Intellectual property rights, taxation, and firms' innovation: Theory and evidence from China

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Abstract

This study develops an R&D-based growth model with corporate taxation to explore the heterogeneous effects of intellectual property rights (IPR) protection on innovation of firms with different tax rates. Our theoretical analysis shows that strengthening IPR stimulates innovation, and a higher tax rate dampens the positive effect of IPR. To account for the interactive effect between IPR and taxation, we find supportive evidence for the theoretical result using firm-level data in China. Moreover, our empirical analysis shows that strengthening IPR is associated with less innovation by high-tax firms and more innovation by low-tax firms.

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1 Introduction

What is the interactive effect of intellectual property rights (IPR) protection and taxation on innovation? In modern industrialized economies, IPR protection has been largely viewed as a pivotal policy instrument for innovation, whereas taxation serves as a commonly-used policy instrument that has an important impact on innovation. Currently, many countries across the world attempt to stimulate innovation (and promoting economic growth) by strengthening IPR protection and reducing tax rates. For instance, on the one hand, the Chinese government has been strengthening the protection of IPR by constantly improving the legal system since the opening-up policy, especially since the accession of World Trade Organization in 2001.[1] On the other hand, on September 20, 2018, China introduced the policy of "tax cut & administrative fees reduction." It is also well known that China has subsequently been implementing and expanding this policy, leading to a significant impact on firm performance (e.g., innovation) and the aggregate economy.[2]

Most of the existing macroeconomic studies have explored the impact of IPR and taxation on innovation separately. One strand of these studies suggests that IPR serves as a crucial policy instrument for stimulating innovation, such as the seminal studies by Nordhaus (1969) and Judd (1985a). Additionally, another strand shows that firm-income tax has an essential impact on innovation and imposing a higher income tax rate on firms may stifle innovation (Long and Pelloni, 2017; Shao and Xiao, 2019).[3] However, in reality, these policy tools are not implemented separately but simultaneously in industrialized countries. Therefore, the contribution of this paper is to focus on the interaction between these two policy instruments, and from the perspective of policy decision, it is of great importance and interest to explore the role of this interactive effect in innovation, economic growth, and social welfare. Up to date, as few studies have investigated the interactive effect of IPR protection and taxation on innovation, this interactive effect is underexploited and deserves further discussion.

To address the aforementioned problem, in this study we develop an endogenous quality-ladder growth model in the fashion of lab-equipment innovation. This model features IPR protection and taxation in order to examine the interactive effect of these policy levers. Specifically, on the one hand, IPR protection is incorporated into the model in terms of *patent breadth*, which determines the markup level of price imposed by monopolistic firms in intermediate-good industries. On the other hand, taxation is incorporated in terms of *corporate income taxes* on the

[1] According to Park (2008), IPR protection in many countries has been strengthened since the agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS). The Ginarte-Park index that measures the strength of IPR protection in 122 countries and sets a scale from 0 to 5, reveals that China's index has been considerably increasing from 3.09 in 2000 to 4.42 in 2015, implying that a significant improvement in the Chinese IPR protection system.

[2] According to Fitch Ratings, China's announced tax and fee cut program will help to relive the burden on small and medium enterprises (SMEs) amid the Covid-19 pandemic and encourage corporate R&D. The program will cut value-added and corporate income taxes for SMEs, increase the income tax R&D super deduction for SMEs operating in the technology sector to 100%, from 75%, and offer favorable tax treatment for basic R&D expenditure.

[3] See Section 1.1 for details in related studies.

profits of monopolistic firms, which represents a macroeconomic measure of taxation in the economy. The government, as a policymaker, can adjust these policy tools to manipulate the market-equilibrium allocation on resources in across sectors, affecting the consequences on innovation. Moreover, given that innovation is the sole engine of growth in this model, the impacts of policy levers on innovation are also transferred to the counterparts on economic growth.

In our theoretical model, we show that, as in the macroeconomic literature on IPR protection and innovation, strengthening IPR protection stimulates innovation and economic growth. More importantly, we analytically identify how the interaction between IPR protection and taxation affects the economy, that is, a higher tax rate dampens the positive effects of IPR protection on innovation and economic growth. Intuitively, stronger IPR protection implies a broadening of patent breadth, so that patent holders (i.e., monopolistic firms) face less intense competition from imitations and thereby are granted a larger market power. As a result, firms are able to charge a higher markup and earn more profits, raising the incentives for R&D activities. In this case, more resources are reallocated from production to R&D, which increases the rates of innovation and economic growth.[4] Nevertheless, heavier taxation implies a higher tax rate on corporate income, which generates adverse effects on firms' incentives for R&D and innovation. As a consequence, the reallocation of resources to research is stifled. In other words, a higher tax rate places on a mitigating effect on the positive effects of IPR protection. The interaction between IPR protection and taxation, as aforementioned, is the novelty to the existing literature. Our model is calibrated to the Chinese economy to perform a quantitative analysis, and the quantitative results support the above analytical findings. Moreover, we modify the baseline model to two variants that consider knowledge-based innovation and variety expansion. It is shown that the result regarding the interactive effect between IPR protection and taxation is analytically robust in these extended models.

In the empirical analysis, this study uses intellectual property court and "Regulation on the Identification of High-tech Firms" as policy shocks to build up the proxy variables, which denote protection of intellectual property and taxation respectively, to empirically explore the interactive effect of IPR and taxation on innovation. Furthermore, a battery of robustness checks are conducted to solve the potential endogeneity issue. Consequently, another contribution of this study is to empirically evaluate the interactive effect between IPR and firm-income tax on innovation. Using merged firm-level data in China, this study conducts an empirical analysis and finds supportive evidence for the theoretical prediction. Specifically, the empirical evidence implies that introducing intellectual property court, considered as strengthening IPR protection, gives rise to an increase in the amount of patents by 19.6% for low income tax firms, and by just 0.9% for high income tax firms. Our results survive through the test of various robustness checks.

[4] The baseline model in Section 2 and the variety-expansion model in Section 4.2 adopt the lab-equipment setting that uses final goods as resources in production and research, whereas the extended model in Section 4.1 adopts the knowledge-based setting that uses labor for resource allocation.

Based on the results as previously mentioned, our study provides a crucial policy implication for the Chinese economy's performance of innovation and economic growth. Given that the Chinese IPR system gas been improving and thereby the protection level becomes sufficiently high (as measured by the Park-Ginarte index), there may be limited room for the policymaker to continue boosting innovation and economic growth by simply using IPR policy. To achieve this purpose, making use of the interactive effect of IPR protection and taxation will be a feasible alternative by reducing burdens on firms' corporate income.

1.1 Literature review

1.1.1 The theoretical and empirical effect of IPR on innovation

This study relates to theoretical literature on innovation and economic growth and the strands that explore the effects of IPR. The seminal studies on innovation and economic growth show that innovation is the engine of economic growth (Romer, 1990; Aghion and Howitt, 1992; Grossman and Helpman, 1991).

A large and growing body of studies reveal that IPR is one major determinant of innovation and growth. Among the strand discussing the theoretical effects of IPR, the seminal study is Nordhaus (1969), who suggests that patent protection stimulates innovation while optimal patent length balances the gain of innovation and the cost of monopolistic distortion. Subsequent studies investigate the effects of IPR using variants of the R&D-based growth model, and our study closely relates to this strand of studies. For instance, Horii and Iwaisako (2007) develop a quality-ladder model to examine the effects of IPR protection on innovation and economic growth. In the form of blocking patents, Chu (2009) and Chu *et al.* (2012) develop an R&D-based growth model to evaluate the effects of patent protection on innovation and welfare. Furthermore, Yang (2018) develops a Schumpeterian growth model to explore the coordination of patent breadth and blocking patents in terms of their implications on economic growth and social welfare. However, some recent studies, such as Furukawa (2010) and Chu *et al.* (2020), find that the relationship between IPR and innovation may be non-monotonic (inverted-U) under various assumptions.

This study also relates to empirical literature that explores the effects of IPR on innovation and economic growth. In this literature, most studies use cross-country panel data and show that strengthening IPR increases innovation by stimulating the accumulation of capital and creating an environment for knowledge spillovers (Hu and Png, 2013; Naghavi and Strozzi, 2015). In addition, Chen and Puttitanun (2005) focus on developing countries and find supportive evidence that increasing IPR is also beneficial for innovation and growth of developing countries. Furthermore, Sweet and Maggio (2015) suggest that only countries with an above-average development level benefit from the positive effects of IPR.

1.1.2 The theoretical and empirical effect of taxation on innovation

This study relates to the literature discussing the theoretical effect of taxation on innovation and economic growth. In this literature, the seminal study by Judd (1985b) explores the relationship between taxation and economic growth in a one-sector endogenous growth model. Subsequent studies develop a two-sector growth model to examine the effects of income tax and tax reform on economic growth, such as Jones *et al.* (1993) and Stokey and Rebelo (1995). These studies suggest that a higher income tax rate hinders economic growth. Moreover, many studies adopt the R&D-based growth framework to discuss the determinants of innovation and growth. For instance, Long and Pelloni (2017) conclude that in most cases increasing the tax burden on capital income leads to the reduced rate of innovation and growth. Similarly, the study by Ferraro *et al.* (2020) suggest that a decrease in tax rates on capital gains can largely increase innovation and aggregate TFP growth in a model considering a realistic tax scheme. Furthermore, some studies predict that the relationship between income taxation and growth is nonlinear Jaimovich and Rebelo (2017) and that taxation has a hump-shaped effect on the growth rate (Aghion *et al.*, 2016). In addition, Akcigit *et al.* (2022) focus on the optimal design of corporate taxation and R&D policies in a growth-theoretic framework.

This study also relates to the literature exploring the empirical effects of taxation on innovation. In this literature, the majority of studies suggest that heavy taxation may stifle innovation and economic growth. For instance, based on firm-level data in the United States, Mukherjee *et al.* (2017) and Atanassov and Liu (2020) argue that reducing the firm-income tax rate boosts firms' innovation, whose result is mostly related to this study. Furthermore, a number of studies investigate the channels through which taxation affects innovation. First, from the human-capital perspective, higher tax rates may affect the international mobility of inventors and then lead to a decrease in domestic superstar inventors, which thereby hinders the innovation process across countries (Akcigit *et al.*, 2016; Moretti and Wilson, 2017). Second, to minimize the tax burden, firms may prefer to locate their intangible assets (e.g., patents, software), which are linked to innovation and growth, at relatively low-tax affiliates, and consequently domestic innovation is stifled (Karkinsky and Riedel, 2012; Schwab and Todtenhaupt, 2021).

In summary, a great number of previous studies have investigated the effects of IPR on economic growth and the effects of taxation on economic growth separately. Additionally, a few existing studies have explored the interactive effect between IPR and other policy instruments such as subsidies, e.g., Li (2001), Chu and Cozzi (2018), and Dai (2018). This study complements the above interesting studies by exploring the interactive effect of IPR and taxation and using firm-level data in China to provide empirical evidence. To the best of our knowledge, this study is the first to focus on the interactive effect between IPR and taxation on innovation, both analytically and empirically.

The rest of this study is organized as follows. Section 2 presents the R&D-based growth model with IPR and taxation. Section 3 quantifies the impacts of IPR and taxation on economic growth and social welfare. Section 4 considers two extensions of the baseline model. Section 5 describes the data and shows the empirical results. Section 6 concludes.

2 An R&D-based growth model with taxation

To explore the interactive effect of IPR and taxation on innovation and economic growth, we incorporate (a) patent breadth, which determines the price-marginal-cost markup in each intermediate goods sector, and (b) the corporate income tax into the canonical Schumpeterian model of Grossman and Helpman (1991).

2.1 Households

There is a unit continuum of identical households and the number of households is constant.[5] The lifetime utility of a representative household is

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

where $\rho > 0$ is subjective discount rate, c_t is households' consumption of final good (also the numeraire in the economy) at time t. Each household supplies L units of labor inelastically to earn wage, and maximizes its utility (1) subject to the following asset-accumulation constraint:

$$\dot{a}_t = r_t a_t + w_t L - c_t + T_t, \tag{2}$$

where r_t is the interest rate, a_t is the value of asset, w_t is the wage rate, and T_t is the lump-sum tax which is transferred by government. Households' optimization yields the familiar Euler equation such that

$$\frac{\dot{c}_t}{c_t} = r_t - \rho. \tag{3}$$

2.2 Production

There is a mass of competitive firms producing a unique final good y_t by aggregating a unit continuum of differentiated intermediate goods $x_t(i)$, according to the following Cobb-Douglas function:

$$y_t = \exp\left(\int_0^1 \ln x_t(i) di\right). \tag{4}$$

[5] By this assumption, we set aside the issue of scale effects for analytical tractability. Alternatively, Segerstrom (1998) and Howitt (1999) provide other micro-founded approaches that remove scale effects in the Schumpeterian growth model.

The profit-maximization decision of final-good firms yields the conditional demand function for $x_t(i)$ given by

$$x_t(i) = \frac{y_t}{p_t(i)}, \tag{5}$$

where $p_t(i)$ denotes the price of $x_t(i)$.

Differentiated intermediate goods are produced by a unit continuum of monopolistic industries. In each industry i, products of a temporary leader, who possesses the latest version of technology, are capable of dominating the market. The production function of the industry leader in industry $i \in [0, 1]$ is

$$x_t(i) = z^{q_t(i)} L_t(i), \tag{6}$$

where $L_t(i)$ is the labor employed for producing intermediate goods in industry i at time t. The parameter $z > 1$ is the exogenous quality step size, and $q_t(i)$ denotes the number of quality improvements that have occurred in industry i as of time t. Therefore, the term $z^{q_t(i)}$ represents the productivity of industry i, and the marginal cost of production in industry i

$$MC_t(i) = \frac{w_t}{z^{q_t(i)}}. \tag{7}$$

To consider the degree of patent protection, we follow Li (2001) and Iwaisako and Futagami (2013) to assume that the monopolist is allowed to charge a markup over the marginal production cost for profit maximization in order to keep competitive fringes inactive in the market. For each industry leader, the profit-maximizing price of $x_t(i)$ is

$$p_t(i) = \mu MC_t(i) = \mu \frac{w_t}{z^{q_t(i)}}, \tag{8}$$

where the markup $\mu \in (1, z]$ represents the level of patent breadth, which is also a patent-policy parameter that captures the judicial protection of intellectual property rights in this study. The wage payment for labor inputs in industry i is

$$w_t L_t(i) = MC_t(i) x_t(i) = \frac{p_t(i) x_t(i)}{\mu} = \frac{y_t}{\mu}, \tag{9}$$

where the third equality uses equation (5). Therefore, the after-tax monopolistic profit in industry i is

$$\pi_t(i) = (1-\tau)[p_t(i)x_t(i) - w_t L_t(i)] = (1-\tau)\left(\frac{\mu - 1}{\mu}\right) y_t, \tag{10}$$

where τ is the firm-income tax rate and the second equality uses equation (9). This equation implies that the monopolistic profit $\pi_t(i)$ is increasing in the level of IPR μ and decreasing in the firm-income tax rate τ.

2.3 R&D and innovation

The value of the monopolistic firm in industry i is denoted by $v_t(i)$. Equation (10) shows that the after-tax profit is symmetric across industries (i.e., $\pi_t(i) = \pi_t$ for $i \in [0,1]$), and thereby the value of invention $v_t(i) = v_t$ is in a symmetric equilibrium.[6] Therefore, the no-arbitrage condition for v_t is

$$r_t = \frac{\pi_t + \dot{v}_t - \lambda_t v_t}{v_t}, \tag{11}$$

where λ_t is the arrival rate of innovation. This no-arbitrage condition shows that the interest rate r_t is equal to the (risk-free) market rate of return on v_t;[7] the return on v_t stems from the sum of after-tax profit π_t, the potential capital gain $\dot{v}_t$, and the expected capital loss $\lambda_t v_t$ due to creative destruction.

Competitive R&D entrepreneurs devote R_t units of final good to develop a quality improvement. The specification of the arrival rate of innovation is

$$\lambda_t = \frac{\varphi R_t}{Z_t}, \tag{12}$$

where the parameter $\varphi > 0$ denotes the productivity of R&D process, and Z_t is the aggregate technology level at time t, capturing the increasing-difficulty effect of R&D. Then the free-entry condition for R&D is

$$\lambda_t v_t = R_t \Leftrightarrow \frac{\varphi v_t}{Z_t} = 1, \tag{13}$$

where the second equality uses (12).

2.4 Government

The government sets the firm-income tax rate $\tau \in (0,1)$ and collects tax revenue T from firms. The amount of tax revenue is given by

$$T_t = \tau \left[p_t(i) x_t(i) - w_t L_t(i) \right] = \tau \left(\frac{\mu - 1}{\mu} \right) y_t. \tag{14}$$

The balanced-budget condition is satisfied by the government's redistribution on T_t from monopolistic firms to the household in terms of a lump-sum transfer.

[6] Cozzi *et al.* (2007) provides a theoretical justification for the symmetric equilibrium in this strand of Schumpeterian growth model.

[7] The interest rate r_t is determined by the prices of equities that households can trade to transfer consumption across dates. The only equity that households hold in this model comes from the value of monopolistic firms. As a result, the interest rate r_t is equal to the risk-free market rate of return on v_t.

2.5 Decentralized equilibrium

The decentralized equilibrium is defined as a time path of allocations $\{a_t, c_t, y_t, x_t(i), R_t\}$, and a time path of prices$\{r_t, w_t, p_t(i), v_t(i)\}$ such that

• the representative household maximizes utility taking $\{r_t, w_t\}$ as given;

• competitive final-good firms produce y_t to maximize profits taking $\{w_t, p_t(i)\}$ as given;

• monopolistic firms in the intermediate-good sector produce $x_t(i)$ and choose $p_t(i)$ to maximize profits taking w_t as given;

• competitive R&D entrepreneurs devote R_t units of final good to maximize profits taking v_t as given;

• the value of all existing monopolistic firms adds up to the value of the household's asset such that $a_t = v_t$;

• the market-clearing condition of labor holds such that $L_t = \int_0^1 L_t(i)di$;

• the market-clearing condition of final good holds such that $y_t = c_t + R_t$.

2.6 Effects of IPR on innovation and economic growth

We define the aggregate technology Z_t as

$$Z_t \equiv \exp\left(\int_0^1 q_t(i)\ln z di\right) = \exp\left(\int_0^t \lambda_\omega \ln z d\omega\right), \tag{15}$$

where the second equality applies the law of large number. Log-differentiating (15) with respect to time yields the growth rate of technology (i.e., the innovation growth rate) such that

$$g_t \equiv \frac{\dot{Z}_t}{Z_t} = \lambda_t \ln z, \tag{16}$$

which is determined by the arrival rate of innovation λ_t. We use the symmetry condition $L(i) = L$ and substitute (6) into (4) to derive the aggregate production given by

$$y_t = \exp\left(\int_0^1 q_t(i)\ln z di + \int_0^1 \ln L_t(i)\right) = Z_t L. \tag{17}$$

Since L is inelastically supplied and constant, equation (17) implies that the growth rate of final good y_t (i.e., the economic growth rate) also equals the growth rate of technology g_t; given that innovation (via R&D investment) is the only engine of growth in this model, equation (17) implies that the impacts of IPR on innovation will be completely transferred to the counterpart on economic growth. Accordingly, we obtain the following proposition.

Proposition 1. *Holding constant the firm-income tax rate τ and the level of patent breadth μ, the economy immediately jumps to a unique and saddle-point balanced growth path, along which each variable grows at a constant (possibly zero) rate.*

Proof. See Appendix A.1. □

Combining (3), (10), (11), (17) and the fact that $g_t = \dot{c}_t / c_t$, the value of an invention in the balanced growth path is given by

$$v_t = \frac{\pi_t}{\rho + \lambda} = (1 - \tau) \left(\frac{\mu - 1}{\mu} \right) \frac{Z_t L}{\rho + \lambda}, \tag{18}$$

which is increasing in the level of IPR μ and decreasing in the firm-income tax rate τ. Substituting (18) into (13) yields the steady-state arrival rate of innovation such that

$$\lambda = \frac{(1 - \tau)(\mu - 1)}{\mu} \varphi L - \rho. \tag{19}$$

Using (16), the steady-state growth rate is

$$g = \lambda \ln z = \left[\frac{(1 - \tau)(\mu - 1)}{\mu} \varphi L - \rho \right] \ln z. \tag{20}$$

Equations (19) and (20) show that the steady-state innovation rate λ and growth rate g are increasing in the level of IPR μ and decreasing in the firm-income tax rate τ. Moreover, a higher τ reduces the positive effects of μ on λ and g. Proposition 2 summarizes these results.

Proposition 2. *Strengthening IPR stimulates innovation and economic growth, whereas a higher tax rate dampens the positive effects of IPR.*

Proof. Differentiating the steady-state innovation rate λ in (19) with respect to IPR μ yields $\partial \lambda / \partial \mu = \varphi L (1 - \tau) / \mu^2 > 0$. Also, differentiating the effect of μ on λ with respect to τ yields $\partial^2 \lambda / (\partial \mu \partial \tau) = -\varphi L / \mu^2 < 0$. This result applies similarly to the effects on the steady-state economic growth rate g in (20). □

Proposition 2 reveals the interactive effect of patent protection μ and firm's income taxation τ on economic growth g through the arrival rate of innovation λ. Intuitively, on the one hand, broadening patent breadth μ increases the monopoly markup that a quality leader can impose in each intermediate-good industry, which raises the value of innovations in (18) and yields more incentives to invest in R&D. This policy change reallocates more resources to R&D investment R_t, thereby increasing λ and g. The comparative static for μ in this study is consistent with those in Li (2001), Iwaisako and Futagami (2013), and Yang (2018). On the other hand, an increase in the income tax rate τ reduces the net-of-tax profits of monopolistic firms and thus decreases the value of innovations. This financing constraint of government expenditure is reflected by the negative relation between the value of patents v_t and the income tax rate τ in (18). Therefore, firms are disincentivized to conduct research activities and less resources will be allocated to R&D expenditure R_t. The effect of taxation in this study is in line with previous theoretical studies such as Long and Pelloni (2017). As a result, a higher tax rate τ mitigates the positive effects of μ on λ and g.[8]

3 Quantitative analysis

In this section, we use data in China to calibrate the model and provide a quantitative assessment on the positive effects of IPR on innovation and economic growth, in addition to the interactive effect of IPR and taxation. The model features the following structural parameters: $\{\rho, \mu, \tau, \lambda, \varphi, z\}$. The discount rate ρ is set to a conventional value of 0.02. For the markup μ, Lu and Yu (2015) use a structural model to estimate the markup in China ranging from 0.825 to 1.372, and thereby we set an intermediate value of 1.3 with this range.[9] As for the tax rate, we consider the average firm-income tax rate in our sample (i.e., 21.08%) as the benchmark tax rate. Then we calibrate the value of R&D productivity φ by setting the arrival rate λ to 12.5%.[10] Finally, based on (20), we calibrate the step size z using the TFP growth rate in the sample period, which is 2.48%. We assume that 30% of TFP growth is driven by domestic R&D in China, so the benchmark growth rate is calibrated at 0.74% (=2.48% × 30%). Moreover, we normalize the size of population L to unity to remove the scale-effect problem. Table 1 summarizes the parameter values in this calibration.[11]

Table 1: Calibrated parameter values

ρ	μ	τ	φ	z
0.02	1.3	0.2108	0.7962	1.0613

[8] According to Young's theorem, it is easy to know that $\partial^2\lambda/(\partial\tau\partial\mu) = \partial^2\lambda/(\partial\mu\partial\tau) < 0$, implying that stronger IPR intensifies the negative effect of taxation on innovation. Stronger IPR leads to a larger markup and increases the profits of monopolistic firms, so the decline in firms' profits by a higher tax rate becomes more significant, which mitigates firms' incentives for R&D to a greater extent.

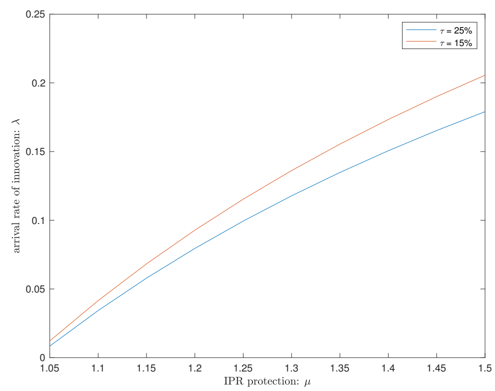
[9] This parameter value of μ is higher than the upper bound of the range of markup value of 1.2 in China in 2007 (Liu and Ma, 2015), given that IPR protection in China is stronger in the sample period compared to 2007.

[10] Previous study by Acemoglu and Akcigit (2012) implies that the innovation-arrival rate in the US ranges from 4% to 33%. Due to the lack of relevant data for China's innovation-arrival rate, we take a relatively low value of 12.5% within this range, considering that China's R&D investment and R&D capability are generally perceived to be lower than those in the US.

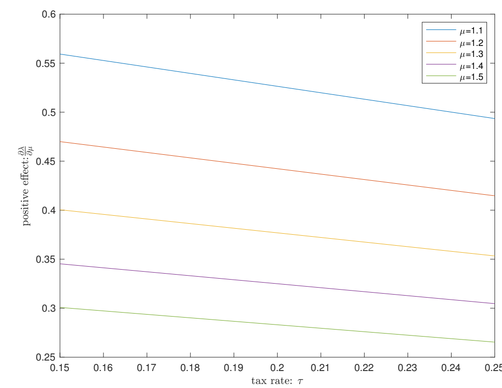
[11] In the empirical analysis, stronger IPR gives rise to an increase of 0.94% in innovation (i.e., an increase of 0.94% in the innovation-arrival rate) at a tax rate of 25%, whereas it can further give rise to an increase of 19.61% in innovation (i.e., an increase of 19.61% in the innovation-arrival rate) at a tax rate of 15%. Using the calibrated parameter values, we have the condition that $[(1+19.61\%)-1]\lambda_{\tau=15\%} > [(1+0.94\%)-1]\lambda_{\tau=25\%}$, which is consistent with the theoretical and empirical results such that a higher tax rate dampens the positive effect of IPR on innovation.

3.1 Benchmark simulation

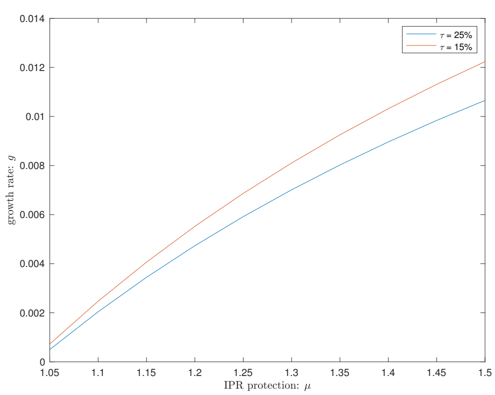
Based on the calibrated parameter values, we first quantify how stronger IPR affects innovation and economic growth. Figures 1(a) and 1(c) plot the resulting effects, showing that the innovation-arrival rate λ and growth rate g are increasing in the level of patent protection μ. Specifically, in the case with a tax rate of 25%, increasing μ from 1.05 to 1.5 leads to an increase in the arrival rate of innovation from 0.84% to 17.90% and an increase in the R&D-driven TFP growth rate from 0.05% to 1.07%. In the case with a tax rate of 15%, an identical increase in μ from 1.05 to 1.5 raises the arrival rate of innovation from 1.22% to 20.56% and R&D-driven TFP growth rate from 0.07% to 1.22%, respectively.



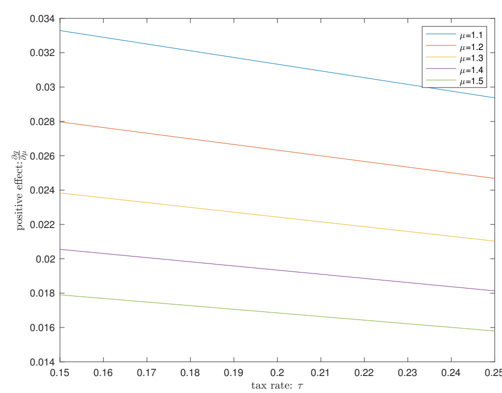
(a) Effects of IPR protection on innovation.



(b) Interactive effects of IPR protection and taxation on innovation.



(c) Effects of IPR protection on economic growth.



(d) Interactive effects of IPR protection and taxation on economic growth.

Figure 1: Effects on innovation and growth in the benchmark case.

Next, we quantify the interactive effect of IPR and taxation on innovation and economic growth under different values of μ. Figures 1(b) and 1(d) demonstrate that a higher tax rate weakens the positive effect of IPR protection on innovation and economic growth. For instance, in the case of $\mu = 1.3$, the positive effect of patent protection $\partial\lambda/\partial\mu$ is 0.4004 at a tax rate of 15%, whereas this positive effect $\partial\lambda/\partial\mu$ decreases to 0.3533 at a tax rate of 25%. Furthermore, the positive growth effect of patent protection $\partial g/\partial\mu$ is 0.0238 at a tax rate of 15%, whereas the positive growth effect $\partial g/\partial\mu$ decreases to 0.0210 at a tax rate of 25%.

Next, we examine the effects of IPR protection and taxation on social welfare. To derive the steady-state welfare, we impose the BGP condition on household's lifetime utility function in (1) and integrate it to obtain

$$U = \frac{1}{\rho}\left(\ln c_0 + \frac{g}{\rho}\right), \tag{21}$$

where $c_0 = (c_0/y_0)\, y_0 = [(1-\tau)/\mu + \tau + \rho/\varphi L]\, Z_0$, and Z_0 and L are normalized to unity.[12] Equation (21) shows that strengthening patent protection affects social welfare through two channels: innovation versus steady-state consumption. Intuitively, a larger patent breadth increases the monopolistic profit and strengthens the innovation incentives. This induces more resources (final good) to be devoted to R&D and less available for consumption. Therefore, the former effect through the R&D channel tends to raise social welfare by increasing the rates of innovation and economic growth, whereas the latter effect through the consumption channel tends to reduce social welfare by decreasing the production volume.[13] Given the benchmark parameters, Figure 2(a) shows that the positive welfare effect dominates the negative effect, and therefore the level of social welfare is increasing in the degree of patent protection. Specifically, in the case with a tax rate of 25%, increasing the level of patent protection μ from 1.05 to 1.5 leads to an increase in social welfare from 0.72 to 13.89, which is equivalent to an increase in consumption of 30.13%.[14] Moreover, in the case with a tax rate of 15%, raising μ from 1.05 to 1.5 increases social welfare from 1.04 to 15.64, which is equivalent to an increase in consumption of 33.91%.

We also simulate the interactive effect of IPR and taxation on social welfare. Given the calibrated parameter values, Figure 2(b) presents the negative interactive effect. Specifically, a higher tax rate dampens the positive effect of IPR on social welfare, which is similar to the effect on innovation in the benchmark case. For instance, in the case of $\mu = 1.3$, the positive welfare effect of patent protection by an increase of 1% in μ is 0.82% of consumption at a tax rate of 15%, whereas the magnitude of the welfare improvement by an increase of 1% in μ decreases to 0.64%

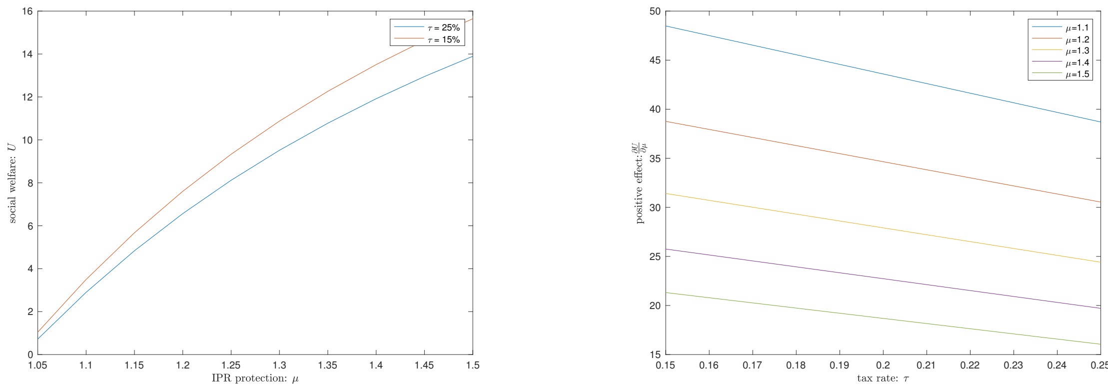
[12] The steady-state consumption-output ratio is obtained by substituting (12), (17) and (19) into the final-good market-clearing condition such that

$$\frac{c_t}{y_t} = 1 - \frac{R_t}{y_t} = 1 - \frac{\lambda_t}{\varphi L} = \frac{1-\tau}{\mu} + \tau + \frac{\rho}{\varphi L}, \tag{22}$$

which is stationary on the BGP.

[13] In Appendix A.2, we derive the detailed conditions that govern the channels through which patent protection affects social welfare.

[14] The change in steady-state welfare ΔU is defined by the usual equivalent variation in consumption flow, namely $\exp(\rho\Delta U) - 1$.



(a) Effects of IPR protection on social welfare.

(b) Interactive effects of IPR protection and taxation on social welfare.

Figure 2: Welfare effects in the benchmark case.

of consumption at a tax rate of 25%.

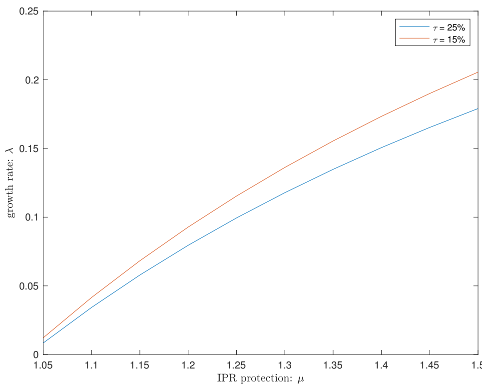
3.2 Sensitivity analysis

In this section, we perform two experiments to examine the sensitivity on structural parameters. First, we consider a smaller z of 1.03. Second, we consider a higher arrival rate λ of 1.33 (Acemoglu and Akcigit, 2012).

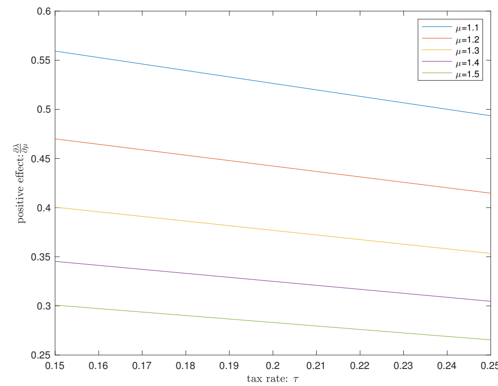
Regarding the effects on innovation and economic growth, these two cases show a similar pattern of results as in the benchmark model. Figures 3 and 5 plot the corresponding positive effects and interactive effects. Specifically, strengthening IPR protection is associated with better performance of innovation and economic growth, whereas a relatively higher tax rate stifles the positive impact of IPR protection.

However, the effects on welfare are slightly different in our sensitivity analysis. In the first case (i.e., $z = 1.03$), the parameter condition $(1 - \ln z)\rho - \tau\varphi L \ln z > 0$ holds. Accordingly, the welfare analysis in Appendix A.2 implies that the relation between IPR protection and social welfare is inverted-U shaped. Figure 4 illustrates this relation quantitatively. If IPR protection is less (greater) than the optimal level $(1 - \tau)\varphi L \ln z / [(1 - \ln z)\rho - \tau\varphi L \ln z]$, social welfare is increasing (decreasing) in IPR protection. In addition, since the parameter condition $(1/\varphi + 1/\rho)/[1/\varphi + \tau/\rho + (1 - \tau)/(\rho\mu)]^2 < \varphi \ln z$ is also satisfied in this exercise, the interactive effect between IPR and taxation is negative, as predicted by the analysis in Appendix A.2. In other word, a higher tax rate dampens (magnifies) the positive (negative) effect of IPR on social welfare through the negative welfare effect of taxation.

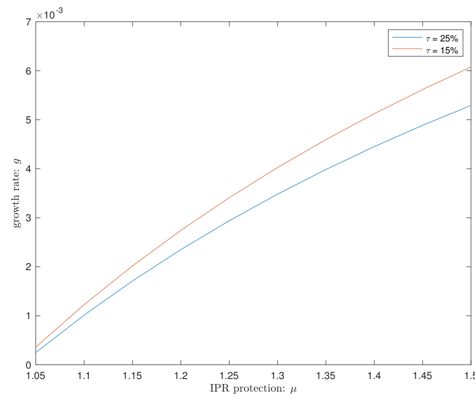
In the second case (i.e., $\lambda = 1.33$), the parameter condition $(1 - \ln z)\rho - \tau\varphi L \ln z > 0$ also holds, and the relation between IPR protection and social welfare is inverted-U according to A.2.



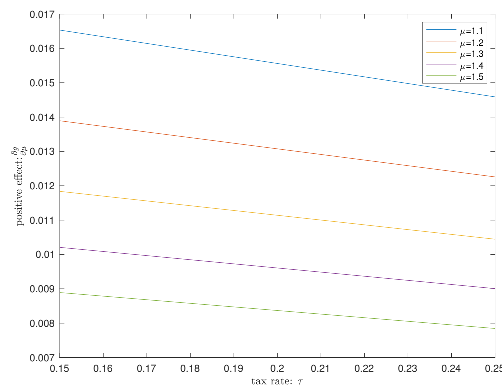
(a) Effects of IPR protection on innovation.



(b) Interactive effects of IPR protection and taxation on innovation.



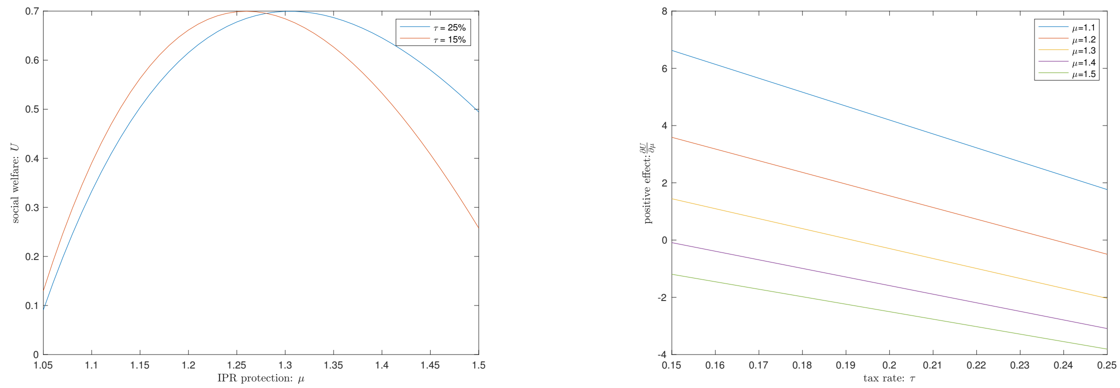
(c) Effects of IPR protection on economic growth.



(d) Interactive effects of IPR protection and taxation on economic growth.

Figure 3: Effects on innovation and growth in the sensitivity analysis ($z = 1.03$).

However, in this case, for $\mu \in [1.05, 1.5]$, the condition $\mu < (1-\tau)\varphi L \ln z / [(1-\ln z)\rho - \tau\varphi L \ln z$ holds, which suggests that IPR protection does not reach the optimal level. Therefore, social welfare is increasing in IPR protection, as in the benchmark case. Figure 5 illustrates this relation accordingly. Additionally, in this exercise, the parameter condition $(1/\varphi + 1/\rho)/[1/\varphi + \tau/\rho + (1-\tau)/(\rho\mu)]^2 < \varphi \ln z$ is also satisfied, so the interactive effect of IPR and taxation continues to be negative. As in the previous cases, this result also implies that the positive effect of IPR on social welfare would be dampened due to a higher tax rate.



(a) Effects of IPR protection on social welfare.

(b) Interactive effects of IPR protection and taxation on social welfare.

Figure 4: Welfare effects in the sensitivity analysis ($z = 1.03$).

4 Extensions

In our baseline model, innovation features the lab-equipment fashion and is driven by quality improvement, respectively. To examine the robustness of our theoretical results, in this section we consider two extensions. In Section 4.1, we consider knowledge-based innovation instead of lab-equipment innovation. In Section 4.2, we assume that innovation is driven by variety expansion instead of quality improvement.

4.1 Knowledge-based innovation

In this extension, there two types of labor: labor for manufacturing and labor for R&D process. Replacing L_t with $L_{X,t}$, equation (9) becomes

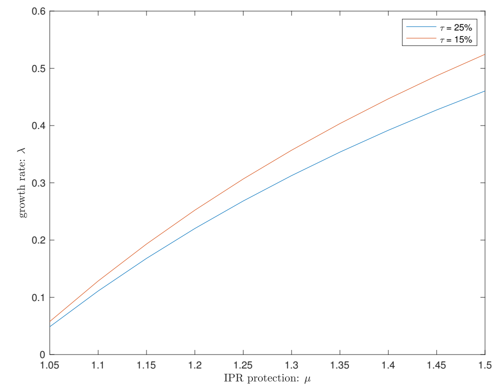
$$w_t L_{X,t}(i) = \frac{y_t}{\mu}, \tag{23}$$

where $L_{X,t}$ is the level of manufacturing labor. Moreover, R&D entrepreneurs use labor as the factor input to innovate, so equation (12) is modified to

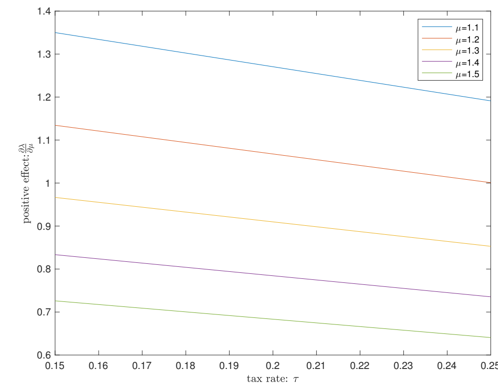
$$\lambda_t = \varphi L_{R,t}, \tag{24}$$

where $L_{R,t}$ is the level of R&D labor. Then the free-entry condition is given by

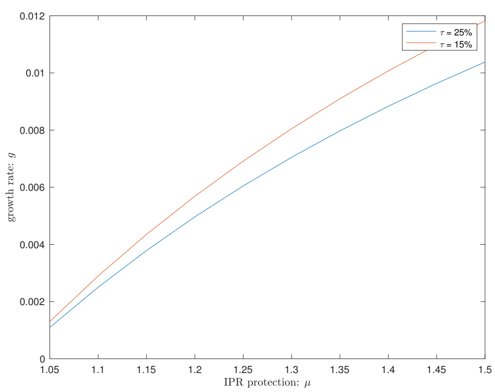
$$\lambda_t v_t = w_t L_{R,t} \Leftrightarrow \varphi v_t = w_t \tag{25}$$



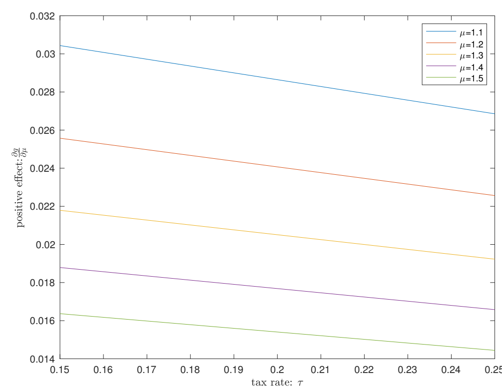
(a) Effects of IPR protection on innovation.



(b) Interactive effects of IPR protection and taxation on innovation.



(a) Effects of IPR protection on economic growth.



(b) Interactive effects of IPR protection and taxation on economic growth.

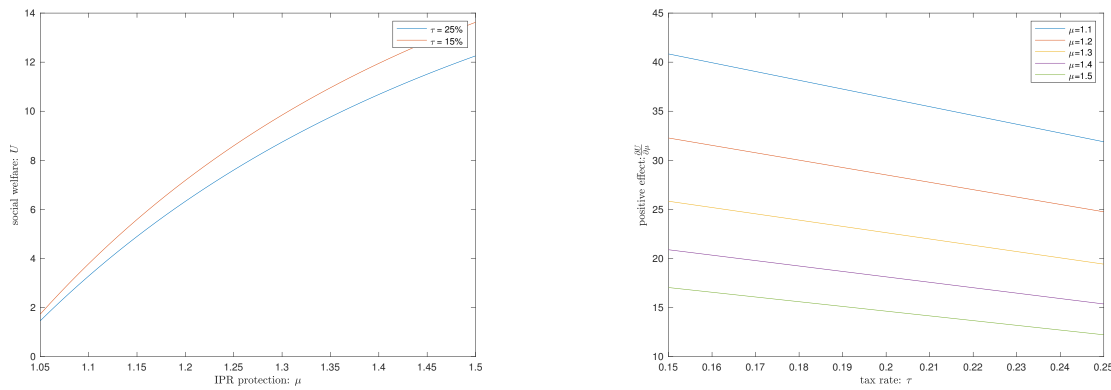
Figure 5: Effects on innovation and growth in the sensitivity analysis ($\lambda = 1.33$).

where the second equality uses (24). In addition, equation (18) becomes

$$v_t = (1-\tau)\left(\frac{\mu-1}{\mu}\right)\frac{Z_t L_X}{\rho+\lambda}, \tag{26}$$

Substituting (10), (23), (26) and the labor-market-clearing condition $L = L_X + L_R$ into (25) yields

$$L_R = \frac{L}{1+\frac{1}{(1-\tau)(\mu-1)}} - \frac{\rho/\varphi}{1+(1-\tau)(\mu-1)}, \tag{27}$$



(a) Effects of IPR protection on social welfare.

(b) Interactive effects of IPR protection and taxation on social welfare.

Figure 6: Welfare effects in the sensitivity analysis ($\lambda = 1.33$).

where we use the symmetry condition $L_X(i) = L_X$ for $i \in [0, 1]$. The resource constraint is modified to $y_t = c_t$. Then the steady-state growth rate along the BGP is given by

$$g = \lambda \ln z = (\varphi \ln z) L_R. \tag{28}$$

According to (27) and (28), we obtain

$$\begin{aligned} \text{sign}\left(\frac{\partial g}{\partial \mu}\right) &= \text{sign}\left(\frac{\partial L_R}{\partial \mu}\right) > 0 \\ \text{sign}\left(\frac{\partial^2 g}{\partial \mu \partial \tau}\right) &= \text{sign}\left(\frac{\partial^2 L_R}{\partial \mu \partial \tau}\right) < 0, \end{aligned} \tag{29}$$

which implies that the key result in the knowledge-based innovation specification is consistent with the counterpart in the benchmark model: strengthening patent protection stimulates innovation, whereas a higher firm-income tax stifles this positive effect.

4.2 Variety expansion

In this subsection, we alter the process of innovation from quality improvement in baseline model to variety expansion. Accordingly, we consider the following production function of the final good:

$$y_t = A_t \left[\int_0^{N_t} x_t(i)^\alpha di \right]^{\frac{1}{\alpha}}, \tag{30}$$

where $\alpha \in (0, 1)$ denotes the elasticity of substitution between intermediate goods. We follow Acemoglu *et al.* (2012) to specify $A_t \equiv N_t^{2-\frac{1}{\alpha}}$, which represents an aggregate externality. Moreover, we replace (6) by a simple one-to-one production function given by $x_t(i) = L_t(i)$. Given that the markup μ captures the level of patent breadth, the price of monopolistic firms in the intermediate-good industry is $p_t(i) = \mu w_t$. Then the after-tax profit of monopolistic firms is given by

$$\pi_t(i) = (1-\tau)\left[p_t(i)x_t(i) - w_t x_t(i)\right] = (1-\tau)\left(1-\frac{1}{\mu}\right)p_t(i)x_t(i) = (1-\tau)\left(1-\frac{1}{\mu}\right)\frac{y_t}{N_t}, \quad (31)$$

where the third equality uses the symmetry condition such that $L_t(i) = L_t/N_t$ for all $i \in [0, N_t]$ and the profit-maximizing decision in (30). R&D entrepreneurs devote R_t units of final good to innovate, and the innovation production function is given by

$$\dot{N}_t = \varphi R_t, \quad (32)$$

where $\varphi > 0$ denotes productivity of R&D process. Free entry into the R&D sector implies

$$\dot{N}_t v_t = R_t. \quad (33)$$

Combining (32) and (33) yields the value of invention such that

$$v_t = \frac{1}{\varphi}. \quad (34)$$

Furthermore, the amount of tax revenue becomes

$$T_t = N_t \tau \left[p_t(i)x_t(i) - w_t x_t(i)\right] = \tau\left(\frac{\mu-1}{\mu}\right)y_t. \quad (35)$$

Simplifying (30) yields the aggregate production function such that

$$y_t = N_t L, \quad (36)$$

where uses the symmetry condition $x_t(i) = x_t$ and $L(i) = L/N_t$ for all $i \in [0, N_t]$. Given that labor is inelastically supplied, equation (36) implies that along the BGP the growth rate of final good y_t is equivalent to the growth rate of the number of variety N_t (i.e., the innovation growth rate). Combining (3), (11), (34) and (36) and the symmetry conditions $v_t(i) = v_t$, $\pi_t(i) = \pi_t$ for all $i \in [0, N_t]$ yields

$$g_t = r_t - \rho = (1-\tau)\left(\frac{\mu-1}{\mu}\right)\varphi L - \rho. \quad (37)$$

Therefore, we obtain

$$\frac{\partial g}{\partial \mu} = \left(\frac{1-\tau}{\mu^2}\right)\varphi L > 0, \quad \frac{\partial^2 g}{\partial \mu \partial \tau} = -\frac{\varphi L}{\mu^2} < 0, \quad (38)$$

which also implies that stronger patent protection stimulates innovation and growth and that a higher firm-income tax rate stifles the positive effect of patent protection on innovation and growth.

5 Empirical analysis

In this section, we perform an empirical analysis to estimate the interactive effects of IPR protection and firms' income taxation on innovation by using a panel data of China.

5.1 Empirical specification

In 2014, the Chinese government set up intellectual property courts in Beijing, Shanghai and Guangzhou to strengthen the judicial protection of intellectual property rights. The intellectual property courts hear infringement cases inside their provinces and municipalities. With the establishment of intellectual property courts, IP cases are heard professionally and efficiently, which has greatly strengthened intellectual property rights protection and improved the enforcement of intellectual property laws in these regions.

In addition, for the purpose of encouraging innovation, the Chinese government implemented a policy called "Regulation on the Identification of High-tech Firms" in 2008. Firms that receive a "High-tech" identification through this regulation are entitled to enjoy a preferential firm-income tax rate of 15%, which is much lower than the general firm-income tax rate of 25%.

The institutional background in China provides a realistic scene on policy experiment, according to which an empirical analysis is conducted to test the analytical result obtained in the theoretical model. Therefore, this empirical analysis is performed to explore the heterogeneous effects of IPR on firms' innovation with different tax rates using the Poisson regression:[15]

$$\mathbf{E}\left(patent_{it}\right) = \exp\left(\beta_1 IPR_{it} \times tax_{it} + \beta_2 IPR_{it} + \beta_3 tax_{it} + X_{it} + \Phi_i + \Phi_t + \epsilon_{it}\right), \tag{39}$$

and

$$IPR_{it} = court \times post. \tag{40}$$

Due to the prevailing phenomenon of Chinese firms pursuing non-substantial research to obtain policy benefits, the number of patent applications is a better proxy to reflect the real innovation output rather than R&D expenditure (Dang and Motohashi, 2015). Accordingly, this study uses patent applications to denote innovation. The variable $patent_{it}$ denotes the number of patent applications by firm i in year t.[16]

[15] We follow Balsmeier *et al.* (2023) to employ the Poisson regression for patent data. See also Cohn *et al.* (2022) for different econometric approaches on count-based data.

[16] We also consider the number of patent grants as independent variable and the results are shown to be robust. In addition, we follow Acemoglu *et al.* (2016) and Liu and Qiu (2016) to use $\ln\left(patent_{it}+1\right)$ and $\ln(patent_{it} + (patent_{it}{}^2 +$

The variable *court* is a policy dummy that indicates whether the firms are situated in Beijing, Shanghai or Guangdong Province, and the variable *post* is a time dummy that indicates whether the year is after 2014. Therefore, the variable IPR_{it} indicates whether the region where firm i is located features strong protection of intellectual property rights. Specifically, $IPR_{it} = 1$ implies that IPR protection is relatively strong, whereas $IPR_{it} = 0$ implies that IPR protection is relatively weak.

Moreover, the variable tax_{it} denotes the firm-income tax rate of firm i in year t. Specifically, $tax_{it} = 0.25$ if the tax rate of enterprise i is 25% in year t, and $tax_{it} = 0.15$ if the tax rate of firm i is 15% in year t otherwise. X_{it} is a vector of control variables, including the return on assets (roa_{it}), the leverage ratio (lev_{it}), a dummy variable for whether the chairman also serves as a general manager ($indep_{it}$), the number of board members ($board_{it}$), and the logarithm of city GDP (gdp_{it}). Φ_i denotes firm fixed effects, Φ_t denotes year fixed effects, and ϵ_{it} is the error term.

Consequently, the coefficient β_2 captures the effects of IPR on innovation of firms with a low income tax rate. The term $0.25\beta_1 + \beta_2$ captures the effects of IPR on innovation of firms with a high income tax rate, whereas the term $0.15\beta_1 + \beta_2$ captures the effects for low income-tax firms. Therefore, the term $0.1\beta_1$ ($= 0.25\beta_1 - 0.15\beta_1$) captures the differential between firms with a high income tax rate and those with a low income tax rate. According to the theoretical prediction, β_2 is expected to be positive and β_1 is expected to be negative, suggesting that a high tax rate dampens the positive effect of IPR on innovation.

5.2 Data

This study uses four data sources: (1) firm-level patent applications data from Chinese Innovation Research Database (CIRD) in China Research Data Services Platform, (2) firm-level production data and "High-tech" identification data from China Stock Market & Accounting Research Database (CSMAR), (3) city-level GDP data from China City Statistical Yearbook, and (4) policy information of intellectual property court from official websites of local governments.

The first dataset is patent data from CIRD. This dataset contains patenting information of listed firms since 1990, including patent applications, patent grants, and the patent type (i.e., invention, utility model, or design).

The second dataset is firm-level production data from CSMAR. This dataset has been widely used in existing studies. This dataset contains abundant firm-level information of Chinese listed firms (e.g., stock code, firm name, address, owned property) and complete information on the three major accounting statements.

We match the above two firm-level datasets and "High-tech" identification data by stock codes. Then we match the intellectual property court information (i.e., IPR_{it} in (39)) and city

$1)^{1/2}$) as alternative proxies for innovation in OLS estimation. The results, which are available upon request, are also robust in these cases.

GDP to firm-level merged data based on city-year dimension, and finally obtain the dataset used for this empirical analysis.

5.3 Empirical results

This section reports empirical results to verify the theoretical implications and conducts a battery of robustness checks.

5.3.1 Baseline regression

Table 2 reports the correlation between IPR and patent applications of firms using (39). The odd columns do not include control variables except for fixed effects, whereas the even columns include firm-level and city-level control variables. Column (1)-(2) include firm fixed effects and year fixed effects, whereas column (3)-(4) consider industry-year fixed effects as well. As shown in column (2) in Table 2, the coefficient of the interaction term ($IPR_{it} \times tax_{it}$) is -1.8667, which is significantly negative at 1% significance level. The coefficient of IPR_{it} is 0.4761, which is significantly positive at 1% significance level. This implies that strengthening patent protection gives rise to an increase in patent applications by 19.61% ($= 0.4761 - 1.8667 \times 0.15$) for firms with a lower tax rate, whereas a higher tax rate dampens this positive effect by 18.67% ($= 0.1\beta_1$). In summary, these results suggest that strengthening IPR protection increases the number of patent applications in all firms, but the increase in patent applications of firms with a higher income tax rate is roughly 20% smaller than firms with a relatively lower income tax rate. Recall the policy implication based on the steady-state growth rate (20), such that a higher tax rate dampens the positive effect of IPR on innovation. Our baseline regression result is consistent with the theoretical prediction, which is also supported by other empirical studies (for example, Chen and Miller 2007, Mukherjee *et al.* 2017 and Atanassov and Liu 2020).

It is interesting to note that there is a large reduction on the positive effects of IPR on innovation when the tax rate is relatively high. This provides a sound empirical support for the rationale behind the implementation of "tax cut & administrative fees reduction" policy by the Chinese government in recent years. Based on our empirical results, one can expect that the "tax cut & administrative fees reduction" policy effectively relieves firm's tax burdens and thereby increases their corporate incomes, which provides strong motives for firms to conduct R&D activities. Therefore, the "tax cut & administrative fees reduction" policy plays a crucial role in China's economic development by reinforcing the policy effect of strengthening intellectual property rights.

5.3.2 Robustness checks

Although we consider industry-year fixed effects to control time-varying industry characteristics in baseline regression, there still may be potential endogeneity issues caused by selection

Table 2: Baseline regression

	Dependent variable: $patent_{it}$			
	(1)	(2)	(3)	(4)
$IPR_{it} \times tax_{it}$	-2.0793**	-1.8667***	-1.8250**	-2.0918***
	(0.9073)	(0.6703)	(0.9044)	(0.8001)
IPR_{it}	0.4887***	0.4761***	0.4875**	0.5373***
	(0.1621)	(0.1399)	(0.1916)	(0.1704)
Control variables	No	Yes	No	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Industry-year fixed effects	No	No	Yes	Yes
Observations	16509	15870	16414	15774
Pseudo R^2	0.90606	0.90952	0.92069	0.92341

Notes: Robust standard errors clustered at city level in parentheses. $* : p < 0.1, ** : p < 0.05, *** : p < 0.01$

bias and omitted variable. In this section, we conduct several checks to verify whether our results are robust. First, we reselect firm observations as the estimate sample to mitigate the potential endogenous problems. Second, we conduct a placebo test to avoid estimate results from being statistically significant due to a random chance or omitted variables. Third, we consider firms with oversea subsidiaries as this type of firms may locate their intangible assets that are related to innovation in low-tax countries (regions); in this case, the negative effect of domestic taxation on the policy implication of IPR may become irrelevant.

Endogeneity issue. Given that the R&D-to-sales ratio of firms must reach at least 3% for applying the "High-tech" identification according to the "Regulation on the Identification of High-tech Firms", we select firm sample with an R&D-to-sales ratio greater than 3% as our regression sample to solve the selection bias. Furthermore, we follow Fan *et al.* (2018) to select firms within cities located near borders of different provinces. This approach can help to mitigate potential endogenous problems because the economic characteristics of neighboring cities are generally similar (Dube *et al.*, 2010).

Columns (1)-(2) in Table 3 report the results of using the sample of firms with an R&D-to-sales ratio greater than 3%. Column (3)-(4) use the sample of firms within cities located near borders of different provinces. Odd columns do not include control variables except for fixed effects, whereas even columns include control variables. The pattern of the results is identical to the counterpart in the baseline regression; all coefficients regarding the interaction term are still negative and significant at least at 10% significant level, whereas the coefficients of IPR_{it} are positive and at least significant at 5% significant level.

Placebo test. The current study measures the impacts of IPR by a policy shock in Beijing,

Table 3: Robustness checks

	Dependent variable: $patent_{it}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$IPR_{it} \times tax_{it}$	-1.9026*	-2.1695**	-2.1931***	-2.4882***	-1.8805 **	-2.5600 *
	(1.1093)	(0.9543)	(0.6520)	(0.7719)	(0.9409)	(1.5248)
IPR_{it}	0.5074**	0.5402***	0.4623***	0.5097***	0.5202 **	0.7678**
	(0.2016)	(0.1771)	(0.1231)	(0.1471)	(0.2098)	(0.3048)
Control variables	No	Yes	No	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Industry-year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10849	10534	8960	8731	10541	4198
Pseudo R^2	0.91059	0.91429	0.91707	0.91942	0.93281	0.95173

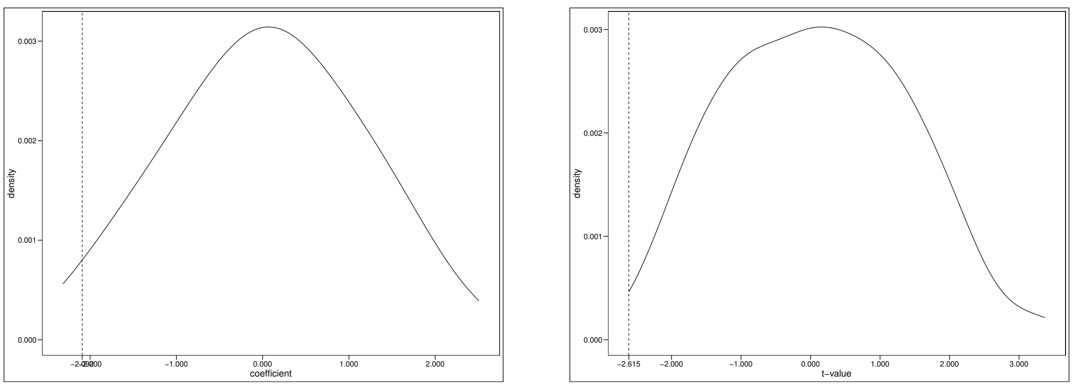
Notes: Robust standard errors clustered at city level in parentheses. $* : p < 0.1, ** : p < 0.05, *** : p < 0.01$

Shanghai and Guangdong Province, and it measures the impacts of the firm-income tax rate by "High-tech" identifications. However, these measures may not preclude the possibility that some unobserved factors correlated to these regions and "High-tech" firms could also affect firms' innovation. If this is the case, then the empirical specification becomes suspect, which suggests that the baseline regression is significant just due to random chance like other policy shocks (i.e., omitted variables). Therefore, we randomly assign provinces or municipalities as the regions with strong IPR, and randomly assign firms as "High-tech" firms that enjoy a lower income tax rate. As the regions with strong IPR and "High-tech" firms are assigned randomly in the placebo test, the coefficient and t-value of the interaction term $IPR_{it} \times tax_{it}$ is expected to be zero, and the corresponding estimates from the baseline regression should be located at the tail of the placebo distribution if the empirical specification was correct.

Figure 7 displays the distribution of the coefficient and t-value of the interaction term in 200 random assigned placebo tests. The dashed lines indicate the coefficient and t-value of the interaction term in baseline regression. As shown in Figure 7, the coefficient and t-value of the interaction term in the placebo test are around zero, suggesting that no potential omitted variables are likely to bias the estimation. In addition, the corresponding estimates from the baseline regression can be regarded as a small probability event in placebo tests, which indicates that the baseline regression is not significant due to random chance. Consequently, the baseline regression results are considered to be robust and convincing.

Oversea subsidiaries. Considering some firms with oversea subsidiaries can locate their intangible assets linked to innovation in low-tax regions, taxation may have no relationship with the effect of IPR on innovation in this case. Regarding this concern, we reselect our sample in two ways as follows. First, we use firms who possess oversea subsidiaries as a sample for regressions;

the estimated results are reported in column (5) in Table 3. Second, we further select firms with oversea subsidiaries in low-tax countries (regions), which are known as "tax havens"; results are reported in column (6) in Table 3. We find the robust results to support the conclusion that a high tax rate dampens the positive effect of IPR on innovation. For firms with oversea subsidiaries, the interactive effect between taxation and IPR is still significantly negative, implying that firms would not relocate all their intangible assets to low-tax regions. One possibility for the departure of our results from those in Karkinsky and Riedel (2012) and Schwab and Todtenhaupt (2021) is that our sample focuses on firms in China instead of European data.[17] As there are many tax credit or subsidy policies for R&D process in China, firms may not have additional incentives for relocating their intangible assets to overseas. Another possibility for firms to retain intangible assets in the domestic market is the time cost and monetary cost for technology transfer.[18]



(a) coefficient of $IPR_{it} \times tax_{it}$ (b) t-value of $IPR_{it} \times tax_{it}$

Figure 7: Placebo test.

6 Conclusion

This study develops an R&D-based growth model with patent breadth and taxation to explore the heterogeneous effects of IPR protection on innovation of firms with different income tax rates. The model shows that strengthening IPR protection (in terms of patent breadth) stimulates innovation and economic growth, and a higher firm-income tax rate dampens the positive effects of IPR protection. In addition, this study uses firm-level data in China to test the theoretical prediction on the interactive effect of patent protection and taxation, and finds that the empirical evidences are consistent with our theoretical results. In particular, our empirical anal-

[17]For instance, by matching patent applications at the European PatentOffice (EPO) to the European firm data base AMADEUS, Karkinsky and Riedel (2012) find that multinational enterprises tend to locate their patents at low-tax affiliates to minimize the corporate tax burden.

[18]See Wang and Blomström (1992) and Goh (2005) for more details about the learning and adaption cost, and Branstetter *et al.* (2006) and Gustafsson and Segerstrom (2011) about the monetary cost of technology transfer.

ysis shows that in the cities with an IPR court, the level of innovation (i.e., the number of patent applications) increases by roughly 20%, as compared to other cities. Nevertheless, a higher tax rate on corporate income (from 15% to 25%) tends to mitigate the positive effect of IPR protection on innovation by approximately 20%.

The main implication of previous analysis demonstrates that the "tax cut & administrative fees reduction" policy in China is expected to considerably stimulate innovation performance and promote the long-term economic growth. This policy also will facilitate the positive impacts of strengthening IPR protection that has been in effect in China over the past two decades. In other words, our current analysis anticipates that the interactive effect of IPR protection and tax reduction on innovation will continue to play an important role in enhancing growth and raising welfare in China, especially during the country's transition to an innovation-driven economy. Consequently, this policy is suggested to be maintained in effect. Nevertheless, the recent estimate on the Park-Ginarte index reveals that the level of China's IPR protection is so high that it may be increasingly difficult for a further strengthening. In this case, our story implies that more tax reductions on corporate incomes would be a good direction to stimulate China's innovation in the next stage.

References

Acemoglu, D. and Akcigit, U. (2012). Intellectual property rights policy, competition and innovation. *Journal of the European Economic Association*, **10** (1), 1–42.

—, Gancia, G. and Zilibotti, F. (2012). Competing engines of growth: Innovation and standardization. *Journal of Economic Theory*, **147** (2), 570–601.

—, Moscona, J. and Robinson, J. A. (2016). State capacity and american technology: evidence from the nineteenth century. *American Economic Review*, **106** (5), 61–67.

Aghion, P., Akcigit, U., Cage, J. and Kerr, W. R. (2016). Taxation, corruption, and growth. *European Economic Review*, **86**, 24–51.

— and Howitt, P. (1992). A model of growth through creative destruction. *Econometrica*, **60** (2), 323–351.

Akcigit, U., Baslandze, S. and Stantcheva, S. (2016). Taxation and the international mobility of inventors. *American Economic Review*, **106** (10), 2930–2981.

—, Hanley, D. and Stantcheva, S. (2022). Optimal taxation and r&d policies. *Econometrica*, **90** (2), 645–684.

Atanassov, J. and Liu, X. D. (2020). Can corporate income tax cuts stimulate innovation? *Journal of Financial and Quantitative Analysis*, **55** (5), 1415–1465.

Balsmeier, B., Fleming, L. and Lück, S. (2023). Isolating personal knowledge spillovers: Coinventor deaths and spatial citation differentials. *American Economic Review: Insights*, **5** (1), 21–33.

Branstetter, L., Fisman, R. and Foley, C. F. (2006). Do stronger intellectual property rights increase international technology transfer? Empirical evidence from U.S. firm-level panel data. *Quarterly Journal of Economics*, **121** (1), 321–349.

Chen, W.-R. and Miller, K. D. (2007). Situational and institutional determinants of firms' r&d search intensity. *Strategic Management Journal*, **28** (4), 369–381.

Chen, Y. and Puttitanun, T. (2005). Intellectual property rights and innovation in developing countries. *Journal of Development Economics*, **78** (2), 474–493.

Chu, A. C. (2009). Effects of blocking patents on r&d: a quantitative dge analysis. *Journal of Economic Growth*, **14** (1), 55–78.

— and Cozzi, G. (2018). Effects of patents versus r&d subsidies on income inequality. *Review of Economic Dynamics*, **29**, 68–84.

—, —, Fan, H. C., Pan, S. Y. and Zhang, M. B. (2020). Do stronger patents stimulate or stifle innovation? the crucial role of financial development. *Journal of Money Credit and Banking*, **52** (5), 1305–1322.

—, — and Galli, S. (2012). Does intellectual monopoly stimulate or stifle innovation? *European Economic Review*, **56** (4), 727–746.

Cohn, J. B., Liu, Z. and Wardlaw, M. I. (2022). Count (and count-like) data in finance. *Journal of Financial Economics*, **146** (2), 529–551.

Cozzi, G., Giordani, P. E. and Zamparelli, L. (2007). The refoundation of the symmetric equilibrium in schumpeterian growth models. *Journal of Economic Theory*, **136** (1), 788–797.

Dai, D. (2018). Intellectual property rights and r&d subsidies: are they complementary policies? *Journal of Economics*, **125**, 27–49.

Dang, J. W. and Motohashi, K. (2015). Patent statistics: A good indicator for innovation in china? patent subsidy program impacts on patent quality. *China Economic Review*, **35**, 137–155.

Dube, A., Lester, T. W. and Reich, M. (2010). Minimum wage effects across state borders: Estimates using contiguous counties. *The Review of Economics and Statistics*, **92** (4), 945–964.

Fan, H., Lin, F. and Tang, L. (2018). Minimum wage and outward fdi from china. *Journal of Development Economics*, **135**, 1–19.

Ferraro, D., Ghazi, S. and Peretto, P. F. (2020). Implications of tax policy for innovation and aggregate productivity growth. *European Economic Review*, **130**.

Furukawa, Y. (2010). Intellectual property protection and innovation: an inverted-u relationship. *Economics Letters*, **109** (2), 99–101.

Goh, A.-T. (2005). Knowledge diffusion, input supplier's technological effort and technology transfer via vertical relationships. *Journal of International Economics*, **66** (2), 527–540.

Grossman, G. M. and Helpman, E. (1991). Endogenous product cycles. *Economic Journal*, **101** (408), 1214–1229.

Gustafsson, P. and Segerstrom, P. S. (2011). North–South trade with multinational firms and increasing product variety. *International Economic Review*, **52** (4), 1123–1155.

Horii, R. and Iwaisako, T. (2007). Economic growth with imperfect protection of intellectual property rights. *Journal of Economics*, **90**, 45–85.

Howitt, P. (1999). Steady endogenous growth with population and r & d inputs growing. *Journal of Political Economy*, **107** (4), 715–730.

Hu, A. G. Z. and Png, I. P. L. (2013). Patent rights and economic growth: evidence from cross-country panels of manufacturing industries. *Oxford Economic Papers-New Series*, **65** (3), 675–698.

Iwaisako, T. and Futagami, K. (2013). Patent protection, capital accumulation, and economic growth. *Economic Theory*, **52** (2), 631–668.

Jaimovich, N. and Rebelo, S. (2017). Nonlinear effects of taxation on growth. *Journal of Political Economy*, **125** (1), 265–291.

Jones, L. E., Manuelli, R. E. and Rossi, P. E. (1993). Optimal taxation in models of endogenous growth. *Journal of Political Economy*, **101** (3), 485–517.

Judd, K. L. (1985a). On the performance of patents. *Econometrica*, **53** (3), 567–585.

— (1985b). Redistributive taxation in a simple perfect foresight model. *Journal of Public Economics*, **28** (1), 59–83.

Karkinsky, T. and Riedel, N. (2012). Corporate taxation and the choice of patent location within multinational firms. *Journal of International Economics*, **88** (1), 176–185.

Li, C.-W. (2001). On the policy implications of endogenous technological progress. *Economic Journal*, **111** (471), 164–179.

Liu, Q. and Qiu, L. D. (2016). Intermediate input imports and innovations: Evidence from chinese firms' patent filings. *Journal of International Economics*, **103**, 166–183.

Liu, Z. and Ma, H. (2015). *Trade liberalization, market structure, and firm markup: Evidence from China*. Report.

Long, X. and Pelloni, A. (2017). Factor income taxation in a horizontal innovation model. *Journal of Public Economics*, **154**, 137–159.

Lu, Y. and Yu, L. H. (2015). Trade liberalization and markup dispersion: Evidence from china's wto accession. *American Economic Journal: Applied Economics*, **7** (4), 221–253.

Moretti, E. and Wilson, D. J. (2017). The effect of state taxes on the geographical location of top earners: Evidence from star scientists. *American Economic Review*, **107** (7), 1858–1903.

Mukherjee, A., Singh, M. and Zaldokas, A. (2017). Do corporate taxes hinder innovation? *Journal of Financial Economics*, **124** (1), 195–221.

Naghavi, A. and Strozzi, C. (2015). Intellectual property rights, diasporas, and domestic innovation. *Journal of International Economics*, **96** (1), 150–161.

Nordhaus, W. D. (1969). *Invention, growth and welfare: a theoretical treatment of technological change*. Report.

Park, W. G. (2008). Intellectual property rights and international innovation. *Intellectual Property, Growth and Trade*, **2**, 289–327.

Romer, P. M. (1990). Endogenous technological-change. *Journal of Political Economy*, **98** (5), S71–S102.

Schwab, T. and Todtenhaupt, M. (2021). Thinking outside the box: The cross-border effect of tax cuts on r&d. *Journal of Public Economics*, **204**.

Segerstrom, P. S. (1998). Endogenous Growth without Scale Effects. *American Economic Review*, **88** (5), 1290–1310.

Shao, Y. C. and Xiao, C. R. (2019). Corporate tax policy and heterogeneous firm innovation: Evidence from a developing country. *Journal of Comparative Economics*, **47** (2), 470–486.

Stokey, N. L. and Rebelo, S. (1995). Growth effects of flat-rate taxes. *Journal of Political Economy*, **103** (3), 519–550.

Sweet, C. M. and Maggio, D. S. E. (2015). Do stronger intellectual property rights increase innovation? *World Development*, **66**, 665–677.

Wang, J.-Y. and Blomström, M. (1992). Foreign investment and technology transfer: A simple model. *European Economic Review*, **36** (1), 137–155.

Yang, Y. (2018). On the optimality of ipr protection with blocking patents. *Review of Economic Dynamics*, **27**, 205–230.

Appendix A

A.1 Proof of Proposition 1

We define a transformed variable such that $\chi_t \equiv c_t / Z_t$. Therefore, the law of motion for χ_t is given by

$$\frac{\dot{\chi}_t}{\chi_t} = \frac{\dot{c}_t}{c_t} - \frac{\dot{Z}_t}{Z_t}. \tag{A.1}$$

From (13), we know $\dot{v}_t / v_t = \dot{Z}_t / Z_t$. Using this condition, we can rewrite (A.1) as

$$\frac{\dot{\chi}_t}{\chi_t} = \frac{\dot{c}_t}{c_t} - \frac{\dot{v}_t}{v_t}. \tag{A.2}$$

By substituting (3) and (11) into (A.2), we further reduce (A.2) to

$$\frac{\dot{\chi}_t}{\chi_t} = \frac{\pi_t}{v_t} - \lambda_t - \rho. \tag{A.3}$$

Next, we derive the relation between χ_t and λ_t. First, using (13) and the final-good market-clearing condition, we have

$$\lambda_t = \frac{\varphi R_t}{Z_t} = \varphi\left(\frac{y_t}{Z_t} - \frac{c_t}{Z_t}\right) = \varphi(L - \chi_t). \tag{A.4}$$

Substituting (10), (13) and (A.4) into (A.3) yields

$$\frac{\dot{\chi}_t}{\chi_t} = \frac{(1-\tau)\left(\frac{\mu-1}{\mu}\right) y_t}{Z_t/\varphi} - \varphi(L-\chi_t) - \rho = \varphi\chi_t - \left[1 - (1-\tau)\frac{\mu-1}{\mu}\right]\varphi L - \rho = \varphi\chi_t - \Phi - \rho, \tag{A.5}$$

where $\Phi \equiv \left[1 - (1-\tau)\frac{\mu-1}{\mu}\right]\varphi L$ and the second equality applies (17). Hence, the dynamics of χ_t is characterized by saddle-point stability such that χ_t jumps to its interior steady state given by $\chi = (\Phi + \rho)/\varphi$, which is stationary, and therefore $\dot{c}_t/c_t = \dot{Z}_t/Z_t$. Then combining (9), (10) and (17) yields

$$\frac{\dot{y}_t}{y_t} = \frac{\dot{w}_t}{w_t} = \frac{\dot{\pi}_t}{\pi_t} = \frac{\dot{Z}_t}{Z_t}. \tag{A.6}$$

Therefore, the variables $\{y_t, w_t, \pi_t, v_t, c_t\}$ all grow at the same growth rate as Z_t.

A.2 Social welfare

First, by applying the consumption-output ratio, we rewrite the steady-state welfare function in (21) as follows:

$$U = \frac{1}{\rho}\left[\ln\left(\frac{1-\tau}{\mu} + \tau + \frac{\rho}{\varphi L}\right) + \frac{g}{\rho}\right]. \tag{A.7}$$

Substituting (20) into (A.7) further reduces it to

$$U = \frac{1}{\rho}\left[\ln\left(\frac{1-\tau}{\mu} + \tau + \frac{\rho}{\varphi L}\right) + \frac{1}{\rho}\frac{(1-\tau)(\mu-1)}{\mu}\varphi L \ln z - \ln z\right]. \tag{A.8}$$

Taking the derivative of (A.8) with respect to μ, we obtain

$$\frac{\partial U}{\partial \mu} = \frac{1}{\rho}\left(-\frac{\frac{1-\tau}{\mu^2}}{\frac{1-\tau}{\mu} + \tau + \frac{\rho}{\varphi L}} + \frac{1-\tau}{\mu^2}\frac{\varphi L \ln z}{\rho}\right) = \frac{1}{\rho\mu^2}\left[-\frac{1-\tau}{\frac{1-\tau}{\mu} + \tau + \frac{\rho}{\varphi L}} + (1-\tau)\frac{\varphi L \ln z}{\rho}\right]. \tag{A.9}$$

If the parameter condition $[(1-\ln z)\rho - \tau\varphi L \ln z] > 0$ holds, the relation between IPR protection and social welfare exhibits an inverted-U shape. In contrast, if the parameter condition $[(1 -$

$\ln z)\rho - \tau\varphi L \ln z] < 0$ holds, then the relation is monotonically increasing since $\partial U/\partial\mu > 0$. These cases can be specified as follows:

$$
\begin{aligned}
\frac{\partial U}{\partial \mu} > 0 \Leftrightarrow \mu < \frac{(1-\tau)\varphi L \ln z}{\rho(1-\ln z) - \tau\varphi L \ln z}, \quad if \quad [(1-\ln z)\rho - \tau\varphi L \ln z] > 0 \\
\frac{\partial U}{\partial \mu} < 0 \Leftrightarrow \mu > \frac{(1-\tau)\varphi L \ln z}{\rho(1-\ln z) - \tau\varphi L \ln z}, \quad if \quad [(1-\ln z)\rho - \tau\varphi L \ln z] > 0 \\
\frac{\partial U}{\partial \mu} > 0, \quad if \quad [(1-\ln z)\rho - \tau\varphi L \ln z] < 0
\end{aligned}
\tag{A.10}
$$

because $z > 1$ ensures that $\ln z > 0$ must hold.

To explore the interactive effect of IPR protection and taxation on social welfare, we derive the cross derivative of U with respect to μ and τ such that

$$
\begin{aligned}
\frac{\partial^2 U}{\partial\mu\partial\tau} &= \frac{1}{\rho\mu^2}\left[- \frac{-\left(\frac{\rho}{\varphi L} + \tau + \frac{1-\tau}{\mu}\right) - (1-\tau)\frac{\mu-1}{\mu}}{\left(\frac{\rho}{\varphi L} + \tau + \frac{1-\tau}{\mu}\right)^2} - \frac{\varphi L \ln z}{\rho} \right] \\
&= \frac{1}{\rho\mu^2}\left[\frac{\frac{\rho}{\varphi L} + 1}{\left(\frac{\rho}{\varphi L} + \tau + \frac{1-\tau}{\mu}\right)^2} - \frac{\varphi L \ln z}{\rho} \right]
\end{aligned}
\tag{A.11}
$$

Therefore, we derive the following conditions that specify whether taxation stimulates or stifles the effect of patent protection on social welfare:

$$
\begin{aligned}
\frac{\partial^2 U}{\partial\mu\partial\tau} > 0 \Leftrightarrow \frac{\frac{1}{\varphi L} + \frac{1}{\rho}}{\left(\frac{1}{\varphi L} + \frac{\tau}{\rho} + \frac{1-\tau}{\rho\mu}\right)^2} > \varphi L \ln z, \\
\frac{\partial^2 U}{\partial\mu\partial\tau} < 0 \Leftrightarrow \frac{\frac{1}{\varphi L} + \frac{1}{\rho}}{\left(\frac{1}{\varphi L} + \frac{\tau}{\rho} + \frac{1-\tau}{\rho\mu}\right)^2} < \varphi L \ln z.
\end{aligned}
\tag{A.12}
$$