represents the number of innovations that have occurred in final good $i$ by time $t$. Given the productivity improvement, $\lambda^{N_{x,t}(i)}$, the marginal cost of production for the leader producing final good $i$ is:

$$MC_{x,t}(i) = \frac{P_{y,t}}{\lambda^{N_{x,t}(i)}}, \tag{7}$$

where $P_{y,t} \equiv \exp\left(\int_0^1 \ln p_{y,t}(z) dz\right)$ represents the price index for intermediate goods and $p_{y,t}(z)$ is the price of intermediate good $z$.

Before considering the pricing strategy of final goods firms, the paper considers patent policy.[6] In this model, patent breadth protects inventions against imitation by the former leader who succeeded in the second-latest innovation. Here, this study adopts Li's (2001) formulation of patent breadth, which encompasses incomplete patent breadth. The protected range of an invention is represented by $\lambda^b$ with $b \in (0, 1]$. Therefore, the former leader can increase its productivity by a factor of $\lambda^{1-b}$, $b \in (0, 1]$ by partially imitating the current leader's invention without infringing the current leader's patent; thus, the current leader has a productivity advantage over the former leader which is represented by $\lambda^b$. In this study, $b$ is defined as the level of patent protection. Following the standard approach in the literature, the paper imposes the assumption that the current and former leaders engage in Bertrand competition. Under these circumstances, the current leader's profit-maximizing price is a constant markup over its marginal cost, i.e.:

$$p_{x,t}(i) = \mu \frac{P_{y,t}}{\lambda^{N_{x,t}(i)}}, \tag{8}$$

where $\mu = \lambda^b$. Hereafter, $\mu = \lambda^b$ is defined as patent breadth. Given (4) and (6)–(8), the monopolistic profit for the leader of final goods is:

$$\pi_{x,t}(i) = \pi_{x,t} = \left(\frac{\mu - 1}{\mu}\right) E_t, \tag{9}$$

for $i \in [0, 1]$. From the cost-minimization problem and the above expressions, the demand for intermediate good $z$ becomes:

$$y_t(z) = y_t(i, z) = \frac{E_t}{\mu p_{y,t}(z)}, \tag{10}$$

for $i \in [0, 1]$. An increase in patent breadth decreases the demand for intermediate goods.[7]

### 2.3. Intermediate goods

In this sector, the environment for firms is similar to that of the final goods sector. Each intermediate good $z$, indexed by $z \in [0, 1]$, is temporarily produced by a monopolistic leader until the arrival of the next innovation, and the current and former leaders engage in Bertrand competition. There is incomplete patent breadth, as in the final goods sector. The only difference is the production structure, as each intermediate good $z$ is produced by using labor. The production function for the leader of intermediate good $z$ is:

$$y_t(z) = \lambda^{N_{y,t}(z)} \ell_{y,t}(z), \tag{11}$$

where $\ell_{y,t}(z)$ represents the labor input used in the production of intermediate good $z$. Given the environment for intermediate goods firms, the profit-maximizing price is a constant markup over its marginal cost:

[5] In Goh and Olivier (2002) and Chu (2011), the levels of patent protection can differ between the two sectors. In Section 5, the present paper discusses the case of sector-specific patent breadths (i.e., the levels of patent protection are different).

[6] This study assumes that the government can only control patent protection by changing patent breadth; patent length is assumed infinite and fixed. Judd (1985); Iwaisako and Futagami (2003), and Futagami and Iwaisako (2007) investigate the effects of patent length on welfare.

[7] Goh and Olivier (2002) also show that extending patent breadth in the final goods sector reduces the demand for intermediate goods.