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

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Abstract

We construct a growth model with status preference to explore the effects of patents on innovation and social welfare. We find a non-monotonic effect of patent protection on innovation. Additionally, the growth-rate-maximizing degree of patent protection decreases when the strength of status preference is larger. The effect of patent protection on social welfare is ambiguous, depending on the strength of status preference. Moreover, wealth inequality widens as patent protection is reinforced. Finally, by using cross-section regression analysis, we document that a non-monotonic relationship between patent protection and economic growth is statistically significant and that the growth-rate-maximizing degree of patent protection decreases with the strength of status preference.

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1 Introduction

In existing endogenous growth models on patent protection, an individual's utility is usually stated in terms of consumption. However, new evidence shows that people do not only care about their absolute levels of consumption, income, or wealth. They also care about their status in society; see Bakshi and Chen (1996) and Easterlin (1974, 1995). Indeed, Keynes pointed out:

> "Now it is true that the needs of human beings may seem to be insatiable. But they fall into two classes–those needs which are absolute in the sense that we feel them whatever the situation of our fellow human beings may be, and those which are relative in the sense that we feel them only if their satisfaction lifts us above, makes us feel superior to, our fellows. Needs of the second class, those which satisfy the desire for superiority, may indeed be insatiable; for the higher the general level, the higher still are they." (Keynes, 1930)

Thus, in this paper, we develop a growth model with status preference to examine the effects of patent protection (patent breadth) on innovation and social welfare.

In our model, the Marginal Rate of Substitution (MRS) between assets and consumption decreases in the amount of assets and increases in the amount of consumption. On the one hand, patent protection promotes innovation by raising the value of innovation. On the other hand, the existence of status preference makes agents choose a higher level of asset holdings to improve their social rankings when patent protection is stronger. This squeezes out the contemporary consumption and makes it less attractive to accumulate capital for future consumption, discouraging the rate of asset accumulation and innovation.[1] In the model, this negative effect of patent protection is reflected by reducing the MRS between assets and consumption. We define this as the *substitution effect* of patent protection on innovation. When the degree of patent protection is low (high), the MRS is large (small), and therefore

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

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 the 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 depends on status preference. Social welfare decreases in patent protection when status preference is strong (i.e., the *substitution effect* of patent protection on innovation is large), whereas there exists a non-monotonic relationship between patent protection and social welfare when the strength of status preference is weak. We furthermore show that wealth inequality goes up when patent protection becomes strong in an extended model with heterogeneous agents, since patent protection lowers the ratio of wages to assets.

We also examine the empirical evidence of our theoretical model. By using cross-section regressions we find that there is a significantly non-monotonic relationship between patent protection and economic growth when the status preference is considered, and the degree of patent protection that maximizes the growth rate also decreases with the strength of status preference according to our regression model specification. At the same time, the empirical results are relatively robust to a series of sensitivity checks as well.

Various macroeconomic papers have studied the link between patent protection 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), and Chu and Pan (2013), 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

[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 strengthened.

protection on innovation and social welfare, complementary to the existing work. 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 asset 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.

The related literature also includes Cozzi and Galli (2011) and Adams (2008). Cozzi and Galli (2011) emphasize that a strengthening of intellectual property rights will lead to an increase in wage inequality. Adams (2008) reports that the strengthening of intellectual property rights and openness are positively correlated with income inequality in developing countries. The main difference between our paper and theirs is that we take status preference into account.

This paper also relates to the cross-country studies of patent protection and growth of economy. 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 or insignificant. This paper takes a different perspective. We are the first to empirically examine the effects of patent protection on growth when status preference affects utility. Using the index of capitalist spirit developed from the World Values Survey (WVS), we determine a non-monotonic relationship between patent protection and economic growth.

The rest of this paper is organized as follows. Section 2 introduces the model, and 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 a *substitution effect* of patent protection on innovation. Section 4 shows by simulation that the effect of patent protection on social

[4] Corneo and Jeanne (1997), Futagami and Shibata (1998) focus on the relative wealth (the status), while Zou (1994, 1995, 1998), Smith (1999, 2001) and Luo et al (2009) give attention to the absolute wealth. Furthermore, it is useful to notice that there is a lot of evidence supporting the existence of status preference; see Heffetz and Frank (2010).

welfare varies, depending on the strength of status preference. Section 5 extends the model to examine distributional effects of patent protection on wealth. We find that wealth inequality enlarges when the degree of patent protection increases. Section 6 presents an econometric model to investigate the empirical evidence of the relationship between patent protection and economic growth, and Section 7 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 the time preference. $c_i(t)$ and $a_i(t)$ represent, respectively, the consumption and assets of agent i, and $\overline{a}(t)$ represents the average level of wealth in the economy. Coefficients μ and ν measure the extent to which the agent cares about consumption and relative asset holdings. As shown in (3), it is the relative value ν/μ, rather than their absolute values, that plays an important role in our model. Hence, we only assume $\mu > 0$ and $\nu \geq 0$, and focus on the economic interpretation of ν/μ in the following analysis. We further assume that $1 - \mu(1-\gamma) > 0$ holds.[6] The assumption that instantaneous utility depends on the status (the person's relative wealth

[5]A similar utility function is employed by Bakshi and Chen (1996). Moreover, alternative preferences according to which utility depends on the absolute level of wealth like Bakshi and Chen (1996) would not alter our qualitative result. In an online supplementary appendix we provide an extended theoretical model with absolute wealth preference; see Part B.1 in this appendix for details.

[6]As in Futagami and Shibata (1998), this condition ensures that the elasticity of intertemporal substitution of consumption without status preference ($\nu = 0$) is positive.

position in the society) captures the idea of Hume, Marx, Veblen and others.[7]

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 the time derivative. Here, we normalize the price of consumption (the final good) to be unitary and drop the time index as long as it is unlikely to cause confusion.

The maximization of (1) subject to (2) gives rise to the following Euler equation along the balanced growth path:[8]

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

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, $\theta = \frac{\nu}{\mu} \geq 0$ measures the strength of status preference. Due to the presence of status preference, agents allocate resources between consumption and investment by balancing the benefits from consumption and contemporary social status in asset holdings. This trade-off affects the growth rate of consumption by adding the MRS between assets and consumption. When θ equals zero, (3) becomes the standard Euler equation.

[7] Hume (1978) states: "One of the most considerable of these passions is that of love or esteem in others, which therefore proceeds from 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).

[8] 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.

At the same time, 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) suggests $\rho - g\mu(1-\gamma) > 0$ in equilibrium.

2.2 Production

We assume that the final goods sector is perfectly competitive. In this sector, firms employ intermediate goods and labor to produce final goods 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 and k_j is the quantity used of intermediate good j.

Firm's profit maximization requires the demand for intermediate goods to be as follows:

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

Here χ_j is the price of intermediate good j.

To simplify, suppose the patent's length is infinite.[9] Suppose further that any firm can produce one unit of intermediate goods by using one unit of the final goods. We introduce the patent breadth $B \geq 1$ as the policy variable such that

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

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. Following Goh and Oliver (2002), patent breadth is defined as the ability of the

[9] Finite patent length would not change the main results; see Part B.2 in the supplementary appendix for details.

patentee to raise the price for the single product that embodies the innovation. Greater breadth increases the number of substitute products that infringe on the patent or raises the costs of imitation, thus permitting the patentee to raise prices and reduce output. That is, the wider the patent breadth, the greater the firm's ability to raise the price.

Combining (6) and (7), we obtain the following

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

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

2.3 R&D

Innovators can discover a new design of intermediate goods at a cost of 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 quantity of 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, we have the following

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

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

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

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

Note, this equilibrium condition holds if there is positive investment in R&D. When the degree of patent protection is too weak, the condition may not hold, since the monopolistic profit is too small. Thus, in the following analysis, we assume there is a lower bound of B, i.e. $\underline{B}$, such that $\underline{B}\geq 1$ and the growth rate is positive on $B \geq\underline{B}$. We only focus on this equilibrium. It is natural to assume that the above equilibrium condition holds and there is a positive growth rate when $B = 1/(1-\alpha)$. 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

$$\frac{dr}{dB} = \frac{1-(1-\alpha)B}{\alpha B}\left(\frac{1-\alpha}{B}\right)^{1/\alpha}\frac{L}{\eta} > 0 \tag{13}$$

for every $B \in \left(\underline{B}, \frac{1}{1-\alpha}\right)$. Hence, we state the following lemma:

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

Stringent patent protection (broad patent breadth) raises the value of innovation, therefore driving up the interest rate (the return on assets). It is useful to note that the equilibrium growth rate is $\frac{r-\rho}{1-\mu(1-\gamma)}$, when there is no status preference (i.e., $\nu = 0$). In this case, Lemma 1 implies the following result.

Lemma 2 *When no status preference is present, patent protection promotes innovation.*

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

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

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:

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

By differentiating (16) with respect to B, we reveal

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

This leads us to the following result:

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,* $\frac{\partial(\frac{\theta c}{a})}{\partial B}|_{B=\underline{B}} \leq 0, \frac{\partial(\frac{\theta c}{a})}{\partial B}|_{B=1/(1-\alpha)} = -\theta(1-\alpha)^{2/\alpha} L/\eta < 0$.

We refer to $\frac{\partial(\theta c/a)}{\partial B} \leq 0$ as the *substitution effect* of patent protection on innovation. Our lemma thus states that patent protection lowers the growth rate through lowering the MRS between assets and consumption. Intuitively, when the average value of asset holdings is higher, that is, when patent protection is stronger, a given foregone level of asset holdings will make an agent fall behind others in social status. So, the agent has incentives to improve his/her social ranking by choosing a higher level of asset holdings. At the same time, stronger patent protection also lowers the level of output in the same period by strengthening the monopoly power in the intermediate goods sector. These effects of patent protection (increasing the average value of asset holdings and strengthening monopoly power) squeeze out the contemporary consumption, which increases the marginal utility of consumption and decreases the marginal utility of assets. As a consequence, the *substitution effect* is negative.

Now we are ready to explore the relationship between patent protection and innovation. Clearly, the equilibrium growth rate is

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

When $B = \frac{1}{1-\alpha}$, $g > 0$. It follows that $\alpha\left(1-\alpha\right)^{\frac{2-2\alpha}{\alpha}}\left[\left(2-\alpha\right)\theta + 1 - \alpha\right]\frac{L}{\eta} > \rho$. Equations (16) and (18) imply that

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

where $\partial\left(\theta c/a\right)/\partial g = -\theta < 0$. Consequently, the effect of patent breadth is straightforward, due to Lemmas 1 and 3. The positive effect of raising interest rate dominates when $B \rightarrow \underline{B}$, while the negative effect of declining MRS is dominant when $B \rightarrow 1/\left(1-\alpha\right)$. 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 Appendix A. ■

The *substitution effect* of patent protection makes it less attractive to innovate (accumulate assets) for future consumption. It follows that increasing patent protection lowers the growth rate. At the same time, a marginal change in patent breadth does not affect the interest rate when $B = 1/(1-\alpha)$, because the monopoly price maximizes profits. 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 the status preference θ changes.

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

Proof. As determined in the proof of Proposition 1, $B^* = \frac{1+\theta}{1+\theta-\alpha}$, thus $\frac{\partial B^*}{\partial \theta} = -\frac{\alpha}{\left(1+\theta-\alpha\right)^2} < 0$. ■

Apparently, the larger θ, the greater the marginal change in the MRS between assets and consumption. That is, a bigger θ leads to a higher *substitution effect*. On the other hand, status preference itself is also directly connected with economic growth, due to its effects on capital accumulation. Since status preference only positively affects the MRS between assets and consumption, it is intuitive that stronger status preference leads to a higher economic growth rate. More specifically, we have the following proposition:

Proposition 3 *The economic growth rate increases in the strength of status preference.*

Proof. Differentiating (18) with respect to θ reveals $\frac{\partial g}{\partial \theta} = \frac{c/a}{1-\mu(1-\gamma)+\theta} > 0$. ■

4 Social Welfare

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

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

where $W = \frac{[(\frac{1-\alpha}{B})^{1/\alpha} \frac{L(B+\alpha-1)}{1-\alpha} - g\eta]^{\mu(1-\gamma)}}{\rho - g\mu(1-\gamma)}$. As a result, we state the following proposition:

Proposition 4 *Strengthening patent protection reduces social welfare when* $B = \frac{1}{1-\alpha}$.

Proof. See Appendix A. ■

As typical in these models, stringent patent protection decreases social welfare through monopoly pricing. In addition, it lowers social welfare via stifling growth when $B = \frac{1}{1-\alpha}$. Accordingly, social welfare decreases when patent protection is strengthened, if $B = \frac{1}{1-\alpha}$.

The qualitative analysis is complicated. Thus we use a quantitative method to explore the effect of patent protection on social welfare for $B \in \left(\underline{B}, \frac{1}{1-\alpha}\right)$. 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 to roughly 3%. Without loss of generality, we unitize total labor force, i.e., $L = 1$. Moreover, we assume $N(0)$ to be 100, for convenience. Using (12), we then pin down the innovation cost parameter η to 0.061. Table I presents the calibrated values of the parameters $\{\alpha, \rho, \mu, \gamma, \theta\}$ for $\theta \in (0, 3]$.[11]

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 results for the relationship between patent protection and social welfare are reported in Figure 1.[12] Thus, we have the following claim:

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

When status preference is strong (so 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 decrease when patent protection becomes stronger. By contrast, the positive effect of patent protection is large when the strength of the status preference is small (and as a result the

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

[12] A simple calculation shows that given the above calibrated parameters, the growth rate is positive for all $B \geq 1$ and $\theta \geq 0.8$. So in these three cases we have $\underline{B}= 1$. The results in Figures 1 are robust to the scale on the horizontal axis.

substitution effect of patent protection on innovation is weak). Consequently, the relationship between patent protection and social welfare is non-monotonic.[13]

Basu (1996) and Basu and Fernald (1997) document that the aggregate profit share is about 3% in the US, while Laitner and Stolyarov (2004) report that the markup is about 1.1 (i.e. a 10% markup) in the US. The empirical evidence shows that B takes values in [1.03, 1.1]. From our simulation results, we conclude that a marginal increase in patent protection may raise or reduce social welfare. This result occurs regardless of the initial patent protection level, given strong enough status preference.[14]

5 Extended Model with Heterogeneous Agents

We now examine the effect of patent protection on innovation in an extended model with heterogeneous agents. To this end, we follow Futagami and Shibata (1998) in that we assume that there exist two types of agents, each of whom have different time and status preferences, and that each type of agent has size $L/2$. Using the same reasoning as before, we conclude that, on a balanced growth path, the Euler equation for agent type i is

$$\frac{\dot{c}_i}{c_i} = \frac{1}{1-\mu(1-\gamma)}\left[\frac{\nu_i}{\mu}\cdot\frac{c_i}{\epsilon_i\overline{a}} + (r-\rho_i)\right]. \tag{21}$$

[13]According to Claim 1, the effect of patent protection on innovation depends on the strength of the status preference. For a qualitative analysis, putting $\underline{B}=1$, we have

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

Therefore, $\frac{\partial S}{\partial B}|_{B=\underline{B}} > 0$ 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 $\frac{\partial S}{\partial B}|_{B=\underline{B}} < 0$ 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]The literature does not provide a precise estimate for θ.

Here $\epsilon_i = \frac{a_i}{\overline{a}}$ is the share of wealth of agent type i, measuring wealth inequality. Wealth inequality widens as $|\epsilon_1 - \epsilon_2|$ becomes large. Combining (2) and (21), we get the equilibrium growth rate,

$$g_i = \frac{[1+\theta_i]\, r + \theta_i \frac{w}{\epsilon_i \overline{a}} - \rho_i}{1 - \mu(1-\gamma) + \theta_i}, \tag{22}$$

where $\theta_i = \frac{\nu_i}{\mu}$, $r = (B-1)\left(\frac{1-\alpha}{B}\right)^{1/\alpha} \frac{L}{\eta}$, $w = \alpha\left(\frac{1-\alpha}{B}\right)^{(1-\alpha)/\alpha} N$ and $\overline{a} = \frac{\eta N}{L}$. Note that θ_i captures the strength of status preference for agent i.

In equilibrium $g_1(\epsilon_1) = g_2(\epsilon_2)$. This implies[15]

$$\begin{aligned} F\left(\epsilon_1, r, \frac{w}{\overline{a}}\right) \equiv\ & \mu(1-\gamma)[\theta_2 - \theta_1]\, r + \frac{w}{\overline{a}}\left\{\frac{\theta_1[1-\mu(1-\gamma)+\theta_2]}{\epsilon_1}\right. \\ & \left. - \frac{\theta_2[1-\mu(1-\gamma)+\theta_1]}{2-\epsilon_1}\right\} - \rho_1[1-\mu(1-\gamma)+\theta_2] \\ & + \rho_2[1-\mu(1-\gamma)+\theta_1] = 0. \end{aligned} \tag{23}$$

Differentiating (23) with respect to B yields $\frac{d\epsilon_1}{dB} = -\frac{1}{\partial F/\partial \epsilon_1}\left[\frac{\partial F}{\partial r}\frac{\partial r}{\partial B} + \frac{\partial F}{\partial (w/\overline{a})}\frac{\partial (w/\overline{a})}{\partial B}\right]$, where

$$\begin{cases} \frac{\partial F}{\partial r}\frac{\partial r}{\partial B} = \frac{L\mu(1-\gamma)[\theta_2-\theta_1]}{\eta}\left(\frac{1-\alpha}{B}\right)^{1/\alpha}\frac{1-(1-\alpha)B}{\alpha B}, \\ \frac{\partial F}{\partial (w/\overline{a})}\frac{\partial (w/\overline{a})}{\partial B} = \frac{L}{\eta}\left(\frac{1-\alpha}{B}\right)^{1/\alpha}\left[-\frac{\theta_1[1-\mu(1-\gamma)+\theta_2]}{\epsilon_1} + \frac{\theta_2[1-\mu(1-\gamma)+\theta_1]}{2-\epsilon_1}\right]. \end{cases} \tag{24}$$

Usually, the poor are more impatient than the rich.[16] Thus we assume that $\theta_1 = \theta_2$ and $\rho_1 > \rho_2$ in the current model. In equilibrium, (24) results in the following proposition.

Proposition 5 *Strengthening patent protection enlarges wealth inequality.*

Proof. See Appendix A. ∎

Patent protection raises interest rate and thereby widens wealth inequality, since the rich holds more assets. At the same time, patent protection lowers the relative

[15]Clearly, $\epsilon_1 + \epsilon_2 = 2$ because the size of each type of agent is the same.
[16]See Lawrance (1991) for some evidence.

income of the poor via decreasing the wage rate. As a result, the income gap $\frac{ra_2+w}{ra_1+w} = \frac{r/w \cdot a_2+1}{r/w \cdot a_1+1}$ is enlarged.[17]

We now explore the effect of patent protection on innovation in the case where agents are asymmetric. Using (22) we find

$$\frac{dg}{dB} = \frac{dg_2}{dB} = \frac{\partial g_2}{\partial B} + \frac{\partial g_2}{\partial \epsilon_2}\frac{d\epsilon_2}{dB} = \frac{[1+\theta_2]\frac{dr}{dB} + \frac{\theta_2}{\epsilon_2}\frac{\partial (w/\overline{a})}{\partial B}}{1-\mu(1-\gamma)+\theta_2} + \frac{\partial g_2}{\partial \epsilon_2}\frac{d\epsilon_2}{dB}. \tag{25}$$

Proposition 6 *Strengthening patent protection stifles innovation when initial patent protection is already great.*

Proof. See Appendix A. ■

The intuition behind Proposition 6 is the same as that behind Proposition 1, except that patent protection retards innovation by enlarging wealth inequality (because $\frac{\partial g_2}{\partial \epsilon_2}\frac{d\epsilon_2}{dB} < 0$) in the case of asymmetric agents. Propositions 5 and 6 suggest that reinforcing patent protection is harmful to economic growth and wealth distribution when patent protection is already strong.

6 Empirical Evidence

In this section, we base our index of status preferences on the capitalist spirit developed by Dorius and Baker (2012) and empirically investigate both 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.

6.1 Data

For our main sample, we use a panel dataset that runs from 1980 to 2009. The database includes variables of economic growth, patent protection, the strength of status preference, and control variables. The data sources for our growth and control

[17] The rich would accumulate more assets if they care more about social status. Thus the qualitative results remain unchanged, if we alternatively assume $\theta_1 < \theta_2$.

variables are the Penn World Table 7.1 (PWT) constructed by Heston et al (2012) and World Development Indicators (World Bank, 2013) . The data on human capital stock comes from Barro and Lee (2013). The measure of patent protection is from Park (2008) and Ginarte and Park (1997). The measure of the strength of status preference comes from the World Values Survey (WVS) cumulative file (WVS, 2015).[18]

The growth rate of a country is taken to be the average annual growth rate of GDP per capita between 1980 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. The overall index is the unweighted sum of these five values, with higher values reflecting a greater level of protection.

So far, the available data for wealth preference are limited. Moreover, there are few literatures which provide proper measures. In this paper, the measure of the strength of status preferences 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. The samples from each wave are randomly chosen, so the panel is unbalanced. Some countries have five observations and some only have a single one. Thus, we employ this data in a cross-section regression.

The measure of status preference in this paper is created from a subset of items in the WVS.[19] In the survey, respondents were asked to choose up to five qualities that

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

[19] Our reason for using WVS is based on the statement of Dorius and Baker (2012): "The WVS, which surveys the opinions of people from a large number of countries, 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 and as such, has been used extensively in previous research."

children can be encouraged to learn at home.[20] From our perspective, the choice of these qualities reflects the basic character of a society's overall culture. This reflects the formation of individuals' preferences. For our purposes, we choose *thrift saving money and things* as a proxy for status preference.[21] Aggregated to the national level, we use the percentage of respondents who selected *thrift saving money and things* as an important quality for each country-wave as our measure of strength of status preference. Hence, this measure is a percentage that represents the fraction of individuals who regard status preference as important, and its range lies in $[0, 1]$. The higher the measure, the stronger the preference for status. The reason for using this measure is that the preference of saving reflects the incentive of accumulating wealth and changing the relative position of wealth holding, which is directly driven by status preference. Our proxy for status preference is also supported by some empirical evidence. Guiso et al (2006) regresses national savings rate on this measure and finds that this measure has a positive and significant effect on the savings rate, both in OLS and IV regressions. For convenience, we refer to this measure as "status preference values".

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, Table I in Part A of the supplementary appendix reports basic descriptive statistics for this measure. The mean value of the overall sample is 34.98% and the standard deviation is 15.57%. The number of observations per country is as follows: 21 countries have a 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 the East Asia & Pacific and South Asia regions tend to have higher overall status preference values. Examples of these countries include Bangladesh, China, Indonesia, India, Japan and

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

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

South Korea. Furthermore, note that the countries with multiple observations differ greatly in their standard deviations and the differences between maximum and minimum. The largest standard deviation is 31.89% in Poland and the lowest standard deviation is 0.40% in Canada. The differences between the maximum and minimum for these two countries are 56.81% and 0.57%, respectively. Since the number of observations per country is so few that it may not represent the overall level of status preference values per country, we attempt a sensitivity analysis, whereby we do the regressions on the subsamples which have better data coverage. For example, we consider the sample of countries with more than 2 observations of status preference values.

6.2 Identification Strategy

To test Propositions 1 and 2, we follow and extend Gould and Gruben (1996) and Park and Ginarte (1997). We use the following cross-section model for estimation:

$$y_i = \alpha_1 p_i^2 + \alpha_2 p_i + \alpha_3 \theta_i p_i + \alpha_4 \theta_i + \mathbf{x}_i' \boldsymbol{\gamma} + \mu_i, \tag{26}$$

where $i = 1, 2, ..., N$ (and N is the total number of countries). The dependent variable y_i measures the average economic growth rate of output per capita (1980-2009) for country i. The main independent variables, p_i and θ_i, are the measures of patent protection and status preference values. The larger the p_i and θ_i, the stronger the patent protection and status preference, respectively. The vector $\mathbf{x}_i$ captures other influence factors of innovation and growth. The $\mathbf{x}_i$ act as control variables in our model; the intercept term is also included among the $\mathbf{x}_i$ components. We first control the effects of GDP, investment, education and population growth, as emphasized in the literature. 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 square of patent protection and the interacted term, patent protection multiplied by status preference value, follow the two results of our theory. First, according to Lemma 3 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 the growth rate decreases with the value of status preference. In our regression model, the square term of patent protection captures the negative effect and non-monotonic relationship. The interacted term of patent protection and status preference represents the non-monotonic relationship. More specifically, α_1 and α_3 are expected to be negative, α_2 should be positive, and the coefficient of the linear term of patent protection should be positive (i.e., $\alpha_2 + \alpha_3\theta_i > 0$). Then, a simple calculation reveals that the growth-maximizing degree of patent protection is $(\alpha_2 + \alpha_3\theta_i) / (-2\alpha_1) > 0$, which decreases with θ_i.

In the cross-section model, the data are averaged over the year 1980-2009. We start by using an Ordinary Least Square method for estimation, assuming that the independent variables and control variables are independent of the error term. For the potential problem of heteroskedasticity, we use a robust standard error for the hypothesis test of coefficients. In addition, it is still necessary to consider another three potential problems of endogeneity: omitted variables, causal effects and measurement error. These three problems exist not only in the relationships between patent protection and growth, but also in the impact of status preference on growth. This is because the measures of patent protection and status preference are both derived from the combination of a series of dummy variables. We address these concerns by using instrumental variables and the GMM method in complement with the OLS estimation. For the degree of patent protection, we use the average degree of measure of patent protection before 1980 (i.e., the available sample years are 1960, 1965, 1970, 1975) as the instrument variable. For the degree of status preference, we follow Guiso et al (2006) in using the dummies of religious denominations for each country as instruments; i.e., the dummy of one religious denomination for one country is equal to 1 if the percentage of people belonging to this denomination is highest relative to other denominations in this country. We refer to them as dummy variables of country-specific denomination. The denominations are Catholic, Protestant, Orthodox, Jewish, Muslim, Hindu, Buddhist and other affiliations.[22] To check whether patent protection and status preference are endogenous, we use three strategies. First, we only control the endogeneity of patent protection and assume status preference is exogenous. Second, status preference is instrumented while patent protection is left as exogenous. Finally, the two variables are both instrumented. Then we compare these GMM regression results with our OLS results.

6.3 Results

6.3.1 OLS Estimation

For a comparison, we first examine the OLS regressions.[23] Tables II in Appendix B.2 presents the baseline OLS regression results, including three variations: (i) the benchmark regression with patent protection and status preference as linear terms, (ii) the benchmark regression with the linear and square terms of patent protection and the linear term of status preference, (iii) the baseline regression of the complete equation (26). In all of the benchmark regressions, the linear terms of patent protection and status preferences both exhibit positive effects on growth, while the square term displays a negative relationship. Moreover, the interaction term has a negative effect on the growth rate. However, the coefficients mentioned above are all insignificant. These results are within our expectation, since the problem of endogeneity may generate biased estimation and expand the estimated standard deviation of coefficients.

Although our main conclusion is not fully proved in the OLS regressions, the regressions above are supported by the results of other control variables. In all of the four regressions, the coefficients of four control variables (initial per capita GDP, annual investment rate, initial human capital stock and population growth rate) and the intercept term are strongly significant at the level of 5% or 1%, and their signs

[22]See Part A.1 of the supplementary appendix for country classification of religious denominations.

[23]In the published version of this paper, we only display the regression results of baseline OLS and GMM estimation with the variables of main interest. The tables with complete regression results and sensitivity analysis are relegated to the supplementary appendix.

are in line with numerous papers in the growth literature (e.g., Barro, 1991; Mankiw et al, 1992; Park and Ginarte, 1997).[24]

6.3.2 GMM Estimation

The results of baseline regression with the GMM method are reported in Table III, IV and V in Appendix B.2. In Table III, we assume only patent protection is endogenous and use the average degree of patent protection from 1960 to 1979 and its square term as well as its interaction term with status preference. In Table IV, we instrument the measure of status preference with the dummy variables of country religious denominations and their interaction terms with patent protection. In Table V, both patent protection and status preference are regarded as endogenous variables, and we instrument them with the two sets of instruments mentioned above and their interaction terms.

We first report the regression results in Table III. Regression (1) and (2) show that if the interaction term is not included, the estimated effects of patent protection and status preferences are still considered insignificant. However, after we introduce the interaction term, as displayed in Regression (3), the coefficients of the square term and linear term of patent protection, the status preference term, and the interaction term are all of expected signs and significant at the level of 10% or lower. However, Regression (4) reports that after the additional control variables are included, the coefficients of the square term and linear term of patent protection become insignificant again. Second, in Table IV, we report that the results in the first two columns follow those in Table III, except that the coefficient of status preference in Regression (2) is positively significant at 10%. In addition, the four main coefficients are all of expected signs and significant at the 5% or 1% level in Regression (3) and (4). Finally, in Table V we obtain more significant results. Even though the interaction term is not included, the coefficients of patent protection and status preference are significant in the first two regressions, except for the linear term of patent protection in Regression (1). Furthermore, the results in Regression (3) and (4) are similar to

[24] See Table II in Part A.2 of the supplementary appendix for details.

those in the previous two tables.

In addition to the signs and significance, the values of the four main coefficients are also consistent with our theory and can generate non-monotonic effects of patent protection. For instance, in Regression (3) of Table IV, the coefficients of the patent protection square term, linear term and interacted term are -0.00379, 0.0347 and -0.0347. Thus the growth-maximizing degree of patent protection is $p^* = 4.578 - 4.578\theta$. If we set the value of status preferences to its mean, which is 34.98%, then the growth-maximizing degree of patent protection is about 2.98. Since the value of the patent protection varies from 0 to 5, the negative effect dominates when $p \in (2.98, 5)$ and the non-monotonic relationship is found in the empirical evidence. The coefficient of status preference is 0.133. Thus, the partial effect of status preference on the growth rate is $0.133 - 0.0347p$. If the degree of patent protection is set to its mean value 2.82, then this partial effect is 0.0351.

The actual size of patent effects on innovation is also worth discussing. According to the regression results, the coefficient of the square term varies between -0.007 and -0.002, the coefficient of the linear term of patent protection varies between 0.02 and 0.06, and the coefficient of the interacted term varies between -0.06 and -0.02. If we use the coefficients in Regression (3) of Table IV as an example, still setting the value of status preferences to 34.98%, the partial effect of patent protection on growth rate is $-0.00758p + 0.0226$. Thus the marginal effect of patent protection on innovation varies from 0.0226 to -0.0153 when p changes from 0 to 5. The size of the marginal effect is quite considerable since the average annual growth rate in our data is about 1.99%.

The indicator OID reports the p-value of Hansen's J test for overidentification. The results show that we cannot reject the null hypothesis for any of the GMM regressions, which supports our choice of instrumental variables. The indicator Endog reports the p-value of the GMM C test for endogeneity. The p-values of this indicator in Regression (3) and (4) of Table III and IV, and Regression (4) in Table V are all lower than 10%, which imply the endogeneity of instrumented variables. However, note that when patent protection is instrumented, the test of endogeneity may not reject the null hypothesis, as reported in Regression (3) in Table V, so the problem of endogeneity in patent protection may not be so strong.

After we instrument the key variables, the main results present significant evidence that economic growth is non-monotonic in patent protection, and the degree of patent protection that maximizes the growth rate is decreasing in the status preference values. Considering the limitations of our data and measure of status preference, these results provide relatively consistent evidence that is in line with our theoretical predictions.

6.4 Sensitivity Analysis

To examine the robustness of our baseline results above, a series of sensitivity tests are used, by using alternative measures of status preference and different subsamples of countries.

We use two alternative measures based on the World Values Survey. The first one is the proxy for capitalist's value used by Dorius and Baker (2012). It is measured as the average fraction of respondents who selected both *thrift saving money and things* and *hard work* as important qualities of each country. The second one is the averaged fraction of respondents who strongly agree or agree with the view "*people who don't work turn lazy*" in each country. The second alternative measure is conceptually similar to status preference.[25] There are some missing data in the sample. Hence we drop the data of respondents who did not answer these questions or were not asked this question. Both the OLS method and GMM method are employed. As reported in Table VI and Table VII in Part A.2 of the supplementary appendix, the results show that the main conclusion is not altered, and that the GMM method again helps to eliminate the problem of endogeneity. It should be noted that when only the degree of patent protection is instrumented, the coefficients of patent protection

[25] Dorius and Baker (2012) states, "Three indicators from the Schwartz's scale (*being successful*, *getting rich*, and *having a good time*) and two measures of work beliefs ('*people who don't work turn lazy*' and '*work should always come first*') were conceptually similar to the identical orientation described in Weber's theory. Factor analysis of the six measures among a subset of 45 countries in which all six measures were asked produced a single latent factor with loadings ranging from .51 to .78." Here we take the measure of work belief "people who don't work turn lazy" in our sensitivity analysis.

and the interaction term are insignificant. However, the results become significant when status preference is instrumented, as shown in Regression (3) and (4).

We also consider regressions on different subsamples in our sensitivity analysis. Several criteria are used for the choice of subsamples. First, the overall culture and preference of a society may differ in different regions. Thus, we do three regressions in which we omit the countries of a specific region in each regression. The three regions are Middle East & North Africa, South Asia and Sub-Sahara. Moreover, since there is only a single observation of status preference values in some countries, one sensitivity test is based on the countries with at least two observations of status preference values. The results are presented in Table VIII-XI in Part A.2 of the supplementary appendix. The coefficients of patent protection, status preference, the square term and the interacted term have correct signs in all regressions. These coefficients are always significant at the 5% or 1% level in Table X, where only status preference is instrumented, except the coefficient of the square term and interaction term in Regression (1). Moreover, the significance of several control variables is also weakened. The estimations on subsamples still confirm that the non-monotonic relationship between patent protection and economic growth is robust.

To summarize, the sensitivity tests above imply that the conclusions of our empirical model are relatively robust and support our theoretical results.

7 Conclusion

An endogenous growth model with status preference has been constructed to examine the impacts of patent protection on innovation and social welfare. As is standard in the literature, we find patent protection stimulates innovation by enlarging the value of innovation. The existence of status preference makes agents choose a higher level of asset holdings to enhance their social rankings as patent protection rises. This implies that a greater innovation value can lower the MRS between assets and consumption by squeezing out the contemporary consumption, thus reducing agents' incentives to innovate (accumulate assets). 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 patent protection is initially stringent. In addition, we show that the growth-rate-maximizing degree of patent protection decreases with the strength of status preference. The reason is that the stronger the status preference, the larger the *substitution effect*.

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. We have also shown 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 then have shown that patent protection amplifies wealth inequality in an extended model with heterogeneous agents, since patent protection reduces the ratio of wages to assets.

Finally, we have investigated the empirical evidence supporting our theoretical model. We have shown that there exists a significantly non-monotonic relationship between patent protection and economic growth when status preference is considered. The negative effect on growth comes from the square term. The degree of patent protection that maximizes the growth rate also decreases with the strength of status preference, due to the interaction term in our econometric model. The empirical results are robust to a series of sensitivity checks.

It is complicated to explore the effects of patent length on innovation and social welfare. However, we expect that the qualitative results will 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 derive

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

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 $B^*=\frac{1+\theta}{1+\theta-\alpha}<\frac{1}{1-\alpha}$.

Moreover, since $g|_{B=B^*}>g|_{B=1/(1-\alpha)}>0$, we have $1\leq\underline{B}<B^*$. Thus Proposition 1 holds on $\left(\underline{B},\frac{1}{1-\alpha}\right)$. ■

Proof of Proposition 4

Proof. Equation (20) reveals

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

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 $1-\mu(1-\gamma)>0$. ■

Proof of Proposition 5

Proof. We first prove $\frac{\partial F}{\partial \epsilon_1} < 0$ and $\epsilon_1 < 1 < \epsilon_2$ in equilibrium. Equation (23) shows

$$\frac{\partial F}{\partial \epsilon_1} = -\left\{ \frac{\theta_1 \left[1 - \mu (1 - \gamma) + \theta_2\right]}{\epsilon_1^2} + \frac{\theta_2 \left[1 - \mu (1 - \gamma) + \theta_1\right]}{\epsilon_2^2} \right\} \frac{w}{\bar{a}} < 0. \tag{A4}$$

From $\theta_1 = \theta_2$ we obtain

$$F\left(1, r, \frac{w}{\bar{a}}\right) = -\left(\rho_1 - \rho_2\right)\left[1 - \mu (1 - \gamma) + \theta_1\right] < 0. \tag{A5}$$

Notice that $F\left(0, r, \frac{w}{\bar{a}}\right) = +\infty$, so we have $\epsilon_1 < 1 < \epsilon_2$. This implies that

$$\frac{d\epsilon_1}{dB} = -\frac{1}{\partial F / \partial \epsilon_1} \cdot \frac{L}{\eta} \left(\frac{1-\alpha}{B}\right)^{1/\alpha} \left\{ -\left[1 - \mu (1 - \gamma)\right] \left(\frac{\theta_1}{\epsilon_1} - \frac{\theta_2}{\epsilon_2}\right) - \frac{\theta_1 \theta_2 \left(\epsilon_2 - \epsilon_1\right)}{\epsilon_1 \epsilon_2} \right\} < 0, \tag{A6}$$

because $\frac{\theta_1}{\epsilon_1} - \frac{\theta_2}{\epsilon_2} > 0$ for any $B \in \left(\underline{B}, \frac{1}{1-\alpha}\right)$, and we have assumed $1 - \mu (1 - \gamma) > 0$. Thus the proposition is established. ■

Proof of Proposition 6

Proof. Equation (22) implies:

$$\frac{\partial g_i}{\partial \epsilon_i} = -\frac{w}{\bar{a}} \cdot \frac{\theta_i}{\epsilon_i^2} \cdot \frac{1}{1 - \mu (1 - \gamma) + \theta_i} < 0. \tag{A7}$$

It follows that $\frac{\partial g_2}{\partial \epsilon_2} \frac{d\epsilon_2}{dB} < 0$ due to $\frac{d\epsilon_2}{dB} = -\frac{d\epsilon_1}{dB} > 0$. At the same time, $\frac{\partial g_2}{\partial B}|_{B=1/(1-\alpha)} = -\frac{\theta_2/\epsilon_2}{1-\mu(1-\gamma)+\theta_2} (1-\alpha)^{2/\alpha} L/\eta < 0$. As a consequence, $\frac{dg}{dB}|_{B=1/(1-\alpha)} < 0$. In other words, strengthening patent protection stifles innovation when initial patent protection is strong. ■

Appendix B

B.1 Description of the Dataset in the 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 the annual change rate (i.e., economic growth rate, population growth rate and inflation rate) are calculated through logged differences. In the cross-section regression, the data of the annual variables are averaged between years 1980 and 2009.

- y: the average 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 (2013).
- 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 an important quality of each country in each wave of the World Values Survey. The first alternative measure is the averaged fraction of respondents who selected both *thrift saving money and things* and *hard work* as important qualities of each country. The second one

is the averaged fraction of respondents who strongly agree or agree with the view “people who don’t work turn lazy” in each country. Source: World Values Survey (WVS, 2015).

- pop: the average annual growth rate of the population. Source: Penn World Table 7.1.
- inf: the average annual rate of inflation. Source: Penn World Table 7.1.
- trd: the degree of openness, measured by the average ratio of export plus import to GDP. Source: Penn World Table 7.1.
- gov: the average ratio of government consumption to GDP. Source: Penn World Table 7.1.
- fdi: the net inflow of FDI as a share of GDP. The data for Taiwan is unavailable, so it is excluded in the regression where fdi is included. Source: World Development Indicators (World Bank, 2013).

List of countries or regions:

Algeria, Argentina, Australia, Bangladesh, Brazil, Bulgaria, Canada, Chile, China, Columbia, Cyprus, Dominican Rep., Egypt, El Salvador, Finland, France, Germany, Ghana, Guatemala, Hong Kong, Hungary, 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 II Baseline Regression 1: OLS Method

	(1) OLS	(2) OLS	(3) OLS	(4) OLS
ipr	0.000393	0.0102	0.0208	0.0172
	(0.17)	(0.85)	(1.43)	(1.27)
ipr^2		-0.00169	-0.00212	-0.00136
		(-0.87)	(-1.12)	(-0.76)
spv×ipr			-0.0214	-0.0212
			(-1.60)	(-1.55)
spv	0.00128	0.00415	0.0625	0.0675
	(0.10)	(0.29)	(1.47)	(1.60)
Observations	61	61	61	60
Adjusted R^2	0.486	0.483	0.498	0.507
F	6.099	5.333	5.530	5.146

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The t statistics, in parentheses, are based on standard errors clustered by country. In Regression (1), (2) and (3), the control variables are ly0, lki, ledu and pop. In Regression (4), four additional control variables are included, which are trade, inflation, gov and fdi.

Table III Baseline Regression 2: GMM Method
(Instrumented: Patent Protection)

	(1)	(2)	(3)	(4)
	GMM	GMM	GMM	GMM
ipr	0.00111	0.0106	0.0345^{**}	0.0260
	(0.42)	(0.82)	(2.50)	(1.58)
ipr^2		-0.00163	-0.00337^{*}	-0.00208
		(-0.79)	(-1.75)	(-0.95)
spv×ipr			-0.0386^{***}	-0.0315^{**}
			(-3.03)	(-2.66)
spv	0.00448	0.00738	0.113^{***}	0.102^{***}
	(0.35)	(0.53)	(2.70)	(2.84)
Observations	56	56	56	55
OID				
Endog	[0.914]	[0.988]	[0.020]	[0.090]
Adjusted R^2	0.400	0.394	0.333	0.422
F	8.749	7.383	8.789	4.814

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The t-statistics, in parentheses, are based on robust standard errors with a small sample. OID represents the Hansen's J test of overidentification. Endog stands for the GMM C chi-2 test of endogeneity. The corresponding p-values are in square brackets. In Regression (1), (2) and (3), the control variables are ly0, lki, ledu and pop. In Regression (4), we additionally control trade, inflation, gov and fdi.

In this table, we assume ipr and spv×ipr are endogenous and use ipr_pre and spv×ipr_pre as instruments. The variable ipr_pre is the average degree of patent protection from 1960 to 1979. Due to missing data on average degree of patent protection between 1960 and 1979, the samples of Bulgaria, China, Hungary, Poland and Romania are dropped.

Table IV Baseline Regression 3: GMM Method
(Instrumented: Status Preference)

	(1)	(2)	(3)	(4)
	GMM	GMM	GMM	GMM
ipr	-0.000963	0.0188	0.0347^{***}	0.0496^{***}
	(-0.43)	(1.58)	(3.58)	(3.41)
ipr^2		-0.00332	-0.00379^{***}	-0.00473^{**}
		(-1.66)	(-3.67)	(-2.42)
spv×ipr			-0.0347^{**}	-0.0564^{***}
			(-2.17)	(-3.32)
spv	0.0403	0.0520^{*}	0.133^{**}	0.246^{***}
	(1.21)	(1.69)	(2.61)	(4.21)
Observations	61	61	61	60
OID	[0.183]	[0.180]	[0.419]	[0.312]
Endog	[0.230]	[0.169]	[0.015]	[0.006]
Adjusted R^2	0.377	0.333	0.405	0.054
F	11.06	7.875	10.06	6.267

Note: The basic information of this table is the same as that of Table III. See the first paragraph of the note in Table III for details. In this table, we assume spv×ipr and spv are endogenous variables and use dummy variables of country religious denomination and their interaction terms with ipr as instruments.

Table V Baseline Regression 4: GMM Method
(Instrumented: Both)

	(1)	(2)	(3)	(4)
	GMM	GMM	GMM	GMM
ipr	0.00365	0.0287**	0.0460***	0.0579**
	(1.15)	(2.39)	(3.56)	(2.38)
ipr^2		-0.00423**	-0.00543***	-0.00623*
		(-2.35)	(-3.26)	(-1.94)
spv×ipr			-0.0262*	-0.0417**
			(-1.86)	(-2.10)
spv	0.0545***	0.0500**	0.120***	0.213***
	(3.05)	(2.16)	(2.94)	(4.29)
Observations	56	56	56	55
OID	[0.490]	[0.473]	[0.256]	[0.353]
Endog	[0.065]	[0.074]	[0.233]	[0.070]
Adjusted R^2	0.153	0.209	0.181	.
F	15.36	11.70	16.96	24.61

Note: The basic information of this table is the same as that of Table III. See the first paragraph of the note in Table III for details. In this table, we assume ipr, spv×ipr and spv are endogenous variables and use ipr_pre, dummy variables of country religious denominations and the interaction terms between the dummy variables and ipr_pre as instruments. Due to missing data on average degree of patent protection between 1960 and 1979, the samples of Bulgaria, China, Hungary, Poland and Romania are dropped.

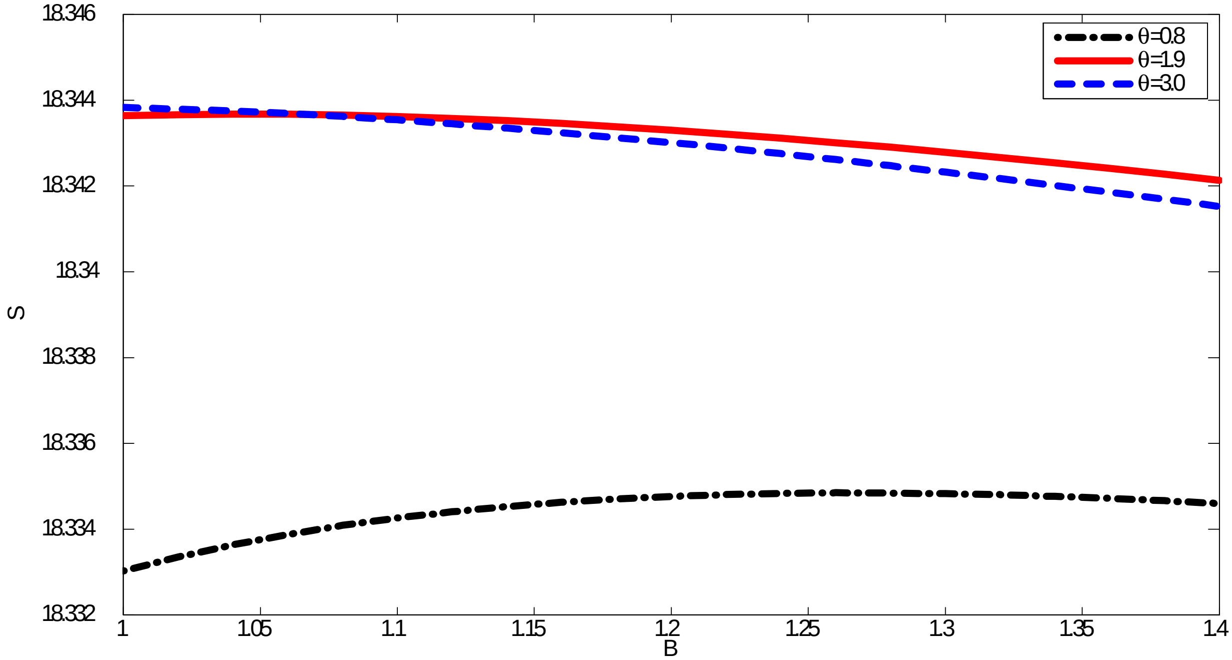

Figure 1: Effects of Patent Protection on Social Welfare