

# Patents, Innovation, and Imitation in a North-South Model with Increasing Product Variety\*

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## Abstract

To understand the relationship between patent protection and technology transfer across countries and to equip policymakers with insights to balance innovation promotion and technology dissemination, this paper investigates the cross-country effects of patent protection on relative wages, innovation, technology transfer, and welfare in a North-South model with variety expansion. In this dynamic general equilibrium model, firms in the North perform innovative R&D, while firms in the South perform imitative R&D for technology transfer. Innovation occurs through the invention of new varieties of goods, and IPR protection is modeled in the form of patent breadth. We find that strengthening patent protection in the North permanently raises the relative wage between the North and the South, permanently decreases the rate of technology transfer, and temporarily increases the northern innovation rate. Conversely, strengthening patent protection in the South permanently reduces the relative wage, permanently increases the rate of technology transfer, and temporarily boosts the northern innovation rate. Calibrating this model to US-China data, our quantitative analysis reveals that when a country unilaterally strengthens patent protection, its domestic welfare increases. However, when both countries strengthen patent protection bilaterally, the South experiences a welfare gain while the North suffers a welfare loss.

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*Keywords:* Innovation; Patent Protection; R&D; Technology Transfer; Variety Expansion.

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# 1 Introduction

Intellectual property right (IPR) protection has become increasingly important in international trade, especially after the introduction of the TRIPS Agreement – the most extensive multinational agreement on IPR. Essential for innovation and trade, it helps settle trade disputes and allows WTO members to pursue national policy goals. The Agreement highlights the IPR system’s role in social welfare, innovation, and technology transfer, recognizing the crucial links between IPR and trade and the need for a balanced IPR system.<sup>1</sup> It establishes the minimal standards for the enforcement of IPR of member nations, particularly for developing nations.<sup>2</sup> Since then, many countries have strengthened patent protection. For example, between 2000 and 2017, the number of patent applications by residents and non-residents in the US increased from 295,895 to 606,956, and in China from 51,906 to 1,381,594.<sup>3</sup> However, the enforcement and protection of intellectual property rights vary widely across the globe, sparking debate on the optimal level of patent protection. These disparities are a source of tension in international economic relations, and the adoption of intellectual property rights is seen as a way to resolve disputes. Some studies argue that patents stifle innovation (see [Shapiro 2000](#), [O’Donoghue and Zweimüller 2004](#), and [Chu et al. 2012](#)), while others suggest that patent policies encourage research and development (R&D) (see [Judd 1985](#), [Dinopoulos and Kottaridi 2008](#), [Iwaisako et al. 2011](#), and [Chu and Peng 2011](#)).

In addition to innovation, imitation is a crucial factor for policymakers and firms to consider when designing IPR regimes.<sup>4</sup> Imitation serves as a potent form of technology diffusion, enhancing the innovation capacity of developing countries (i.e., the South). It plays a vital role in the transfer of technology from developed countries (i.e., the North) by replicating or reproducing technological knowledge, processes, or products without the need for original research. Developing countries often lack the resources and expertise to develop cutting-edge technologies independently. By imitating technologies from advanced economies, they can leapfrog certain developmental stages and quickly adopt innovations without incurring the high costs and risks associated with R&D.

Innovation and imitation influence each other in various ways. Innovations can serve as models and benchmarks for imitation, with firms replicating new technologies or products to profit

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<sup>1</sup>The balance between imposing intellectual property rights and allowing fair use is often debated. In particular, determining IPR with public health concerns is a controversial topic. [Jung and Kwon \(2015\)](#) show that strengthening IPR for medicines will cause low-income countries to suffer from a deficiency of pharmaceutical supply and limited access to medicines, as they lack the capacity to develop and produce medicines themselves. The high costs of patented drugs and medicines limit access to essential medicines in developing countries, sparking debates and calls for reforms.

<sup>2</sup>Under the TRIPS Agreement, WTO countries can tailor IPR protection and enforcement to their needs and public policy objectives. The Agreement allows members to balance incentivizing innovation with minimizing short-term access restrictions by using techniques such as exclusions or exceptions to IPR. Additionally, the WTO dispute resolution system is available for TRIPS-related trade disputes

<sup>3</sup>The data on patent applications are obtained from the World Development Indicators.

<sup>4</sup>Imitation can stifle innovation by reducing the incentives for firms to engage in R&D, leading to less innovation and slower economic growth. However, imitation can also drive innovation. [Grossman and Helpman \(1991\)](#) find that strengthening southern imitation leads to faster steady-state innovation in the North. [Aghion et al. \(2001\)](#) show that a low level of imitation enhances growth, as innovating firms must continually develop better products to stay ahead.

from their success. Conversely, imitation can act as a catalyst for new innovation, incentivizing firms to create new product varieties. This iterative process of imitation and innovation (in terms of variety expansion) promotes ongoing advancements in an economy.<sup>5</sup> Thus, investigating the role of IPR policy in the interaction between innovation and imitation within the North-South framework is particularly interesting.

This study reexamines how strengthening patent protection in developed and developing countries affects innovation, technology transfer, and social welfare. Building on the seminal work of [Gustafsson and Segerstrom \(2010\)](#), we develop a North-South variety expansion model featuring innovative R&D in the North and imitative R&D in the South. Specifically, the model incorporates a one-way product cycle, where production shifts from the North to the South when southern firms successfully imitate northern varieties, using imitation as the vehicle for technology transfer. There are two main differences between our model and that of [Gustafsson and Segerstrom \(2010\)](#). First, the form of protection of intellectual property rights differs. While [Gustafsson and Segerstrom \(2010\)](#) use imitative R&D productivity as a measure of IPR protection, affecting the cost of innovation, our study uses patent breadth, a common policy instrument used by patent authorities.<sup>6</sup> The level of patent breadth determines the scope of protection for an invention, influencing the markup and profits of the monopoly firm holding the patent. Second, the focus of policy implications differs. While [Gustafsson and Segerstrom \(2010\)](#) examine the effects of southern IPR protection, our study investigates the cross-country effects of both northern and southern patent policies. In the model setting of [Gustafsson and Segerstrom \(2010\)](#), increased IPR protection leads to a permanent decrease in technology transfer, a temporary decrease in innovation, and a permanent increase in the relative North-South wage. Our dynamic general equilibrium framework, which employs patent breadth as a form of intellectual property rights protection, yields different results from their findings as follow.

Stronger patent protection in the North leads to a temporary increase in the rate of innovation, a permanent decrease in the rate of imitation, and a permanent increase in the relative wage. By enhancing northern patent protection, northern firms gain more market power to charge higher prices and increase profits. This incentivizes northern firms to invest more in innovative R&D, increasing the demand for R&D labor and raising the North-South relative wage. Consequently, the increased allocation of labor to innovative R&D stimulates the innovation rate, while making it more difficult for southern firms to imitate northern varieties, thus reducing the imitation rate. Conversely, stronger patent protection in the South results in a temporary increase in the rate of innovation, a permanent increase in the rate of imitation, and a permanent decrease in the relative wage. Enhanced southern patent protection increases the market power of southern firms, leading to higher prices and greater profits. This increases incentives for southern firms

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<sup>5</sup>See [Mukoyama \(2003\)](#) and [Collins \(2015\)](#) for more details.

<sup>6</sup>In our framework, patent breadth represents the scope of legal protection for innovators, influencing both innovation incentives and the degree of imitation. Although this abstraction simplifies analysis, we recognize that real-world IPR enforcement varies significantly across countries and is shaped by broader institutional, legal, and administrative factors. Patent breadth in our model should be interpreted as a composite proxy of the strength and scope of the enforcement of IPR, which includes legal definitions, judicial effectiveness and administrative capacity.

to engage in imitative R&D, raising labor demand in this activity and decreasing the relative wage between the North and South. As a result, the higher imitation rate reduces the number of products produced in the North, reallocating more northern labor to the innovative R&D sector and thus increasing the innovation rate.

Next, we calibrate our model using data from the US and China to quantify the cross-country effects of IPR protection in the North and the South. Increasing patent protection in the US (the North) by one percentage point raises the relative R&D difficulty by 2.85%, leading to a temporary increase in innovation rate. Additionally, the imitation rate decreases by 4.06%, and the relative wage increases by 0.62%. Tightening US patent policy results in a welfare gain of 0.73% in the US and a slight welfare loss of 0.0004% in China (the South). The marginal change in China's welfare is due to the nearly offsetting positive impact on innovation and negative impact on the portion of goods produced in China. In contrast, a one percentage point increase in Chinese patent protection temporarily raises the innovation rate by 0.17% and permanently increases the imitation rate by 5.186%. The US-China wage gap decreases by 1.108%. The US experiences a welfare loss of 1.45%, while China benefits from a welfare gain of 0.469%, partially due to the decrease in the US-China relative wage. When both the US and China increase patent protection by one percentage point, the temporary innovation rate and the imitation rate increase by 3.018% and 0.917%, respectively, while the relative wage decreases by 0.492%. The US faces a welfare loss of 0.397%, whereas China enjoys a welfare gain of 0.469%. Stronger patent protection in both countries leads to higher consumer prices. These increased prices, coupled with the decline in the US-China relative wage, negatively impact US consumer welfare. However, the decreasing relative wage indicates faster increase in purchasing power for Chinese workers. The temporary increase in innovation and imitation rates in China expands product availability. Thus, the combined effects of increased innovation and imitation rates, along with the positive impact on relative wages, improve the overall welfare of Chinese consumers.

## 1.1 Literature Review

Our research extends the existing literature on the effects of IPR on innovation and welfare, traditionally studied within a closed economy context. For example, [Horii and Iwaisako \(2007\)](#) explore the impact of IPR protection in a quality-ladder growth model, finding that stronger IPR protection stifles imitation and stimulates innovation. [Futagami and Iwaisako \(2007\)](#) analyze the effects of patent length on growth and welfare in an endogenous growth model, showing that extending patent length reduces growth, whereas a finite patent length maximizes social welfare on a balanced growth path. [Chu \(2009\)](#) evaluates the effects of blocking patents in a quality-ladder growth model with overlapping IPR, concluding that reducing the degree of blocking patents increases innovation, consumption, and social welfare. [Iwaisako and Futagami \(2013\)](#) find that in a model where both innovation and capital accumulation drive economic growth, stronger patent breadth protection stimulates innovation but hampers capital accumulation, potentially impeding growth. While previous studies have primarily focused on closed economies,

our research broadens the scope by examining how patent protection impacts innovation and economic growth across different countries. This approach provides new insights into the global implications of patent policies.

Our research also contributes to the literature that examines the impact of IPR protection in the South on innovation and technology transfer. [Helpman \(1993\)](#) shows that higher southern patent protection coupled with a low imitation rate harms both the South and the North; conversely, with a high imitation rate, the South suffers while the North benefits. [Glass and Saggi \(2002\)](#) and [Parelo \(2008\)](#) use the cost of imitation as a measure of IPR protection in the South. In [Glass and Saggi \(2002\)](#)'s model, they find that an increase in southern IPR raises the cost of imitation, leading to resource-wasting and imitation-disincentive effects that reduce innovation and foreign direct investment (FDI). [Parelo \(2008\)](#) show that stronger IPR in the South has a temporary effect on innovation rate and a permanent decrease in technology transfer and imitation rates. In addition, [Glass and Wu \(2007\)](#) use imitation intensity as a proxy for IPR protection. They find that the effects of strengthening southern IPR protection depend on the nature of innovation: it increases technology transfer and innovation when innovation involves inventing new varieties, but reduces them when it involves improving quality.<sup>7</sup> [Lorenczik and Newiak \(2012\)](#) use imitation difficulty to measure IPR protection in the South and examine its effects on imitation of southern and northern varieties. They show that if IPR protection exceeds a threshold level, strengthening it accelerates southern innovation and yields welfare gains in both the North and the South. [Tanaka and Iwaisako \(2014\)](#) incorporate exogenous imitation risk as an IPR protection proxy, along with R&D and FDI subsidies in their North-South quality-ladder model, showing that stronger IPR protection encourages innovation and FDI. This paper differs from the above-mentioned literature by featuring both northern and southern IPR protection, using patent breadth as a proxy for IPR protection in a variety expansion growth model.<sup>8</sup>

Additionally, our study contributes to the broader literature exploring these effects within a two-country R&D-based growth model. Our study closely relates to [Zheng \*et al.\* \(2020\)](#), who analyze the cross-country effects of patent breadth on innovation, technology transfer, and relative wage in a North-South quality-ladder model.<sup>9</sup> Their model considers a two-way product cycle: production shifts from the North to the South when southern affiliates engage successfully in adaptive R&D, and returns to the North when northern innovators invent higher-quality products. Our paper differs by considering a distinct mode of technology transfer: while [Zheng](#)

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<sup>7</sup>See also [Chen \(2015\)](#), who finds that strengthening southern IPR protection increases outsourcing but decreases technology transfer.

<sup>8</sup>This study also relates to the strategic patent literature, which examines how firms use patents to shape competition and innovation. Existing studies identify strategic patenting as a barrier to technological diffusion and market entry, with a notable rise in diagonally integrated non-practicing entities (NPEs) acquiring patents primarily for assertion against competitors (e.g., [Morton and Shapiro 2013](#); [Hovenkamp and Cotter 2015](#)). This practice imposes costs on rivals and hinders downstream innovation in sectors like computers and electronics, while having limited impact on others (e.g., drugs, chemicals). The effect is primarily driven by patent invalidation, which encourages follow-up innovation from smaller companies ([Galasso and Schankerman, 2015](#)).

<sup>9</sup>See the table in Online Appendix C that compares our measurements and results with three closely related studies: [Helpman \(1993\)](#), [Gustafsson and Segerstrom \(2010\)](#), and [Zheng \*et al.\* \(2020\)](#).

*et al.* (2020) focus on FDI as the mode of technology transfer, we consider imitation. While FDI is an important mode of technology transfer, examining imitation can provide new insights, as firms may find it more cost-effective to imitate existing technologies rather than invest in adaptive R&D. This makes imitation a realistic and important mechanism when studying the effects of IPR on innovation, technology transfer, and relative wages.<sup>10</sup> Our paper complements the findings of *Zheng et al.* (2020) regarding the implications of IPR protection. For southern IPR protection, our study aligns with existing literature: stronger southern patent protection temporarily increases the innovation rate and the rate of technology transfer. In contrast, *Zheng et al.* (2020) find that strengthening northern IPR protection decreases the rate of technology transfer and has an ambiguous effect on the innovation rate. Under the one-way variety expansion setting in our model, we find that strengthening northern patent protection similarly impacts the rate of technology transfer (specifically the imitation rate) and has a deterministic effect on the innovation rate. Consequently, our study clarifies the implications of northern IPR protection on innovation, highlighting the important roles played by the mode of technology transfer and the nature of product cycles.<sup>11</sup>

Empirical studies have investigated the effects of IPR on innovation and technology transfer. For example, *Chen and Puttitanun* (2005) use a panel dataset of developing countries to examine the impacts of IPR on innovation, finding a positive effect of IPR on innovation in these countries and a U-shaped relationship between IPR and economic development. In contrast, *Schneider* (2005), using panel data from developed and developing countries from 1970-1990, shows that strengthening IPR positively impacts domestic innovation in developed countries but negatively affects innovation in developing countries. *Park and Lippoldt* (2008) focus on the effects of IPR on technology transfer to developing countries, showing that stronger levels of patent protection are positively and significantly associated with the inflows of high-tech products. Additionally, *Hudson and Minea* (2013), using a dataset of 62 developed and developing countries from 1980-2009, employ panel smooth threshold regressions of panels to demonstrate that the impacts of IPR on innovation are complex and non-linear, varying in sign and magnitude depending on the initial level of IPR and GDP per capita. Our paper contributes to this empirical literature by providing a theoretical framework that explains how IPR policy in different countries affects innovation and international technology transfer.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 derives the conditions for the steady-state equilibrium and social welfare. Section 4 presents the quantitative analysis and robustness checks. Section 5 modifies the model to fully-endogenous growth in the long run. Finally, Section 6 concludes the study.

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<sup>10</sup>See *Schmitz Jr* (1989) and *Jovanovic and MacDonald* (1994) for details.

<sup>11</sup>Our paper also relates to the recent North-South Schumpeterian growth literature with wage dynamics. *Afonso* (2012) develops a dynamic, scale-independent North-South model to analyze how international trade influences technological change and intra-country wage inequality, linking knowledge diffusion to wage dynamics through trade-induced price effects. *Afonso and Sequeira* (2023) extend this analysis by incorporating sector-specific cash-in-advance constraints and differing inflation rates to show how inflation exacerbates wage inequality and reduces specialization in skilled-intensive goods, particularly in financially constrained Southern economies.

## 2 The Model

### 2.1 Overview

This study builds on [Gustafsson and Segerstrom \(2010\)](#)'s North-South model of variety expansion by incorporating patent breadth in both the North (i.e., a developed country) and the South (i.e., a developing country). In this model, the North uses labor for manufacturing and innovative research and development (R&D) to create new products, while the South uses labor to manufacture and imitate northern products. Labor is immobile across regions but perfectly mobile across different activities within a region, namely labor is homogeneous across sectors within a region. There are trade costs between the two regions.

Additionally, northern firms' technologies are at risk of being imitated by southern firms. Production of varieties occurs in the North if they have not been imitated. However, once a variety is successfully imitated by the South, its manufacturing shifts to the South to leverage lower production costs.<sup>12</sup>

### 2.2 Households

The number of households is fixed in both the North and the South. We assume that the population growth rates in both regions are identical and equal to  $g_L > 0$ . Each household member is endowed with one unit of labor, supplied inelastically. Thus, the labor supply in the North at time  $t$  is  $L_{N,t} = L_{N,0}e^{g_L t}$ , and in the South, it is  $L_{S,t} = L_{S,0}e^{g_L t}$ . Consequently, the total global labor force at time  $t$  is  $L_t = L_{N,t} + L_{S,t}$ .

Households in both the North and the South have identical preferences and each maximizes their discounted lifetime utility given by:

$$U \equiv \int_0^{\infty} e^{-(\rho - g_L)t} \ln u(t) dt, \quad (1)$$

where  $\rho > g_L$  is the subjective discount rate and  $u(t)$  is the static individual utility at time  $t$ . The static constant elasticity of substitution (CES) utility function is given by:<sup>13</sup>

$$u(t) = \left[ \int_0^{n_t} x_t(j)^\alpha dj \right]^{1/\alpha}, \quad (2)$$

where  $x_t(j)$  is the per capita quantity demanded of product variety  $j$  at time  $t$ ,  $\alpha \in (0, 1)$  is the degree of product differentiation, the elasticity of substitution between product varieties is

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<sup>12</sup>See the figure in Online Appendix D that explains the product cycle composition of our model.

<sup>13</sup>Using a non-constant elasticity of substitution utility function in the current model would significantly complicate the analysis, making it challenging to obtain closed-form solutions in the steady-state equilibrium. Therefore, the CES utility function is a pragmatic choice for practical applications in our model due to its analytical tractability. Moreover, the CES utility function is widely adopted in existing endogenous growth models with IPR policy and North-South technology transfer (see [Gustafsson and Segerstrom 2010](#), [Dinopoulos and Segerstrom 2010](#), and [Zheng et al. 2020](#)). This choice facilitates comparison of IPR policy effects between our study and previous studies.

$\epsilon = 1/(1 - \alpha)$ , and  $n_t$  is the total number of product varieties available in the global market. Each household maximizes (1) subject to the following budget constraint:

$$\dot{a}_t = (r_t - g_L)a_t + w_t - c_t - \tau_t, \quad (3)$$

where  $a_t$  is the real value of assets per capita,  $r_t$  is the real interest rate,  $w_t$  represents the real wage rate,  $c_t$  denotes consumption expenditures, and  $\tau_t$  denotes the lump-sum tax for subsidization. Solving the consumer maximization problem yields the demand function:

$$x_t(j) = \frac{c_t p_t(j)^{-\epsilon}}{P_t^{1-\epsilon}}, \quad (4)$$

where  $p_t(j)$  is the price of variety  $j$  and  $P_t = [\int_0^{n_t} p_t(j)^{1-\epsilon} dj]^{1/(1-\epsilon)}$  is the aggregate price index. Maximizing (1) subject to (2) and substituting (4) for  $x_t(j)$  yields the intertemporal optimization problem:

$$\frac{\dot{c}_t}{c_t} = r_t - \rho, \quad (5)$$

which implies that consumer expenditure per capita grows over time when the real interest rate  $r_t$  exceeds the subjective discount rate  $\rho$ .

### 2.3 Innovation and Imitation

In this model, only the North can innovate and develop new varieties, while production shifts to the South when southern firms successfully imitate northern varieties.<sup>14</sup> All invented varieties are gross substitutes. The number of varieties invented in the North is  $n_{N,t}$ , and the number of varieties imitated by southern firms at time  $t$  is  $n_{S,t}$ . Therefore, the total number of varieties available in the global market is

$$n_t = n_{N,t} + n_{S,t}. \quad (6)$$

Northern firms devote  $a_N/K_{N,t}^\theta$  units of labor to innovate and develop a new variety, where  $K_{N,t}$  is the amount of existing knowledge available to northern firms,  $\theta > 0$  is the intertemporal knowledge spillover parameter, and  $a_N$  is a parameter for innovative R&D productivity.<sup>15</sup> The existing knowledge grows over time and is available to all firms in the global market. Following [Gustafsson and Segerstrom \(2010\)](#), we assume that  $K_{N,t}$  equals the total number of varieties globally, such that  $K_{N,t} = n_t$ . Thus, the existing amount of knowledge grows as the total number of varieties increases. Given the state-of-the-art technology in innovative R&D, the aggregate

<sup>14</sup>We have extended our model to incorporate innovation in both the North and the South, as detailed in [Online Appendix A](#). The effects of patent breadth on innovation and imitation remain largely robust under this extended framework.

<sup>15</sup>The innovative R&D parameter  $a_N$  and the imitative R&D parameter  $a_S$  in (7) and (8) capture the aggregate effects of technological capabilities, institutional frameworks, and market dynamics. These can be influenced by labor skill levels, the quality of technological infrastructure, the effectiveness of regulatory bodies, market size, and the level of competition.

flow of products to the North is

$$\dot{n}_{N,t} = \frac{L_{R,t}n_t^\theta}{a_N}, \quad (7)$$

where  $\dot{n}_{N,t} = \dot{n}_t$  and  $L_{R,t}$  is the total number of northern labor hired in innovative R&D activities.

Similarly, southern firms devote  $a_S/K_{S,t}^\theta$  units of labor to imitate northern varieties. Hence, the aggregate flow of varieties to the South is:

$$\dot{n}_{S,t} = \frac{L_{C,t}K_{S,t}^\theta}{a_S}, \quad (8)$$

where  $K_{S,t} \equiv n_{S,t} + kn_{N,t}$  is the amount of knowledge available to southern firms,  $k \in (0,1]$  is a spillover parameter,  $a_S$  is a parameter for imitative R&D productivity, and  $L_{C,t}$  is the total number of southern labor hired in imitative R&D activities. Following [Jones \(1995\)](#) and [Gustafsson and Segerstrom \(2011\)](#), we set the intertemporal knowledge spillover parameter bounded by  $0 < \theta < 1$ . For  $\theta > 0$ , the production of inventions becomes more efficient as the existing amount of knowledge available to R&D labor increases. For  $\theta < 1$ , this setting mitigates the strong scale effect.

## 2.4 Production

One unit of northern labor produces  $h > 1$  units of products, where  $h$  is the human capital parameter, reflecting that northern labor is more productive than southern labor. In contrast, one unit of southern labor produces 1 unit of product. Therefore, a northern firm's constant marginal cost of production is  $w_N/h$ , while a southern firm's constant marginal cost of production is  $w_S$ . As in [Gustafsson and Segerstrom \(2010\)](#), firms in both regions face a trade cost  $\tau \geq 1$  when goods are produced and exported to the other region. Trade costs encompass policy barriers such as tariffs, transportation, communication, information, and regulatory costs. This model features a one-way product cycle: production only shifts from the North to the South when the northern marginal cost, inclusive of trade costs, exceeds the southern marginal cost, i.e., when  $w_N/h > \tau w_S$ .

Next, we examine the prices and profits of northern firms when they sell products domestically and export to the other region. A northern firm exports  $\tau x_{N,t}^* L_{S,t}$  units of goods to southern consumers and pays its workers  $w_N/h$  for each unit of goods produced.<sup>16</sup> Hence, the export profits of a northern firm are given by  $\pi_{N,t}^* = (p_{N,t}^* - \tau w_N/h)x_{N,t}^* L_{S,t}$ , where  $p_{N,t}^*$  is the export price of northern innovated goods charged to southern consumers,  $x_{N,t}^* = (p_{N,t}^*)^{-\epsilon} c_S / (P_{S,t})^{1-\epsilon}$  is the southern consumers' demand for northern innovated goods, and  $(P_{S,t})^{1-\epsilon} = \int_{n_{N,t}} p_{N,t}^*(j)^{1-\epsilon} dj + \int_{n_{S,t}} p_{S,t}(j)^{1-\epsilon} dj$ .

We assume that if products have not yet been imitated by southern firms and the technology transfer process has not yet taken place, production is carried out entirely in the North. In this

<sup>16</sup>An asterisk denotes exports,  $d$  denotes domestic, and subscript denotes where the product is produced.

scenario, northern firms only face competition from competitive fringes in the domestic market. For this reason, similar to [Zheng \*et al.\* \(2020\)](#), northern IPR policy in terms of patent breadth  $\mu_N$  captures the quality lead over the competitive fringes, thereby eliminating the competition from these fringes. As a result, northern patent breadth  $\mu_N$  determines northern firms' monopolistic markup prices in the domestic market and when exporting products to the South.<sup>17</sup> Therefore, the price and profit of a northern firm for exporting products to the South are given by

$$p_{N,t}^* = \frac{\tau\mu_N w_N}{h}, \quad (9)$$

$$\pi_{N,t}^* = \frac{w_N}{h} (\tau\mu_N - 1) x_{N,t}^* L_{S,t}. \quad (10)$$

The domestic profit of a northern firm is  $\pi_{N,t}^d = (p_{N,t}^d - w_N/h)x_{N,t}^d L_{N,t}$ , where  $p_{N,t}^d$  is the domestic price of northern innovated goods charged to northern consumers,  $x_{N,t}^d = (p_{N,t}^d)^{-\epsilon} c_N / (P_{N,t})^{1-\epsilon}$  is northern consumers' demand for northern innovated goods, and  $(P_{N,t})^{1-\epsilon} = \int_{n_{N,t}} p_{N,t}(j)^{1-\epsilon} dj + \int_{n_{S,t}} p_{S,t}^*(j)^{1-\epsilon} dj$ . Hence, the price and profit of a northern firm for selling products domestically are given by

$$p_{N,t}^d = \frac{\mu_N w_N}{h}, \quad (11)$$

$$\pi_{N,t}^d = \frac{w_N}{h} (\mu_N - 1) x_{N,t} L_{N,t}. \quad (12)$$

Therefore, the total profit  $\pi_{N,t} = \pi_{N,t}^* + \pi_{N,t}^d$  of a northern firm is

$$\pi_{N,t} = \frac{(\mu_N - 1)w_N \bar{x}_{N,t} L_t}{h}, \quad (13)$$

where  $\bar{x}_{N,t} = (x_{N,t} L_{N,t} + \tau x_{N,t}^* L_{S,t}) / L_t$  is the average quantity demanded of northern goods by world consumers.

Similar to [Li \(2001\)](#) and [Goh and Olivier \(2002\)](#), our model's setting of IPR policy implies that patent protection is incomplete. The potential rivals of northern firms are northern imitators who have easier access to the latest technology in the North. Additionally, the enforcement of patent protection across countries can be inherently complex. Gaps or limitations in the protection provided may exist, and difficulties may arise due to differences in legal systems, jurisdictional issues, and varying enforcement capabilities. Despite these challenges, southern firms can

<sup>17</sup>In [Parelo \(2008\)](#)'s quality-ladder model, it is shown that the quality step size times its own marginal cost of production is the only pricing strategy for a northern industry leader, regardless of whether the strongest rival is from the North or South. If the strongest rival is from the North, it produces goods that are one quality step below the highest-quality product and charges a marginal-cost price. The northern leader can capture the entire market by charging a price that is not greater than the quality step size times its own marginal cost. On the other hand, if the strongest rival is from the South, it charges a price equal to its marginal cost. Then the northern leader can capture the entire market by setting a price that is not greater than the quality step size times the marginal cost of the southern rival. In that case, the southern strongest rival exits the market, and the northern leader can then raise the price to the level of the quality step size times its marginal cost of production.

still imitate northern products by adapting technologies to meet specific needs in the southern market. This adaptation involves making modifications to patented products, addressing local preferences, and conforming to regulatory requirements in the southern region.

A southern firm exports  $\tau x_{S,t}^* L_{N,t}$  units of goods to northern consumers and pays its workers  $w_S$  for each unit of goods produced. Hence, the export profit of a southern firm is  $\pi_{S,t}^* = (p_{S,t}^* - \tau w_S) x_{S,t}^* L_{N,t}$ , where  $p_{S,t}^*$  is the export price of southern goods charged to northern consumers, and  $x_{S,t}^* = (p_{S,t}^*)^{-\epsilon} c_N / (P_{N,t})^{1-\epsilon}$  is northern consumers' demand for southern goods. We also assume that once southern firms have imitated northern products, production stays in the South in this one-way product cycle model. Then the rivals of southern firms are competitive fringes in the South. Similar to the pricing strategy of a northern firm, southern IPR protection in terms of patent breadth  $\mu_S$  determines southern firms' markup and thereby the prices in both domestic and foreign markets.<sup>18</sup> Hence, the export price and profit of a southern firm are given by

$$p_{S,t}^* = \tau \mu_S w_S, \quad (14)$$

$$\pi_{S,t}^* = \tau w_S (\mu_S - 1) x_{S,t}^* L_{N,t}. \quad (15)$$

The domestic profit of a southern firm is  $\pi_{S,t}^d = (p_{S,t}^d - w_S) x_{S,t}^d L_{S,t}$ , where  $p_{S,t}^d$  is the domestic price of southern goods charged to southern consumers, and  $x_{S,t}^d = (p_{S,t}^d)^{-\epsilon} c_S / (P_{S,t})^{1-\epsilon}$  is southern consumers' demand for southern goods. Hence, the price and profit of a southern firm for selling products domestically are given by

$$p_{S,t}^d = \mu_S w_S, \quad (16)$$

$$\pi_{S,t}^d = w_S (\mu_S - 1) x_{S,t}^d L_{S,t}. \quad (17)$$

The total profit  $\pi_{S,t} = \pi_{S,t}^* + \pi_{S,t}^d$  of a southern firm is given by

$$\pi_{S,t} = (\mu_S - 1) w_S \bar{x}_{S,t} L_t, \quad (18)$$

where  $\bar{x}_{S,t} = (x_{S,t} L_{S,t} + \tau x_{S,t}^* L_{N,t}) / L_t$  is the average quantity demanded of southern goods by world consumers.

#### 2.4.1 Financial Sectors

Let  $V_{N,t}$  and  $V_{S,t}$  denote the expected discounted profits for northern and southern firms at time  $t$ , respectively. There is free entry into R&D activities in both the North and the South, implying that the expected discounted profit equals the cost of innovation activities. R&D activities in the North and the South are subsidized at constant rates of  $s_R \in (0, 1)$  and  $s_C \in (0, 1)$ ,

<sup>18</sup>Parelo (2008) explains that a southern firm can capture the entire market by charging its price lower than the marginal cost of the northern leader. In this case, the northern leader exits the market, and the strongest rival of the southern firm becomes southern competitive fringes. Consequently, the southern firm can raise its price to the quality step size times its own marginal cost to out-compete the fringes.

respectively. Using (7) and (8), the firm values for northern and southern firms are given by

$$V_{N,t} = \frac{(1 - s_R)w_N a_N}{n_t^\theta}, \quad (19)$$

$$V_{S,t} = \frac{(1 - s_C)w_S a_S}{(K_{S,t})^\theta}. \quad (20)$$

The market portfolio with a safe return of  $r_N V_{N,t}$  for northern firms is equal to the sum of the profit flow  $\pi_{N,t}$ , the potential capital gain  $\dot{V}_{N,t}$ , and the expected capital loss from imitation  $\phi V_{N,t}$ , where  $\phi = \dot{n}_{S,t}/n_{N,t}$  is the imitation rate. As will be shown in the next section (i.e., Subsection 2.5), the steady-state value of  $\phi$  will be endogenously determined by the northern and southern steady-state conditions (34) and (35), and thereby affected by the values of patent policies  $\mu_N$  and  $\mu_S$ . Furthermore, the market portfolio with a safe return of  $r_S V_{S,t}$  for southern firms is equal to the sum of the profit flow  $\pi_{S,t}$  and the potential capital gain  $\dot{V}_{S,t}$ . Hence, the no-arbitrage conditions for northern and southern firms are given by

$$r_N V_{N,t} = \pi_{N,t} + \dot{V}_{N,t} - \phi V_{N,t}, \quad (21)$$

$$r_S V_{S,t} = \pi_{S,t} + \dot{V}_{S,t}. \quad (22)$$

#### 2.4.2 Labor Markets

In the North, labor is allocated to innovative R&D and production sectors such that  $L_{N,t} = L_{R,t} + L_{Y,t}$ . Northern firms use  $a_N/n_t^\theta$  units of labor for each invention, so the total innovative R&D labor is  $(a_N \dot{n}_t)/n_t^\theta$ . Northern firms use  $\bar{x}_{N,t} L_t$  units of labor to produce a variety, so the total labor for northern production is  $n_{N,t} \bar{x}_{N,t} L_t$ . Therefore, the labor-market-clearing condition in the North is given by

$$L_{N,t} = \frac{a_N \dot{n}_t}{n_t^\theta} + n_{N,t} \bar{x}_{N,t} L_t. \quad (23)$$

In the South, labor is allocated to imitation of northern goods and production sectors such that  $L_{S,t} = L_{C,t} + L_{P,t}$ . Southern firms use  $a_S/(K_{S,t})^\theta$  units of labor to imitate a variety, so the total imitative R&D labor is  $(a_S \dot{n}_{S,t})/(K_{S,t})^\theta$ . Moreover, southern firms use  $\bar{x}_{S,t} L_t$  units of labor to produce  $n_{S,t}$  varieties, so the total labor employed in southern production is  $n_{S,t} \bar{x}_{S,t} L_t$ . Therefore, the labor-market-clearing condition in the South is given by

$$L_{S,t} = \frac{a_S \dot{n}_{S,t}}{(K_{S,t})^\theta} + n_{S,t} \bar{x}_{S,t} L_t. \quad (24)$$

#### 2.4.3 Government Budget

The governments in the two regions run a balanced budget between taxes and subsidies at every period of time  $t$ . The subsidies in the two regions are financed by lump-sum taxes on

households such that:

$$T_{N,t} \equiv \tau_{N,t} L_{N,t} = s_R w_N L_{N,t}, \quad (25)$$

$$T_{S,t} \equiv \tau_{S,t} L_{S,t} = s_C w_S L_{S,t}, \quad (26)$$

where the left-hand side of equation (25) (equation (26)) represents the tax revenue collected from households in the North (South), and the right-hand side represents the expenditures for subsidizing activities in innovative R&D (imitative R&D).<sup>19</sup>

## 2.5 Solving the model

In this subsection, the model is solved for a unique steady-state equilibrium where all endogenous variables increase over time at a constant (but possibly different) rate. The imitation rate of northern varieties,  $\phi$ , and the relative R&D difficulty parameter,  $\delta$ , are the two unknowns that will be determined to derive the unique steady-state equilibrium.

In the steady-state equilibrium, the number of varieties produced by each type of firm ( $n_{N,t}$  and  $n_{S,t}$ ) must grow at the same rate  $g$ , such that:

$$g \equiv \frac{\dot{n}_t}{n_t} = \frac{\dot{n}_{N,t}}{n_{N,t}} = \frac{\dot{n}_{S,t}}{n_{S,t}}. \quad (27)$$

Moreover, the variety shares  $\zeta_N \equiv n_{N,t}/n_t$  and  $\zeta_S \equiv n_{S,t}/n_t$  are constant and satisfy  $\zeta_N + \zeta_S = 1$ . Given that the total labor supply in the two countries grows at the same rate  $g_L$ , the northern R&D labor employment  $L_{R,t}$  also grows at the same rate. Dividing (7) by  $n_t$  yields  $g = L_{R,t} n_t^{\theta-1} / a_N$ , and the stationarity of  $g$  implies:

$$g = \frac{g_L}{1 - \theta}. \quad (28)$$

The equilibrium growth rate is proportional to the population growth rate  $g_L$  and is determined by the intertemporal knowledge spillover parameter  $\theta$ . The value of  $\theta$  can be either positive or negative.<sup>20</sup> We follow [Gustafsson and Segerstrom \(2011\)](#) and consider  $\theta \in (0, 1)$ . As in [Jones \(1995\)](#), given positive population growth, the equilibrium growth rate is positive and finite under  $\theta < 1$ , and this assumption rules out the scale effect. From (28), we know that this model features semi-endogenous growth, as the equilibrium growth rate  $g$  is independent of government policies. Any policy changes, such as increases in subsidies or stronger IPR protection, have no effect on the equilibrium growth rate.

<sup>19</sup>In reality, governments frequently run budget deficits or surpluses. Given that the tax source for subsidization stems from consumers in our model, considering government budget imbalances might affect the consumers' intertemporal optimization problem and thereby complicate the analysis. Therefore, to make our model tractable, we follow the existing literature (e.g., [Iwaisako and Tanaka 2024](#)) to assume a balanced government budget.

<sup>20</sup>When  $\theta > 0$ , R&D labor becomes more productive over time (known as the *standing on the giant's shoulders effect*). As the stock of knowledge in research increases, firms can devote less labor to innovate a new variety. When  $\theta < 0$ , R&D labor becomes less productive over time (known as the *fishing-out effect*); it becomes more difficult for firms to innovate, requiring more labor to create a new variety.

Next, we denote  $\delta$  as a measure of relative R&D difficulty such that:

$$\delta = \frac{n_t^{1-\theta}}{L_{N,t}}, \quad (29)$$

where the variable  $\delta$  relates the difficulty of conducting research,  $1/n_t^\theta$ , to the relative market size,  $n_t/L_{N,t}$ . Log-differentiating (29) and using (28), we can show that  $\delta$  is stationary in the steady-state equilibrium. Moreover, differentiating (19) yields the growth rate of northern firm value such that  $\dot{V}_{N,t}/V_{N,t} = -\theta g$ . Given  $\theta \in (0,1)$  and increasing R&D difficulty, firms encounter a shrinking market size since the growth rate of varieties outpaces the population growth, implying that firms have to share consumer demand with more rivals. Realizing that the growth rates of firm values satisfy  $\dot{V}_{N,t}/V_{N,t} = \dot{V}_{S,t}/V_{S,t} = -\theta g$ , we combine (19) with (21) and (20) with (22), respectively, to derive the no-arbitrage conditions for northern and southern innovators such that

$$\frac{\pi_{N,t}}{\rho + \theta g + \phi} = \frac{(1 - s_R)w_N a_N}{n_t^\theta}, \quad (30)$$

$$\frac{\pi_{S,t}}{\rho + \theta g} = \frac{(1 - s_C)w_S a_S}{(K_{S,t})^\theta}. \quad (31)$$

In (30), the left-hand side is the discounted profit from an innovative activity of a northern firm, whereas the right-hand side is the associated cost. The expected discounted profit of a northern firm is equal to the profit flow  $\pi_{N,t}$ , discounted by the market interest rate  $\rho$ , the capital loss  $\theta g$ , and the imitation rate  $\phi$ . The associated cost of a northern firm depends on the subsidy rate  $s_R$  and the wage payments to the labor,  $w_N a_N/n_t^\theta$ . Analogously, in (31), the left-hand side is the discounted profit from an imitating activity of a southern firm, and the right-hand side is the cost of the respective activity. The expected discounted profit of a southern firm is equal to the profit flow  $\pi_{S,t}$ , discounted by the market interest rate  $\rho$  and the capital loss  $\theta g$ . The cost of a southern firm depends on the subsidy rate  $s_C$  and the wage payments to the labor,  $w_S a_S/(K_{S,t})^\theta$ .

Substituting (13) into (30) and dividing both sides by  $L_{N,t}/n_t$ , we derive the northern innovation condition such that

$$\frac{(\mu_N - 1)X_N L_0}{(\rho + \theta g + \phi)h\zeta_N L_{N,0}} = a_N \delta (1 - s_R), \quad (32)$$

where  $X_N = \bar{x}_{N,t} n_{N,t}$ . Similarly, substituting (18) into (31) and dividing both sides by  $L_{N,t}/n_t$ , we derive the southern imitation condition such that

$$\frac{(\mu_S - 1)X_S L_0}{(\rho + \theta g)\xi_S L_{N,0}} = \frac{a_S \delta (1 - s_C)}{(\gamma_S + \kappa \gamma_N)^\theta}, \quad (33)$$

where  $X_S = \bar{x}_{S,t} n_{S,t}$ . Then, substituting (29) and (33) into the northern labor-market-clearing condition (23), we derive *the northern steady-state condition* such that

$$1 = a_N \delta \left[ 1 + \left( \frac{\rho + \theta g + \phi}{g + \phi} \right) \left( \frac{1 - s_R}{\mu_N - 1} \right) \right], \quad (34)$$

which contains two endogenous variables,  $\{\phi, \delta\}$ , and features a positive slope and a positive  $\delta$ -intercept in the  $\{\phi, \delta\}$  space in Figure 1, where "North" represents the northern steady-state condition. The positive slope of the northern steady-state condition can be explained as follows. Given the supply of labor, a higher imitation rate of northern varieties  $\phi$  implies that more varieties are manufactured in the South and fewer varieties are manufactured in the North. As a result, northern labor is shifted from production to innovative R&D. Hence, relative R&D difficulty  $\delta$  increases.

Similarly, substituting (18) and (31) into the southern labor-market-clearing condition (24), we derive the southern steady-state condition such that

$$1 = \frac{a_S \delta \phi L_{N,0}}{(g + \phi)^{1-\theta} (\phi + g\kappa)^\theta L_{S,0}} \left[ g + \frac{(\rho + \theta g)(1 - s_C)}{(\mu_S - 1)} \right], \quad (35)$$

which contains two endogenous variables,  $\{\phi, \delta\}$ , and features a negative slope with no intercept in the  $\{\phi, \delta\}$  space in Figure 1, where "South" represents the southern steady-state condition. The "South" curve asymptotically approaches zero as  $\delta$  goes to infinity. The intuition behind the negative slope of the southern steady-state condition is as follows: an increase in relative R&D difficulty  $\delta$  implies a higher level of difficulty for southern firms to imitate northern varieties. Therefore, the imitation rate of northern varieties  $\phi$  declines, leading to a reduction in the imitative R&D labor in the South.

Finally, given that the northern steady-state condition is upward sloping with a positive  $\delta$ -intercept and that the southern steady-state condition is downward sloping and asymptotically approaches zero as  $\delta$  goes to infinity, these two curves must intersect once at the equilibrium  $E$ . This intersection uniquely determines the equilibrium values of  $\{\phi, \delta\}$ .

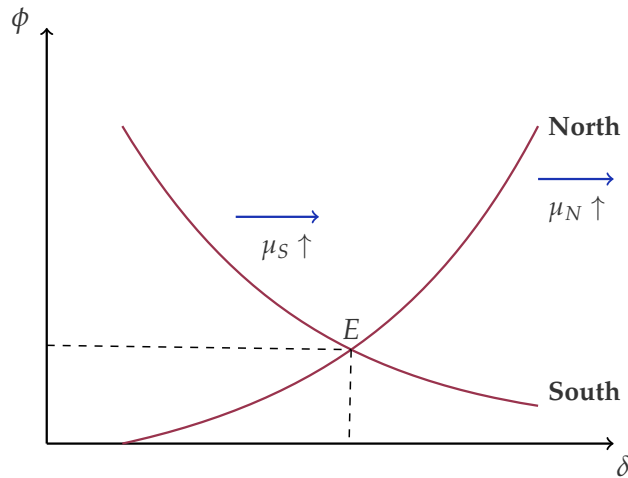


Figure 1: The steady-state equilibrium.

## 2.6 Decentralized Equilibrium

The equilibrium is defined as a time path of prices,  $\{r_t, w_N, w_S, P_{N,t}(j), P_{S,t}(j), V_{N,t}(j), V_{S,t}(j)\}_{t=0}^{\infty}$ , and a time path of allocations,  $\{c_{N,t}, c_{S,t}, x_{N,t}(j), x_{S,t}(j), L_{R,t}(j), L_{Y,t}(j), L_{C,t}(j), L_{P,t}(j)\}_{t=0}^{\infty}$ , for  $j \in [0, 1]$ . At each instance of time:

- the representative household in the North maximizes lifetime utility taking  $\{r_t, P_{N,t}(j), w_N\}$  as given;
- the representative household in the South maximizes lifetime utility taking  $\{r_t, P_{S,t}(j), w_S\}$  as given;
- Northern innovators choose  $p_{N,t}(j)$  and produce  $x_{N,t}(j)$  to maximize profits taking  $w_N$  as given;
- Southern imitators choose  $p_{S,t}(j)$  and produce  $x_{S,t}(j)$  to maximize profits taking  $w_S$  as given;
- Northern innovators employ  $L_{R,t}(j)$  to perform innovative R&D taking  $\{r_t, w_N, V_{N,t}(j)\}$  as given;
- Southern imitators employ  $L_{C,t}(j)$  to perform imitative R&D taking  $\{r_t, w_S, V_{S,t}(j)\}$  as given;
- the market-clearing condition for goods holds and
- the labor-market-clearing conditions and balanced government budgets hold in both countries.

## 3 Patent Policy, Innovation, and Technology Transfer

In this section, we first examine the effects of patent breadth in the two countries,  $\{\mu_N, \mu_S\}$ , on the relative wage between the North and the South,  $\omega = w_N/w_S$ . By dividing (31) by (30) and using the definitions of  $\bar{x}_{N,t}$ ,  $\bar{x}_{S,t}$ ,  $(P_{N,t})^{1-\epsilon}$ , and  $(P_{S,t})^{1-\epsilon}$ , we can obtain the following steady-state relative wage condition:

$$\frac{(\mu_S)^{-\epsilon} \left[ \bar{\xi}_N \left( \frac{\mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\xi}_S (\tau \mu_S)^{1-\epsilon} \right] + \tau (\tau \mu_S)^{-\epsilon} \eta \left[ \bar{\xi}_N \left( \frac{\tau \mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\xi}_S (\mu_S)^{1-\epsilon} \right]}{\eta \left( \frac{\mu_N w_N}{h} \right)^{-\epsilon} \left[ \bar{\xi}_N \left( \frac{\tau \mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\xi}_S (\mu_S)^{1-\epsilon} \right] + \tau \left( \frac{\tau \mu_N w_N}{h} \right)^{-\epsilon} \left[ \bar{\xi}_N \left( \frac{\mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\xi}_S (\tau \mu_S)^{1-\epsilon} \right]} = \frac{a_S (1 - s_C) (\mu_N - 1) (\rho + \theta g) (g + \phi)^\theta}{h a_N (1 - s_R) (\mu_S - 1) (\rho + \theta g + \phi) (\phi + \kappa g)^\theta} \quad (36)$$

where  $\eta = \frac{c_N L_{N,t}}{c_S L_{S,t}}$  is the relative consumption expenditure between the North and the South. Since equation (36) is analytically complicated to solve, we consider the case with no trade cost (i.e.,  $\tau = 1$ ) in our theoretical model. We then solve the model numerically in Section 4, considering a positive trade cost ( $\tau > 1$ ). Therefore, when there is no trade cost, equation (36) simplifies to:

$$\omega = h^{1-\frac{1}{\epsilon}} \frac{\mu_S}{\mu_N} \left[ \frac{a_S (1 - s_C) (\mu_N - 1) (\rho + \theta g) (g + \phi)^\theta}{a_N (1 - s_R) (\mu_S - 1) (\rho + \theta g + \phi) (\phi + \kappa g)^\theta} \right]^{\frac{1}{\epsilon}}. \quad (37)$$

Consequently, the following proposition summarizes the effects of patent policies in each country on the relative wage.

**Proposition 1.** *In the case of no trade cost, increasing northern patent breadth  $\mu_N$  raises the relative wage rate between the North and the South, whereas increasing southern patent breadth  $\mu_S$  reduces the relative wage rate.*

The result of Proposition 1 can be explained as follows. When northern patent breadth increases, a northern firm can charge higher markup prices and enjoy more profits. As shown in (30), an increase in the reward of a northern firm must correspond to an increase in innovative R&D cost. The increased R&D costs come from the higher demand for northern innovative R&D labor. Hence, this raises the relative wage rate between northern and southern labor. Similarly, increasing southern patent breadth generates stronger market power for southern firms, who can charge higher markup prices and benefit from higher profits. The increased reward must correspond to an increase in imitative R&D cost, as indicated in (31). The higher imitative R&D cost comes from the increased demand for southern imitative R&D labor. Consequently, this decreases the relative wage rate between northern and southern labor.

Our findings regarding the impacts of patent policy on the relative wage are consistent with those in Zheng *et al.* (2020)'s quality ladder model with a two-way product cycle, although the process of innovation differs. In the quality ladder model, broader patent breadth in the North slows the progression along the quality ladder for firms in the South, delaying southern firms' ability to produce higher-quality products that can compete globally. Similarly, in the variety expansion model, broader northern patent breadth also slows the technological progress of southern firms and their ability to imitate northern varieties. This increases northern firms' incentives to engage in more innovative R&D, thus raising the relative wage between the North and the South. On the other hand, in the quality ladder model, increasing southern patent breadth induces more technology transfer, and multinational firms are more willing to transfer their technologies from the North to the South. In the variety expansion model, broader southern patent breadth leads southern firms to copy more existing northern technologies, generating more incentives for imitative R&D. In both models, broader southern patent breadth leads to higher demand for southern labor, yielding a decrease in the North-South relative wage.

When there are trade costs, trade between the two regions becomes more costly, but the impact of increasing patent breadth on the relative wage remains the same as in the case without trade costs. This is because trade costs only dampen the volume of trade in products, not the incentives to conduct innovative or imitative activities. Increasing northern patent breadth boosts innovation in the North, resulting in higher demand and wages for northern innovative R&D labor. Similarly, with broader southern patent breadth, southern firms have more incentives to engage in imitative R&D, which demands more imitative labor and thereby reduces the relative wage. In Section 4, we examine how patent breadth affects other economic variables when there are trade costs. We also vary the values of trade costs to perform robustness checks for our results in Subsection 4.3.

After exploring the effects of patent breadth on the relative wage rate  $\omega$ , we examine the effects on relative R&D difficulty  $\delta$  and the imitation rate  $\phi$ . First, the following proposition illustrates the impacts of an increase in  $\mu_N$  on  $\delta$  and  $\phi$ .

**Proposition 2.** *Increasing northern patent breadth  $\mu_N$  leads to (i) a temporary increase in the rate of innovation  $\delta$ , and (ii) a permanent decrease in the rate of imitation  $\phi$ .*

The intuition of Proposition 2 is illustrated as follows. In Figure 1, an increase in  $\mu_N$  shifts the North curve to the right, yielding a higher  $\delta$  and a lower  $\phi$  unambiguously. Intuitively, broader patent breadth provides a higher level of protection for innovators' new technologies against competitors who try to imitate and prevents others from entering the market with similar products or technologies. This helps innovators strengthen their dominant positions in the market, allowing them to charge higher prices and enjoy more profits. Therefore, northern firms have more incentives to engage in innovative R&D because they can earn returns on their R&D investments. As a result, northern labor is reallocated from production to innovative R&D sector. The increase in innovative R&D labor raises the rate of innovation temporarily and makes it more difficult for southern firms to imitate northern varieties due to increasing research complexity. In this case, imitators must pay extra costs to transfer the technology (via imitation) from the North, thus the imitation rate declines permanently. Therefore, strengthening patent policy in the North reduces the rate of imitation by creating a more favorable environment for innovation.

Next, we summarize the impacts of an increase in  $\mu_S$  on  $\delta$  and  $\phi$  in the following proposition.

**Proposition 3.** *Increasing southern patent breadth  $\mu_S$  leads to (i) a temporary increase in the rate of innovation  $\delta$ , and (ii) a permanent increase in the rate of imitation  $\phi$ .*

The intuition of Proposition 3 is illustrated as follows. In Figure 1, an increase in  $\mu_S$  shifts the South curve to the right, yielding a higher  $\delta$  and a higher  $\phi$  unambiguously. Intuitively, strengthening southern patent protection grants more market power to southern firms as they can deter competitive fringes from developing imitative R&D technologies, enabling southern firms to charge higher prices and make more profits. Consequently, southern firms' incentives for imitative R&D rise, which reallocates southern labor from production to imitative R&D sector. As a result, an increase in  $\mu_S$  leads to a higher imitation rate, meaning that fewer products are manufactured in the North. Therefore, the demand for manufacturing labor in the North declines, and the reduction in northern production labor causes more northern labor to be reallocated to the innovative R&D sector, leading to the invention of new products and an increase in the rate of innovation.

Then we solve for the remaining endogenous variables in the model. We proceed by solving for asset holdings, consumption expenditures, consumer utilities, and the economic growth rate. Let  $A_{N,t}$  and  $A_{S,t}$  denote the aggregate value of the northern and southern financial assets, respectively, and let  $A_t = A_{N,t} + A_{S,t}$  denote the aggregate value of global assets. The aggregate value of northern assets is the product of the number of innovated varieties and the values of northern firms,  $A_{N,t} = n_{N,t}V_{N,t}$ . The aggregate value of southern assets is the product of the number of

imitated varieties and the values of southern firms,  $A_{S,t} = n_{S,t}V_{S,t}$ . Substituting (19) and using (29) yields the northern per-capita financial asset such that  $\tilde{a}_{N,t} = A_{N,t}/L_{N,t} = (1 - s_R)\xi_N w_N a_N \delta$ . Similarly, substituting (20) and using (29) yields the southern per-capita financial asset such that  $\tilde{a}_{S,t} = A_{S,t}/L_{S,t} = \frac{\xi_S(1-s_C)w_S a_S \delta L_{N,t}}{(\xi_S + \kappa \xi_N)^\theta L_{S,t}}$ . Since  $\dot{a}_t = 0$  in the steady-state equilibrium, from (3), it follows that  $c_N = (\rho - g_L)\tilde{a}_{N,t} + w_N$  and  $c_S = (\rho - g_L)\tilde{a}_{S,t} + w_S$ . Therefore, the northern and southern consumer expenditure levels are given by

$$c_N = w_N [(\rho - g_L)(1 - s_R)a_N \xi_N \delta + 1], \quad (38)$$

$$c_S = w_S \left\{ (\rho - g_L)(1 - s_C) \frac{\xi_S a_S \delta L_{N,t}}{(\xi_S + \kappa \xi_N)^\theta L_{S,t}} + 1 \right\}. \quad (39)$$

As in the existing literature, the real consumption expenditure is used to represent the consumers' utility level. The price index is given by

$$P_t = \left[ \xi_N (P_{N,t})^{1-\epsilon} + \xi_S (P_{S,t})^{1-\epsilon} \right]^{1/(1-\epsilon)} n_t^{1/(1-\epsilon)}. \quad (40)$$

The per-capita consumer expenditure is constant over time, but the price index decreases as the variety  $n_t$  increases (with  $\epsilon > 1$ ) in the steady-state equilibrium. Therefore, consumer utilities grow over time. Finally, as is common practice, the growth rate of consumer utility denotes the rate of economic growth. Taking the log-differentiation of (38) and (39) yields:

$$g_u \equiv \frac{\dot{u}_{N,t}}{u_{N,t}} = \frac{\dot{u}_{S,t}}{u_{S,t}} = \frac{g}{\epsilon - 1}. \quad (41)$$

## 4 Quantitative Analysis

In this section, we calibrate our model to the US (North) and China (South) data and perform a quantitative analysis to examine the effects of northern and southern patent breadth on the imitation rate, relative R&D difficulty, relative wage, and welfare, respectively.<sup>21</sup> When choosing the values of parameters, we either use conventional values from previous literature or relevant moments from existing empirical/realistic evidence. Subsequently, we perform robustness checks by altering the values of certain parameters at the end of this section.

The model contains the following set of structural parameters:  $\{\rho, \alpha, \mu_N, \mu_S, L_{N,0}, L_{S,0}, \theta, a_N, a_S, \kappa, h, \tau, s_R, s_C\}$ . To facilitate comparison with Gustafsson and Segerstrom (2010), we adopt their parameter values when possible. Specifically, in the benchmark case, we set the population

<sup>21</sup>The US and China are the two largest economies in the world, and their economic relationship is of paramount importance. The US and China have had different approaches to intellectual property rights protection and enforcement, making them interesting cases for comparison. The US has traditionally maintained strong enforcement mechanisms for patent protection, while China's intellectual property rights regime has undergone significant improvements and reforms in recent decades. Analyzing the effects of patent protection between these two economies can provide valuable insight into global innovation and technology transfer dynamics. In particular, selecting China as our southern country provides a compelling example for other developing countries to learn from and emulate.

growth rate to  $g_L = 0.014$ , the economic growth rate to  $g = 0.02$ , the degree of product differentiation to  $\alpha = 0.714$ , the international knowledge spillover to  $\kappa = 0$ , and the innovative R&D parameter to  $a_N = 1$ . Additionally, we follow [Acemoglu and Akcigit \(2012\)](#) and set the discount rate to  $\rho = 0.05$ . According to [Anderson and Van Wincoop \(2004\)](#), based on US data estimates, the trade cost for industrialized countries is approximately 170%, so we set  $\tau = 1.7$ . For the levels of patent protection in the South and the North, we follow [Zheng \*et al.\* \(2020\)](#) and set  $\mu_S = 1.25$  and  $\mu_N = 1.3$ . Based on population data from the World Development Indicators in 2021, the population size of China is 4.26 times larger than that of the US. Thus, we set  $L_{N,0} = 1$  and  $L_{S,0} = 4.26$ . We calibrate the imitative R&D productivity parameter  $a_S$  by matching the US-China relative wage condition. The relative wage between the US and China is  $\omega = 4.1$  according to the average and projected values from the US Bureau of Labor Statistics and the National Bureau of Statistics of China from 2013 to 2021, leading us to derive a calibrated  $a_S = 27$ . We choose the value of the human capital parameter  $h = 1.55$  to satisfy the condition  $w_N/h > \tau w_S$ . Finally, the steady-state values of the two subsidies are assigned as  $s_R = s_C = 0$ , and we increase their values to analyze how subsidies affect the imitation rate, the innovation rate, and welfare, respectively. Given the calibrated parameter values, we derive the equilibrium values of  $\delta = 5.04$  and  $\phi = 0.0012$ . Table 1 summarizes the benchmark parameter values.

Table 1: Parameter values

$\rho$	$\alpha$	$\mu_N$	$\mu_S$	$g_L$	$g$	$L_{N,0}$	$L_{S,0}$	$\kappa$	$h$	$\omega$	$\tau$	$s_R$	$s_C$	$a_N$	$a_S$
0.05	0.714	1.3	1.25	0.014	0.02	1	4.26	0	1.55	4.1	1.7	0	0	1	27

#### 4.1 Benchmark Results

Given the benchmark estimated parameters, we examine how the economic variables are affected when we increase the levels of patent protection and subsidies in China and the US, respectively. The results are reported in Table 2. When increasing the level of patent protection in the US ( $\mu_N$ ) by 1 percentage point (from 1.3 to 1.31), the relative R&D difficulty ( $\delta$ ) increases by 2.85%, yielding a temporary increase in the innovation rate in the US. Additionally, the imitation rate ( $\phi$ ) decreases by 4.06%, and the relative wage increases by 0.62%. Strengthening patent policy in the US leads to a welfare gain of 0.73% in the US and a minor welfare loss of 0.0004% in China. From (38), we know that increases in  $w_N$  and  $\zeta_N \delta$  contribute to the increase in  $c_N$ , implying that US consumers have a higher welfare level due to higher wages and more newly innovated product choices. The welfare loss in China is minimal; the negative impacts of relative wage, imitation rate, and the number of goods produced in China marginally surpass the positive effect on innovation, resulting in a small welfare loss in China.<sup>22</sup>

<sup>22</sup>We conduct a sensitivity analysis (detailed in Online Appendix B) by varying key parameters related to patent breadth and assessing their influence on the model's economic outcomes. Our findings indicate that the effect of US patent policy on China's welfare could be considerably enlarged under different initial levels of patent protection and

In contrast, a one percentage point increase in the level of patent protection in China ( $\mu_S$ ) (from 1.25 to 1.26) raises the innovation rate ( $\delta$ ) temporarily by 0.17% and increases the imitation rate ( $\phi$ ) permanently by 5.186%. Moreover, the US-China wage gap decreases by 1.108%. The US suffers a welfare loss of 1.454%, while China benefits from a welfare gain of 0.469%, partially due to the decreased relative wage. When both  $\mu_N$  and  $\mu_S$  are increased by one percentage point simultaneously (i.e.,  $\mu_N$  from 1.3 to 1.31 and  $\mu_S$  from 1.25 to 1.26), the temporary innovation rate and the permanent imitation rate increase by 3.018% and 0.917%, respectively, and the US-China wage gap decreases by 0.492%. Additionally, the welfare of China increases by 0.469%, while the welfare of the US decreases by 0.397%. **This divergence is primarily driven by the narrowing wage gap between the two countries. China benefits from enhanced imitation capacity, which accelerates its technological catch-up and raises relative wages. These gains translate into higher domestic consumption and improved overall utility. In contrast, as China closes the technological gap, the US experiences a relative decline in its innovation advantage. This diminishment of technological leadership reduces the rents the US can extract from innovation and weakens its dominant position in global markets, ultimately leading to a decline in welfare.**

When the northern innovative R&D subsidy ( $s_R$ ) is increased by one percentage point (from 0 to 0.01), it increases the innovation rate ( $\delta$ ) temporarily by 0.866% and decreases the imitation rate ( $\phi$ ) by 1.262%. Furthermore, the US-China wage gap increases by 0.443%, as the innovative R&D subsidy encourages northern firms to innovate more and demand more innovative R&D labor in the North, resulting in higher wage payments to northern innovative R&D labor. Consequently, US consumers enjoy a welfare gain of 0.1%, partially due to more newly innovated products with higher wage payments. The welfare in China increases slightly by 0.0052%, indicating that the positive impact of the innovation rate slightly outweighs the negative impacts on the imitation rate and relative wage.

When the imitative R&D subsidy ( $s_C$ ) is increased by one percentage point (from 0 to 0.01), the innovation rate ( $\delta$ ) increases temporarily by 0.043%, and the imitation rate ( $\phi$ ) increases permanently by 1.305%. The US-China wage gap decreases by 0.443%, and the welfare in the US and China decreases by 0.777% and 0.0105%, respectively. The welfare loss in the US is due to the decreased relative wage, as the imitative R&D subsidy encourages southern imitators to imitate more and demand more southern imitative R&D labor.

When both the innovative R&D subsidy ( $s_R$ ) and imitative R&D subsidy ( $s_C$ ) are increased by one percentage point simultaneously (i.e.,  $s_R$  from 0 to 0.01 and  $s_C$  from 0 to 0.01), the temporary innovation rate ( $\delta$ ) and the permanent imitation rate ( $\phi$ ) increase by 0.908% and 0.0259%, respectively. From equation (36), if the sizes of  $s_R$  and  $s_C$  are the same, it does not affect  $\omega$ . However, production shifts from the US to China, decreasing  $\xi_N$  by 0.0015% and increasing  $\xi_S$  by 0.0243%. Both the US and China suffer welfare losses 0.346% and of 0.0147%, respectively.

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other calibrated parameters.

Table 2: Benchmark simulation

	$\phi$	$\delta$	$\omega$	$\zeta_N$	$\zeta_S$	$c_N$	$c_S$
	0.00124	5.0398	4.063	0.9417	0.0583	4.7653	1.146860
$\Delta\mu_N$	0.00119	5.1835	4.088	0.9440	0.0560	4.8001	1.146855
$\Delta\mu_S$	0.00130	5.0484	4.018	0.9389	0.0611	4.6960	1.152240
$\Delta\mu_N$ & $\Delta\mu_S$	0.00125	5.1920	4.043	0.9412	0.0588	4.7463	1.152240
$\Delta s_R$	0.00122	5.0835	4.081	0.9424	0.0576	4.7701	1.146920
$\Delta s_C$	0.00125	5.0420	4.045	0.9410	0.0590	4.7282	1.146740
$\Delta s_R$ & $\Delta s_C$	0.00124	5.0856	4.063	0.9417	0.0583	4.7488	1.146740

## 4.2 Robustness Check on International Knowledge Spillover

In this subsection, we follow [Currie \*et al.\* \(1999\)](#) to vary the value of international knowledge spillover to perform robustness checks by considering alternative values of  $\kappa \in \{0.06, 0.08, 0.11, 0.13\}$ . The results are shown in [Table 5](#). We observe that the higher the value of  $\kappa$ , the smaller the effects of an increase in northern patent breadth ( $\mu_N$ ) on the variables, except for  $\zeta_N$  and  $c_S$ . In the case of  $\kappa = 0.13$ , when  $\mu_N$  increases from 1.3 to 1.31, the imitation rate decreases by 3.30% (compared to the decrease of 4.06% in the benchmark), while the innovation rate, relative wage, and northern social welfare increase by 2.83%, 0.39%, and 0.83%, respectively (compared to the increase of 2.85%, 0.62%, and 1.07%, respectively in the benchmark). For  $\kappa = 0.13$ , a one percentage point increase in  $\mu_N$  decreases  $\zeta_S$  by 3.04% (compared to the decrease of 3.83% in the benchmark) and increases  $\zeta_N$  by 0.27% (compared to the increase of 0.24% in the benchmark). The effect of  $\mu_N$  on  $c_S$  is observed to be very small. China experiences a decrease in welfare of 0.0003% in response to a one percentage point increase in northern patent breadth when  $\kappa = 0.06$ . However, when  $\kappa = 0.08$ , the change is reversed, resulting in an increase of 0.0003%. For  $\kappa = 0.13$ , China experiences a welfare gain of 0.0065%.

Moreover, the higher the value of  $\kappa$ , the smaller the effects of an increase in southern patent breadth ( $\mu_S$ ) on the variables, except for  $\delta$ ,  $\zeta_N$ , and  $c_S$ . In the case of  $\kappa = 0.13$ , when  $\mu_S$  increases by 1 percentage point (from 1.25 to 1.26),  $\phi$  and  $\zeta_S$  increase by 4.21% and 3.85%, respectively, while  $\omega$  decreases by 0.8% (compared to the increase in  $\phi$  and  $\zeta_S$  is 5.186% and 4.869%, respectively and the decrease in  $\omega$  is 1.108% in the benchmark). When  $\mu_S$  increases by one percentage point, it increases  $\delta$  and  $c_S$  by 0.19% and 1.41% (compared to the increase of 0.17% and 1.408%, respectively in the benchmark), respectively, and decreases  $\zeta_N$  by 0.34% (compared to the decrease of 3.01% in the benchmark). When both  $\mu_S$  and  $\mu_N$  increase simultaneously by one percentage point, the higher the value of  $\kappa$ , the smaller the effects of patent breadth on the economic variables except for  $c_N$ . We observe that when  $\kappa = 0.13$ , northern consumer welfare increases by 0.01% (compared to the decrease of 0.4% in the benchmark).

When the knowledge spillover parameter is higher, an increase in  $s_R$  has larger effects on  $\delta$ ,  $\omega$ ,  $c_N$ ,  $c_S$ , and  $\zeta_N$ . In the case of  $\kappa = 0.13$ , when  $s_R$  increases from 0 to 0.1,  $\omega$  increases by 0.39% (compared to 0.35% in the benchmark) and  $\zeta_N$  increases by 0.083% (compared to 0.074% increase in the benchmark), while  $\phi$  and  $\zeta_S$  decrease by 1.03% and 0.94%, respectively (compared to decrease of 1.26% and 1.19%, respectively in the benchmark), and  $c_N$  and  $c_S$  increase by 0.38% and 0.01%, respectively (compared to increase of 0.1% and 0.0052%, respectively in the benchmark).

The higher the value of the knowledge spillover parameter, the smaller the effects of an increase in  $s_C$  on the variables, except for  $\delta$  and  $\zeta_N$ . In the case of  $\kappa = 0.13$ , when  $s_C$  increases from 0 to 0.1,  $\delta$  increases by 0.05% (compared to 0.043% increase in benchmark) and  $\zeta_N$  decreases by 0.09% (compared to 0.076% decrease in benchmark), while  $\phi$  and  $\zeta_S$  increase by 1.06% and 0.97%, respectively (compared to increase of 1.305% and 1.23%, respectively in the benchmark), and  $\omega$  and  $c_N$  decrease by 0.36% each (compared to decrease of 0.443% and 0.777%, respectively in the benchmark). A one percentage point increase in  $s_C$  decreases  $c_S$  by 0.0105% for various values of  $\kappa$ . When  $s_R$  and  $s_C$  increase simultaneously by one percentage point, the higher the value of  $\kappa$ , the higher the values of  $\zeta_N$  and  $c_N$ .

### 4.3 Robustness Check on Trade Cost

Irrazabal *et al.* (2015) argue that trade costs are overstated in Anderson and Van Wincoop (2004) by using the gravity model, as it is difficult to match the actual trade flows. Using firm-level trade data, Irrazabal *et al.* (2015) estimate the magnitude of additive trade costs for various countries and products. They show that trade costs are, on average, 14% of the median price of the products. Therefore, in this exercise, we first set the trade cost parameter to 1.14. Furthermore, Arvis *et al.* (2016) show that the average trade costs for manufactured goods between upper-middle-income countries and high-income countries are roughly 184.32%. Hence, we vary our trade cost parameter to 1.33, 1.42 (i.e., the average of the two values 1.7 and 1.14),<sup>23</sup> and 1.84 to cover the range of estimates from Irrazabal *et al.* (2015) and Arvis *et al.* (2016), while keeping other parameters the same to perform the quantitative analysis.<sup>24</sup> The simulation results are reported in Table 6.

We observe that when trade costs are reduced, the magnitudes of the effects of patent policies  $\{\mu_N, \mu_S\}$  and subsidy policies  $\{s_R, s_C\}$  on the US-China relative wage and social welfare in the US decrease, whereas other economic variables are unaffected by the reduced trade cost. Specifically, in the case of  $\tau = 1.14$ , a one percentage point increase in  $\mu_N$  yields increases of 0.56% and 1.01% in  $\omega$  and  $c_N$ , respectively (compared to increases of 0.62% and 1.07% in the benchmark case); a one percentage point increase in  $\mu_S$  yields decreases of 0.79% and 0.81% in  $\omega$  and  $c_N$ , respectively (compared to decreases of 1.11% and 1.45% in the benchmark case); a one percentage

<sup>23</sup>This value is also consistent with Novy (2013)'s trade-weighted average trade cost measure of 42% for the six largest exporters (Canada, Germany, Japan, Korea, Mexico, and the UK) to the US in 2000.

<sup>24</sup>Trade costs can be dynamic and influenced by various factors; the magnitudes and patterns vary across countries, regions, and goods. For more details, see Anderson and Van Wincoop (2004) and Jacks *et al.* (2011).

point increase in  $s_R$  yields increases of 0.4% and 0.39% in  $\omega$  and  $c_N$ , respectively (compared to increases of 0.44% and 0.43% in the benchmark case); and a one percentage point increase in  $s_C$  yields decreases of 0.4% and 0.41% in  $\omega$  and  $c_N$ , respectively (compared to decreases of 0.44% and 0.45% in the benchmark case). When both  $\mu_N$  and  $\mu_S$  are increased by one percentage point simultaneously, the lower the value of the trade cost, the smaller the effects of patent breadth on  $\omega$ . In the case of  $\tau = 1.14$ , a simultaneous one percentage point increase in  $\mu_N$  and  $\mu_S$  reduces  $\omega$  by 0.23% (compared to the decrease of 0.49% in the benchmark model). When both  $s_R$  and  $s_C$  increase by one percentage point simultaneously, there is no change in the relative wage  $\omega$ . This is because in (36), when  $s_R$  and  $s_C$  increase by the same magnitude, their effects on  $\omega$  neutralize each other.

#### 4.4 Robustness Check on Population Size

According to the population data from the World Development Indicators, the relative China-to-US population ratio ( $L_{S,0}/L_{N,0}$ ) decreased from 4.47 in 2000 to 4.24 in 2022. This change accounts for variations in population and labor movement between the two countries. We choose these values to perform a robustness check. Additionally, considering the impact of immigration, we incorporate the number of Chinese immigrants residing in the United States. In 2022, there were 494,578 Chinese immigrants in the US, as reported in the Yearbook of Immigration Statistics by the US Department of Homeland Security.<sup>25</sup> After accounting for immigration in 2022, the relative ratio becomes 4.25, which we use in our robustness check. In this subsection, we adjust the values of  $L_{S,0}$  to  $\{4.24, 4.25, 4.47\}$ . The robustness results are displayed in Table 7.

Despite the variations in the China-to-US population ratio over time, our results remain robust. For example, with  $L_{S,0} = 4.47$ , increasing northern patent breadth ( $\mu_N$ ) by one percentage point results in a 4.06% decrease in the imitation rate, a 2.84% increase in the innovation rate, and a 0.61% increase in the relative wage between northern and southern labor (compared to the benchmark case: decrease of 4.06%, increases of 2.85% and 0.62%, respectively). On the other hand, increasing southern patent breadth ( $\mu_S$ ) by one percentage point leads to a 5.19% increase in the imitation rate, a 0.18% increase in the innovation rate, and a 0.88% decrease in the relative wage (compared to the benchmark case: increases of 5.186% and 0.17%, and decrease of 1.11%, respectively). The stability of our findings across different population ratios assures the reliability of our benchmark results.

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<sup>25</sup>This figure includes individuals obtaining the status of lawful permanent residents (persons granted lawful permanent residence), refugees and asylees (persons seeking residence in the US to avoid persecution in their country), naturalizations (persons aged 18 who become US citizens), and non-immigrant admissions (persons authorized to stay in the US for a limited period). For more details, see the 2022 Yearbook of Immigration Statistics.

## 5 Fully-Endogenous Growth

In this section, we modify our model to fully-endogenous growth in the long run. Researchers and scientists are the main creators of R&D, and endogenous growth is sustainable with knowledge spillovers from past R&D. Therefore, the aggregate flow of products to the North now becomes

$$\dot{n}_{N,t} = \frac{n_{N,t}L_{R,t}}{a_N L_{N,t}}, \quad (42)$$

Equation (42) implies that the greater the  $n_{N,t}$ , the more productive the northern innovative R&D labor, capturing spillovers from the stock of existing knowledge. The term  $L_{N,t}$  in the denominator ensures that the growth rate of northern varieties is constant over time.

Similarly, southern firms employ  $L_{C,t}$  to conduct imitative activities. Hence, the aggregate flow of products to the South now becomes

$$\dot{n}_{S,t} = \frac{n_{S,t}L_{C,t}}{a_S L_{S,t}}. \quad (43)$$

Analogously, the term  $L_{S,t}$  in the denominator ensures that the growth rate of southern varieties is constant over time. Therefore, the endogenous imitation rate is given by  $\phi = \dot{n}_{S,t}/n_{N,t}$ . In addition, the corresponding firm values for northern and southern firms are given by

$$V_{N,t} = \frac{(1 - s_R)w_N a_N}{n_t}, \quad (44)$$

$$V_{S,t} = \frac{(1 - s_C)w_S a_S}{K_{S,t}}. \quad (45)$$

Substituting (44) into (21) and (45) into (22), we derive the corresponding northern innovation and southern imitation conditions such that

$$\frac{(\mu_N - 1)X_N L_0}{(\rho + \theta g + \phi)h} = a_N \xi_N (1 - s_R), \quad (46)$$

$$\frac{(\mu_S - 1)X_S L_0}{(\rho + \theta g)} = \frac{a_S \xi_S (1 - s_C)(g + \phi)}{\phi + gk}. \quad (47)$$

The total amount of labor employed in the North becomes

$$L_{N,t} = \frac{a_N \dot{n}_{N,t}}{n_t} + n_t \bar{x}_{N,t} L_t. \quad (48)$$

Thus, using (42) and (46), the northern labor-market-clearing condition becomes

$$\frac{a_N g}{(g + \phi)L_{N,0}} \left[ g + \frac{h(1 - s_R)(\rho + \theta g + \phi)}{\mu_N - 1} \right] = 1. \quad (49)$$

Analogously, the total amount of labor employed in the South becomes

$$L_{S,t} = \frac{a_S \dot{n}_{S,t}}{K_{S,t}} + n_t \bar{x}_{S,t} L_t. \quad (50)$$

Combining (43) and (47), the southern labor-market-clearing condition becomes

$$\frac{a_S \phi}{L_{S,t}} \left[ \frac{g}{\phi + gk} + \frac{(1 - s_C)(\rho + \theta g)}{\mu_S - 1} \right] = 1. \quad (51)$$

Dividing (47) by (46) and using the definitions  $\bar{x}_{N,t}$ ,  $\bar{x}_{S,t}$ ,  $(P_{N,t})^{1-\epsilon}$ , and  $(P_{S,t})^{1-\epsilon}$ , the steady-state relative wage condition in this fully endogenous growth framework is given by

$$\frac{(\mu_S)^{-\epsilon} \left[ \bar{\zeta}_N \left( \frac{\mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\zeta}_S (\tau \mu_S)^{1-\epsilon} \right] + \tau (\tau \mu_S)^{-\epsilon} \eta \left[ \bar{\zeta}_N \left( \frac{\tau \mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\zeta}_S (\mu_S)^{1-\epsilon} \right]}{\eta \left( \frac{\mu_N w_N}{h} \right)^{-\epsilon} \left[ \bar{\zeta}_N \left( \frac{\tau \mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\zeta}_S (\mu_S)^{1-\epsilon} \right] + \tau \left( \frac{\tau \mu_N w_N}{h} \right)^{-\epsilon} \left[ \bar{\zeta}_N \left( \frac{\mu_N w_N}{h} \right)^{1-\epsilon} + \bar{\zeta}_S (\tau \mu_S)^{1-\epsilon} \right]} = \frac{a_S (1 - s_C) (\mu_N - 1) (\rho + \theta g) (g + \phi)}{h a_N (1 - s_R) (\mu_S - 1) (\rho + \theta g + \phi) (\phi + gk)}. \quad (52)$$

Again, since equation (52) is analytically difficult to solve, we simplify it by assuming there is no trade cost in the analytical model and solve it numerically later. Consequently, when there is no trade cost (i.e.,  $\tau = 1$ ), the relative wage condition is simplified as

$$\omega = h^{1-\frac{1}{\epsilon}} \frac{\mu_S}{\mu_N} \left[ \frac{a_S (1 - s_C) (\mu_N - 1) (\rho + \theta g) (g + \phi)}{a_N (1 - s_R) (\mu_S - 1) (\rho + \theta g + \phi) (\phi + gk)} \right]^{\frac{1}{\epsilon}}. \quad (53)$$

Moreover, the values of northern and southern per-capita financial assets now become  $\tilde{a}_{N,t} = A_{N,t}/L_{N,t} = a_N w_N \bar{\zeta}_N (1 - s_R)$  and  $\tilde{a}_{S,t} = A_{S,t}/L_{S,t} = a_S w_S \bar{\zeta}_S (1 - s_C) (g + \phi) / (\phi + gk)$ , respectively. As we know that  $c_N = (\rho - g_L) \tilde{a}_{N,t} + w_N$  and  $c_S = (\rho - g_L) \tilde{a}_{S,t} + w_S$ , the northern and southern consumer expenditure levels are given by

$$c_N = w_N [(\rho - g_L) (1 - s_R) a_N w_N \bar{\zeta}_N + 1], \quad (54)$$

$$c_S = w_S \left[ \frac{(\rho - g_L) (1 - s_C) (g + \phi) a_S \bar{\zeta}_S}{(\phi + gk)} + 1 \right]. \quad (55)$$

Due to the complexity, we solve the model quantitatively hereafter. We use the same parameter values  $\{\rho, \alpha, \mu_N, \mu_S, L_{N,0}, L_{S,0}, \kappa, h, \tau, s_R, s_C, a_N\} = \{0.05, 0.714, 1.3, 1.25, 1, 4.26, 0, 1.55, 1.7, 0, 0, 1\}$  as in the baseline model. For the parameter  $a_S$ , it is calibrated to match the relative wage between the US and China  $\omega = 4.1$ , yielding  $a_S = 19.5$ . Table 3 summarizes the parameter values. Given these calibrated parameter values, the equilibrium values are  $g = 0.1458$  and  $\phi = 0.0928$ .

We now examine how economic variables are affected by increasing the levels of patent protection in China ( $\mu_S$ ) and the US ( $\mu_N$ ) by 1 percentage point, respectively. The simulation results for this fully endogenous model are reported in Table 4. When  $\mu_N$  is increased by 1 percent-

Table 3: Parameter values: fully-endogenous growth model

$\rho$	$\alpha$	$\mu_N$	$\mu_S$	$L_{N,0}$	$L_{S,0}$	$\kappa$	$h$	$\omega$	$\tau$	$s_R$	$s_C$	$a_N$	$a_S$
0.05	0.714	1.3	1.25	1	4.26	0	1.55	4.1	1.7	0	0	1	19.5

age point (from 1.3 to 1.31), the economic growth rate  $g$  and the relative wage  $\omega$  between the North and the South increase by 2.51% and 3.25%, respectively, whereas the imitation rate  $\phi$  reduces by 6.76%. The welfare in the US increases by 3.33%, whereas the welfare in China increases by only 0.1%. While the overall qualitative patterns between the fully endogenous and semi-endogenous models remain consistent, namely, that stronger patent protection in the North boosts innovation, raises relative wages, and reduces imitation, the welfare impact on China differs. In the fully endogenous model, China experiences a small welfare gain, whereas in the semi-endogenous model, there is a slight welfare loss. This divergence arises because the fully endogenous model allows for stronger innovation spillovers and dynamic feedback effects, which can benefit China despite reduced imitation. In contrast, the semi-endogenous setting weakens these mechanisms, so the negative effects of reduced imitation and relative wage shifts dominate, leading to a marginal welfare decline in China. Advanced economies like the US benefit significantly from modest increases in patent breadth. However, the decline in imitation suggests a trade-off with global knowledge diffusion. On the other hand, when  $\mu_S$  is increased by 1 percentage point (from 1.25 to 1.26), the economic growth rate and the imitation rate rise by 0.314% and 3.104%, respectively, whereas the relative wage declines by 1.428%. The welfare in the US and China reduces by 1.45% and 0.019%, respectively. While both fully-endogenous and semi-endogenous models show that increasing southern patent breadth reduces US welfare, they diverge on the impact for China. The fully-endogenous model predicts a welfare loss, driven by falling wages, whereas the semi-endogenous model finds a welfare gain, due to enhanced imitation and improved wage parity. This contrast reflects the models' differing assumptions about the role of imitation and the structure of innovation incentives in developing economies. Developing countries should pursue adaptive IPR policies that reflect their stage of development.

Lastly, a simultaneous increase in both  $\mu_S$  and  $\mu_N$  by one percentage point (i.e.,  $\mu_N$  from 1.3 to 1.31 and  $\mu_S$  from 1.25 to 1.26) leads to an increase in  $g$  and  $\omega$  by 2.82% and 1.77%, respectively, while  $\phi$  decreases by 3.89%. Moreover, the joint increase in  $\mu_S$  and  $\mu_N$  leads to a welfare gain of 1.83% in the US and a tiny welfare loss of 0.02% in China. The effect of the rise in both  $\mu_S$  and  $\mu_N$  on the imitation rate differs from the counterpart in the semi-endogenous growth model. On the one hand, Chinese firms have more market power as stronger patent protection deters competitors from entering the market, allowing them to charge higher prices and earn more profits. As a result, Chinese firms have more incentive to engage in imitative R&D activities, yielding an increase in the imitation rate. On the other hand, the increased imitation rate implies more products to be manufactured in China, which tends to reallocate more labor from the imitative

Table 4: Simulation results under fully endogenous growth

	$\Delta\phi$	$\Delta g$	$\Delta\omega$	$\Delta c_N$	$\Delta c_S$
$\Delta\mu_N$	-6.76%	2.51%	3.25%	3.33%	0.1%
$\Delta\mu_S$	3.10%	0.31%	-1.43%	-1.45%	-0.019%
$\Delta\mu_N\&\Delta\mu_S$	0.05%	0.714%	1.3%	1.25%	-0.02%

R&D sector to the production sector. This effect becomes so strong that the imitation rate declines in the new steady-state equilibrium. **Strong patent protection in advanced economies, like the US, is highly effective in stimulating innovation, growth, and welfare. However, in developing countries, like China, premature or overly strong IPR enforcement can reduce imitation, lower relative wages, and lead to welfare losses.**

## 6 Conclusion

This paper develops a North-South variety expansion model featuring northern innovative R&D and southern imitative R&D to explore the cross-country effects of the IPR policy (in terms of patent breadth) on innovation, technology transfer, relative wages and welfare. We find that strengthening northern patent protection permanently raises the relative wage between the North and the South, permanently decreases the rate of technology transfer, and temporarily increases the northern innovation rate. Intuitively, when northern patent breadth increases, northern firms can charge a larger markup, imposing higher prices, and earning more profits. The increased rewards for northern firms must correspond to higher innovative R&D costs to satisfy free entry in research, generating a demand for northern innovative R&D labor. Hence, the relative wage rate increases. As more northern innovative R&D labor is devoted to the innovation sector, it temporarily increases the rate of innovation and the relative R&D difficulty due to the semi-endogenous growth property. Southern imitators find it more challenging to imitate northern varieties, leading to a permanent decrease in the imitation rate. **Our findings indicate that strengthening patent protection in advanced economies stimulates innovation by increasing the profitability of new technologies. However, this also leads to stronger monopolistic behavior, potentially reducing competition and raising consumer prices. Furthermore, enhanced protection limits technology diffusion to developing countries, contributing to a widening North-South wage gap. Policymakers in high-income countries must therefore balance innovation incentives with the broader economic and distributional consequences, including the risks of reinforcing global inequality and hindering knowledge spread.**

In contrast, strengthening southern patent protection permanently decreases the relative wage, permanently increases the rate of technology transfer, and temporarily increases the northern innovation rate. Similarly, increasing southern patent breadth grants southern firms stronger

market power to charge higher prices and earn more profits, positively affecting incentives for imitative R&D and boosting demand for southern imitative R&D labor. Consequently, the relative wage rate declines. Moreover, more imitative R&D activities lead to a higher imitation rate and fewer products being produced in the North, reallocating more labor to the innovative R&D sector and yielding an increase in the rate of innovation. This suggests that policies promoting imitative activities (such as subsidies for imitative R&D) can ease restrictions on the South's access to foreign technology, thereby enhancing overall technological progress in the South. Such policies are particularly effective in bridging the technological gap between advanced and developing economies. In many southern economies, firms face structural barriers such as limited access to capital, weak innovation ecosystems, and insufficient technical expertise. Government support for imitative R&D can help overcome these constraints by mobilizing resources toward capability-building, encouraging knowledge spillovers, and fostering collaboration between universities, research institutions, and industry.<sup>26</sup>

Additionally, this model is calibrated using US-China data to perform a quantitative analysis. It is found that a unilateral increase in one country's patent protection enhances the welfare of its citizens. However, when both the North and the South strengthen IPR protection bilaterally, the South benefits from welfare gains, whereas the North suffers from welfare losses. Consequently, bilateral agreements between the North and the South are important; both countries can negotiate levels of patent enforcement to achieve mutually beneficial outcomes.

There are several limitations in this paper. First, following the canonical North-South Schumpeterian models, we assume that there are no innovative R&D activities in the South. In reality, R&D expenditures in some developing countries have increased considerably in recent decades. Specifically, R&D investment in China increased by 78% from 2016 to 2021, reaching 2.78 trillion yuan in 2021.<sup>27</sup> Hence, it is worth incorporating innovative R&D in the South to examine how our analytical results would alter under this new assumption.<sup>28</sup> Second, this paper aims to delve into the theoretical analysis regarding the effects of patent protection in both northern and southern regions, specifically examining their impacts on innovation, technology transfer, and social welfare. By constructing a comprehensive theoretical model, we provide a structured approach to unravel the underlying mechanisms driving the impacts of patents these contexts. This model enables us to generate hypotheses that can be empirically tested, thereby facilitating a deeper understanding of the complex dynamics associated with patent protection. It is imperative to conduct an empirical study that can validate the predictions derived from our theoretical model. Such a study would serve the dual purpose of affirming the robustness of our findings and uncovering any unforeseen circumstances that may arise in reality. By exploring the actual impacts of patent protection through empirical analyses, we hope to provide policymakers with valuable

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<sup>26</sup>See the table in Online Appendix E that summarizes the key findings in this paper.

<sup>27</sup>The data are obtained from the preliminary estimates of China's Social Research and Experimental Development from the National Bureau of Statistics of China.

<sup>28</sup>See Lorenczik and Newiak (2012) for impacts of IPR protection in a product cycle model in which both the North and the South innovate.

insights to help them make informed decisions. We leave these interesting directions for further research.

Table 5: Simulation under  $\kappa \in \{0.06, 0.08, 0.11, 0.13\}$ .

	$\phi$	$\delta$	$\omega$	$\xi_N$	$\xi_S$	$c_N$	$c_S$
$\kappa = 0.06$							
$\Delta\mu_N$	-3.47%	2.84%	0.42%	0.25%	-3.23%	1.07%	-0.0003%
$\Delta\mu_S$	4.43%	0.18%	-0.87%	-0.32%	4.10%	-1.13%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.79%	3.02%	-0.45%	-0.06%	0.73%	-0.03%	0.469%
$\Delta s_R$	-1.08%	0.86%	0.37%	0.078%	-1.00%	0.36%	0.0068%
$\Delta s_C$	1.12%	0.04%	-0.40%	-0.08%	1.04%	-0.45%	-0.0105%
$\Delta s_R$ & $\Delta s_C$	0.0232%	0.908%	0%	-0.0016%	0.022%	-0.0147%	-0.0105%
$\kappa = 0.08$							
$\Delta\mu_N$	-3.41%	2.84%	0.41%	0.26%	-3.16%	0.86%	0.0003%
$\Delta\mu_S$	4.43%	0.18%	-0.63%	-0.32%	4.00%	-0.65%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.77%	3.02%	-0.22%	-0.06%	0.72%	0.20%	0.469%
$\Delta s_R$	-1.06%	0.86%	0.39%	0.08%	-0.98%	0.38%	0.0004%
$\Delta s_C$	1.10%	0.05%	-0.39%	-0.08%	1.01%	-0.40%	-0.0105%
$\Delta s_R$ & $\Delta s_C$	0.023%	0.91%	0%	-0.0017%	0.021%	-0.0152%	-0.0105%
$\kappa = 0.11$							
$\Delta\mu_N$	-3.34%	2.83%	0.37%	0.26%	-3.08%	0.82%	0.0004%
$\Delta\mu_S$	4.25%	0.19%	-0.60%	-0.33%	3.90%	-0.62%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.76%	3.02%	-0.22%	-0.06%	0.70%	0.02%	0.469%
$\Delta s_R$	-1.04%	0.86%	0.37%	0.082%	-0.96%	0.36%	0.0068%
$\Delta s_C$	1.07%	0.05%	-0.40%	-0.08%	0.99%	-0.40%	-0.0105%
$\Delta s_R$ & $\Delta s_C$	0.023%	0.907%	0%	-0.0017%	0.02%	-0.0147%	-0.0105%
$\kappa = 0.13$							
$\Delta\mu_N$	-3.30%	2.83%	0.39%	0.27%	-3.04%	0.83%	0.0065%
$\Delta\mu_S$	4.21%	0.19%	-0.80%	-0.34%	3.85%	-0.82%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.75%	3.02%	-0.41%	-0.06%	0.69%	0.01%	0.469%
$\Delta s_R$	-1.03%	0.86%	0.39%	0.083%	-0.94%	0.38%	0.01%
$\Delta s_C$	1.06%	0.05%	-0.36%	-0.09%	0.97%	-0.36%	-0.0105%
$\Delta s_R$ & $\Delta s_C$	0.0226%	0.907%	0%	-0.0019%	0.021%	-0.015%	-0.0105%

Table 6: Simulation under  $\tau \in \{1.14, 1.25, 1.33, 1.42\}$ .

	$\phi$	$\delta$	$\omega$	$\xi_N$	$\xi_S$	$c_N$	$c_S$
$\tau = 1.14$							
$\Delta\mu_N$	-4.06%	2.85%	0.56%	0.24%	-3.83%	1.01%	-0.0004%
$\Delta\mu_S$	5.19%	0.17%	-0.79%	-0.30%	4.87%	-0.81%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.92%	3.02%	-0.23%	-0.05%	0.86%	0.20%	0.469%
$\Delta s_R$	-1.26%	0.87%	0.40%	0.07%	-1.19%	0.39%	-0.0004%
$\Delta s_C$	1.31%	0.04%	-0.40%	-0.08%	1.23%	-0.41%	-0.0109%
$\Delta s_R$ & $\Delta s_C$	0.03%	0.91%	0%	-0.001%	0.024%	-0.015%	-0.011%
$\tau = 1.33$							
$\Delta\mu_N$	-4.06%	2.85%	0.58%	0.24%	-3.83%	1.03%	-0.0004%
$\Delta\mu_S$	5.19%	0.17%	-0.81%	-0.30%	4.87%	-0.83%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.92%	3.02%	-0.25%	-0.05%	0.86%	0.18%	0.469%
$\Delta s_R$	-1.26%	0.87%	0.43%	0.07%	-1.19%	0.42%	-0.004%
$\Delta s_C$	1.31%	0.04%	-0.43%	-0.08%	1.23%	-0.43%	-0.014%
$\Delta s_R$ & $\Delta s_C$	0.03%	0.91%	0%	-0.001%	0.024%	-0.015%	-0.0137%
$\tau = 1.42$							
$\Delta\mu_N$	-4.06%	2.85%	0.59%	0.24%	-3.83%	1.04%	-0.0004%
$\Delta\mu_S$	5.19%	0.17%	-0.97%	-0.30%	4.87%	-0.99%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.92%	3.02%	-0.38%	-0.05%	0.86%	-0.05%	0.469%
$\Delta s_R$	-1.26%	0.87%	0.43%	0.07%	-1.19%	0.42%	0.0004%
$\Delta s_C$	1.31%	0.04%	-0.43%	-0.08%	1.23%	-0.43%	-0.03%
$\Delta s_R$ & $\Delta s_C$	0.026%	0.91%	0%	-0.001%	0.024%	-0.015%	-0.011%
$\tau = 1.84$							
$\Delta\mu_N$	-4.06%	2.85%	0.63%	0.24%	-3.83%	1.08%	-0.0004%
$\Delta\mu_S$	5.19%	0.17%	-0.90%	-0.30%	4.87%	-0.91%	0.469%
$\Delta\mu_N$ & $\Delta\mu_S$	0.92%	3.02%	-0.27%	-0.05%	0.86%	0.16%	0.469%
$\Delta s_R$	-1.26%	0.87%	0.45%	0.07%	-1.19%	0.44%	-0.0004%
$\Delta s_C$	1.31%	0.04%	-0.47%	-0.08%	1.23%	-0.47%	-0.0109%
$\Delta s_R$ & $\Delta s_C$	0.03%	0.91%	0%	-0.001%	0.024%	-0.163%	-0.011%

Table 7: Simulation under  $L_{S,0} \in \{4.24, 4.25, 4.47\}$ .

	$\phi$	$\delta$	$\omega$	$\xi_N$	$\xi_S$	$c_N$	$c_S$
$L_{S,0}/L_{N,0} = 4.24$							
$\Delta\mu_N$	-4.06%	2.85%	0.60%	0.24%	-3.83%	1.05%	-0.003%
$\Delta\mu_S$	5.19%	0.17%	-0.89%	-0.30%	4.87%	-0.91%	0.466%
$\Delta\mu_N$ & $\Delta\mu_S$	0.92%	3.02%	-0.27%	-0.05%	0.86%	0.16%	0.465%
$\Delta s_R$	-1.26%	0.87%	0.40%	0.07%	-1.19%	0.39%	-0.0004%
$\Delta s_C$	1.31%	0.04%	-0.40%	-0.08%	1.23%	-0.41%	-0.0109%
$\Delta s_R$ & $\Delta s_C$	0.03%	0.91%	0%	-0.001%	0.024%	-0.015%	-0.011%
$L_{S,0}/L_{N,0} = 4.25$							
$\Delta\mu_N$	-4.06%	2.85%	0.63%	0.24%	-3.83%	1.08%	-0.003%
$\Delta\mu_S$	5.19%	0.17%	-0.87%	-0.30%	4.87%	-0.89%	0.466%
$\Delta\mu_N$ & $\Delta\mu_S$	0.92%	3.02%	-0.27%	-0.05%	0.86%	0.16%	0.465%
$\Delta s_R$	-1.26%	0.87%	0.44%	0.07%	-1.19%	0.43%	-0.003%
$\Delta s_C$	1.31%	0.04%	-0.45%	-0.08%	1.23%	-0.45%	-0.014%
$\Delta s_R$ & $\Delta s_C$	0.03%	0.91%	0%	-0.002%	0.025%	-0.015%	-0.014%
$L_{S,0}/L_{N,0} = 4.47$							
$\Delta\mu_N$	-4.06%	2.84%	0.61%	0.25%	-3.82%	1.06%	-0.003%
$\Delta\mu_S$	5.19%	0.18%	-0.88%	-0.32%	4.85%	-0.91%	0.465%
$\Delta\mu_N$ & $\Delta\mu_S$	0.92%	3.02%	-0.27%	-0.06%	0.86%	0.16%	0.465%
$\Delta s_R$	-1.26%	0.86%	0.45%	0.08%	-1.19%	0.44%	-0.003%
$\Delta s_C$	1.31%	0.05%	-0.45%	-0.08%	1.22%	-0.46%	-0.014%
$\Delta s_R$ & $\Delta s_C$	0.03%	0.91%	0%	-0.002%	0.025%	-0.015%	-0.014%

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