Status Preference and the Effects of Patent Protection: Theory and Evidence

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Abstract

We build a growth model with status preference to explore the effects of patent protection on innovation and social welfare. The main results are as follows. There exists a non-monotonic relationship between patent protection and innovation, and the growth-rate-maximizing degree of patent protection decreases with the strength of status preference. Moreover, the effect of patent protection on social welfare is ambiguous, depending on the strength of status preference. Finally, a cross-section regression based on a cross-country dataset is employed to investigate the empirical evidence of our theory. A significantly non-monotonic relationship between patent protection and economic growth is found when the status preference is considered.

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Keywords: Patent Protection; Status Preference; Innovation; Social Welfare

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1 Introduction

Conventional wisdom argues that the patent system encourages innovation. This argument has been questioned by various empirical studies, such as Kortum and Lerner (1998), Hall and Ziedonis (2001) and Sakakibara and Branstetter (2001). They show that patent protection may retard innovation. Recently, Lerner (2009) and Qian (2007) report that there is an inverted-U shape relationship between patent protection and innovation. Thus, the important question of how patents will impact innovation and social welfare remains unsolved.

We develop a growth model with status preference, in which the Marginal Rate of Substitution (MRS) between assets and consumption is decreasing in the amount of assets, to investigate the effects of patent protection (patent breadth) on innovation and social welfare. On the one hand, as in the standard literature, patent protection promotes innovation by raising the value of innovation. On the other hand, patent protection reduces the MRS between assets and consumption, and thereby discouraging the accumulation of assets and innovation.[1] We define this as the *substitution effect* of patent protection on innovation. When the degree of patent protection is low (high), the MRS is small (large), and therefore the positive (negative) effect of patent protection dominates. As a result, the relationship between patent protection and innovation is non-monotonic. Moreover, the degree of patent protection that maximizes growth rate decreases with the strength of status preference, since the stronger the status preference, the greater the *substitution effect*.

It is shown numerically that the effect of patent protection on social welfare relies on status preference. Strengthening patent protection reduces social welfare when the strength of status preference is large (i.e., the *substitution effect* of patent protection on innovation is great), whereas there exists a non-monotonic relationship between patent protection and social welfare when the strength of status preference is weak.

Various macroeconomic papers have studied the link between patent protection

[1] As in the standard endogenous growth models, the total assets are equal to the value of patents.

and innovation in the framework of endogenous growth theory.[2] Goh and Oliver (2002), Kwan and Lai (2003), O'Donoghue and Zweimuller (2004), Furukawa (2007), Futagami and Iwaisako (2007), Chu (2009), Chu et al (2012), Chen and Iyigun (2011) and Chu and Pan (2012), among others, can be used to explain the fact that stringent patent protection may stifle innovation and economic growth.[3] Our paper provides a novel channel through the *substitution effect* that gives rise to a non-monotonic effect of patent protection on innovation and social welfare, complementary to the existing ones. This paper also relates to models with wealth preference (for example, Zou, 1994, 1995, 1998; Bakshi and Chen, 1996; Corneo and Jeanne, 1997; Futagami and Shibata, 1998; Smith, 1999, 2001; Luo et al, 2009).[4] These models provide an interpretation for many economic phenomena such as savings, growth and assets pricing. To the best of our knowledge, however, the existing models with wealth preference do not address the issue of patent protection. Our paper contributes to this literature by exploring the impacts of patent protection on innovation and social welfare.

This paper is also related to the cross-country studies of patent protection and growth. Park and Ginarte (1997), Gould and Gruben (1996), Varsakelis (2001), Kanwar and Evenson (2003), Schneider (2005), Park (2005), Falvey et al (2006) document that the relationship between patent protection and economic growth may be positive correlation or insignificant. Differently, using the index of the spirit of capitalism developed by WVS (world value survey), we first empirically examine the effect of patent protection on economic growth when the status preference is taken into account. The empirical results are in line with our theoretical predictions.

The rest of this paper is organized as follows. Section 2 introduces the model, and

[2]Indeed, there are also a number of microeconomic perspectives in the literature (e.g., Green and Scotchmer, 1995; Scotchmer, 1996; O'Donoghue et al, 1998; and Segal and Whinston, 2007) analyzing how patent protection affects innovation.

[3]One implication of these models is that social welfare might be low when patent protection is strengthening.

[4]Corneo and Jeanne, Futagami and Shibata focus on the relative wealth (the status), while Zou, Smith and Luo et al give attention to the absolute wealth. Furthermore, it is useful to notice that there are a lot of evidence supporting the existence of status preference; see Heffetz and Frank (2010).

Section 3 characterizes equilibrium and analyzes the effect of patent protection on innovation. A non-monotonic relationship between patent protection and innovation is generated due to the existence of the *substitution effect* of patent protection on innovation. Section 4 shows by simulation that the effect of patent protection on social welfare varies, depending on the strength of status preference. Section 5 presents an econometric model to investigate the empirical evidence of the relationship between patent protection and economic growth, and Section 6 concludes this paper.

2 The Model

2.1 Preferences

In this model economy there exist L workers and each of them inelastically provides one unit of labor. Agent i maximizes discounted utility:[5]

$$U_i(t) = \int_0^\infty u_i \left[c_i(t), \frac{a_i(t)}{\overline{a}(t)} \right] e^{-\rho t} dt = \int_0^\infty \frac{\left\{ [c_i(t)]^\mu \left[a_i(t) / \overline{a}(t) \right]^\nu \right\}^{1-\gamma} - 1}{1-\gamma} e^{-\rho t} dt, \tag{1}$$

where γ represents the inverse of the rate of intertemporal substitution, and ρ represents time preference. $c_i(t)$ and $a_i(t)$ represents respectively consumption and assets of agent i, and $\overline{a}(t)$ represents the average level of wealth in the economy. Following Futagami and Shibata (1998) we assume that $1 - \mu(1-\gamma) > 0$ holds. The assumption that instantaneous utility depends on the status (the person's relative wealth position in the society) captures the idea of Hume, Marx, Veblen and others.[6]

[5] A similar utility function is employed by Bakshi and Chen (1996). Moreover, alternative preferences that utility relies on the absolute level of wealth like Bakshi and Chen (1996) would not alter our qualitative result; see the Appendix C for details.

[6] Hume (1978) states: "One of the most considerable of these passions is that of love or esteem in others, which therefore proceeds from a sympathy with the pleasure of the possessor. But the possessor has also a secondary satisfaction in riches arising from love and esteem he acquires by them, and this satisfaction is nothing but a second reflection of that original pleasure, which proceeded from himself. This secondary satisfaction or vanity becomes one of the principal recommendations of riches, and is the chief reason, why we either desire them for ourselves, or esteem them in others." We took this from Futagami and Shibata (1998).

The individual's budget constraint is standard:

$$\dot{a}_i(t) = r(t)\, a_i(t) + w(t) - c_i(t), \tag{2}$$

where $r(t)$ and $w(t)$ denote the interest rate and the wage rate, respectively. A dot over a variable denotes time derivative. Here we normalize the price of consumption (the final good) to be unitary, and drop the time index as long as it does not cause confusion.

The maximization of (1) subject to (2) gives rise to the Euler equation on balanced growth path:[7]

$$\begin{aligned} \frac{\dot{c}_i}{c_i} &= \frac{1}{1-\mu(1-\gamma)}\left[\frac{\partial u_i/\partial a_i}{\partial u_i/\partial c_i} + (r-\rho)\right] \\ &= \frac{1}{1-\mu(1-\gamma)}\left[\frac{\nu}{\mu}\frac{c_i}{a_i} + (r-\rho)\right] = \frac{\theta c_i/a_i + (r-\rho)}{1-\mu(1-\gamma)}. \end{aligned} \tag{3}$$

It is useful to note that $\frac{\partial u_i/\partial a_i}{\partial u_i/\partial c_i}$ is the MRS between assets and consumption. Moreover, as in Futagami and Shibata (1998), $\theta = \frac{\nu}{\mu} \geq 0$ measures the strength of status preference. Clearly when θ equates zero, (3) becomes the standard Euler equation.

In the meantime, the transversality condition of this dynamic optimization is given by:

$$\lim_{t\to\infty} \lambda_i(t)\, a_i(t) = 0, \tag{4}$$

where $\lambda_i(t)$ is the co-state variable of $a_i(t)$. Equation (4) implies $\rho - g\mu(1-\gamma) > 0$ in equilibrium.

[7] The Euler equation $\frac{\dot{c}_i}{c_i} = \frac{1}{1-\mu(1-\gamma)}\left[\frac{\partial u_i/\partial a_i}{\partial u_i/\partial c_i} + (r-\rho) + \nu(1-\gamma)\left(\frac{\dot{a}_i}{a_i} - \frac{\dot{\overline{a}}}{\overline{a}}\right)\right]$ collapses to (3), since $a_i = \overline{a}$ in symmetric equilibrium.

2.2 Production

The final good sector is perfectly competitive. In this sector firms employ intermediate goods and labor to produce the final good using the following technology:

$$Y = \int_0^N {k_j}^{1-\alpha} dj \cdot L^\alpha, \tag{5}$$

where N is the number of intermediate goods, k_j is the quantity used of intermediate good i.

The maximization of a firm's profit yields the demand for intermediate goods:

$$k_j = \left[(1-\alpha)/\chi_j\right]^{1/\alpha} L, \tag{6}$$

where χ_j is the price of intermediate good j.

To simplify, suppose patent length to be infinite.[8] Suppose further that any firm can produce one unit of intermediate goods by using one unit of the final good. Following Goh and Oliver (2002), we introduce patent breadth $B \geq 1$ as the policy variable such that[9]

$$\chi_j = B. \tag{7}$$

That is, the wider the patent breadth, the greater the firm's ability to raise the price. Combining (6) and (7), we obtain

$$\pi = \pi_j = (B-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha} L, \tag{8}$$

where π_j is the profit of the firm producing intermediate good j.

[8] Finite patent length would not change main results, however; see the Appendix C.

[9] Equation (6) suggests that the monopoly price is equal to $\frac{1}{1-\alpha}$. It follows that $B \in (1, \frac{1}{1-\alpha}]$. We restrict our attention to the case $B < \frac{1}{1-\alpha}$ in the following analysis.

2.3 R&D

Innovators can discover a new design of intermediate goods by inputting η units of the final good. More formally, the equation of knowledge accumulation is[10]

$$\dot{N} = \frac{Z}{\eta}, \tag{9}$$

where Z is the resources devoted to innovation.

3 Patent Protection and Innovation

Denote the value of a new patent at time t as $P(t)$. Then in equilibrium

$$P(t) = \int_t^{\infty} e^{-\int_t^{\tau} r(s)ds} \pi(\tau) d\tau = (B-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha} \frac{L}{r}. \tag{10}$$

Free entry into R&D business suggests that, in equilibrium

$$P = P(t) = \eta. \tag{11}$$

Combining (10) and (11), we derive

$$r = (B-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha} \frac{L}{\eta}. \tag{12}$$

Differentiating (12) with respect to the patent policy instruments, B, results in

$$\frac{dr}{dB} = \frac{1-(1-\alpha)B}{\alpha B}\left(\frac{1-\alpha}{B}\right)^{1/\alpha} \frac{L}{\eta}. \tag{13}$$

Taking advantage of (13), we state the following lemma:

Lemma 1 *The interest rate rises with patent breadth. Moreover,* $\frac{dr}{dB}|_{B=1} = (1-\alpha)^{1/\alpha} L/\eta > 0$, $\frac{dr}{dB}|_{B=1/(1-\alpha)} = 0$.

[10] This refers to the lab-equipment innovation specification in Rivera-Batiz and Romer (1991).

Stringent patent protection (broad patent breadth) raises the value of innovation, therefore driving up the interest rate (the return to assets).

It is useful to note that the equilibrium growth rate becomes $\frac{r-\rho}{1-\mu(1-\gamma)}$, if there is no status preference (e.g., $\nu = 0$). In this case, Lemma 1 implies

Lemma 2 *Patent protection promotes innovation, if there is no status preference.*

As Futagami and Shibata (1998), we only focus on symmetric equilibrium, in which $c_i = c$ and $a_i = \overline{a} = a$. Thus in equilibrium the resource constraint is

$$\begin{aligned} cL &= Y - \int_0^N k_j dj - \dot{N}\eta \\ &= N\left[\left(\frac{1-\alpha}{B}\right)^{1/\alpha} \frac{B+\alpha-1}{1-\alpha} L - g\eta\right], \end{aligned} \tag{14}$$

where $g = \frac{\dot{N}}{N}$. In addition, the total assets owned by households equal the value of all patents. That is,

$$aL = \int_0^N P dj = \eta N. \tag{15}$$

Note that in equilibrium $\theta = \frac{\nu}{\mu}$ is a constant. Thus the MRS between assets and consumption is also a constant:

$$\theta\frac{c}{a} = \theta\frac{(1-\alpha)^{(1-\alpha)/\alpha} L(B+\alpha-1)/B^{1/\alpha} - g\eta}{\eta}. \tag{16}$$

Differentiating (16) with respect to B, we reveal

$$\frac{\partial(\theta c/a)}{\partial B} = -\theta(\frac{1-\alpha}{B})^{1/\alpha}\frac{(B-1)L}{\alpha\eta B}, \tag{17}$$

It is followed by

Lemma 3 *The MRS between assets and consumption decreases with the degree of patent protection, i.e.,* $\frac{\partial(\frac{\theta c}{a})}{\partial B} \leq 0$. *Moreover,* $\frac{\partial(\frac{\theta c}{a})}{\partial B}|_{B=1} = 0, \frac{\partial(\frac{\theta c}{a})}{\partial B}|_{B=1/(1-\alpha)} = -\theta(1-\alpha)^{2/\alpha}L/\eta < 0.$

We refer to $\frac{\partial(\theta c/a)}{\partial B} \leq 0$ as the *substitution effect* of patent protection on innovation. In other words, patent protection lowers the growth rate through lowering the MRS between assets and consumption.

We are now ready to explore the relationship between patent protection and innovation. Clearly, the equilibrium growth rate is:

$$g = \frac{\dot{N}}{N} = \frac{\dot{c}}{c} = \frac{\theta c/a + r - \rho}{1 - \mu(1-\gamma)}. \tag{18}$$

Equations (16) and (18) imply that

$$\frac{dg}{dB} = \frac{\partial(\theta c/a)/\partial B + dr/dB}{1 - \mu(1-\gamma) - \partial(\theta c/a)/\partial g}, \tag{19}$$

where $\partial(\theta c/a)/\partial g = -\theta < 0$. Consequently, the effect of patent breadth is straightforward due to Lemmas 1 and 3. The positive effect of rising interest rate dominates when $B \to 1$, while the negative effect of declining MRS is dominant when $B \to 1/(1-\alpha)$. Thus there is a non-monotonic relationship between patent breadth and innovation.

Proposition 1 *The relationship between patent protection and innovation is non-monotonic.*

Proof. See the Appendix A. ■

A marginal change in patent breadth does not affect the growth rate when $B = 1/(1-\alpha)$, because the monopoly price maximizes profits. At the same time, large value of innovation lowers the growth rate owing to the *substitution effect*. Therefore, finite patent breadth results in the maximization of the growth rate.

Proposition 1 says that intermediate B^* maximizes the growth rate g. In this case, we examine how B^* changes when the strength of status preference θ changes.

Proposition 2 *The growth-rate-maximizing degree of patent breadth decreases with the strength of status preference. That is,* $\frac{\partial B^*}{\partial \theta} < 0$.

Proof. Since $B^* = \frac{1+\theta}{1+\theta-\alpha}$, $\frac{\partial B^*}{\partial \theta} = -\frac{\alpha}{(1+\theta-\alpha)^2} < 0$. ■

Apparently, the larger the θ, the greater the marginal change in the MRS between assets and consumption. It means that bigger θ leads to higher *substitution effect*. Therefore, the result in Proposition 2 is established.

In many developing countries, individuals strive for the accumulation of assets.[11] To some extent, Proposition 2 implies that patent protection in developing countries should be weaker than in developed countries.[12]

4 Social Welfare

In this section, we quantitatively analyze the effect of patent protection on social welfare. Using (1) and (18), we find:

$$S = L \cdot U = \frac{N(0)^{\mu(1-\gamma)} L^{1-\mu(1-\gamma)}}{1-\gamma} W - \frac{L}{\rho(1-\gamma)}, \tag{20}$$

where S is social welfare, and $W = \frac{[(\frac{1-\alpha}{B})^{1/\alpha} \frac{L(B+\alpha-1)}{1-\alpha} - g\eta]^{\mu(1-\gamma)}}{\rho - g\mu(1-\gamma)}$. As a result, we state

Proposition 3 *Strengthening patent protection reduces social welfare when* $B = \frac{1}{1-\alpha}$.

Proof. See the Appendix A. ■

As usual, stringent patent protection decreases social welfare through monopoly pricing. It moreover lowers social welfare via stifling growth when $B = \frac{1}{1-\alpha}$. Accordingly, social welfare goes down when patent protection is strengthening, if $B = \frac{1}{1-\alpha}$.

[11] Zou (1994) discusses how the capitalist spirit contributes to development of Japan, South Korea, Singapore, China Hongkong and China Taiwang.

[12] Deardoff (1992) and Grossman and Lai (2004) also stress that developing countries should implement weaker patent protection than developed countries.

The qualitative analysis is complicated, thus we use a quantitative method to explore the effect of patent protection on social welfare for $B \in \left(1, \frac{1}{1-\alpha}\right)$.[13] To do this, we first calibrate the structural parameters to quantify the model. Following Chu (2009), we set the discount rate ρ to 0.04, the rate of intertemporal substitution $1/\gamma$ to 0.42, the labor share α to 0.7, the average annual TFP growth rate g to 1.33%, the real interest rate r to 0.084 and the markup is about 3%. Without loss of generality, we unitize total labor force, i.e., $L = 1$. Moreover, we assume $N(0)$ to be 100 respectively for convenience. Using (12), we then pin down the innovation cost parameter η to 0.061. Table I presents the calibrated values of parameters $\{\alpha, \rho, \mu, \gamma, \theta\}$ for $\theta \in (0, 3]$.[14]

Table I: Calibrated Parameters

α	0.7	0.7	0.7
ρ	0.04	0.04	0.04
μ	0.5	0.5	0.5
γ	2.36	2.36	2.36
θ	0.8	1.9	3.0

The simulation result of relationship between patent protection and social welfare is reported in Figures 1-3.[15] Thus we have

[13] Simple algebra results in

$$\frac{dS}{dB}|_{B=1} = \frac{\mu N(0)^{\mu(1-\gamma)} L^{1-\mu(1-\gamma)} [V(1)]^{\nu(1-\gamma)} \left[\frac{L(B+\alpha-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha}}{1-\alpha} - g\eta\right]^{\mu(1-\gamma)-1}}{[\rho - g\mu(1-\gamma)]^2} \cdot \frac{\alpha(1-\alpha)^{(1-\alpha)/\alpha} L[1-\mu(1-\gamma)(1-\theta)] - \theta\rho\eta}{1-\mu(1-\gamma)+\theta} \frac{dg}{dB}|_{B=1}.$$

Therefore, $\frac{\partial S}{\partial B}|_{B=1} > 0$ when $\theta < \frac{\alpha(1-\alpha)^{(1-\alpha)/\alpha} L[1-\mu(1-\gamma)]}{\rho\eta - \alpha(1-\alpha)^{(1-\alpha)/\alpha} L\mu(1-\gamma)}$, whereas $\frac{\partial S}{\partial B}|_{B=1} < 0$ when $\theta > \frac{\alpha(1-\alpha)^{(1-\alpha)/\alpha} L[1-\mu(1-\gamma)]}{\rho\eta - \alpha(1-\alpha)^{(1-\alpha)/\alpha} L\mu(1-\gamma)}$. In other words, reinforcing patent protection may or may not improve social welfare, even if patent protection is initially low.

[14] There is no estimate on the value of μ. For simplicity, we only report the result when $\mu = 0.5$. The results are robust to different μ, however. Furthermore, ν is determined once θ is given.

[15] Obviously, $B \in (1, 10/3]$ if $\alpha = 0.7$. The result in Figures 1-3 is robust to the scale on the horizontal axis.

Claim 1 *Strengthening patent protection lowers social welfare when the strength of status preference is large, whereas there exits a non-monotonic effect of patent protection on social welfare when the strength of status preference is small.*

When the strength of status preference is big (the *substitution effect* of patent protection on innovation is great), the positive effect of patent protection on social welfare via stimulating growth tends to be weak. Thus social welfare may go down when patent protection becomes strong. In contrast, the positive effect of patent protection is large when the strength of status preference is small (the *substitution effect* of patent protection on innovation is less). Consequently, the relationship between patent protection and social welfare is non-monotonic.

Basu (1996) and Basu and Fernald (1997) document that the aggregate profit share is about 3%, while Laitner and Stolyarov (2004) reports that the markup is about 1.1 (i.e. a 10% markup) in the US. Thus B is between 1.03 and 1.1. By our simulation result, we conclude that a marginal increase in patent protection may raise or reduce social welfare even if the initial patent protection is low, depending on the strength of status preference.[16]

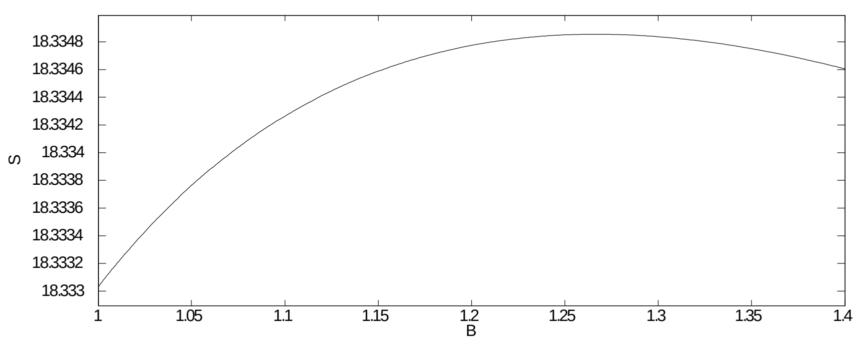

Figure 1: The Effect of Patent Protection on Social Welfare ($\theta = 0.8$)

[16] The literature does not provide a precise estimate for θ.

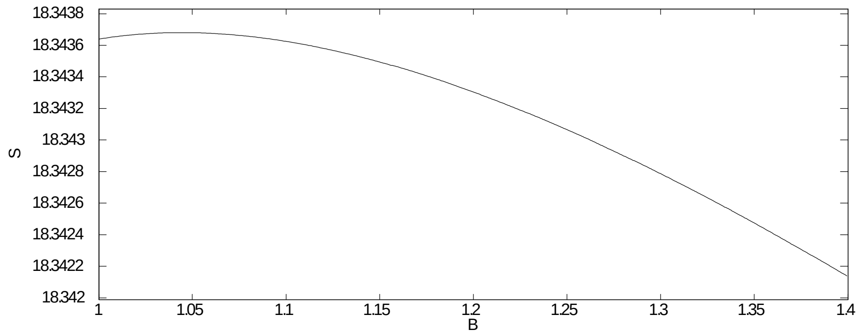

Figure 2: The Effect of Patent Protection on Social Welfare ($\theta = 1.9$)

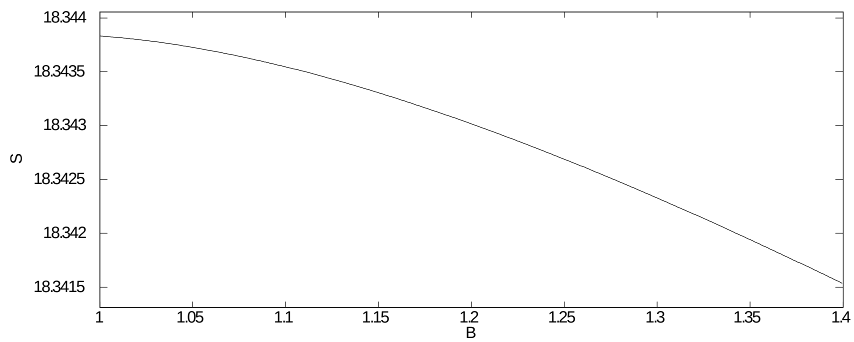

Figure 3: The Effect of Patent Protection on Social Welfare ($\theta = 3.0$)

5 Empirical Evidence

In this section, based on the index of capitalism spirit developed by Dorius and Baker (2012), we empirically investigate how patent protection affects economic growth when status preference is considered and how the growth-rate-maximizing degree of patent protection changes with status preference.

5.1 Data

For our main sample we use a panel dataset between 1980 and 2009. The database includes variables of economic growth, patent protection, the strength of status preference, and control variables. The data source of growth and control variables is Penn World Table 7.1 (PWT) constructed by Heston et al (2012), the data of human capital stock comes from Barro and Lee (forthcoming), the measure of patent protection is from Park (2008) and Ginarte and Park (1997), and the measure of the strength of status preference comes from the World Values Survey (WVS) cumulative file.[17]

The growth data of a country is the annual growth rate of GDP per capita averaged between 1985 and 2009. For the measure of patent protection within a country, we use the index of intellectual property rights developed by Park (2008) and Ginarte and Park (1997). The index covers five dimensions: 1) extent of coverage; 2) membership in international patent agreements; 3) provisions for loss of protection; 4) enforcement mechanisms; and 5) duration of protection. Each dimension is assigned a value between zero and one, and the overall index is the unweighted sum of these five values, with higher values reflecting greater level of protection.

So far the available data for wealth preference are limited, and few literature provides proper measure. In this paper the measure of the strength of status preference is based on the WVS. The WVS is one of the richest and most cross-nationally diverse sources of information on people's attitudes, beliefs and values across a broad range of topics. This dataset covers a time-span of more than 30 years with 5 waves of survey. The five waves correspond to the years 1981-1984, 1989-1993, 1994-1998, 1999-2004 and 2005-2008, respectively. The samples of each wave are randomly chosen so the panel is unbalanced, with some countries have five observations and some others only a single one. Thus we employ these data in a cross-section regression.

As a matter of fact, the measure of status preference in this paper is created from a subset of items in the WVS. In the survey respondents were asked to choose up-to-five qualities that children can be encouraged to learn at home.[18] From where we

[17] See the Appendix B.1 for the description of the variables and the list of countries.

[18] The list of qualities includes good manners, politeness and neatness, independence, hard work,

stand, the choice of these qualities reflects the basic character of a society's overall culture, which affects the formation of individuals' preference. For our purposes we choose *thrift saving money and things* as a proxy for status preference.[19] The reason is that the preference of saving can change the absolute level of wealth as well as the relative position of wealth holding. Aggregated to the national level, we use the fraction of respondents who selected *thrift saving money and things* as important quality of each country in each wave as the measure of strength of status preference. In the remainder of this paper, we refer to this measure as "status preference values" for the convenience of discussion.

After collecting and merging individual and national-level data from various sources, a sample of 134 observations covering 61 countries and regions is constructed for status preference values. To begin with, basic descriptive statistics for this measure are reported in Table II. The mean value of overall sample is 34.98 and the standard deviation is 15.57. The number of observations per country is as follows: 21 countries have single observation; 22 countries have 2 observations; 8 countries have 3; and the numbers of countries with 4 and 5 observations are both 5. We simply note that countries in East Asia & Pacific and South Asia tend to have higher overall status preference values, such as Bangladesh, China, Indonesia, India, Japan and South Korea. Furthermore, note that the countries with multiple observations differ greatly in their standard deviations and the difference between maximum and minimum. The largest standard deviation is 31.89 in Poland and the lowest standard deviation is 0.40 in Canada. And the differences between maximum and minimum of these two countries are 56.81 and 0.57, respectively. Since the number of observations per country is so few that may not represent the overall level of status preference values per country, we attempt to do the regressions on subsamples with better data coverage in the sensitivity analysis, such as the sample of countries with more than 2 observations of status preference values.

honesty, feeling of responsibility, patience, imagination, tolerance and respect for other people, leadership, self-control, thrift saving money and things, determination and perseverance, religious faith, unselfishness, obedience, and loyalty.

[19] Similarly, Dorius and Baker (2012), choose *hard work* and *thrift saving money and things* as a proxy for capitalist value.

Table II Summary Statistics of Status Preference Values (in Percentage)

Code	Nob	Mean	St.dev.	Max	Min	Max-Min
ARG	5	15.45	0.59	16.02	14.57	1.45
AUS	3	22.48	9.66	33.50	15.47	18.03
BGD	2	54.40	4.14	57.33	51.48	5.85
BGR	2	42.66	1.14	43.47	41.86	1.61
BRA	3	32.35	5.48	38.64	28.67	9.97
CAN	2	28.20	0.40	28.48	27.91	0.57
CHE	3	33.88	10.26	41.93	22.32	19.61
CHL	4	32.66	4.10	37.50	28.53	8.97
CHN	4	59.43	3.57	62.73	55.60	7.13
COL	2	36.67	16.35	48.23	25.11	23.12
CYP	1	40.48	-	40.48	40.48	0
DEU	2	51.94	1.24	52.81	51.07	1.74
DOM	1	11.27	-	11.27	11.27	0
DZA	1	17.94	-	17.94	17.94	0
EGY	2	17.90	13.95	27.76	8.03	19.73
ESP	4	21.52	6.82	31.60	16.49	15.11
FIN	3	18.67	16.21	29.18	0	29.18
FRA	1	42.75	-	42.75	42.75	0
GBR	2	27.04	2.91	29.09	24.98	4.11
GHA	1	19.56	-	19.56	19.56	0
GTM	1	38.60	-	38.60	38.60	0
HKG	1	1.84	-	1.84	1.84	0
HUN	2	37.21	6.35	41.69	32.72	8.97
IDN	2	49.67	3.28	51.99	47.34	4.65
IND	4	45.91	16.60	61.94	24.40	17.54
IRN	2	34.40	6.82	39.22	29.58	9.64
IRQ	2	29.90	2.38	31.58	28.22	3.36
ISR	1	19.77	-	19.77	19.77	0
ITA	1	39.43	-	39.43	39.43	0

JOR	2	21.90	3.56	24.42	19.38	5.04
JPN	5	43.00	8.19	52.28	30.81	21.47
KOR	5	58.68	15.75	72.75	33.61	39.14
MAR	2	40.39	6.52	45.00	35.78	9.22
MEX	5	34.17	13.72	48.86	11.87	36.99
MLI	1	44.07	-	44.07	44.07	0
MYS	1	50.71	-	50.71	50.71	0
NLD	1	41.71	-	41.71	41.71	0
NOR	2	13.59	0.52	13.95	13.22	0.73
NZL	2	29.24	5.79	33.33	25.15	8.18
PAK	2	56.37	1.31	57.30	55.45	1.85
PER	3	17.91	6.21	23.45	11.20	12.25
PHL	2	37.58	10.72	45.17	30.00	15.17
POL	3	36.77	31.89	56.81	0	56.81
ROM	2	56.80	5.39	60.61	52.98	7.63
RWA	1	24.09	-	24.09	24.09	0
SGP	1	38.23	-	38.23	38/23	0
SLV	1	29.82	-	29.82	29.82	0
SWE	3	36.95	6.22	42.12	30.05	12.07
THA	1	57.69	-	57.69	57.69	0
TTO	1	32.04	-	32.04	32.04	0
TUR	4	33.37	4.70	38.41	28.53	9.88
TWN	2	58.21	12.88	67.32	49.10	18.22
TZA	1	53.54	-	53.54	53.54	0
UGA	1	10.98	-	10.98	10.98	0
URY	2	24.75	2.48	26.50	23.00	3.50
USA	3	27.21	3.97	30.34	22.75	7.59
VEN	2	42.13	4.42	45.25	39.00	6.25
VNM	2	53.98	8.32	59.87	48.10	11.77
ZAF	5	26.26	10.53	36.91	14.79	22.12
ZMB	1	23.47	-	23.47	23.47	0

ZWE	1	21.16	-	21.16	21.16	0
Overall	134	34.98	15.57	72.75	0	72.75

5.2 Econometric Model

Based on Propositions 1 and 2, we follow and extend Gould and Gruben (1996) and Park and Ginarte (1997) to use the following equation for estimation:

$$y_i = \alpha_1 \theta_i p_i^2 + \alpha_2 p_i + \alpha_3 \theta_i + \mathbf{x}_i' \boldsymbol{\gamma} + \mu_i, \tag{21}$$

where $i = 1, 2, ..., N$ (number of countries). The dependent variable y_i measures the annual economic growth rate of a country. The main independent variables p_i and θ_i are the measure of patent protection and status preference values, the larger the p_i and θ_i, the stronger the patent protection and status preference, respectively. Moreover, the vector $\mathbf{x}_i$ captures other influence factors on innovation and growth, which act as control variables in our model (the intercept term is also included). We first control the effects of GDP, investment, education and population growth as emphasized in the literature. Thus in the baseline model, the initial GDP per capita, gross investment ratio, initial human capital stock and population growth rate are included as control variables. Finally, the error term is denoted by μ_i.

As shown in the estimation equation, the interacted term that the square of patent protection multiplied by status preference value follows two results of our theory. First, according to Lemma 2 and Proposition 1, the negative effect of patent protection on growth, which is called the *substitution effect*, is derived from the interaction of patent protection and status preference, and dominates under strong patent protection. Second, the degree of patent protection that maximizes growth decreases with status preference value. Thus the square term of patent protection captures the negative effect and non-monotonic relationship, while the multiplication of the square term and status preference characterize the second one. More specifically, α_1 and α_2 are expected to be negative and positive, and simple calculation reveals that the growth-maximizing degree of patent protection is $-\alpha_2/(2\alpha_1\theta_i) > 0$, which decreases with θ_i.

In the cross-section model, the data are averaged over the year 1980-2009. We assume that the independent variables and control variables are independent of the error term, so we use Ordinary Least Square (OLS) method for estimation.

5.3 Results

Tables III in the Appendix B.2 presents the baseline regression results, including three variations: (i) the benchmark regression without status preference, (ii) the benchmark regression with status preference as linear term, (iii) the baseline regression with interacted term. In the benchmark regressions, as shown in Columns (1) and (2), the linear term of patent protection exhibits positive effect on growth, while the sqaure term display a negative one. This is within our expectation, but the coefficients are all insignificant. Moreover, the effects are still ambiguous even when the linear term of status preference is introduced, see Columns (3) and (4). In addition, the coefficient of status preference value is positive but insignificant.

However, the result of baseline regression is desirable as the interacted term that the square of patent protection multiplied by status preference value is taken into consideration. The square term of patent protection interacted with status preference is significantly negative at the significance level of 10%, and the linear term of patent protection is also positively significant at the level of 10%, which is consistent with our predictions. Furthermore, the estimated values indicate that the negative effect of interacted term really dominates under stringent patent protection. In Column (5), the coefficients of patent protection and interacted term are 0.0096 and -0.0043. If we set the value of status preference value to its mean, which is 34.98%, then the growth-maximizing degree of patent protection is about 3.19. Since the value of patent protection varies from 0 to 5, the negative effect dominates when $ipr \in (3.19, 5)$ and the non-monotonic relationship is found in empirical evidence.

The regressions above are supported by the results of other control variables. In all of the five regressions, the coefficients of four control variables and the intercept term are strongly significant at the level of 5% or 1%, and their signs are in line with numerous growth literature (e.g., Barro, 1991; Mankiw et al, 1992; Ginarte and

Park, 1997).

As a result, the main results present a significantly empirical evidence that economic growth is non-monotonic in patent protection, and the degree of patent protection that maximizes growth rate is decreasing in status preference values. This provides a relatively robust estimation that supports our theoretical predictions.

5.4 Sensitivity Analysis

To examine the robustness of the baseline results above, a series of sensitivity tests are applied, by adding other variables commonly used in growth regressions and using subsamples of countries.

We first extend the baseline regression by adding more variables to control their effect on growth, including openness, the inflation rate, government consumption ratio. This group of regressions is divided into two steps. In the first step, the backward stepwise method is used in the regressions. The three control variables are firstly all added and then the one with the least significance is deleted backwardly. Secondly, another two regressions are obtained by adding only one control variable to the baseline regression each time. The results are reported in Table IV of Appendix B.2, which yields the main conclusions. For the variables of our interest, the coefficient of patent protection varies slightly in value and is still significantly positive at 10% in all of the five regressions. The coefficients of interacted term and status preference become significant at 5% level when their values remain. Additionally, the coefficients of control variables in baseline model are still strongly significant with similar values, and for the added three variables, only the coefficient of openness term is positively significant at 10%. Furthermore, the adjusted R^2 is larger in the backward stepwise regression than in the baseline regression.

On the other hand, regressions on subsamples are also considered for sensitivity analysis. Several criteria are used for the choice of subsamples. Firstly, the overall culture and preference of a society may differ in different regions, thus three regressions are obtained by omitting the countries of one region each time. The three regions are Latin America & Caribbean, South Asia and Sub-Sahara. Moreover, since there is only single observation of status preference values in some countries, the sensitivity test is based on the countries with at least two observations of status preference values. Nevertheless, the model on the countries with at least three observations of status preference values is regressed as well. The results are presented in Table V of Appendix B.2. The coefficient of interacted term is always negatively significant at 5% level, while the term of patent protection and status preference become insignificant in Columns (1) and (4). However, these coefficients are still significant at 5% level in regression (3) and (5). Moreover, the significance of several control variables is also weakened. Although the results of this group are not so desirable as those in the previous one, the estimations on subsamples still confirm that the non-monotonic relationship between patent protection and economic growth is robust.

In conclusion, the sensitivity tests above provide hard evidence on the robustness of our baseline regression, which supports our theoretical results to a great extent.

6 Conclusion

An endogenous growth with status preference has been constructed to examine the impacts of patent protection on innovation and social welfare. As in standard literature, patent protection stimulates innovation by enlarging the value of innovation. In this model, the MRS between assets and consumption goes down when the amount of assets goes up. Great innovation value reduces individuals' incentive to accumulate assets (innovation) owing to low MRS between assets and consumption, and thus stifling innovation. This is called the *substitution effect* of patent protection on innovation. Strengthening patent protection promotes innovation, owing to a small *substitution effect*, when initial patent protection is weak, whereas it hinders innovation, because of a large *substitution effect*, when initial patent protection is stringent. In addition, it has been shown that the growth-rate-maximizing degree of patent protection decreases with the strength of status preference. The reason is that the larger the strength of status preference, the bigger the *substitution effect*.

Furthermore, we have shown numerically that there exists a non-monotonic relationship between patent protection and social welfare when the strength of status preference is small, whereas reinforcing patent protection is harmful to social welfare when the strength of status preference is large. The intuition is that the strength of status preference determines the *substitution effect* of patent protection on innovation, therefore determining the positive effect of patent protection on social welfare through promoting innovation.

We have finally investigated the empirical evidence of our theoretical model. It has been shown that there exists a significantly non-monotonic relationship between patent protection and economic growth when the status preference is considered. The negative effect just comes from the interacted term, and the degree of patent protection that maximizes the growth rate also decreases with the strength of status preference in our econometric model. In the meantime, the empirical results are robust to a series of sensitivity checks as well.

It is complex to explore the effects of patent length on innovation and social welfare. However, we expect that the qualitative results remain unchanged. This is left for future research.

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Appendix A: Proof of Propositions

Proof of Proposition 1

Proof. Combining (12) and (18), we obtain

$$g = \frac{1}{1+\theta-\mu(1-\gamma)}\left\{\frac{L}{\eta}\left(\frac{1-\alpha}{B}\right)^{1/\alpha}\left[\left(\frac{\theta}{1-\alpha}+1\right)B-(1+\theta)\right]-\rho\right\}. \quad \text{(A1)}$$

Differentiating g with respect to B leads to

$$\frac{dg}{dB} = \frac{L}{[1+\theta-\mu(1-\gamma)]\,\eta}\left(\frac{1-\alpha}{B}\right)^{1/\alpha}\frac{(1+\theta)-(1+\theta-\alpha)\,B}{\alpha B}. \quad \text{(A2)}$$

Thus $\frac{dg}{dB} > 0$ when $B < B^*$, and $\frac{dg}{dB} < 0$ when $B > B^*$, where $B^* = \frac{1+\theta}{1+\theta-\alpha} < \frac{1}{1-\alpha}$. ∎

Proof of Proposition 3

Proof. Equation (20) reveals

$$\begin{aligned}\frac{dS}{dB}\Big|_{B=\frac{1}{1-\alpha}} = \; & \frac{\mu N(0)^{\mu(1-\gamma)}L^{1-\mu(1-\gamma)}\left[\frac{L(B+\alpha-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha}}{1-\alpha}-g\eta\right]^{\mu(1-\gamma)-1}}{[\rho-g\mu(1-\gamma)]^2} \\ & \cdot\left\{-(1-\alpha)^{2/\alpha}[\rho-g\mu(1-\gamma)]\,L\left[1-\frac{\theta}{1+\theta-\mu(1-\gamma)}\right]\right. \\ & \left.+\left[\frac{L(B+\alpha-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha}}{1-\alpha}-g\eta\right]\frac{dg}{dB}\Big|_{B=\frac{1}{1-\alpha}}\right\} < 0, \quad \text{(A3)}\end{aligned}$$

because $\frac{dg}{dB}|_{B=\frac{1}{1-\alpha}} < 0$, $\frac{L(B+\alpha-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha}}{1-\alpha} - g\eta > 0$, $\rho - g\mu(1-\gamma) > 0$ and $1 - \mu(1-\gamma) > 0$. ∎

Appendix B

B.1 Description of the Dataset in Empirical Model

The empirical analysis is based on a panel dataset for 61 countries and regions. Variables used for estimation are listed below with their data sources. The names of countries and the classification of the regions in the dataset are also listed.

The variables of annual change rate (i.e., economic growth rate, population growth rate and inflation rate) are calculated through logged difference. In the cross-section regression, the data of annual variables are averaged between year 1980 and 2009.

- y: the averaged annual growth rate of real GDP per capita. Source: Penn World Table 7.1.

- ly0: the logged value of per capita GDP at the initial year of each sample period. Source: Penn World Table 7.1.

- lki: the average logged value of gross investment ratio, where the gross investment ratio is measured as the investment share of PPP converted GDP per capita at 2005 constant prices. Source: Penn World Table 7.1.

- ledu: the degree of initial human capital stock, measured as the logged value of the average years of secondary education for people above 15 at the initial year of each sample period. Source: Barro and Lee (forthcoming).

- ipr: the degree of patent protection, measured by the averaged index of intellectual property rights in each period. Source: Park (2008).

- spv: status preference values, measured by the fraction of respondents who selected *thrift saving money and things* as important quality of each country in each wave of World Value Survey. Source: World Value Survey.

- pop: the averaged annual growth rate of population. Source: Penn World Table 7.1.

- inf: the averaged annual rate of inflation. Source: Penn World Table 7.1.
- trd: the degree of openness, measured by the averaged ratio of export plus import to GDP. Source: Penn World Table 7.1.
- gov: the averaged ratio of government consumption to GDP. Source: Penn World Table 7.1.

List of countries:

Algeria, Argentina, Australia, Bangladesh, Brazil, Bulgaria, Canada, Chile, China, Columbia, Cyprus, Dominican Rep., Egypt, El Salvador, Finland, France, Germany, Ghana, Guatemala, Hongkong, Hungury, India, Indonesia, Iran, Iraq, Israel, Italy, Jordan, Japan, South Korea, Morocco, Mexico, Mali, Malaysia, Netherlands, Norway, New Zealand, Pakistan, Peru, Philippines, Poland, Romania, Rwanda, Singapore, South Africa, Spain, Sweden, Switzerland, Tanzania, Thailand, Trinidad and Tobago, Turkey, Taiwan, Uganda, United Kingdom, United States, Uruguay, Venezuela, Vietnam, Zambia and Zimbabwe.

B.2 Regression Results

Table III Baseline Regression

	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)
intercept	0.1716	0.1591	0.1700	0.1522	0.1385
	(8.53)***	(6.12)***	(6.59)***	(4.50)***	(4.64)***
ly0	-0.0124	-0.0123	-0.0123	-0.0120	-0.0119
	(-5.96)***	(-5.88)***	(-5.46)***	(-5.23)***	(-5.41)***
lki	0.0252	0.0249	0.0250	0.0242	0.0233
	(5.95)***	(5.83)***	(5.36)***	(5.07)***	(5.05)***
ledu	0.0074	0.0072	0.0074	0.0072	0.0069
	(2.80)***	(2.70)***	(2.78)***	(2.67)**	(2.66)**
pop	-0.7022	-0.7206	-0.6919	-0.6897	-0.6866
	(-3.15)***	(-3.20)***	(-2.82)***	(-2.80)***	(-2.87)***
ipr	0.0004	0.0091	0.0004	0.0102	0.0096
	(0.14)	(0.77)	(0.15)	(0.83)	(1.79)*
ipr^2		-0.0015		-0.0017	
		(-0.76)		(-0.82)	
$spv \cdot ipr^2$					-0.0043
					(-1.96)*
spv			0.0013	0.0042	0.0377
			(0.10)	(0.32)	(1.71)*
F-Stat	12.76	10.65	10.45	8.99	9.98
Adj R^2	0.50	0.49	0.49	0.48	0.51
obs	61	61	61	61	61

Note: t-value in parentheses. *, **, *** represent significance level of 10%, 5% and 1%, respectively.

Table IV Sensitivity Analysis 1: Adding Control Variables

	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)
intecept	0.1399	0.1392	0.1330	0.1453	0.1364
	(4.55)***	(4.64)***	(4.53)***	(4.79)***	(4.51)***
ly0	-0.0121	-0.0120	-0.0121	-0.0118	-0.0117
	(-5.43)***	(-5.55)***	(-5.61)***	(-5.36)***	(-5.21)***
lki	0.0195	0.0197	0.0207	0.0221	0.0241
	(3.65)***	(4.08)***	(4.36)***	(4.68)***	(4.98)***
ledu	0.0071	0.0072	0.0067	0.0075	0.0073
	(2.64)**	(2.77)***	(2.63)**	(2.83)***	(2.70)***
pop	-0.7210	-0.7250	-0.7595	-0.6512	-0.7026
	(-2.95)***	(-3.02)***	(-3.20)***	(-2.71)***	(-2.90)***
ipr	0.0108	0.0107	0.0096	0.0108	0.0095
	(1.97)*	(1.99)*	(1.83)*	(1.98)*	(1.75)*
$spv \cdot ipr^2$	-0.0047	-0.0046	-0.0043	-0.0047	-0.0044
	(-2.12)**	(-2.14)**	(-2.01)**	(-2.12)**	(-1.97)*
status	0.0454	0.0452	0.0398	0.0439	0.0382
	(2.01)**	(2.03)**	(1.84)*	(1.94)*	(1.72)*
trade	0.0054	0.0053	0.0056		
	(1.70)*	(1.72)*	(1.81)*		
inflation	-0.4477	-0.4288		-0.4862	
	(-0.98)	(-1.01)		(-1.13)	
gov	-0.0045				0.0199
	(-0.12)				(0.58)
F-stat	7.57	8.57	9.51	8.93	8.66
Adj R^2	0.52	0.53	0.53	0.51	0.51
obs	61	61	61	61	61

Note: t-value in parentheses. *, **, *** represent significance level of 10%, 5% and 1%, respectively.

Table V Sensitivity Analysis 2: Regression on Subsamples

	OLS	OLS	OLS	OLS	OLS
	(1)	(2)	(3)	(4)	(5)
intecept	0.1505	0.1245	0.1379	0.1953	0.1850
	(4.58)***	(3.18)***	(4.40)***	(5.70)***	(3.62)***
ly0	-0.0138	-0.0110	-0.0122	-0.0144	-0.0203
	(-5.64)***	(-3.56)***	(-5.35)***	(-5.33)***	(-5.13)***
lki	0.0118	0.0181	0.0166	0.0137	0.0020
	(1.82)*	(2.93)***	(2.85)***	(2.07)**	(0.18)
ledu	0.0137	0.0066	0.0071	0.0131	0.0188
	(3.39)***	(2.14)**	(2.59)**	(3.26)***	(3.36)**
pop	-0.9309	-0.7235	-0.6661	-1.0912	-1.0895
	(-3.34)***	(-2.37)**	(-2.63)**	(-3.82)***	(-1.99)*
ipr	0.0081	0.0128	0.0124	0.0089	0.0197
	(1.29)	(1.75)*	(2.18)**	(1.56)	(2.58)**
$spv \cdot ipr^2$	-0.0047	-0.0057	-0.0053	-0.0049	-0.0112
	(-2.06)**	(-2.21)**	(-2.29)**	(-2.15)**	(-2.46)**
status	0.0469	0.0611	0.0560	0.0372	0.1391
	(1.95)*	(2.18)**	(2.21)**	(1.42)	(2.54)**
trade	0.0076	0.0057	0.0057	-0.0086	-0.0080
	(2.34)**	(1.58)	(1.76)*	(-1.56)	(-0.61)
inflation	-0.5418	-0.6050	-0.6494	-1.5056	-1.1235
	(-1.08)	(-0.97)	(-1.31)	(-2.47)**	(-0.98)
gov	0.0200	0.0022	-0.0261	0.0838	-0.0868
	(0.43)	(0.05)	(-0.64)	(1.58)	(-0.94)
F-stat	8.03	5.39	7.21	10.30	16.41
Adj R^2	0.57	0.48	0.52	0.70	0.90
obs	53	49	58	40	18

Note: t-value in parentheses. *, **, *** represent significance level of 10%, 5% and 1%, respectively.

Regression (1) omits sub-Saharan countries; regression (2) omits Latin American & the Caribbean countries; regression (3) excludes South Asian countries; regression (4) is based on the subsample of countries with at least 2 observations of status preference values; regression (5) excludes the countries with less than 3 observations of status preference values.

Appendix C: Extensions of Theoretical Model

We extend our theoretical model with other alternative settings. We first use the utility function with absolute level of wealth to prove that our main results still hold. We then compare the results in the case of infinite length to those in the case of finite length.

C.1 Absolute Wealth Preference

Suppose the utility function to be

$$U_i(t) = \int_0^\infty u_i[c_i(t), a_i(t)] e^{-\rho t} dt = \int_0^\infty \frac{\{[c_i(t)]^\mu [a_i(t)]^\nu\}^{1-\gamma} - 1}{1-\gamma} e^{-\rho t} dt, \quad \text{(A8)}$$

where we assume $1 - (\mu + \nu)(1 - \gamma) > 0$. The maximization of (A8) subject to (2) results in the following Euler equation along the balanced growth path:

$$\begin{aligned} \frac{\dot{c}_i}{c_i} &= \frac{1}{1-(\mu+\nu)(1-\gamma)} \left[\frac{\partial u_i / \partial a_i}{\partial u_i / \partial c_i} + (r - \rho) \right] \\ &= \frac{1}{1-(\mu+\nu)(1-\gamma)} \left[\frac{\nu}{\mu} \frac{c_i}{a_i} + (r-\rho) \right] = \frac{\theta c_i / a_i + (r-\rho)}{1-(\mu+\nu)(1-\gamma)}. \end{aligned} \quad \text{(A9)}$$

The transversality condition implies that $\rho - g(\mu+\nu)(1-\gamma) > 0$. The Euler equation is exactly the same as (3) except for the parameter difference in the denominator.

Moreover, the expression of social welfare here is

$$\begin{aligned} \widetilde{S} &= L \cdot U \\ &= \frac{N(0)^{(\mu+\nu)(1-\gamma)} L^{1-(\mu+\nu)(1-\gamma)} \eta^{\nu(1-\gamma)}}{1-\gamma} \widetilde{W} - \frac{L}{\rho(1-\gamma)}, \end{aligned} \quad \text{(A10)}$$

where $\widetilde{W} = \frac{[(\frac{1-\alpha}{B})^{1/\alpha} \frac{L(B+\alpha-1)}{1-\alpha} - g\eta]^{\mu(1-\gamma)}}{\rho - g(\mu+\nu)(1-\gamma)}$. This is also in the same form as (20), if one ignores the constant term $\eta^{\nu(1-\gamma)}$ and regard $\mu+\nu$ as one constant. Since other things remain unchanged, it is obvious that our main results hold even if utility function depends upon absolute wealth.

C.2 Finite Patent Length

The patent system with finite length adds the fact that some early created innovation will be expired. Denote the patent length as T. Then, intermediate goods $i \in [N_{t-T}, N_t]$ have monopoly rights, while intermediate goods $i \in [0, N_{t-T}]$ are produced competitively. Thus we have

$$\chi_j = \begin{cases} B, \ j \in [N_{t-T}, N_t] \\ 1, \ j \in [0, N_{t-T}] \end{cases}. \tag{A11}$$

And the firms' profit function is

$$\pi_j = \begin{cases} (B-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha} L, & j \in [N_{t-T}, N_t] \\ 0, & j \in [0, N_{t-T}] \end{cases}. \tag{A12}$$

In equilibrium the patent value is given by

$$P(t) = \int_t^{t+T} e^{-\int_t^\tau r(s)ds} \pi(\tau) d\tau = (B-1)(\frac{1-\alpha}{B})^{1/\alpha} L \frac{1-e^{-rT}}{r}. \tag{A13}$$

Combining (A13) and the equilibrium condition $P(t) = \eta$, we reveal

$$\eta = (B-1)(\frac{1-\alpha}{B})^{1/\alpha} L \frac{1-e^{-rT}}{r}. \tag{A14}$$

Using some algebra, the partial derivatives of r with respect to B is:

$$\begin{aligned} \frac{\partial r}{\partial B} &= \frac{[(1-\alpha)/B]^{1/\alpha}[1-(1-\alpha)B]L(1-e^{-rT})/(\alpha B \eta)}{1-[(1-\alpha)/B]^{1/\alpha}(B-1)e^{-rT}TL/\eta} \\ &= \frac{1-(1-\alpha)B}{\alpha B(B-1)} \cdot \frac{(e^{rT}-1)r}{e^{rT}-1-rT}. \end{aligned} \tag{A15}$$

Since $e^{rT}-1-rT > 0$, $e^{rT}-1 > 0$ when $rT > 0$, $\frac{\partial r}{\partial B} > 0$ holds on $B \in \left(1, \frac{1}{1-\alpha}\right)$. Moreover, simple calculation yields $\partial r/\partial B|_{B=1} = +\infty$ and $\partial r/\partial B|_{B=1/(1-\alpha)} = 0$.

On the other hand, the equilibrium resource constraint can be described as

$$
\begin{aligned}
cL &= Y - \int_0^N k_j dj - \dot{N}\eta \\
&= N[\alpha(1-\alpha)^{(1-\alpha)/\alpha} e^{-gT} L + (\frac{1-\alpha}{B})^{1/\alpha} \frac{B+\alpha-1}{1-\alpha}(1-e^{-gT})L - g\eta]. \quad \text{(A16)}
\end{aligned}
$$

In the meantime, the total assets owned by households is

$$
aL = \int_{N_{t-T}}^{N_t} P dj = \eta N(1-e^{-gT}). \quad \text{(A17)}
$$

Thus, the ratio of consumption to assets is

$$
\frac{c}{a} = \frac{(1-\alpha)^{(1-\alpha)/\alpha} L[\alpha e^{-gT} + (B+\alpha-1)(1-e^{-gT})/B^{1/\alpha}] - g\eta}{(1-e^{-gT})\eta}. \quad \text{(A18)}
$$

Differentiating (A18) with respect to B, we find

$$
\frac{\partial(\theta c/a)}{\partial B} = -\theta(\frac{1-\alpha}{B})^{1/\alpha} \frac{(B-1)L}{\alpha\eta B}. \quad \text{(A19)}
$$

As a consequence, we have $\frac{\partial(\theta c/a)}{\partial B} \leq 0$, $\frac{\partial(\theta c/a)}{\partial B}|_{B=1} = 0$, and $\frac{\partial(\frac{\theta c}{a})}{\partial B}|_{B=1/(1-\alpha)} = -\theta(1-\alpha)^{2/\alpha} L/\eta$.

To simplify, we here consider relative wealth preference. Rewrite the equilibrium growth rate as

$$
g = \frac{\dot{N}}{N} = \frac{\dot{c}}{c} = \frac{\theta c/a + r - \rho}{1-\mu(1-\gamma)}. \quad \text{(A20)}
$$

Thus its partial derivative with respect to B is:

$$
\frac{\partial g}{\partial B} = \frac{\partial(\theta c/a)/\partial B + \partial r/\partial B}{1-\mu(1-\gamma) - \partial(\theta c/a)/\partial g}. \quad \text{(A21)}
$$

Since $\partial(\theta c/a)/\partial g < 0$ due to $\alpha - (B+\alpha-1)/B^{1/\alpha} > 0$, we derive $\frac{\partial g}{\partial B}|_{B=1} > 0$ and $\frac{\partial g}{\partial B}|_{B=1/(1-\alpha)} < 0$. Thus the relationship between patent breadth and innovation is non-monotonic, which corresponds to Proposition 1.

Denote the growth-rate-maximizing degree of patent breadth as B^*. Using (A15), (A19) and (A21), we know that B^* satisfies

$$\frac{1-(1-\alpha)B^*}{(B^*-1)} = \frac{\theta e^{rT}(e^{rT}-1-rT)}{(e^{rT}-1)^2}. \tag{A22}$$

It is followed by

$$\left\{ \frac{-\alpha}{(B^*-1)^2} - \frac{\theta T e^{rT}\left[2+rT+(rT-2)e^{rT}\right]}{(e^{rT}-1)^3}\frac{\partial r}{\partial B^*} \right\} \frac{\partial B^*}{\partial \theta} = \frac{e^{rT}(e^{rT}-1-rT)}{(e^{rT}-1)^2}, \tag{A23}$$

Thus $\frac{\partial B^*}{\partial \theta} < 0$. This is also the same as Proposition 2.

Following the previous analysis, the welfare function in this case is

$$S = L \cdot U = \frac{N(0)^{\mu(1-\gamma)} L^{1-\mu(1-\gamma)} \phi^{\mu(1-\gamma)}}{(1-\gamma)\left[\rho - g\mu(1-\gamma)\right]} - \frac{L}{\rho(1-\gamma)}, \tag{A24}$$

where $\phi = \alpha(1-\alpha)^{(1-\alpha)/\alpha} e^{-gT} L + (\frac{1-\alpha}{B})^{1/\alpha} \frac{B+\alpha-1}{1-\alpha}(1-e^{-gT})L - g\eta$. Some calculus gives rise to

$$\begin{aligned} \frac{dS}{dB}|_{B=1} &= \frac{\mu N(0)^{\mu(1-\gamma)} L^{1-\mu(1-\gamma)} \phi^{\mu(1-\gamma)-1}}{\left[\rho - g\mu(1-\gamma)\right]^2} \\ &\quad \cdot \left\{ \alpha(1-\alpha)^{(1-\alpha)/\alpha} L - \rho\eta - g\eta\left[1-\mu(1-\gamma)\right] \right\} \frac{\partial g}{\partial B}, \end{aligned} \tag{A25}$$

and

$$\begin{aligned} \frac{dS}{dB}|_{B=1/(1-\alpha)} &= \frac{\mu N(0)^{\mu(1-\gamma)} L^{1-\mu(1-\gamma)} \phi^{\mu(1-\gamma)-1}}{\left[\rho - g\mu(1-\gamma)\right]^2} \\ &\quad \cdot \left\{ \left[\frac{\partial \phi}{\partial B} + \frac{\partial \phi}{\partial g}\frac{\partial g}{\partial B} \right] \left[\rho - g\mu(1-\gamma)\right] + \phi \frac{\partial g}{\partial B} \right\} |_{B=1/(1-\alpha)}. \end{aligned} \tag{A26}$$

Because $\frac{\partial \phi}{\partial B} + \frac{\partial \phi}{\partial g}\frac{\partial g}{\partial B} < 0$ using (A18) and (A21), $\frac{dS}{dB}|_{B=1/(1-\alpha)} < 0$ is satisfied. Moreover, $\frac{dS}{dB}|_{B=1} > 0$ when $g < \widetilde{g}$, whereas $\frac{dS}{dB}|_{B=1} < 0$ when $g > \widetilde{g}$, where

$$\widetilde{g} = \frac{\alpha(1-\alpha)^{(1-\alpha)/\alpha} L - \rho\eta}{\eta \left[1 - \mu \left(1 - \gamma\right)\right]}. \tag{A27}$$

Taking advantage of (A14), (A18) and (A20), we get

$$\theta = \frac{\left[1 - \mu \left(1 - \gamma\right)\right] g + \rho}{\alpha(1-\alpha)^{(1-\alpha)/\alpha} L - g\eta} \left(1 - e^{-gT}\right) \eta \triangleq \widetilde{\theta}\left(g\right) \tag{A28}$$

when $B = 1$. Clearly $d\widetilde{\theta}/dg > 0$, thus $\frac{dS}{dB}|_{B=1} > 0$ is held when $\theta < \widetilde{\theta}\left(\widetilde{g}\right)$ and $\frac{dS}{dB}|_{B=1} < 0$ is satisfied when $\theta > \widetilde{\theta}\left(\widetilde{g}\right)$. These results are similar to those in the basic model.