# Essays on the Impact of Intellectual Property Rights on Development, Growth, and Innovation

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To my family.

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Munich, December 12, 2011, Monique Newiak

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# Acronyms

| | |
|---|---|
| AJR | Acemoglu, Johnson and Robinson |
| BMA | Bayesian Model Averaging |
| GERD | Gross Expenditures on Research and Development |
| IPRs | Intellectual Property Rights |
| IV | Instrumental Variable |
| Max | Maximum |
| Min | Minimum |
| OECD | Organisation for Economic Co-operation and Development |
| PWT | Penn World Tables |
| R&D | Research and Development |
| RST | Rodrik, Subramanian and Trebbi |
| StDev | Standard Deviation |
| UIS | UNESCO Institute for Statistics |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| 2SBMA | Two-Stage Least Squares Bayesian Model Averaging |
| 2SLS | Two-Stage Least Squares |

# Chapter 1

# Introduction

This dissertation analyzes the circumstances under which intellectual property rights affect a developing or emerging country's ability to catch up to the developed world. Chapter 2 presents a model which explains the empirically observed threshold level of intellectual property rights (IPRs) below which IPRs fail to stimulate innovation and per capita income and above which there is a positive correlation between IPRs and these variables. After explaining this empirical observation, the model is used to compare the consequences of different IPR setting strategies for developing countries. Chapter 3 develops a model to examine the effects of IPRs on the knowledge transfer from developed to developing countries. It points out the circumstances under which policies of weak intellectual property protection can benefit a developing country's research sector. In chapter 4, an empirical analysis is conducted which aims at identifying the aspects of IPRs which can explain per-capita income differences across countries in the data. In the following, I give a short summary of the main results of this dissertation.

The previous literature focuses on North-South setups in which the South, i.e. developing countries, is restricted to imitative activity and all products are designed in the North, i.e. developed countries (see Grossman and Helpman (1991a); Deardorff (1992); Helpman (1993) and more recently Gustafsson and Segerstrom (2010, 2011)). These assumptions contradict the recent data on R&D in developing countries: Developing countries employ almost two fifth of the world's researchers, originate almost one quarter of world expenditures on R&D, and their inventions are subject to imitation (OECD, 2008; UNESCO, 2010). To study the effects of intellectual property rights (IPRs) on development, innovation and the southern catch-up process, theoretical work has to account for these empirical patterns.

In chapter 2 of this dissertation, *"Imitation and Innovation Driven Development under Imperfect Intellectual Property Rights"*,[1] a North-South increasing variety model of non-scale growth is developed to match these empirical findings. In contrast to the previous literature, we allow not only for southern R&D and the imitation of northern goods, but also imitation targeted at southern innovations. We account for research efficiency differences between the two regions and allow the South's research sector to be less developed than the northern one. To obtain policy recommendations about the effect of national treatment IPR policies versus discriminatory policies protecting mainly domestic firms, we endow the South with the possibility to set different IPR levels for domestic and foreign innovations.

We find the effects of IPRs on R&D and welfare to be non-monotonic and dependent on R&D efficiency and initial conditions. For sufficiently strong IPRs the South engages in R&D. In this case, a further strengthening of IPRs for all innovators is shown to promote southern R&D and welfare, and to be able to reduce the North-South wage gap. In countries in which the research efficiency is low and thus no research sector exists, a strengthening of Intellectual Property Rights below a threshold level fails to promote R&D. In this case, it decreases welfare and wages since the loss due to more difficult imitation is not compensated by the benefits of increases in own R&D. We find that discriminatory southern IPR policies (increases in IPRs for

[1] This chapter is based on the paper "Imitation and Innovation Driven Development under Imperfect Intellectual Property Rights", Lorenczik and Newiak (2011).

southern goods only) do not harm either of the two regions if the South does not engage in innovation, but can provide the necessary environment for southern firms to start original R&D. As soon as the South engages in innovation, discriminatory IPR policies benefit both regions by raising the South's R&D incentives and therefore shifting its resources away from the imitation of northern goods.

One of the conclusions of chapter 2 is that the success of IPR policies depends crucially on the southern research efficiency, which is taken as given in the presented set-up. However, IPR policies themselves can have an influence on the R&D efficiency through their effect on knowledge spillovers via imitation and own R&D. The evidence from East-Asian economies which used lax IPR policies to enable domestic firms to imitate foreign technologies, suggests that imitation can be one source of knowledge transfer from North to South, and therefore create a base for original R&D for countries at earlier stages of development (Kawaura and La Croix, 1995; Kumar, 2003; Kim, 2001).

In chapter 3, *"The Dual Role of Intellectual Property Rights under Imitation and Innovation Driven Development"*,[2] I explore this interaction between imitation and innovation by accounting for the endogeneity of the southern R&D development. In particular, I model two channels benefiting the R&D development in the South: The adaption of northern technologies through imitation and the creation of R&D efficiency via own research activities. While chapter 2 focuses on the incentives IPRs set by reducing the risk of imitation, chapter 3 thus additionally takes the effects of IPRs on knowledge spillovers from North to South into account.

For southern countries with high research costs, the model yields multiple equilibria associated with a different emphasis on original R&D and imitation. The innovation equilibrium is characterized by high product variety and welfare in both regions,

[2] This chapter is based in the paper "The Dual Role of Intellectual Property Rights under Imitation and Innovation Driven Development", Newiak (2011).

and by an efficient southern research sector which achieves its productivity via own innovative efforts. If the South raises IPRs for northern innovations in this case, it shifts southern resources away from imitation to own research activity. As the spillovers from imitation are only a minor source of knowledge accumulation at this stage of development, the increase in IPRs spurs the incentives to conduct R&D and raises welfare in both regions. In the imitation equilibrium, the South's main source of learning is the adaption of knowledge from the North through imitation, and its research efficiency is low. If northern goods are protected more strongly in the South at this stage of development, they dampen R&D incentives as they decrease the R&D efficiency by making the main source of learning less accessible. As a result, IPRs affect welfare and southern innovation negatively.

The results from chapters 2 and 3 thus suggest, that while the protection of *domestic* R&D in developing countries is never associated with negative welfare, growth and R&D effects, an increase in the protection of *developed* countries' innovations in the developing region is only beneficial if the research sector in the South is already present (chapter 2) and sufficiently large and developed (chapter 3).

While intellectual property rights (IPRs) are one of the key drivers of economic performance and welfare in R&D based growth models (Romer, 1990; Eicher and García-Peñalosa, 2008), they are largely neglected as development determinants in cross-country regressions in the empirical literature. In chapter 4 of this dissertation, *"Intellectual Property Rights as Development Determinants"*[3], we follow the canonical development determinant approach of Hall and Jones (1999), Acemoglu et al. (2001) and Rodrik et al. (2004), and introduce Intellectual Property Rights as an additional candidate regressor into a well established line of development regressions. In particular, we obtain differentiated protection measures by disaggregating the patent index by Park (2008a)/Ginarte and Park (1997) and test them, together

[3] This chapter is based on the paper "Intellectual Property Rights as Development Determinants", Eicher and Newiak (2011).

with a set of candidate regressor proposed in previous studies, for their relevance in explaining income levels across countries. We use Two-Stage Least Squares Bayesian Model Averaging (2SBMA) proposed by Lenkoski et al. (forthcoming) to address endogeneity issues and account for model uncertainty at both the income determinant and instrument level. The impact of intellectual property rights *enforcement* on development is shown to be of the same magnitude as that of "rule of law", the key regressor in cross-country development regressions in the current literature. We thus show that (1) both dimensions of property rights, physical and intellectual, are crucial prerequisites for a country's development, and that (2) IPRs which are simply "on the books", but are not enforced cannot explain development.

# Chapter 2

# Imitation and Innovation Driven Development under Imperfect Intellectual Property Rights*

## 2.1 Introduction

The distribution of R&D efforts between developed and developing countries is changing. In its Science, Technology and Industry Outlook, the OECD (2008) reports that the distribution of Gross domestic expenditures on R&D (GERD) shifts towards non-OECD countries whose share in global R&D increased from less than 12% to over 18% from 1996 to 2005. A similar pattern arises for business R&D

* This chapter is based on joint work with Christian Lorenczik. I would like to thank Theo Eicher, Matthias Doepke, Gerhard Illing, Niloy Bose, Monika Piazzesi, Martin Schneider, Michele Tertilt, Philip Brock, Oksana Leukhina and Stephen Turnovsky for many helpful comments and suggestions. The chapter has also greatly benefited from the comments and suggestions by various conference participants at the European Economic Association meeting in Oslo, the Midwest International Trade Meeting in Madison, the DEGIT XV conference in Frankfurt, the European Workshop in Macroeconomics in Munich, the Warsaw International Economics Meeting, the Midwest Economic Association Meeting in St. Louis, the Southwestern Society of Economists meeting in Houston and the third PhD conference in Economics in Athens. I would also like to thank the seminar participants at the University of Munich and the University of Washington, Seattle, for their valuable comments.

expenditures of profit-oriented enterprises. In China, South Africa, Russia and India, the ratios of R&D expenditure to GDP exceed those of high income countries like Greece and Portugal. UIS (2009)[4] reports an even higher share of developing countries in world R&D for 2007: developing countries accounted for almost 24% of world GERD and employed almost 38% of world researchers. The extent of investments into R&D is closely correlated with the level of domestic IPR protection. Figure 2.1 plots the Gross expenditures on R&D and GDP per capita against the Ginarte and Park patent index in 2005.[5]

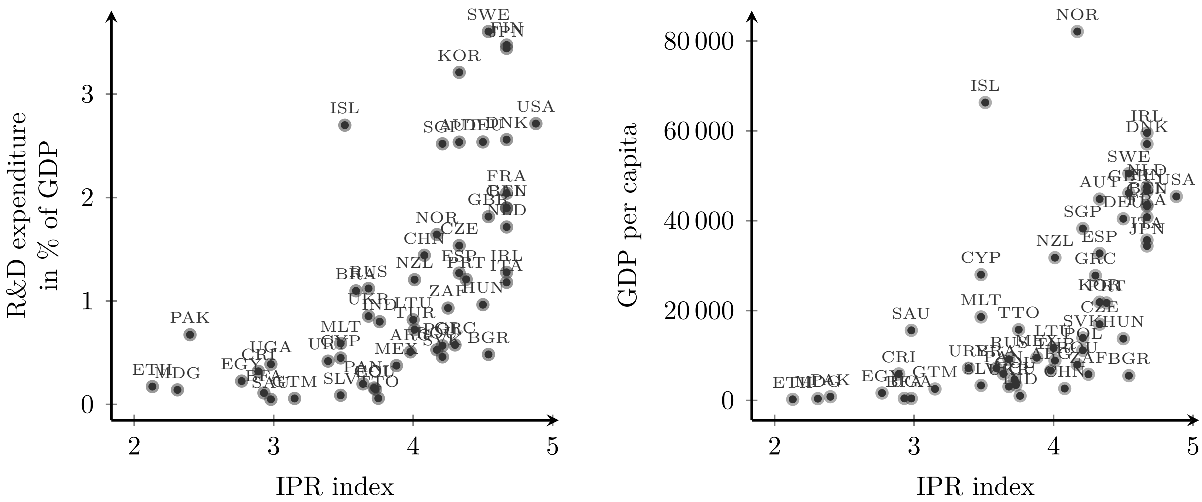


Figure 2.1: R&D expenditures (GERD), IPRs, and GDP per capita

For the group of countries associated with low levels of IPRs (below an index of about 3 to 3.5), R&D expenditures are below 1% with low variations. Above the threshold, there is a clear positive correlation between R&D efforts, the level of IPRs and GDP per capita.[6] Not only do the graphs show that there is a threshold level of IPRs which has to be reached for IPRs to be positively associated with R&D,

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4 The UNESCO Institute for Statistics.

5 Data sources: R&D expenditures for 2007 from UIS (2009), IPR index for 2005 from Park (2008a), GDP per capita for 2007 and country codes are from United Nations Statistics Division: National Accounts. We thank Walter Park for sharing the data on the patent index.

6 For earlier periods, i.e. before TRIPS was established, the plot looks qualitatively similar, but the data are somewhat shifted to the left, i.e. to lower levels of IPRs. See Park (2008a) for the sources of changes in the index. The same observation is made in Ginarte and Park (1997) who find that high income countries provide the highest level of IPR protection.

but also that IPR protection is positively related to income in a country only if it supports a sufficiently developed R&D sector.[7]

The division of countries into industrialized innovating countries (the North) and imitating developing countries (the South) in the theoretical literature does not account for the increasing investments into R&D in developing economies shown by these recent surveys[8] and does not allow for scenarios of a transition of imitator countries to successful innovators as demonstrated by Asian Growth miracles like South Korea, Taiwan and earlier Japan.

In this chapter, we develop a North-South increasing variety model which allows for original innovation in both the North and the South, and also for the imitation of both northern and southern inventions. We show that our model can explain the IPR-R&D threshold level shown in figure 2.1, and determine the conditions under which IPRs can stimulate southern innovative activity and increase welfare. We then use the model to analyze the effects of different IPR policies in the South. For the policy analysis the aspect of southern firms being also subject to imitation has two main advantages: First, it allows us to analyze the effects of stronger IPRs on southern R&D incentives directly. Second, we can thus examine the effects of IPRs protecting northern or southern goods separately.

While international treaties such as the Paris and Berne Conventions prescribe the national treatment principle, i.e. equally strong protection for domestic and foreign innovations, this principle might not be followed by developing countries. For

[7] That there is also a threshold level also for IPRs and growth which is dependent on the level of human capital in a country is shown by Mohtadi and Ruediger (2010) using a threshold estimation technique.

[8] Important contributions with this feature include Grossman and Helpman (1991a), Deardorff (1992) and Helpman (1993) and more recently Gustafsson and Segerstrom (2010). For a criticism of the lack of southern R&D in North-South models see Park (2008b). For two examples of models in which the South can innovate, but is not the subject of imitation itself, see (Currie et al., 1999; Glass, 2010). For firms' private incentives to protect their intellectual property compare Eicher and García-Peñalosa (2008). For a countries decision to set the level of IPRs in a game theoretic framework see Grossman and Lai (2004).

instance, as Kumar (2003) describes for the case of Japan until the 1970s, IPR legislation might be in place to unilaterally advance domestic technology adoption from abroad. Thus the second contribution of this chapter is to analyze the effects of discriminatory southern IPR policies on both regions.

We find that southern R&D takes place if IPRs surpass a critical threshold level. This critical level is lower for higher southern research efficiency and a larger southern population. This implies that large countries with efficient R&D sectors are likely to engage in innovation even under weak IPR regimes. Likewise, to stimulate an inefficient R&D sector in a small country, IPRs have to be very strong. In stimulating southern R&D, the protection of northern and the protection of southern innovations are shown to work as imperfect substitutes. If R&D takes place in the South, strengthening IPRs for both regions' innovators increases welfare in both regions. In contrast, an increase in IPRs that does not surpass the threshold level fails to stimulate R&D, increases the wage gap between the regions and decreases real consumption in the South.

We show that a southern deviation from the national treatment principle (increasing IPRs for domestic firms only), does not harm either region if southern R&D does not take place, and it benefits *both* regions if southern R&D is conducted: By increasing R&D incentives for southern firms, it shifts the southern attention away from the imitation of northern goods.

The next section discusses the related literature, and section 2.3 describes the model. In section 4, we describe the equilibrium, state the conditions under which southern R&D takes place and analyze the effects of different IPR policies on innovative and imitative activity and wages in the two regions. In section 5, the model is calibrated to analyze the welfare and employment effects of stronger IPRs, and section 6 concludes.

## 2.2 Related literature

In this section, we compare our results to the conclusions drawn by papers which are most closely related to our work. These papers are different from the seminal North-South models by, i.a., Grossman and Helpman (1991a), Deardorff (1992) and Helpman (1993) in that they do not focus on the conflict *between* the innovating North and the imitating South, but are more concerned with the trade-off between imitation and innovation *within* the South.

In Currie et al. (1999), the South has the options to imitate the North or innovate with knowledge dissipating gradually from the North to the southern knowledge base. While not treating the effects of changes in IPRs explicitly, Currie et al. (1999) argue that subsidies to the imitation sector have qualitatively the same effects as a loosening of IPRs. The following features distinguish our model from Currie et al. and lead to partially different results: First, we analyze the problem in a semi-endogenous framework to match the empirical observations of non-scale growth as in Jones (1995). Thus policy changes do not imply long-run changes of the growth rate in our model. Second, we include the empirical feature of decreasing returns to R&D into the imitation and innovation processes. This allows the South to engage in R&D even if the wage differences between the regions are large which is not possible in Currie et al.'s framework, but empirically more plausible. Third, while changes in subsidies to imitation do not have any welfare implications for the case in which the South only imitates in Currie et al. (1999), we show that in this no-innovation case, stronger IPRs for innovations of both regions decrease welfare, but can help to stimulate R&D if they surpass a threshold level. Finally and most importantly, we are able to analyze discriminatory IPR policies as we allow for southern goods to be also subject to imitation. The protection of northern IPRs affects innovation incentives for the South only indirectly by making the alternative (imitation) more costly. In our model, general IPR protection has the direct benefit of increased expected profits for southern innovators. We can thus show that IPRs exclusively for southern goods benefit both regions if southern R&D is present: they increase R&D profitability for the South and thus shift resources away from imitation of the North.

Glass (2010) also analyzes imitation and innovation in the South, but focuses on how imitation encourages R&D by providing the South with a sufficient knowledge base. She builds a product-cycle model in which an exogenous fraction of industries has to engage in imitation before being able to target the market for innovations and analyzes subsidies to northern and southern R&D and imitation. IPRs are not treated explicitly but indiscriminate subsidies to imitation and innovation are considered instead. The result suggests that when imitation is a prerequisite to southern innovation, undirected subsidies can increase the rate of innovation relative to imitation. However, these policies do not have any implications for the wage rate if the South innovates, and welfare changes are not considered in her paper. We emphasize that the focus of this chapter is different from Glass (2010): While she analyzes how imitation can serve as a stepping stone to innovation, this chapter examines how the South's choice between innovation and imitation is influenced by different IPR policies.

Newiak (2011) analyzes how imitation can encourage R&D in countries whose innovation sector is small compared to those in which the R&D sector is sufficiently large. The results of her model suggest that the effect of IPR policies depend crucially on the state of the R&D sector's development and the main channel of knowledge accumulation in the country. The model does not allow for imitation of southern products so that IPR policies considered in the two papers are different: while in Newiak (2011) an increase in IPRs always means that one source of knowledge is harder to access, we reveal a channel through which stronger IPRs are never harmful to R&D and welfare in the South while they can also benefit the North: stronger IPRs for southern innovations.

## 2.3 The Model

### 2.3.1 Basic set-up of the model

Two regions interact in our model, a group of developed countries (the North) and a group of developing countries (the South). Firms in North and South hire labor for the production of consumption goods and for innovative and imitative research and development (R&D). Labor is perfectly mobile within all sectors across one region, but immobile between the two regions. Thus a single wage rate is paid to all workers within one region. Trade between the two regions is costless. North and South differ in their R&D activities. The North engages in innovation only. As long as a northern variety has not been imitated, its production takes place in the North, and the innovating firm charges the monopoly price on the global market. Once a northern variety has been imitated by the South, its production shifts to the South. The South engages in innovation and the imitation of both northern and southern inventions. If a southern variety has been imitated, its production stays in the South, but it is produced at lower costs by southern imitators.

### 2.3.2 Households

Each region is inhabited by a fixed measure of households whose size grows exponentially at a constant rate $g_L$. Each member of a household is endowed with one unit of labor which he supplies inelastically to the labor market. So the labor supply in North and South at time $t$ is given by $\ell_t^* = \ell_0^* e^{g_L t}$ and $\ell_t = \ell_0 e^{g_L t}$, respectively.[9] Households in the two regions are identical concerning their preferences and symmetric in their maximization problem. We restrict the outline of the household's problem to the South in the following. Agents in the South maximize the discounted lifetime flow of utility

$$U(t) = \int_t^\infty e^{-(\rho - g_L)t} \ln u(t) dt, \qquad u(t) = \left[ \int_0^{N_t} x_{j,t}^\alpha dj \right]^{\frac{1}{\alpha}} \tag{2.1}$$

arising from the consumption of $N_t$ differentiated varieties in each period. $\rho > g_L$ is the rate of time preference. $x_{j,t}$ denotes the per capita quantity demanded of variety $j$, and $\alpha$ is the degree of product differentiation so that the elasticity of substitution between varieties is $\varepsilon = \frac{1}{1-\alpha}$. Individuals are constrained by their wage and asset income: $\dot{a}_t = (r_t - g_L)a_t + w_t - e_t$ in which $e_t$ stands for consumption expenditure, $w_t$ represents the wage income and $r_t$ is the interest rate paid on asset holdings $a_t$. Solving the consumer's maximization problem for both regions we obtain $\bar{x}_{j,t}$, the average per capita demand for variety $j$ by the world consumer at time $t$:

$$\bar{x}_{j,t} = \frac{\bar{e}_t}{P_t} \left( \frac{p_{j,t}}{P_t} \right)^{-\varepsilon} \tag{2.2}$$

in which $\bar{e}_t$ represents average consumption expenditures per consumer defined as $\bar{e}_t = (e_t^* \ell_t^* + e_t \ell_t)/L_t$, $p_{j,t}$ is the price of variety $j$ and $L_t = \ell_t + \ell_t^*$. The aggregate price index is defined as $P_t = \left[ \int_0^{N_t} p_{j,t}^{1-\varepsilon} dj \right]^{\frac{1}{1-\varepsilon}}$. Expenditures in the South grow at $\frac{\dot{e}_t}{e_t} = r_t - \rho$ such that individual consumption expenditures $e_t$ grow over time only if the market interest rate $r_t$ exceeds the discount rate $\rho$.

[9] Throughout this dissertation the convention is used to indicate quantities referring to the North by '*' and to use no superscript for quantities of the South.

### 2.3.3 Research and Development

#### 2.3.3.1 Innovation

Varieties are invented in the North and in the South. The total amount of varieties invented in the North is given by $n^*_t = n^*_{R,t} + n_{C_N,t}$ in which $n^*_{R,t}$ and $n_{C_N,t}$ represent the number of not imitated and imitated varieties, respectively. Similarly, $n_t = n_{R,t} + n_{C_S,t}$ is the total number of varieties invented in the South with $n_{R,t}$ not yet imitated and $n_{C_S,t}$ already imitated innovations. The total number of varieties available to the world consumer is then given by:[10]

$$N = n^* + n = n^*_R + n_{C_N} + n_R + n_{C_S}. \tag{2.3}$$

To produce a new variety, R&D firms in the North and South have to develop an innovation blueprint. To obtain this innovation blueprint they hire researchers $\ell^*_R$ and $\ell_R$. The employed researchers' productivity depends on the available amount of knowledge capital which we model as a function of the number of already existing varieties: $N^\theta$. We assume that it is available to both regions equally, but that the regions differ in how efficiently they use it:

$$\dot{n}^* = \dot{n}^*_R + \dot{n}_{C_N} = \frac{\ell^*_R N^\theta}{ag} \tag{2.4a}$$

$$\dot{n} = \dot{n}_R + \dot{n}_{C_S} = \frac{\ell_R N^\theta}{ag\beta}, \quad \beta > 1, \quad 0 < \theta < 1, \quad g = \frac{\dot{N}}{N}. \tag{2.4b}$$

We follow Jones (1995) and Gustafsson and Segerstrom (2011) in setting $0 < \theta < 1$ such that the R&D difficulty is decreasing in the number of blueprints, intertemporal knowledge spillovers become weaker over time and strong scale effects are ruled out. The parameter $a$ captures the difficulty to innovate in the North so that $\beta > 1$ means

[10] To simplify the notation we drop time scripts whenever no risk of ambiguity arises.

that the South is relatively less productive in the innovation process. Further we account for decreasing returns to innovation by letting the global variety growth rate $g = \frac{\dot{N}}{N}$ enter the innovation functions in the denominator.[11]

#### 2.3.3.2 Imitation

Imitation takes place in the South only. In order to obtain the imitation blueprint of a northern or southern innovation, imitation firms hire labor $\ell_{C_N}$ and $\ell_{C_S}$ and use the existing knowledge capital $N^\theta$. In modelling imitation as a costly process we follow the study by Mansfield et al. (1981) who find average imitation costs of about 65% and an imitation time requirement of 70% compared to innovation. So the imitation functions for northern and southern products are described as:

$$\dot{n}_{C_N} = \frac{\ell_{C_N} N^\theta}{\phi_N d a \iota_N}, \quad \iota_N = \frac{\dot{n}_{C_N}}{n_R^*} \tag{2.5a}$$

$$\dot{n}_{C_S} = \frac{\ell_{C_S} N^\theta}{\phi_S a \iota_S}, \quad \iota_S = \frac{\dot{n}_{C_S}}{n_R}. \tag{2.5b}$$

$\phi_N$ and $\phi_S$ capture the difficulty of imitating northern and southern varieties and are interpreted as the strength of IPR protection in the South. The higher $\phi_N$ and $\phi_S$, the stronger the level of IPR protection and the higher the costs of imitation. Note that we allow for different IPR levels for the inventions from the two regions, so that the South is allowed to discriminate between domestic and foreign firms. $\iota_N$ and $\iota_S$ are the imitation rates of northern and southern varieties which enter the imitation functions as in Gustafsson and Segerstrom (2011), but with an elasticity of imitation supply of one. Including the imitation rates in the imitation functions again

11 The growth rate $g$ in the denominator captures decreasing returns to innovation as follows: The total number of varieties invented in period $t$ by both regions is $\dot{N}_t = \frac{\ell_R^* N^\theta}{ag} + \frac{\ell_R N^\theta}{ag\beta} = \frac{N_t^\theta}{ag}(\ell_R^* + \ell_R/\beta)$. Given the definition of $g$, this expression can be rewritten as $\dot{N}_t = \left(\frac{N_t^{1+\theta}}{a}(\ell_R^* + \ell_R/\beta)\right)^{1/2}$ which implies decreasing returns to innovation. For literature on decreasing returns to innovation, compare Griliches et al. (1989) and Kortum (1993).

captures the idea of decreasing returns to R&D[12]. Finally, we introduce a distance parameter $d$ to allow for a higher imitation difficulty for northern varieties (due to the remote original development and production and possibly higher technological sophistication).

As they operate in the same region as the innovator, imitators of southern goods do not have a labor cost advantage. In order to generate positive profits from imitation, they hire process innovators who improve the production process such that the imitating firm can produce the variety cheaper than the innovation firm. The cost advantage in production $\eta$ is a positive function of the amount of process innovators $\ell_P$ employed and a negative function of the cost of developing the imitation blueprint: If it is difficult to copy the technology in the first place, improving the production process should be also more difficult. So $\eta$ is modeled as a negative function of the labor input $\ell_{C_S}$ needed to develop the imitation blueprint: $\eta = \bar{\eta}\left(\frac{\ell_P}{\ell_P+\ell_{C_S}}\right)^{\frac{1}{\gamma}}$ with $\eta \in [0, \bar{\eta})$, implying an upper bound for the cost reduction and $\gamma$ as the difficulty to improve the production process.

### 2.3.4 Production

Labor is the only factor of production. For northern and southern innovators, one unit of labor produces one unit of output. As long as the invention has not been imitated, innovators have monopoly power and maximize their profit $\pi_R^{(*)} = (p_R^{(*)} - w_t^{(*)})\bar{x}_R^{(*)}L$ subject to the demand function (2.2). Monopolists in the North and South charge a constant mark-up over their marginal costs $w^*$ and $w$, such that

12 Compare footnote 11.

prices and profits for northern and southern innovation firms are given by:

$$p_R^* = \frac{w^*}{\alpha}, \quad \pi_R^* = \frac{1-\alpha}{\alpha} w^* \bar{x}_R^* L \tag{2.6a}$$

$$p_R = \frac{w}{\alpha}, \quad \pi_R = \frac{1-\alpha}{\alpha} w \bar{x}_R L. \tag{2.6b}$$

In the case of imitation, imitators and innovators compete in prices which drives the price down to the innovator's marginal cost of production and the innovating firm shuts down. If the wage differential is not too high ($w^* \leq w/\alpha$), the southern imitator charges a price equal to the northern wage rate $w^*$ to force the northern innovator out of the market. If the wage gap is high ($w/\alpha \leq w^*$), the imitator can charge the monopoly price.[13] As none of our results depends qualitatively on whether narrow or wide gap case is present, we present the model for the wide gap case in the following and outline how the model changes for the narrow-gap case in appendix A. Due to the process innovation described in the previous section, an imitator of southern innovations produces goods at lower marginal costs $(1-\eta)w$. We assume an upper bound on this cost advantage ($\eta \leq 1-\alpha$) so that the imitator charges a price equal to the southern wage rate. The price and the profits for imitated northern and southern goods are given by:

$$p_{C_N} = \frac{w}{\alpha}, \qquad \pi_{C_N} = \frac{1-\alpha}{\alpha} w \bar{x}_{C_N} L, \qquad w^* \geq \frac{w}{\alpha} \tag{2.7a}$$

$$p_{C_S} = w, \qquad \pi_{C_S} = \eta w \bar{x}_{C_S} L, \qquad \eta \leq 1-\alpha. \tag{2.7b}$$

[13] These cases are referred to as the narrow-gap case and the wide-gap case by Grossman and Helpman (1991a).

### 2.3.5 Financial sectors

The value of an innovating or imitating firm $v_R$ or $v_C$ is given by its expected discounted profits. As there is free entry to R&D and imitation, these expected discounted profits have to be equal to the cost of the respective activity. For innovating firms, the cost consists of the wage paid to the researchers. For imitating firms, it is the wage paid to the reverse engineers (and process innovators for imitators of southern varieties). Using (2.4) and (2.5) to determine the amount of labor for these activities, the firm values for innovators in North and South and imitators in the South are:

$$v_R^* = \frac{w^* a g}{N^\theta} \tag{2.8a}$$

$$v_R = \frac{w \beta a g}{N^\theta} \tag{2.8b}$$

$$v_{C_N} = \frac{w \phi_N a \iota_N}{N^\theta} \tag{2.8c}$$

$$v_{C_S} = \frac{w \phi_S a \iota_S}{N^\theta (1 - (\eta/\bar{\eta})^\gamma)} \tag{2.8d}$$

There is perfect capital mobility between innovation, imitation and production sectors within one region, but financial autarky in North and South. Agents in the North can decide between holding the market portfolio with a safe return $r^*$ or shares of the northern innovation firms which pay a return $\pi_R^*/v_R^*$. This return has to be adjusted by the change in the value of the firm $\dot{v}_R^*/v_R^*$ and the risk of being copied $\dot{n}_{C_N}/n_R^*$. In the South, agents have the choice between gaining the risk free rate $r$ and holding shares of southern innovation or imitation firms. No-arbitrage between these choices within North and South implies:

$$\frac{\pi_R^*}{v_R^*} + \frac{\dot{v}_R^*}{v_R^*} - \frac{\dot{n}_{C_N}}{n_R^*} = r^* \tag{2.9a}$$

$$\frac{\pi_R}{v_R} + \frac{\dot{v}_R}{v_R} - \frac{\dot{n}_{C_S}}{n_R} = r = \frac{\pi_{C_N}}{v_{C_N}} + \frac{\dot{v}_{C_N}}{v_{C_N}} = \frac{\pi_{C_S}}{v_{C_S}} + \frac{\dot{v}_{C_S}}{v_{C_S}}. \tag{2.9b}$$

### 2.3.6 Labor markets

Finally, labor market clearing in the North and South requires that the sum of workers employed in the R&D and production sectors equals the total labor force in each region. In the North, labor is allocated into R&D and production: $\ell^* = \ell_R^* + \ell_Y^*$. In the South, labor is allocated into R&D, the imitation of northern goods, the imitation of southern goods, process innovation and production: $\ell = \ell_R + \ell_{C_N} + (\ell_{C_S} + \ell_P) + \ell_Y$ which, using the innovation and imitation functions (2.4) and (2.5) implies the following two labor market clearing conditions:

$$\ell^* = \frac{ag}{N^\theta}(\dot{n}_R^* + \dot{n}_{C_N}) + n_R^* \bar{x}_R^* L \tag{2.10a}$$

$$\begin{aligned} \ell = {} & \frac{ag\beta}{N^\theta}(\dot{n}_R + \dot{n}_{C_S}) + \frac{ad\phi_N \iota_N}{N^\theta}\dot{n}_{C_N} + \frac{a\phi_S \iota_S}{N^\theta(1-(\eta/\bar{\eta})^\gamma)}\dot{n}_{C_S} \\ & + (n_R \bar{x}_R + n_{C_N}\bar{x}_{C_N} + (1-\eta)n_{C_S}\bar{x}_{C_S})L. \end{aligned} \tag{2.10b}$$

## 2.4 The balanced growth path and the effects of intellectual property rights

In this section, we define the equilibrium and analyze the conditions under which innovation takes place in the South. We then analyze the effect of different IPR policies for an equilibrium with southern innovation. The model without southern innovation is described in appendix B.

### 2.4.1 Definition of the equilibrium and long-run growth

The equilibrium is given by a set of prices, wages and interest rates in North and South such that the allocation of labor into the different sectors, varieties and their supply, consumption expenditures and asset holdings (1) solves the households' utility maximization problem and firms' profit maximization problem and (2) labor, goods and financial markets clear given the free market entry of firms. In this steady state equilibrium, variety growth $g \equiv \dot{N}/N$, the South-North wage ratio $\omega \equiv w/w^*$, the imitation rates $\iota_N$ and $\iota_S$, the optimal cost advantage of southern imitative production $\eta^\star$, the variety shares $\xi_R^* \equiv n_R^*/N$, $\xi_R \equiv n_R/N$, $\xi_{C_N} \equiv n_{C_N}/N$ and $\xi_{C_S} \equiv n_{C_S}/N = 1 - \xi_R^* - \xi_R - \xi_{C_N}$, and the shares of labor employed in the different sectors of each region are constant. Further, constant consumption expenditures imply that the risk-free interest rates in North and South are equal to the rate of time preference $\rho = r^* = r$.

As the variety shares are constant in equilibrium, the number of varieties of each kind has to grow at the same rate $g = \dot{N}/N = \dot{n}_R^*/n_R^* = \dot{n}_R/n_R = \dot{n}_{C_N}/n_{C_N} = \dot{n}_{C_S}/n_{C_S}$. Dividing (2.4) by $N$ and using the fact that the R&D employment ratio $\ell_R^*/\ell^*$ is constant in steady state the equilibrium growth rate is determined as

$$g = \frac{g_L}{1-\theta}. \tag{2.11}$$

The growth rate is finite and positive for $\theta < 1$. This semi-endogenous growth implies that policy actions do not have any effect on the long-run growth rate.

### 2.4.2 The threshold to innovation in the South

We turn now to answering the first question of this chapter: Which factors determine the innovation threshold observed in the data (compare figure 2.1)? To answer this question, we consider the conditions under which innovation and imitation are beneficial in the two regions: Rearranging the no-arbitrage conditions with respect to the firm values and equating with (2.8) and realizing that $\dot{v}_R^*/v_R^* = \dot{v}_R/v_R = \dot{v}_{C_N}/v_{C_N} = \dot{v}_{C_S}/v_{C_S} = -\theta g$, we arrive at four conditions balancing profits and costs of innovative and imitative activities in North and South:

$$\frac{\pi_R^*}{\rho + \theta g + \iota_N} = \frac{w^* a g}{N^\theta} \tag{2.12a}$$

$$\frac{\pi_R}{\rho + \theta g + \iota_S} = \frac{w \beta a g}{N^\theta} \tag{2.12b}$$

$$\frac{\pi_{C_N}}{\rho + \theta g} = \frac{w \phi_N d a \iota_N}{N^\theta} \tag{2.12c}$$

$$\frac{\pi_{C_S}}{\rho + \theta g} = \frac{w \phi_S a \iota_S}{N^\theta (1 - (\eta/\bar{\eta})^\gamma)}. \tag{2.12d}$$

The left-hand side of (2.12) represents the benefit (the appropriately discounted profits) from innovation and imitation, whilst the right-hand side represents the cost (wage payments) of the respective activity.[14] These conditions are crucially affected by the level of IPRs ($\phi_S$ and $\phi_N$): first, they directly determine the cost of imitation (the right-hand sides of (2.12c) and (2.12d)) and second, via their effect on the imitation rates, they affect the expected profits from innovation (the left-hand sides of equations (2.12a) and (2.12b)). As the South does only engage in R&D if the expected profits and the associated costs from performing R&D are at least as attractive as the imitation of northern varieties we thus expect three parameters to crucially influence the existence of southern innovation: First, the higher the relative research inefficiency $\beta$ the higher the cost of developing one blueprint and the higher

14 Note that the cost advantage in the production of southern products $\eta$ is determined optimally by the southern imitation firm. To set $\eta$ optimally, the marginal revenue (the increase in profits due to the decrease in the production costs) and the marginal cost of hiring a process innovator (the wage rate) are equated. Thus, both sides of (2.12d) are differentiated with respect to $\ell_P$. The optimal cost advantage can then be written as $\eta^\star = \bar{\eta} \left( \frac{1}{1+\gamma} \right)^{\frac{1}{\gamma}}$.

the required profits to cover these costs. Second, expected profits to R&D depend negatively on the risk of being imitated $\iota_S$ which is directly determined by the level of IPRs for southern innovations $\phi_S$ (which we explicitly show in the next section). Third, the decision to engage in R&D depends on the ease of imitation of northern goods which is influenced by the protection of northern goods $\phi_N$: the lower $\phi_N$ the easier is imitation compared to innovation. Finally, the southern decisions have to be consistent with the southern resource constraint (labor market clearing).

Combining the southern cost-benefit conditions (2.12b)-(2.12d) with the southern labor market clearing equation, we obtain the condition under which employment in the southern innovation sector is positive:

$$\frac{\ell}{\ell^*} > d\phi_N \left(\frac{\iota_N}{g}\right)^2 \left(\frac{\Lambda_1}{\Lambda_1 + \iota_N}\right), \qquad \iota_N = \frac{\beta}{d\phi_N} \frac{\Delta_1 \phi_S(\rho + \theta g)g}{\Delta_1 \phi_S(\rho + \theta g) - \eta^\star \beta g} \tag{2.13}$$

with $\Lambda_1 = (1-\alpha)g + \alpha(\rho+\theta g)$. From (2.13) follows that the higher the protection of northern or southern innovations (the higher $\phi_S$ and $\phi_N$) the more likely the South engages in research. Intuitively, the South is, c.p., more likely to engage in R&D if its research efficiency is high ($\beta$ is low). For a given southern R&D efficiency, IPRs for northern and southern IPRs are substitutes to a certain degree: If $\phi_N$ is high and therefore the costs of imitating the North are high compared to conducting own research, expected profits from R&D can be smaller and therefore IPRs for southern goods can be weaker. Further, the higher the cost of original research in the South (the higher $\beta$) the stronger IPRs have to be for northern and southern products in order to make R&D comparatively profitable. Finally, the existence of southern R&D is more likely if the southern labor force is large. This implies that for given levels of IPR protection and research ability, large countries are more likely to engage in innovation. We plot the IPR threshold ($\ell_R = 0$) in figure 2.2 for illustration.

Innovation takes place for all combinations of $\phi_S$ and $\phi_N$ on the right-hand side of the isoquant. The figure demonstrates that the South can go from a phase of solely

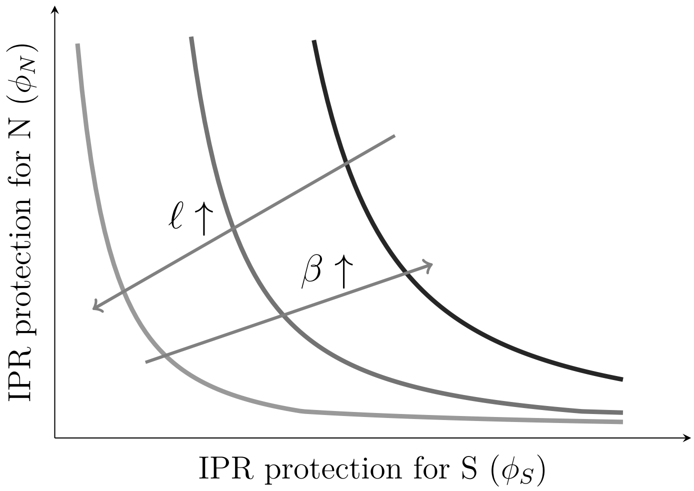


Figure 2.2: IPR threshold for southern research employment.

imitating the North to a phase with own original R&D if the southern research efficiency or IPRs are sufficiently increased. It also reveals that in order to stimulate R&D in countries with a less efficient research sector IPR protection has to be stronger than in countries with efficient R&D sectors. The results are summarized in

**Proposition 1** *(i) Stronger IPRs can stimulate southern innovation if they surpass a threshold level. (ii) This threshold level is higher the less efficient the southern research sector and the smaller the relative size of the southern population. (iii) The protection of southern and northern innovations work as imperfect substitutes in encouraging southern R&D.*

If (2.13) is not satisfied, the cost-benefit conditions (2.12b) and (2.12d) do not apply and the model collapses to the standard North-South model without southern innovation. While we focus on the case in which southern R&D takes place in the following, we describe the no-innovation case in appendix B.

### 2.4.3 Intellectual property rights policy effects on the incentives to innovate and imitate

To obtain the rates at which northern and southern products are imitated, we combine the cost-benefit conditions (2.12b) and (2.12d) as well as (2.12a) with (2.12d), substitute for the profits and use the demands for varieties (2.2):

$$\iota_S = \frac{\eta^\star \beta(\rho + \theta g)g}{\Delta_1 \phi_S(\rho + \theta g) - \eta^\star \beta g} \tag{2.14a}$$

$$\iota_N = \frac{\beta}{d\phi_N} \frac{\Delta_1 \phi_S(\rho + \theta g)g}{\Delta_1 \phi_S(\rho + \theta g) - \eta^\star \beta g}, \tag{2.14b}$$

with $\Delta_1 = (1-\alpha)\alpha^{\varepsilon-1}\frac{(1+\gamma)}{\gamma}$.[15] Suppose first that the South follows the national treatment principle and chooses to protect domestic and foreign goods equally (formally: set $\phi_N = \phi_S = \phi$ ). Increasing $\phi$ will then decrease the rates at which domestic and foreign goods are imitated. However, the South could also choose to discriminate between domestic and foreign innovators by increasing only either $\phi_N$ or $\phi_S$. Increasing IPRs for northern firms will decrease the rate at which northern firms are imitated, but leave the risk of being imitated for southern innovators unaffected. In contrast, if the South chooses to increase IPRs for domestic innovations only ($\phi_S \uparrow$), both rates of imitation decrease. This effect results from the impact of $\phi_S$ on southern innovation: If southern goods are better protected, southern innovators face a lower risk of being imitated and consequently their expected profits increase. This makes own innovation more attractive compared to the imitation of both northern and southern goods which leads to the decline of the imitation rates.

In line with this reasoning, policies which aim at increasing the southern research efficiency (decreasing $\beta$) decrease the imitation rates by decreasing the innovation costs and thus making southern innovation more attractive compared to imitation.

[15] As $\iota_S$ has to be non-negative, the parameters of the model are constrained to $\eta^\star \beta g < \phi_S \Delta_1(\rho + \theta g)$.

**Proposition 2** *In an equilibrium with southern innovation, the rates at which northern and southern innovations are imitated are decreasing in (i) an increase in IPRs for all varieties, (ii) an increase in IPRs exclusively for southern innovations and (iii) an increase in the southern research efficiency. Increases in IPRs exclusively for northern goods decrease the imitation risk for northern goods, but leave the imitation rate for southern innovations unaffected.*

How do these changes of imitation risks relate to the allocation of labor into the different sectors in North and South? We use the northern labor market clearing condition and combine it with the cost-benefit conditions to get the amount of labor allocated into R&D and production in the North:

$$\ell_R^* = \frac{(1-\alpha)(g+\iota_N)}{\Lambda_1 + \iota_N}\ell^* \tag{2.15a}$$

$$\ell_Y^* = \frac{\alpha(\rho + \theta g + \iota_N)}{\Lambda_1 + \iota_N}\ell^*. \tag{2.15b}$$

The amount of labor employed in the northern R&D sector is increasing in the rate at which northern products are copied: If northern innovations are copied at a high rate, the production of northern inventions shifts to the South quickly. As a consequence, labor is set free from the production sector to the innovation sector. It follows that policies which decrease the imitation risks for northern firms ($\phi_N \uparrow$ or $\phi_S \uparrow$ or $\beta \downarrow$), also decrease the share of labor employed in the northern research sector.

To obtain the allocation of southern labor into the imitation of northern goods, we combine (2.15) with the imitation function for northern goods:

$$\ell_{C_N} = \frac{\phi_N \iota_N^2}{g}\frac{(1-\alpha)}{(\Lambda_1 + \iota_N)}\ell^*. \tag{2.16}$$

Using (2.14b), we can show that employment in the imitation sector for northern goods is decreasing in the strength of IPR protection for northern and southern goods $\phi_N$ and $\phi_S$ and increasing in the southern research inefficiency $\beta$. The higher the protection of northern goods $\phi_N$, the costlier the imitation of northern goods, so that southern innovation and imitation of southern goods become more attractive. The higher the protection of southern goods $\phi_S$, the smaller the risk of being copied for the South, the more attractive is southern research which shifts resources from the imitation of northern goods to own innovation. This result again reveals that an IPR policy in favor of domestic innovators (increase $\phi_S$ only) can shift resources away from the imitation of foreign innovations.

To obtain the number of workers employed in the southern innovation sector, we use (2.16) and the cost-benefit conditions (2.12b)-(2.12d) :

$$\ell_R = \left(\ell - \phi_N \left(\frac{\iota_N}{g}\right)^2 \left(\frac{\Lambda_1}{\Lambda_1 + \iota_N}\right) \ell^*\right) \frac{(1-\alpha)(g+\iota_S)}{\Lambda_1 + \iota_S + \frac{1-\alpha}{\eta^\star}\frac{\gamma+1}{\gamma}\frac{\phi_S}{\beta}\left(\frac{\iota_s}{g}\right)^2 \Lambda_2}, \qquad (2.17)$$

in which $\Lambda_2 = \eta^\star g + (1-\eta^\star)(\rho + \theta g)$. Equation (2.17) consists of two terms. The number of workers which are *not* employed in the imitation of northern products and their production is given by the first factor. The second factor gives the fraction of these workers employed in original southern R&D. Southern R&D employment is increasing in the level at which northern and southern inventions are protected ($\phi_N$ and $\phi_S$).[16] When protecting northern goods more strongly, imitation of these goods becomes more costly and thus becomes relatively unattractive compared to innovation, thus R&D employment increases. When protecting southern inventions more strongly, R&D employment increases for two reasons: First, imitation of southern products becomes more costly and therefore relatively less attractive compared to R&D. Second, southern R&D becomes more attractive as the risk of being imitated declines. We summarize these findings in the following proposition:

16 A sufficient (but not necessary) condition for the latter statement is that $\phi_S < \frac{2}{\Delta_1(\rho+\theta g)}$.

**Proposition 3** *An increase in the level of IPRs for northern or southern goods or an increase in the efficiency of the southern research sector (i) increases employment in the southern research sector, (ii) decreases employment in the northern research sector and (iii) decreases employment in the imitation sector which targets northern goods.*

The effects of IPR policies on the labor allocated to the imitation of southern inventions $\ell_{C_S} = \frac{\phi_S \iota_S}{g\beta} \frac{\iota_S}{\iota_S + g} \ell_R$ is explored in the numerical part (section 2.5).

### 2.4.4 Policy effects of stronger Intellectual Property Rights on wages and welfare

After analyzing how IPRs influence the southern incentives to innovate and imitate, we now look at whether these changes in incentives and labor allocation are beneficial to either of the regions. First, we look at the response of the wage differential between the two regions as a measure of their difference in development. Second, we outline the way we are going to measure changes in welfare due to IPR changes which will be quantified in the numerical section. Combining the cost-benefit conditions (2.12a) and (2.12b) with the equations for the imitation rates, we determine the relative wage between South and North $\frac{w}{w^*}$:

$$\omega = \left( \frac{1}{\beta} + \frac{1}{d\phi_N(\rho + \theta g)} - \frac{\eta^\star}{\Delta_1 \phi_S(\rho + \theta g)} \right)^{\frac{1}{\varepsilon}}. \tag{2.18}$$

The relative wage between South and North is determined by the southern research inefficiency ($\beta$) and the IPRs for northern and southern goods ($\phi_N$ and $\phi_S$). Intuitively, the more efficient the southern research sector compared to the northern one (the lower $\beta$), the lower the wage differential between the regions. The equilibrium wage reveals that the protection of northern and southern goods have different effects on how far the South is behind in terms of wages: Stronger protection of northern goods increases the wage gap, stronger protection for domestic innovators decreases the wage gap. While both IPR policies increase the cost of imitation, stronger protection for southern goods also raises the profitability of southern R&D and thus southern wages. Suppose again, that the South follows the national treatment principle and protects northern and southern innovations equally strong ($\phi_N = \phi_S = \phi$). Then differentiating (2.18) with respect to $\phi$ gives the following condition:

$$\frac{\partial \omega}{\partial \phi} \gtreqless 0 \quad \text{if} \quad \iota_S \gtreqless \iota_N. \tag{2.19}$$

This condition says that stronger IPRs increase the southern wage rate relative to the northern one if southern products are imitated at a higher rate, but decreases it if northern products are subject to higher imitation. For the national treatment case $\iota_S > \iota_N$ is fulfilled if $d > \frac{\Delta_1}{\eta^\star}$. This says that stronger IPRs decrease the wage difference between the regions only if northern products are sufficiently difficult to imitate.

**Proposition 4** *In an equilibrium with southern innovation, an increase in IPRs for southern innovations decreases the wage gap between South and North, while stronger IPRs for northern goods increase the wage gap. A simultaneous increase in IPRs for northern and southern goods decreases the wage differential between the regions only if northern innovations are sufficiently difficult to imitate.*

Finally, in order to make welfare predictions for IPR policy changes, we solve for asset holdings, consumer expenditures and the economic growth rate. The aggregate value of northern assets $A^*$ is the product of the number of non-copied northern innovations and the value of a northern innovation firm $A^* = n_R^* v_R^*$. Substituting $v_R^*$ by (2.8) yields $A^* = \xi_R^* w^* a g N^{1-\theta}$. The southern aggregate asset value $A$ consists of the sum of the values of the assets from innovating and the two kinds of imitating firms, so that it is given by $A = \left(\xi_R g \beta + \xi_{C_N} \phi_N \iota_N + \xi_{C_S} \frac{1+\gamma}{\gamma} \phi_S \iota_S\right) a w N^{1-\theta}$. It follows that per capita asset holdings in the North $a^* = A^*/\ell^*$ and the South $a = A/\ell$

are constant in equilibrium. We can then use the budget constraint of the representative consumer to determine the per capita consumption expenditure levels $e^*$ and $e$ as functions of the variety shares and wage rates. The aggregate price level is given by $P_t = N_t^{1/(1-\varepsilon)} \left(\xi_R^*(p_R^*)^{1-\varepsilon} + \xi_R(p_R)^{1-\varepsilon} + \xi_{C_N}(p_{C_N})^{1-\varepsilon} + \xi_{C_S}(p_{C_S})^{1-\varepsilon}\right)^{1/(1-\varepsilon)}$. Let $c_t^* \equiv e_t^*/P_t$ and $c_t \equiv e_t/P_t$ denote real consumption expenditure in North and South. Following Dixit and Stiglitz (1977), this measure also represents consumers' utility at time $t$; we thus have $c_t^{(*)} = u_t^{(*)}$. We solve for the equilibrium utilities of North and South using (2.1):

$$u_t^* = \frac{e_t^*}{P_t} \equiv c_t^*, \quad u_t = \frac{e_t}{P_t} \equiv c_t. \tag{2.20}$$

As nominal per capita consumption expenditure $e^{(*)}$ is constant in steady state, but the aggregate price level $P_t$ is decreasing over time, utility is growing over time. As utility is proportional to consumption expenditure when prices are held fixed it can be interpreted as real consumption growth. Thus the growth rate of the utility can be interpreted as economic growth. Real consumption growth in this model is given by $\dot{u}^*/u^* = \dot{u}/u = \dot{c}^*/c^* = \dot{c}/c = g/(\varepsilon - 1) \equiv g_c > 0$. As the steady state growth rate of real consumption in both regions is equal and independent of the policy parameters, a long-run welfare analysis of changes in the parameters of interest on welfare can be simplified to looking at changes in $c_0^*$ and $c_0$.[17] As the changes in $c_0^*$ and $c_0$ due to changes in IPRs are ambiguous, we leave the analysis of welfare changes in response to stronger IPR protection and different development stages of the southern research sector for the numerical analysis in this chapter.

[17] This approach has been taken by Gustafsson and Segerstrom (2011).

## 2.5 Numerical analysis

### 2.5.1 Calibration of the model

Providing analytical results for the effects of chances in IPR protection on certain economic outcomes proved to be unfeasible in the previous section. In this section, to analyze the effects of changes in IPR protection on real consumption levels in both regions and the allocation of labor into the imitation of southern innovations, we calibrate the model with empirically sound parameters. The main aim of this section is not to get reliable quantitative predictions of the effects of stronger IPRs, but mainly to provide a qualitative idea about their effects on welfare, as measured in real consumption, in both regions.

To calibrate the model, parameters are set to match the following target moments[18]: The real interest rate takes a value of 7% according to the average real US stock market return over the past century estimated by Mehra and Prescott (1985). This implies a subjective discount rate $\rho$ of the same value. Basu (1996) and Norrbin (1993) estimate a markup of 40% over marginal costs, determining the degree of differentiation between varieties $\alpha$ to be 0.714. The population growth rate $g_L = 0.0168$ represents the average annual world population growth rate of 1.68% between 1960-2008 reported by the World Bank World Development Indicators 2009 (World Bank, 2009). Only the ratio of population size, $\ell_0/\ell_0^*$, is relevant for the steady state equilibrium. Comparing population in middle-income to high-income coutries, this ratio is given by approximately 4.35, including low-income countries in the southern population, the ratio is about 5.27 for 2008 figures (World Bank, 2009). Due to our general notion of the South we include low-income countries and use a value of $\ell_0/\ell_0^* = 5.27$. To achieve a utility growth rate $g_c$ of about 2%, reflecting the average

[18] For the sake of comparability, we calibrate the target moments as in Gustafsson and Segerstrom (2011) when applicable.

US GDP per capita growth rate from 1950-1994 as reported in Jones (2005), we set the value of intertemporal R&D spillovers $\theta = 0.67$. Following Gustafsson and Segerstrom (2011), we aim for a cost advantage of imitators of the South of $\eta^\star = 10\%$, leading to a parameterization of $\bar{\eta} = 0.18$ and $1/\gamma = \theta$. As only the relative research difficulty determines the steady state of the model, we set $ag = 1$ to normalize the parameters. For the benchmark case, we assume a research inefficiency of the South of $\beta = 3$, which implies a three times higher R&D labor requirement. The distance parameter for imitation $d$ is set to 10. Given those values, we set the parameters for IPR protection to $\phi_N = \phi_S = 1.5$ which results in plausible imitation rates of about 2% of northern innovations and 9% of southern innovations.

### 2.5.2 Change of intellectual property rights protection for northern and southern innovations

The first simulation shows the effects of a general change in IPR protection in the South, i.e. when $\phi_N = \phi_S = \phi$. The fourth column contains the benchmark case with $\phi = 1.5$ for which the South is active in original R&D ($\ell_R > 0$) and the wage differential is such that the wide-gap case applies ($\omega < \alpha$). For lower values of $\phi$ up to the threshold value of about 1, no innovation takes place in the South as R&D incentives are too weak given the ease of imitating the North. Table 2.1 shows that the South loses from the strengthening of IPR protection both in terms of real consumption and relative wage until the innovation threshold is reached. This is due to the detrimental effect of IPR protection for northern varieties. The South relies on imitation of the North to obtain production blueprints. With higher protection, imitation employment leads to fewer imitation blueprints. The lower marginal productivity reduces wages and leads to an increase in production of each variety as their prices decline. Overall, employment shares do not change in the South up to the threshold. However, fewer varieties are produced in larger quantities for lower prices. Northern research declines slightly before and more noticeable after the threshold is passed.

| | | no innov. | | with innov. | | |
|---|---|---|---|---|---|---|
| IPR protection | $\phi_S = \phi_N$ | 0.6 | 1 | 1.1 | 1.5 | 2.25 |
| relative wage S/N | $\omega$ | 0.647 | 0.594 | 0.599 | 0.641 | 0.674 |
| imitation rate N | $\iota_N$ | 0.062 | 0.046 | 0.038 | 0.019 | 0.010 |
| imitation rate S | $\iota_S$ | 0 | 0 | 0.181 | 0.090 | 0.047 |
| innov. labor N | $\ell_R^*/\ell^*$ | 0.214 | 0.205 | 0.201 | 0.185 | 0.176 |
| fraction innov. labor S | $\ell_R/\ell$ | 0 | 0 | 0.005 | 0.029 | 0.054 |
| fracion labor imit. N | $\ell_{C_N}/\ell$ | 0.164 | 0.164 | 0.134 | 0.053 | 0.023 |
| fraction labor imit. S | $\ell_{C_S}^a/\ell$ | 0 | 0 | 0.008 | 0.027 | 0.030 |
| real cons. N | $c_0^*$ | 6.028 | 5.989 | 6.222 | 7.488 | 8.865 |
| real cons. S | $c_0$ | 4.148 | 3.743 | 3.825 | 4.609 | 5.621 |
| rel. cons. N/S | $c_0^*/c_0$ | 1.453 | 1.600 | 1.627 | 1.625 | 1.577 |

Notes: [a] sum of imitators of the South and process innovators.

Table 2.1: Changing IPR protection for northern and southern goods

Figure 2.3 shows the detailed development of research employment in the South and real consumption. The change in the labor allocation in the South is comparable to the case in which only the protection of southern innovations is improved. However, the fall in imitation of the North is more pronounced as both IPR protection levels contribute to a shift from imitation of the North to research in the South.

After an initially high imitation employment and therewith imitation rate of southern innovations, both reduce as a consequence of better protection and increased profitability of southern original R&D compared to imitation. Surprisingly, the North does not benefit from an increase in the protection of its goods before the threshold. This is due to the reduction of innovation on the one side, but more importantly due to reduced supply of lower priced imitated goods on the other side. Once the threshold is passed, both regions experience an increase in real consumption with the South starting to catch up in relative consumption.

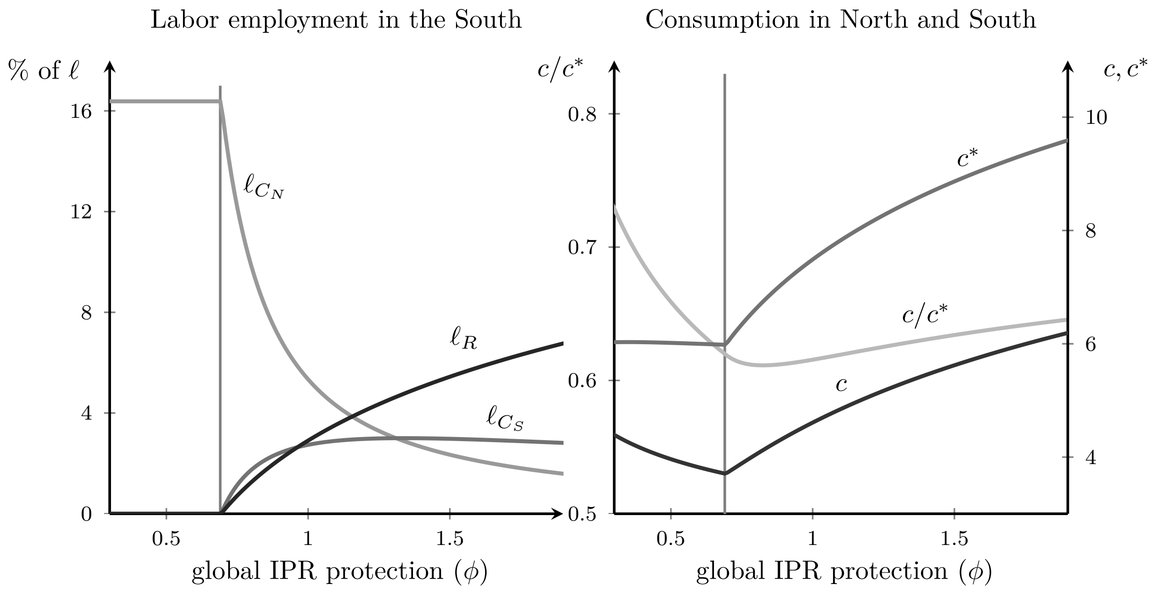


Figure 2.3: Proportionate change of IPR protection.

### 2.5.3 Change of intellectual property rights protection for southern innovations

The simulation in table 2.2 shows the change of key variables that result from changes of the level of IPR protection for southern innovations $\phi_S$ only, i.e. a deviation from the national treatment principle. As the northern IPR protection level is unchanged, the threshold has slightly decreased to about $\phi_S = 0.95$. For lower values of $\phi_S$, no innovation takes place in the South. As only southern IPR protection is varied, changes up to the threshold level do not affect the equilibrium. Once the threshold is passed, innovation in the South starts and new varieties developed in the South attract imitation. Thus labor employed in the imitation of southern goods first increases, but later declines steadily with the rise of IPR protection. At the same time, northern products are less frequently imitated as southern resources are shifted to innovation and imitation of the South. As more innovations stay in the North, its R&D employment decreases slightly.

| | | no innov. | | with innov. | | |
|---|---|---|---|---|---|---|
| IPR S innov. | $\phi_S$ | 0.75 | 0.95 | 1 | 1.5 | 1.75 |
| relative wage S/N | $\omega$ | 0.555 | 0.555 | 0.563 | 0.641 | 0.660 |
| imitation rate N | $\iota_N$ | 0.036 | 0.036 | 0.033 | 0.019 | 0.017 |
| imitation rate S | $\iota_S$ | 0 | 0 | 0.237 | 0.090 | 0.069 |
| innov. labor N | $\ell^*_R \ell^*$ | 0.199 | 0.199 | 0.197 | 0.185 | 0.183 |
| fraction innov. labor S | $\ell_R/\ell$ | 0 | 0 | 0.002 | 0.029 | 0.038 |
| fracion labor imit. N | $\ell_{C_N}/\ell$ | 0.164 | 0.164 | 0.146 | 0.053 | 0.043 |
| fraction labor imit. S | $\ell^a_{C_S}/\ell$ | 0 | 0 | 0.005 | 0.027 | 0.028 |
| real cons. N | $c^*_0$ | 5.927 | 5.927 | 6.047 | 7.488 | 7.954 |
| real cons. S | $c_0$ | 3.433 | 3.433 | 3.507 | 4.609 | 5.007 |
| rel. cons. N/S | $c^*_0/c_0$ | 1.726 | 1.726 | 1.724 | 1.625 | 1.589 |

Notes: [a] sum of imitators of the South and process innovators.

Table 2.2: Changing protection of southern goods

Figure 2.4 illustrates the development of southern research employment and real consumption in greater detail. Up to the threshold level, indicated by the gray vertical bar, changes in $\phi_S$ remain without effect. Concerning the labor employment in the South, resources are quickly withdrawn from the imitation of the North once the threshold is passed and shifted to southern innovation and imitation of the South. While employment in imitating the South[19] initially exceeds the research employment, original research eventually becomes the largest research sector in the South. Real consumption expenditure and therewith utility are positively affected by increases in $\phi_S$ above the threshold level. The North benefits from higher returns to innovation as well as more product varieties provided by the South which more than compensates the higher fraction of goods supplied monopolistically. The same holds for the South, which can catch up in relative consumption to the North.

19 Note that $\ell_{C_S}$ includes both imitators and process innovators in the graphs.

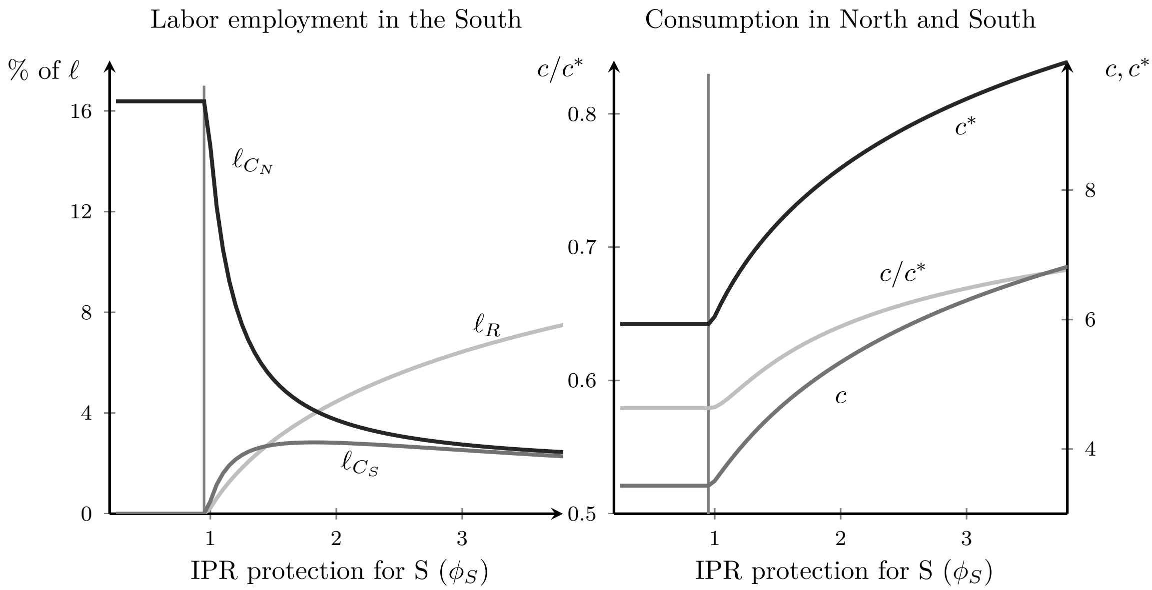


Figure 2.4: Change of protection of southern innovations.

### 2.5.4 Summary of main numerical results

The long-run consequences of a strengthening of IPRs for northern and southern innovations in the South is welfare decreasing for the South and has negligible effects for the North if the South does not engage in innovation. An increase in IPRs exclusively for southern goods is shown to have no effect on any of the regions welfare outcomes if it fails to pass the threshold level and thus fails to stimulate R&D in the South. With southern innovation, stronger IPRs for both northern and southern goods are related to higher welfare in both regions. Finally, a deviation of the South from the national treatment principle by raising IPR standards exclusively for domestic firms raises welfare in *both* regions by shifting the southern resources away from imitation to original innovation.

## 2.6 Concluding Remarks

This chapter gives a theoretical explanation for the empirically observed threshold level in the relationship between IPRs and innovative activity. To explain this relationship, we account for the increased R&D efforts by developing countries and extend the previous literature to allow not only for southern R&D and imitation of northern goods, but also for imitation of southern inventions. Further, to analyze the effects of southern IPR policies deviating from the national treatment principle (by raising IPRs for southern goods more strongly than for northern goods), we allow for different degrees of IPR protection for northern and southern varieties.

We show that for low levels of IPRs and low research efficiency in the South, southern R&D does not take place. The model therefore nests the results of "standard" North-South models for the no-innovation case: If IPRs are strengthened in this stage of southern development, they do not stimulate R&D and decrease wages and welfare in the South. However, in accordance with the empirically observed patterns, we show that if IPRs surpass a critical level, they help to spur innovation in the South and increase welfare in both regions. The critical IPR level depends on the southern R&D efficiency and labor resources such that large countries or countries with a high research efficiency engage in R&D even under relatively weak protection. Likewise, to stimulate an inefficient R&D sector in a small country, IPRs have to be very strong.

We show that the protection of southern and northern innovations can work as imperfect substitutes in encouraging southern R&D though they work via different channels: While the protection of southern innovations affects expected profits from R&D directly, stronger protection of northern goods achieves this effect mainly by making the imitation of northern goods more expensive. Finally, we can show that an increase of IPRs exclusively for southern goods does not harm any region in the no-innovation case. However, if southern R&D takes place, such a policy benefits both regions by increasing the southern innovation incentives and thus shifting its resources away from the imitation of northern goods.

# Chapter 3

# The Dual Role of Intellectual Property Rights under Imitation and Innovation Driven Development*

## 3.1 Introduction

For many former developing countries initial phases of high imitation and weak intellectual property rights (IPRs) provided the possibility to adopt foreign technologies and gain experience from reverse engineering. In Japan, weak intellectual property protection was chosen as a policy instrument to facilitate the adoption of foreign technologies in order to develop a domestic R&D sector: The exclusion of certain products such as food, beverage and pharmaceutical products from patenting as well

* I would like to thank Theo Eicher, Matthias Doepke, Gerhard Illing and Christian Lorenczik for many helpful comments and suggestions. This chapter has also greatly benefited from several comments made by seminar participants at the Ludwig-Maximilians-University Munich and University of Washington, Seattle.

as the application of utility models, compulsory licenses and the first-to-apply system created a climate of weak protection for foreign innovators, but helped domestic firms to acquire foreign knowledge through imitation (Kumar, 2003). Only in the mid 1970s, when the research sector was sufficiently developed, product patents for chemicals and pharmaceuticals were introduced (Kawaura and La Croix, 1995). Today, Japan is one of the world's top innovators; it accounted for about 16% of world gross expenditures on R&D (GERD) in 2008 (3.4% of Japan's GDP) and its number of researchers per million inhabitants was as high as 5,573 in 2007 (UNESCO, 2010; OECD, 2010).[20] Many developing and emerging countries have followed or are currently following a path similar to the one demonstrated by Japan. Taiwan and South Korea followed a similar path of maintaining a weak IPR system which helped them to obtain relevant know-how through imitation (Kim, 2001; Kumar, 2003). South Korea targets a GERD share in GDP of 5% for 2012 and achieved 3.4% in 2008; it inhabited 4,627 researchers per million inhabitants in 2007 (OECD, 2010; UNESCO, 2010). Taiwan's share of GERD in GDP was 2.6% in 2007 (OECD, 2009). Glass (2010) presents similar statistics obtained from the International Institute for Management Development (2009) and argues that trends similar to Japan's path can be observed increasingly also for China, Indonesia, Malaysia and Thailand.

While imitation can be a "stepping stone to innovation" (Glass, 2010) at early stages of development, the empirical evidence suggests that Intellectual Property Rights (IPRs) are related to higher growth for countries in which the original research activity is sufficiently high, i.e. a significantly sized research sector exists (Ginarte and Park, 1997; Kim et al., 2011).[21] Maskus (2000) finds a U-shaped relationship

[20] These figures compare to 2.7% GERD in GDP and 4,707 researchers per million inhabitants for the United States of America.

[21] Ginarte and Park (1997) argue that the effects of IPRs on growth realize mainly through the incentives they create for R&D, such that IPRs are positively related to growth for developed countries, but do not have an effect on growth in developing countries in which the research sectors' sizes are insignificant. Kim et al. (2011) argue that patent rights enhance innovation and growth in countries which have the capacity to innovate, but a system which protects incremental innovations is more appropriate in countries in which this capacity is missing.

between a country's level of IPR protection and development, and Chen and Puttitanun (2005) find that IPRs have a positive impact on innovation, but that a country's optimal level of IPRs depends on its level of development.

In this chapter, I propose a model of international trade between developed and developing countries ("North" and "South") which is consistent with the above empirical findings. To this end, I incorporate a southern R&D sector and a learning channel into a standard North-South increasing variety model of non-scale growth. In particular, I let the development of the southern research sector be endogenously determined by the degree of innovative and imitative activity in the South.

The results suggest that for countries with research costs above a threshold level multiple equilibria associated with different emphases on imitative and innovate activities in the South can exist. I show that the same level of IPRs can be associated with an either high or low level of development depending on the country's R&D specialization: In the innovation equilibrium, the welfare in the South is high, southern firms efficiently invent a large number of varieties, northern firms face a low risk of imitation, and the number of available varieties in the world is high. In contrast, the imitation equilibrium is characterized by a southern focus on adopting northern varieties, the southern research sector is less efficient, the welfare in the South is low, and the number of available varieties on the world market is small.

Higher levels of IPRs are associated with larger differences between the equilibria: In the innovation equilibrium, an increase in IPRs increases the incentives to conduct own R&D via two channels: First, it makes imitation more costly relative to innovation. Second, by raising the research activity, it creates learning spillovers from own R&D. These spillovers overcompensate the loss of spillovers from imitation. Consequently, IPRs accompany higher R&D and welfare in that scenario. In the imitation equilibrium, however, the loss in imitation spillovers is not compensated by the initial gain in R&D related knowledge, so that the cost of innovation increases, the final effect on research is negative, and welfare is affected negatively.

The next section relates this chapter and its results to the literature. Section 3.3 presents the model which is solved in section 3.4. Section 3.5 then analyzes the effects of stronger IPRs on innovation, imitation and research efficiency, and section 3.6 numerically analyzes the impact of IPRs on welfare. Section 3.7 concludes.

## 3.2 Related literature

The model presented in this chapter is closely related to the literature which analyzes the trade-off between imitation and innovation in developing countries. Rather than analyzing the conflicting interests between North and South in the protection of intellectual property as done in the seminal models by Helpman (1993), Deardorff (1992), Segerstrom et al. (1990) and Grossman and Helpman (1991a,b), this literature is interested in policies which help developing countries to catch up to developed ones not only in welfare, but also in their R&D activity. Consequently, this literature relaxes the previous restriction of the South to imitation and the assumption that all innovation is conducted in the North.

Currie et al. (1999) analyze the effects of subsidies on southern economies at different stages of development. While IPRs are not treated explicitly in their analysis, they argue that subsidies to imitation have qualitatively the same effect as a loosening in IPRs. Following this argument, an increase in IPRs would increase the world rate of innovation and stimulate southern research activity if the South engages in both imitation and innovation. Chapter 2 augmented this analysis by introducing the imitation of southern goods and showed that stronger IPRs are associated with more southern R&D and higher welfare if they surpass a threshold level. This threshold level was shown to be decreasing in the southern research efficiency: If southern research is inefficient, then an increase in IPRs fails to stimulate R&D and decreases welfare. However, the southern research efficiency which determines the IPR threshold level in chapter 2 of this thesis and implicitly whether the South is a pure imitator or both imitator and innovator in Currie et al. (1999), is exogenous in both models.

To account for the fact that imitation can increase the knowledge transfer from North to South and therefore encourage innovation, Glass (2010) presents a product cycle model in which a given fraction of industries in the South has to engage in imitation before they are able to conduct original R&D. While not treating the effects of increases in IPRs explicitly, she shows that a general subsidy to the South (to both innovation and imitation sector) increases the rate of innovation.

My model combines the approaches by Currie et al. (1999) and chapter 2 with the one by Glass (2010) by endogenizing the southern R&D efficiency. Like Glass (2010), I account for the idea that imitation can increase the southern innovative capability, but I additionally introduce own R&D efforts as a source of efficiency gains. I thereby endogenously capture the idea that the R&D enhancing effect of imitation becomes less important if the own R&D sector becomes large. Consequently, I am able to analyze the effects of IPRs on both, imitation and innovation focused countries, while the model by Glass is more suitable for the former case.

The results of my model relate to the ones obtained in the literature on endogenous IPRs. Eicher and García-Peñalosa (2008) show in a closed economy set-up that if R&D firms face the costs of enforcing their intellectual property, multiple equilibria with different levels of R&D and institutions (IPRs) can exist. As IPRs emerge from innovators' incentives to protect their returns to innovation, higher research is related to higher levels of IPRs. While imitation decreases the expected returns to innovation in their model, in my model, imitation can additionally raise the incentive to conduct R&D through a learning channel. Consequently IPRs can decrease the innovation incentives in my model and are thus not necessarily associated with higher

R&D levels. Chen and Puttitanun (2005) model the trade-off between facilitating technology adoption and encouraging original R&D in a developing county's choice of IPRs to explain the U-shaped relationship between a country's level of development and IPRs. While I try to explain the same pattern in the data, my model treats the relationship between IPRs from a different perspective: Whilst the causation in Chen and Puttitanun (2005) goes from the level of development to the strength of IPRs in a country, my theory explains how the same levels of IPRs can cause different levels of development.

## 3.3 Model

### 3.3.1 General set-up

Developed and developing countries are represented by two regions in this model: the North and the South. Firms in North and South hire labor for the production of consumption goods as well as for innovation and imitation. The two regions differ in their R&D activities. The North engages only in innovation and is subject to imitation by the South. The South imitates the North, engages in innovation and is not subject to imitation. As long as a northern variety has not been copied, its production takes place in the North, and the innovating firm charges the monopoly price on the global market. Once a northern variety has been copied by the South, its production shifts to the South and the northern firm shuts down. Labor is perfectly mobile within all sectors across one region, but immobile between the regions such that the same wage rate is paid to all workers within each region. Finally, trade between North and South is costless.

### 3.3.2 Households

Each region is endowed with a fixed number of households the size of which grows at a constant rate $g_L$ so that the population size in North and South at time $t$ is $\ell_t^* = l_0^* e^{g_L t}$ and $\ell_t = l_0 e^{g_L t}$. Throughout the model northern variables are indicated with a star. As households in both regions are symmetric in their preferences and face the same maximization problem, I restrict the outline to the southern households' problem in the following. Each member of the household is endowed with one unit of labor which he supplies inelastically to the labor market and earns a wage rate $w$. Agents maximize their life time utility which arises from the consumption of a basket of $N_t$ different varieties available on the world market in each period:

$$U(t) = \int_t^\infty e^{-(\rho - g_L)t} \ln u(t) dt, \qquad u(t) = \left[ \int_0^{N_t} x_{j,t}^\alpha dj \right]^{\frac{1}{\alpha}}. \tag{3.1}$$

$\rho$ it the rate of time preference and $g_L < \rho$; $x_{j,t}$ is the per capita quantity demanded of variety $j$, $\alpha$ is a measure of the degree of product differentiation, and $\varepsilon = \frac{1}{1-\alpha}$ is the intertemporal elasticity of substitution. Agents face the budget constraint $\dot{a}_t = (r_t - g_L)a_t + w_t - c_t$ which equates the change in per capita asset holdings $a_t$ to the sum of income from interest payments $r_t$ (adjusted by population growth $g_L$) and wage income $w$ minus per capita consumption expenditures $c_t$. Maximizing (3.1) subject to the income constraint yields the average demand by the world consumer for variety $j$:

$$\bar{x}_t(j) = \frac{\bar{c}_t}{P_t} \left( \frac{p_t(j)}{P_t} \right)^{-\varepsilon}. \tag{3.2}$$

In this equation, average consumption expenditures are $\bar{c}_t = \frac{c_t \ell_t + c_t^* \ell_t^*}{L_t}$ with $L_t = \ell_t + \ell_t^*$, and the price index is defined as $P_t = \left[ \int\limits_0^{N_t} p(i)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$. Consumption expenditures in North and South grow at the rate $\frac{\dot{c}_t^*}{c_t^*} = r_t^* - \rho$ and $\frac{\dot{c}_t}{c_t} = r_t - \rho$, respectively. This means that northern (southern) per-capita consumption expenditures $c_t^*$ ($c_t$) grow over time only if the market interest rate $r_t^*$ ($r_t$) exceeds the individual discount rate $\rho$.

### 3.3.3 Innovation

Innovation takes place in both regions. The total number of varieties invented in the North (not imitated plus already imitated by the South) is $n_{R_t}^* + n_{C_t}$. As southern innovations do not face the risk of being imitated, the number of varieties invented in the South is simply $n_{R_t}$. Thus the total number of varieties $N_t$ available on the world market is given by:

$$N_t = n_{R_t}^* + n_{C_t} + n_{R_t}. \tag{3.3}$$

Before a new variety can be produced, R&D firms in both regions have to hire researchers $\ell_{R_t}^*$ and $\ell_{R_t}$ for the development of the research blueprint. Northern and southern researchers invent new varieties according to the following R&D functions:

$$\dot{n}_{R_t}^* + \dot{n}_{C_t} = \frac{N_t^\theta}{a_R^*} \ell_{R_t}^* \tag{3.4a}$$

$$\dot{n}_{R_t} = \frac{N_t^\theta}{a_R \beta_t} \ell_{R_t}. \tag{3.4b}$$

$a_R^*$ and $a_R$ are the northern and southern R&D cost parameters. The knowledge capital used in the innovation process $N_t^\theta$ is an increasing function of the number of existing varieties in which the intertemporal knowledge spillover parameter $\theta$ is restricted to $0 < \theta < 1$ so that knowledge spillovers become weaker over time. While the knowledge capital is available to both regions, North and South differ in their ability to efficiently use it. In particular, the development of the southern research sector $1/\beta_t$ is endogenized by letting southern R&D firms benefit from the research environment in their region:

$$\frac{1}{\beta_t} = \frac{n_{R_t} + \phi n_{C_t}}{N_t}, \qquad \phi < 1. \tag{3.5}$$

This R&D efficiency function captures the following aspects: If the South's share in world innovation is high, the South is relatively more experienced in conducting own R&D and more familiar with existing technologies which leads to a more efficient use of the available world knowledge capital $N_t^{\theta}$. Further, the function also accounts for an efficiency gain from imitation: The more the South engages in reverse engineering, the more it is familiar with existing innovations and the easier is original R&D. However, knowledge creation is just a by-product of imitation so that the research efficiency benefits less from imitation than from original R&D ($\phi < 1$).

In the production of non-copied varieties, one unit of labor produces one unit of output. Innovators in both regions maximize profits $\pi^*_{R_t} = (p^*_{R_t} - w^*_t)\bar{x}^*_{R_t} L_t$ and $\pi_{R_t} = (p_{R_t} - w_t)\bar{x}_{R_t} L_t$ subject to the demand function (3.2). They charge a constant mark-up over marginal costs and earn monopoly profits as long as they are not copied:

$$p^*_R = \frac{w^*_t}{\alpha}, \quad \pi^*_R = \frac{1-\alpha}{\alpha} w^*_t \bar{x}^*_{R_t} L_t \tag{3.6a}$$

$$p_R = \frac{w_t}{\alpha}, \quad \pi_R = \frac{1-\alpha}{\alpha} w_t \bar{x}_{R_t} L_t. \tag{3.6b}$$

If an innovator is copied, he shuts down his firm and earns zero profits.

### 3.3.4 Imitation

Before an imitated variety can be produced, imitation firms have to hire workers who engage in reverse engineering. In modeling imitation as a costly activity I follow Mansfield et al. (1981) who report that the costs of imitation are on average as high as 65% of the cost of innovation and that it takes 70% of the original innovation time to imitate an innovation. Reverse engeneering is easier the more non-copied goods are currently available $(n^*_{R_t})^\theta$ as imitators are likely to target the most technologically advanced innovations the latest. This modelling approach is in the spirit of the model by Van Elkan (1996) in which imitation is easier the larger the difference between the total number of innovations and already copied goods. However, as southern inventions are not subject to imitation in my model, it is more intuitive to define this distance as the number of northern innovations minus copied northern innovations which is $n^*_{R_t}$. The imitation function is thus given by:

$$\dot{n}_{C_t} = \frac{(n^*_{R_t})^\theta}{a_C \beta_t} \ell_{C_t}. \tag{3.7}$$

The parameter $a_C$ captures the cost of imitation and is interpreted as the strength of intellectual property rights protection. The efficiency of the imitation sector should also benefit from the innovation environment in the country: if workers are able to better use the world knowledge capital in the innovation process, it should be also easier for them to discover how already existing varieties are constructed. Consequently, I let the R&D efficiency function $1/\beta_t$ as defined in (3.5) enter the imitation function.

In the production of copied varieties, one unit of labor also produces one unit of output.[22] Imitation of northern products takes advantage of the relatively low wage rate in the South, such that by limit pricing the imitator can expel the innovator from the market. I solve the model for an equilibrium in which the southern wage rate is

22 In a previous version of the model, the model was solved under the assumption that production in the imitation sector is less efficient than in the innovation sector because one can argue that the imitator does not have access to the original blueprint and no support from the R&D firm to optimize the production process (Eicher and García-Peñalosa (2008)). This assumption guarantees that the profits from imitation are lower than those from innovation, and so will be the cost of developing the imitation blueprint in equilibrium. However, as none of the results change without this inefficiency assumption, I relaxed it in favor of an improved tractability of the model.

lower than the northern one: $w^* > w$. If the wage difference is high, i.e. $w^* > w/\alpha$, the imitator's monopoly price is lower than the innovators marginal cost, so that the innovating firm has to shut down as soon as it is imitated. If the wage difference is small, i.e. $w^* < w/\alpha$, it would be profit maximizing for the imitator to engage in limit pricing and charge the innovator's marginal cost. Following Gustafsson and Segerstrom (2010) I assume that the reversal of the decision to shut down a firm is costly and that the maintenance of production facilities in the case of zero sales incurs a positive cost. Consequently, it is profit maximizing for the northern firm to shut down immediately once it is imitated. As a result, in both cases, southern imitators maximize profits $\pi_{C_t} = (p_{C_t} - w_t)\bar{x}_{R_t} L_t$ subject to the demand function (3.2) and earn the following monopoly prices and profits:

$$p_{C_t} = \frac{w_t}{\alpha}, \quad \pi_{C_t} = \frac{1-\alpha}{\alpha} w_t \bar{x}_{C_t} L_t. \tag{3.8}$$

Southern innovations are not subject to imitation, because neither the North nor the South have an advantage in production costs which gives the incentive for imitation.[23]

### 3.3.5 Financial sectors

The value of an R&D or imitation firm $v_{R_t}$, $v^*_{R_t}$ or $v_C$ is given by its expected discounted profits. As there is free entry into R&D and imitation, these expected discounted profits have to be equal to the cost of the respective activity. This cost is the wage paid to the innovators and reverse engineers. Using (3.4) and (3.7) to determine the amount of labor required to develop one blueprint yields the following

[23] To explicitly analyze the increase in incentives the southern R&D sector gains from stronger IPRs, chapter 2 relaxed this assumption by introducing process innovation into a similar framework. As the focus of this chapter is the analysis of the effects of IPRs on knowledge spillovers from North to South, the imitation of southern products would not add much to analysis, but make the model less tractable. It is thus not considered in this chapter.

firm values:

$$v^*_{R_t} = \frac{a^*_R}{N_t^\theta} w^*_t \tag{3.9a}$$

$$v_{R_t} = \frac{a_R \beta_t}{N_t^\theta} w_t \tag{3.9b}$$

$$v_{C_t} = \frac{a_C \beta_t}{(n^*_t)^\theta} w_t. \tag{3.9c}$$

There is perfect capital mobility between the innovation and imitation sectors within one region, but financial autarky in North and South. Agents in the North choose between holding the market portfolio with return $r^*_t$ and holding shares of the northern innovation firms which pay a return $\pi^*_{R_t}/v^*_{R_t}$. The return to innovation has to be adjusted by the change in the value of the firm $\dot{v}^*_{R_t}/v^*_{R_t}$ and the risk of being copied $\iota_t = \dot{n}_{C_t}/n^*_{R_t}$. Southern agents choose between gaining the market rate $r_t$ and holding shares of southern innovation or imitation firms. Southern returns to innovation $\pi_{R_t}/v_{R_t}$ and imitation $\pi_{C_t}/v_{C_t}$ are adjusted by the firm value changes $\dot{v}_{R_t}/v_{R_t}$ and $\dot{v}_{R_t}/v_{R_t}$. No-arbitrage within these choices in each region implies the following conditions for North and South:

$$r^*_t = \frac{\pi^*_{R_t}}{v^*_{R_t}} + \frac{\dot{v}^*_{R_t}}{v^*_{R_t}} - \frac{\dot{n}_{C_t}}{n^*_{R_t}} \tag{3.10a}$$

$$r_t = \frac{\pi_{R_t}}{v_{R_t}} + \frac{\dot{v}_{R_t}}{v_{R_t}} = \frac{\pi_{C_t}}{v_{C_t}} + \frac{\dot{v}_{C_t}}{v_{C_t}}. \tag{3.10b}$$

### 3.3.6 Labor markets

Finally, labor market clearing requires $\ell^*_t = \ell^*_{R_t} + \ell^*_{Y_t}$ for the North and $\ell_t = \ell_{R_t} + \ell_{C_t} + \ell_{Y_t}$ for the South, in which $\ell^*_{Y_t}$ and $\ell_{Y_t}$ represent the employment in the production sectors in North and South. Using the innovation and imitation functions (3.4) and (3.7) to determine the labor requirement for the development of one innovation or imitation blueprint, these labor market clearing conditions can be written as:

$$\ell_t^* = (\dot{n}_{R_t}^* + \dot{n}_{C_t})\frac{a_R^*}{n_t^\theta} + n_{R_t}^* \bar{x}_{R_t}^* L_t \tag{3.11a}$$

$$\ell_t = \dot{n}_{R_t}\frac{a_R \beta_t}{n_t^\theta} + \dot{n}_{C_t}\frac{a_C \beta_t}{(n_{R_t}^*)^\theta} + (n_{R_t}\bar{x}_{R_t} + n_{C_t}\bar{x}_{C_t})L_t. \tag{3.11b}$$

The conditions say that the total labor force is allocated into innovation and production in the North and into innovation, imitation and production in the South.

## 3.4 Balanced growth path

### 3.4.1 Definition of an equilibrium

In this model, an equilibrium (balanced growth path) consists of wages in North and South and prices for the different varieties such that the allocation of (1) labor into innovation and production in the North and innovation, imitation and production in the South, (2) the number of varieties invented by both regions and imitated by the South and (3) the amount of these varieties demanded by households and supplied by firms solves (A) the households' utility maximization problem and (B) the firms' profit maximization problem. Labor, goods and financial markets have to clear given free entry into innovation and imitation in both regions.

On a balanced growth path, the variety shares $\xi_R^* = n_{R_t}^*/N_t$, $\xi_R = n_{R_t}/N_t$ and $\xi_C = n_{C_t}/N_t$, the shares of labor allocated into the different sectors in North ($\ell_{R_t}^*/\ell_t^*$, $\ell_{Y_t}^*/\ell_t^*$) and South ($\ell_{R_t}/\ell_t$, $\ell_{C_t}/\ell_t$, $\ell_{Y_t}/\ell_t$), the South-North wage ratio $\omega = w/w^*$, the imitation rate $\iota = \dot{n}_{C_t}/n_{R_t}^*$ and per capita consumption expenditures $c^*$ and $c$ are constant. Constant consumption expenditures imply that the risk free rates $r$ and $r^*$ are equal to the rate of time preference $\rho$ in equilibrium. Constant variety shares imply that the number of each kind of variety grows at the same constant rate $g$.

When dividing the northern or southern innovation function by the total number of varieties $N_t$ it thus follows that the equilibrium world growth rate is given by:

$$\frac{\dot{N}_t}{N_t} = \frac{\dot{n}^*_{R_t}}{n^*_{R_t}} = \frac{\dot{n}_{R_t}}{n_{R_t}} = \frac{\dot{n}_{C_t}}{n_{C_t}} = \frac{g_L}{1-\theta} \equiv g. \tag{3.12}$$

As the knowledge spillover parameter $\theta$ is smaller than one, the growth rate is positive. From the semi-endogenous growth rate (3.12) follows that policy changes do not have a long-run effect on growth.

### 3.4.2 Equilibrium characteristics

As there is free entry into R&D and imitation in both regions, the expected profits from selling a variety have to be equal to the cost of developing its blueprint and thus the firm values given in (3.9). As all varieties grow at a constant rate, (3.9) implies that the firm values grow at the rate $-\theta g$. Using these facts in the no-arbitrage conditions (3.10), rearranging with respect to the firm values and equating with (3.9) gives the cost-benefit conditions for innovation in the North (3.13a) and innovation and imitation in the South (3.13b) and (3.13c):

$$\frac{\pi^*_{R_t}}{\rho + \theta g + \iota} = \frac{a^*_R}{N_t^\theta} w^* \tag{3.13a}$$

$$\frac{\pi_{R_t}}{\rho + \theta g} = \frac{a_R \beta}{N_t^\theta} w \tag{3.13b}$$

$$\frac{\pi_{C_t}}{\rho + \theta g} = \frac{a_C \beta}{(n^*_{R_t})^\theta} w. \tag{3.13c}$$

The left-hand sides of the relations represent the benefit (appropriately discounted profits from innovation or imitation), while the right-hand sides represent the cost of the respective activities (wages paid to researchers and reverse engineers for the development of one blueprint). If the research efficiency $1/\beta$ was exogenous, then the effect of strengthening IPRs would clearly increase the costs of imitation and therefore make southern innovation comparatively more attractive. Note, however, that $1/\beta$ is a function of the imitative and innovative activity in the South, so that we cannot immediately infer from the cost-benefit condition whether stronger IPRs make imitation less attractive compared to innovation.

The relative demands for the different kinds of goods can be obtained from the demand equation (3.2). The demand for non-copied northern innovations relative to southern innovations is $\bar{x}^*_{R_t}/\bar{x}_{R_t} = (w^*/w)^{-\varepsilon} = \omega^\varepsilon$ and thus depends on the relative wage between South and North. The demand for southern innovations relative to imitations is $\bar{x}_{R_t}/\bar{x}_{C_t} = 1$. Substituting the profits (3.6b) and (3.8) into the southern cost-benefit conditions (3.13b) and (3.13c) and combining them gives the share of non-copied northern inventions in all varieties $n^*_{R_t}/N_t = \xi^*_R$:

$$\xi^*_R = \left(\frac{a_C}{a_R}\right)^{\frac{1}{\theta}} \equiv R. \tag{3.14}$$

As the sum of the different variety shares has to add up to one, $1 = \xi^*_R + \xi_C + \xi^*_R$, the share of varieties produced in the South (own inventions and copied northern goods) is

$$\xi_R + \xi_C = 1 - R. \tag{3.15}$$

In a next step, I obtain the production quantity for a non-copied northern good $\bar{x}^*_{R_t} L_t$ from inserting the profit equation (3.6a) into the northern cost-benefit condition (3.13a) and use the resulting relation $\bar{x}^*_{R_t} L_t = \frac{\alpha}{1-\alpha}\frac{a^*_R}{N^\theta_t}(\rho + \theta g + \iota)$ in the northern labor market clearing condition (3.11a). Substituting for the imitation rate by $\iota = \dot{n}_C/n^*_R = g\xi_C/\xi^*_R = g\frac{1-\xi_R-R}{R}$ and dividing the resulting equation by the northern labor force $\ell^*_t$ then yields the following equilibrium relationship:

$$\delta = \frac{1-\alpha}{a^*_R\Big(g(1-\xi_R) + \alpha R(\rho - g_L)\Big)}, \tag{3.16}$$

in which $\delta$ is a measure of product variety and is defined as

$$\delta = \frac{N_t^{1-\theta}}{\ell_t^*}. \tag{3.17}$$

$\delta$ relates the difficulty of conducting research $1/N_t^{\theta}$ to the relative market size $N_t/\ell_t^*$ and is constant in equilibrium.[24] Equation (3.16) is the first equilibrium condition in $\delta$ and the share of southern inventions in the total number of varieties $\xi_R$. It yields a positive relationship between the two variables. As $\delta$ is an increasing function of the total number of varieties $N_t$ and the labor force size is exogenous, this means that the number of varieties is higher the stronger the South's focus on innovation. As expression (3.16) is derived from the northern labor market clearing condition, this positive effect is driven by the increase of northern innovation incentives: If the southern research share increases, southern agents focus more on original R&D than on imitation so that the share of copied goods and the imitation rate decrease and the expected profits from northern innovation rise.

To analyze the second equilibrium condition, I insert the production quantities $\bar{x}_{R_t} L_t$ and $\bar{x}_{C_t} L_t$ obtained from the southern cost-benefit conditions into the southern labor market clearing condition (3.11b). Substituting for the research efficiency $1/\beta$ from (3.5), rewriting the imitation rate and dividing the resulting expression by the size of the northern labor force $\ell_t^*$ gives:

$$\delta = \frac{(1-\alpha)}{\Delta} \frac{\ell_t}{\ell_t^*} \frac{(1-\phi)\xi_R + \phi(1-R)}{a_R(1-R)}, \tag{3.18}$$

in which $\Delta = (1-\alpha)g + \alpha(\rho + \theta g)$. This second equilibrium condition also yields a positive relationship between the measure of product variety $\delta$ and the southern research share $\xi_R$. As the expression is derived from the southern labor market

24 See Gustafsson and Segerstrom (2011) for a more detailed introduction of $\delta$. Gustafsson and Segerstrom (2011) refer to $\delta$ as the relative research difficulty in their paper. In the context of my work, I find it more intuitive to label $\delta$ as the measure of product variety so that it cannot be confused with the research efficiency $1/\beta$.

clearing condition, the effect results from the positive impact of the innovation share on the southern R&D efficiency which raises the incentives for the South to invent new varieties.

Figure 3.1 illustrates the two equilibrium conditions and reveals the possibility of multiple equilibria. Equating the two equilibrium conditions gives the solution for

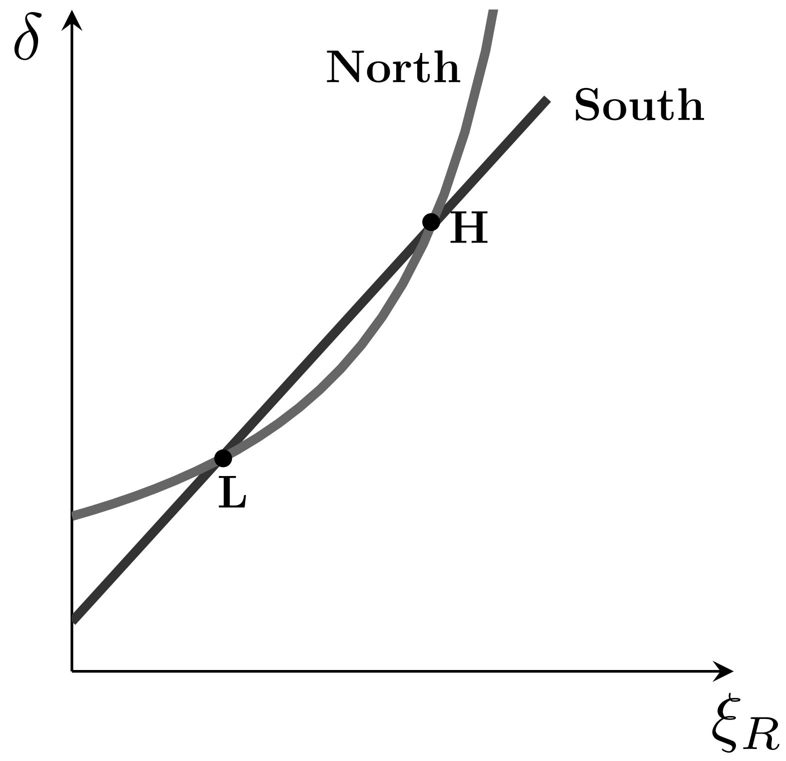


Figure 3.1: Southern research share $\xi_R$ and measure of product variety $\delta$. $L$ refers to the imitation equilibrium, $H$ refers to the innovation equilibrium.

the equilibrium southern research share(s) $\xi_R$:

$$\xi_R^2 = \left(\frac{1-\phi(2-R)}{1-\phi} + \alpha R \frac{\rho - g_L}{g}\right)\xi_R - \frac{1-R}{1-\phi}\left(\frac{a_R}{a_R^*}\frac{\Delta}{g}\frac{\ell_t^*}{\ell} - \phi\Big(\alpha R \frac{\rho - g_L}{g} + 1\Big)\right). \tag{3.19}$$

This quadratic equation can yield none, one or two solutions associated with a positive southern research share $\xi_R$. As the aim of this chapter is to relate IPRs to different stages of innovative activity and development in a country, I will focus on the multiple solution case in the following. Equation (3.19) has two positive solutions or no solution if the following condition is satisfied:

$$\frac{\frac{a_R}{a_R^*}\Delta\frac{\ell_t^*}{\ell_t}}{g+\alpha\left(\frac{a_C}{a_R}\right)^{\frac{1}{\theta}}(\rho-g_L)} > \phi. \tag{3.20}$$

This condition says that the following factors favor the possibility of multiple equilibria (balanced growth paths) in this model: (1) An inefficient southern research sector (high $a_R$), (2) low initial IPRs (low $a_C$), (3) a relatively small southern labor force (small $\ell_t$) and (4) small learning effects from imitation (small $\phi$). This is equivalent to saying that for given labor force sizes, learning efficiency from imitation, level of IPRs and northern R&D efficiency, there exists an innovation inefficiency threshold for the South $\bar{a}_R$.[25] If this research inefficiency threshold is surpassed (i.e. $a_R > \bar{a}_R$), the model yields multiple equilibria. The inefficiency threshold is higher the stronger IPRs, the larger the southern labor force and the less effective learning from imitation. If condition (3.20) is fulfilled, then a sufficient condition for two positive equilibria to exist is $\frac{1}{2-R} > \phi$.[26]

For the case in which the multiple equilibria condition (3.20) is not satisfied, the equilibrium with the lower southern innovation share ceases and only the equilibrium with the higher innovation share prevails. This means that for a South which does not face high research costs ($a_R < \bar{a}_R$) there exists a unique equilibrium with a higher southern research share. It is important to note that, as $a_C < a_R$ by (3.14), the equilibrium with low R&D activity cannot be ruled out by simply setting the level of IPRs $a_C$ at a very high level: For the highest possible value of $a_C$, the denominator in (3.20) becomes $g+\alpha(\rho-g_L)$, so that the equilibrium with the lower

[25] This can be seen by rewriting condition (3.20) as $\left(\frac{a_R}{a_C}\right)^{1/\theta}\left(\frac{a_R}{a_R^*}\Delta\frac{\ell^*}{\ell}-\phi g\right) > \phi\alpha(\rho-g_L)$. The left-hand side of this expression is increasing in $a_R$ so that for sufficiently large $a_R = \bar{a}_R$ condition (3.20) is fulfilled.

[26] Naturally, the only interesting solutions are those in which the other variety shares are non-negative as well, so that from (3.15) follows $\xi_R < (1-R)$ which I assume to be true in the following.

research share is still possible if southern R&D is very costly.

**Proposition 1***(i) If southern research is sufficiently costly ($a_R > \bar{a}_R$), the model features two equilibria associated with positive southern research activity. (ii) The inefficiency threshold $\bar{a}_R$ is increasing in the strength of IPR protection, in the size of the southern labor force and the northern research costs; it is decreasing in the intensity of learning from imitation.*

What are the characteristics of these two equilibria in terms of the economic outcomes? As both equilibrium conditions are increasing functions in $\xi_R$, the equilibrium with the high southern research share $\xi_R$ is associated with a high measure of product variety $\delta$. It is thus labeled as the "innovation equilibrium" (see intersection $H$ in figure 3.1). In the equilibrium in which $\xi_R$ is low, the product variety is also low. As the share of goods produced in the South $1 - R$ is the same in both equilibria, the second equilibrium is associated with a higher share of imitated goods than the innovation equilibrium and is therefore labeled "imitation equilibrium" (see intersection $L$ in figure 3.1). Whilst the share of goods produced in the North $\xi_R^*$ is thus the same in both equilibria, the South specializes in innovation or imitation. If it specializes in innovation (higher $\xi_R$, lower $\xi_C$), the absolute number of non-copied northern varieties and southern inventions will be higher in every period on the balanced growth path.[27] If it specializes in imitation (lower $\xi_R$, higher $\xi_C$), then these numbers will be smaller.

The southern research efficiency is given by $1/\beta = (1 - \phi)\xi_R + \phi(1 - R)$ in equilibrium. From this relation follows that the South's research efficiency is higher in the innovation equilibrium and lower in the imitation equilibrium.

[27] This follows from the fact that a higher southern research share $\xi_R$ is associated with a higher measure of product variety $\delta$ and thus with a higher total number of varieties $N_t$ in every period.

I now turn to the determination of the remaining important variables of the model. The relative wage rate $\omega = w/w^*$ between South and North is an indicator of how close the two regions are in their development. It is obtained by combining the northern cost-benefit condition (3.13a) with one of the southern cost-benefit conditions. Substituting for the research efficiency $1/\beta$ from (3.5) and the shares of copied and non-copied northern goods $\xi_C$ and $\xi_R^*$ from (3.14) and (3.15) gives an expression for the relative wage between South and North $\omega$ and the share of southern innovations $\xi_R$:

$$(\rho + \theta g)\omega^{\varepsilon} = \frac{a_R^*}{a_R}\Big((1-\phi)\xi_R + \phi(1-R)\Big)\left(\rho + \theta g + g\frac{1-R-\xi_R}{R}\right). \tag{3.21}$$

The first term in (3.21) on the right-hand side is increasing in the southern research share: When $\xi_R$ increases, the South becomes more efficient in R&D and imitation. This effect increases the southern wage and thus the relative wage in (3.21). The second term is decreasing in the southern research share: When $\xi_R$ increases, by (3.15) the share of copied northern goods decreases which decreases the risk of being copied for the North. This effect increases the northern wage rate and thereby decreases the relative wage in (3.21). To determine whether the relative wage is higher in the innovation or in the imitation equilibrium, I substitute the two solutions from (3.19) into the wage equation (3.21) and compare the expressions. The results reveal that the wage gap between the regions is lower in the innovation equilibrium.

Equilibrium utility, per-capita asset holdings and consumption in each region are determined in the next step. From the budget constraint, constant equilibrium wages $w$ and $w^*$ and per-capita asset holdings imply that per capita consumption in North and South is given by $c^* = w^* + (\rho - g_L)a^*$ and $c = w + (\rho - g_L)a$, respectively. As domestic savings finance domestic investments in this model, total asset holdings in the North are $A_t^* = n_{R_t}^* v_{R_t}^*$, and total asset holdings in the South are $A_t = n_{R_t} v_{R_t} + n_{C_t} v_{C_t}$. Substituting for the firm values from (3.9) and multiplying and dividing by the northern labor force size $\ell_t^*$, per-capita asset holdings can be expressed as $a^* = Rw^* a_R^* \delta$ and $a = (1-R) a_R w \beta \delta \frac{\ell_t^*}{\ell_t}$. Substituting $a^*$ and $a$ back into the expressions for $c^*$ and $c$ gives the following per-capita consumption in North and South:

$$c^* = w^*(1 + (\rho - g_L) R a_R^* \delta) \tag{3.22a}$$

$$c = w\left(1 + (\rho - g_L)(1-R) a_R \beta \delta \frac{\ell_t^*}{\ell_t}\right). \tag{3.22b}$$

The northern wage rate can be used as the numeraire and therefore set equal to one. Then the relative wage $\omega$ is equal to the southern wage rate $w$. As $\omega$ is higher in the innovation equilibrium, substituting for $\delta$ and $\beta$ reveals that per capita asset holdings and consumption expenditures in both regions are high in the innovation equilibrium and low in the imitation equilibrium. However, these quantities are nominal, and to obtain real consumption and thus equilibrium welfare, the price level has to be considered.

Substituting the solutions for the variety shares from (3.14) and (3.15) into the definition of the price index gives an expression of the price index as a function of wages and the number of varieties: $P_t = \frac{1}{\alpha}(R(w^*)^{1-\varepsilon} + (1-R)w^{1-\varepsilon})^{\frac{1}{1-\varepsilon}} n^{\frac{1}{1-\varepsilon}}$. According to Dixit and Stiglitz (1977), real consumption $c^*/P_t$ and $c/P_t$ then represents consumers' utility at time $t$, so that utilities in North and South are given by:

$$u_t^* = \frac{c^*}{P_t}, \qquad u_t = \frac{c}{P_t}. \tag{3.23}$$

Substituting for the southern consumption expenditures it can then be shown that the southern balanced growth path utility is higher in the innovation equilibrium than in the imitation equilibrium. Nominal per capita consumption expenditures $c^*$ and $c$ are constant, and the aggregate price level $P_t$ is decreasing over time so that northern and southern utilities $u_t^*$ and $u_t$ are growing over time. As utility is proportional to consumption expenditures holding prices fixed, its growth rate can be interpreted as real consumption growth or economic growth. The equilibrium economic growth rate is thus given by $\dot{u}_t^*/u_t^* = \dot{u}_t/u_t = g/(\varepsilon - 1) > 0$. As utility grows constantly and at the same rate in both regions in equilibrium, looking at a the changes of one-period equilibrium utility $u_0^*$ and $u_0$ is equivalent to looking at the long-run welfare changes.

I summarize the findings in the following proposition:

**Proposition 2** *(i) In the innovation (imitation) equilibrium, the total number of existing varieties, non-copied northern goods and southern inventions as well as the southern research share and the southern research development are high (low), the share of copied goods is low (high), the imitation rate is low (high), the wage gap between the regions is small (large), and per capita consumption and assets in both regions as well as southern welfare are high (low). (ii) For a sufficiently efficient southern research sector ($a_R < \bar{a}_R$) the imitation equilibrium ceases, and the model has a unique innovation equilibrium.*

## 3.5 Balanced growth path effects of stronger intellectual property rights

In this section, I analyze how stronger IPRs affect the distribution of production to North and South, both regions' R&D activities and world product variety depending on whether the South is in an innovation or imitation equilibrium. The effects on equilibrium utility will be analyzed numerically in section 3.6. Please note that the effects described in this section can be only interpreted as a comparison between two worlds which are in the innovation equilibrium (one with stronger and one with weaker IPRs) and a comparison between two worlds in the imitation equilibrium (again one with stronger and one with weaker IPRs), respectively. To analyze the effects of changes in IPRs on a single country would require a detailed stability analysis of the equilibria which proved to be analytically unfeasible for the given set-up.

Independently of the equilibrium of the model, the share of non-copied northern goods ($\xi_R^*$) as well as the share of goods produced in the South ($\xi_R + \xi_C$) is given by equations (3.14) and (3.15). Clearly, the share of non-copied southern goods is increasing in the level of IPR protection ($a_C$) and decreasing in the cost of southern R&D ($a_R$). As $\xi_R + \xi_C = 1 - \xi_R^*$, the effects go in the opposite direction for the share of varieties produced in the South. The intuition is as follows: when IPRs increase, imitation costs and therefore the labor requirement for imitation rises such that northern innovations are targeted less frequently, and a higher share of products is produced in the North. On the other hand, if research becomes more expensive in the South, imitations becomes more attractive relative to innovation, so the share of non-copied southern goods decreases which means that a higher share of products is produced in the South.

However, the decrease in the share of goods produced in the South caused by an increase in the level of IPRs can have several sources: Either both, the share of copied goods and southern inventions, decrease, or one share increases and the other share decreases more strongly. To analyze the effect of IPRs on the southern innovation share, I apply the implicit function theorem to the southern research share equation (3.19) which reveals the following conditions:

$$\frac{\partial \tilde{\xi}_R}{\partial a_C} > 0 \quad \text{if} \quad \tilde{\xi}_R > \frac{g\Big(1 - \phi(2 - R)\Big) + \alpha R(\rho - g_L)(1 - \phi)}{2g(1 - \phi)} \tag{3.24a}$$

$$\frac{\partial \tilde{\xi}_R}{\partial a_C} < 0 \quad \text{if} \quad \tilde{\xi}_R < \frac{g\Big(1 - \phi(2 - R)\Big) + \alpha R(\rho - g_L)(1 - \phi)}{2g(1 - \phi)}. \tag{3.24b}$$

These conditions indicate that an increase in IPRs increases the southern research share if the South's initial research share surpasses a threshold level, and decreases it otherwise. Solving the quadratic equation in $\xi_R$ (3.19) in the last section shows that condition (3.24a) is fulfilled in the innovation equilibrium, and condition (3.24b) holds in the imitation equilibrium.

The different effects of changes in IPRs on the research share can be intuitively explained by looking at the dominant source of research development in the South. The research efficiency function $1/\beta$ in (3.5) captures two sources of R&D development: innovation and imitation. If the economy is in the innovation equilibrium, R&D is mainly driven by $\xi_R$, such that higher IPRs ($a_C \uparrow$) decrease the incentives to conduct imitation (the minor source of development) and thereby increase the incentives for innovation (the major source of development).

In the imitation equilibrium, the R&D development is more driven by imitation. In this case, increasing IPRs (=costlier imitation) leads to a deterioration in the research environment in both sectors by increasing $\beta$, but it hurts the imitation sector less than proportionately, because imitation becomes easier compared to innovation if the share of non-copied northern goods increases.

While the innovation and production shares give an idea of how the distribution of R&D in the world changes with stronger IPRs, the assessment of the actual research output requires a look at the total number of invented varieties in equilibrium. I therefore examine the equilibrium effect of a change in IPRs on $\delta = \frac{N_t^{1-\theta}}{\ell_t^*}$ by inserting the equilibrium southern innovation shares $\tilde{\xi}_R$ into one of the equilibrium conditions (3.16) and (3.18).[28] As $\tilde{\delta}$ is increasing in both IPRs and research share in (3.18), and $\frac{\partial \xi_R}{\partial a_C} > 0$ for the innovation equilibrium, it follows that $\frac{\partial \tilde{\delta}}{\partial a_C} > 0$, and thus IPRs increase the equilibrium total number of varieties if the economy is in the

28 The effect of an increase in IPRs is most easily to be seen if substituting the high-R&D-$\tilde{\xi}_R$ into (3.18) and the low-R&D-$\tilde{\xi}_R$ into (3.16).

innovation equilibrium. As $\delta$ is increasing in $\xi_R$, but decreasing in IPRs in (3.18) and $\frac{\partial \tilde{\xi}_R}{a_C} < 0$ in the imitation equilibrium, IPRs decrease $\delta$ and therefore the total number of existing varieties in that case. Figure 3.2 depicts these equilibrium effects graphically.

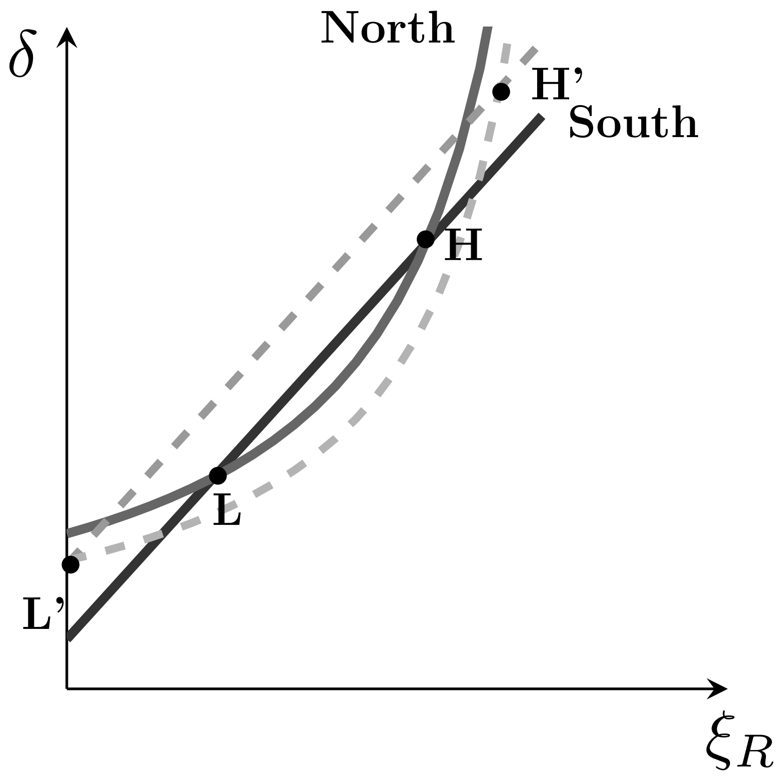


Figure 3.2: Effects of stronger IPRs ($a_C \uparrow$) on the southern research share $\xi_R$ and the measure of product variety $\delta$. $H$ and $L$ denote innovation equilibrium and imitation equilibrium for a low level of IPRs. $H'$ and $L'$ depict the innovation equilibrium and imitation equilibrium for a case with stronger IPRs.

From the effect on the total number of varieties also immediately follows that the number of southern inventions increases (decreases) with stronger IPRs in the innovation (imitation) equilibrium. These results reveal a U-shaped relationship between research activity and IPRs: For economies whose major source of learning is imitation, stronger IPRs are c.p. associated with less own R&D efforts. For economies which rely less on the imitation of foreign goods, because their research sector has reached a critical size and is therefore sufficiently efficient, stronger IPRs are associated with a higher share in world R&D and a higher absolute research output.

**Proposition 3:** *(a) For innovation equilibria, stronger IPRs are associated with larger shares of southern inventions, higher total numbers of varieties and higher absolute numbers of southern inventions. (b) For imitation equilibria, stronger IPRs accompany smaller shares of southern inventions, lower total numbers of varieties and lower absolute numbers of southern inventions. (c) Stronger IPRs always increase the share of non-copied northern goods and decrease the share of products produced in the South.*

## 3.6 Numerical welfare analysis

The effects of changes in IPRs on welfare in both regions are hard to obtain analytically so that I have to calibrate the model to look at them numerically.
The World Bank (2009) reports that the ratio of low and middle income countries to high income countries was given by $\frac{\ell}{\ell^*} = 5.27$ in 2008 and the average world population growth rate between 1960 and 2008 was 1.68% ($g_L = 0.0168$). Analoguously to Gustafsson and Segerstrom (2010, 2011) and chapter 2 of this dissertation, I set the intertemporal knowledge spillover parameter to $\theta = 0.67$ to target the average US GDP per capita growth rate from 1950-1994 (Jones, 2005) and the measure of product differentiation to $\alpha = 0.714$ to target a 40% markup over marginal cost as estimated by Basu (1996) and Norrbin (1993).

The rate of time preference is set to $\rho = 0.02$. The northern wage rate is used as the numeraire and thus set to $w^* = 1$. Also, the cost parameter in the northern R&D function is normalized to $a_R^* = 1$. The southern R&D cost parameter is set to $a_R = 2.5$ which leads to about five to six times higher R&D costs in the South depending on whether the innovation or imitation equilibrium is considered. The cost of imitation is set to $a_C = 1.5$ so that the costs of imitation (without accounting for knowledge capital) constitute 60% of the innovation cost in the same country which is in line with the estimates reported by Mansfield et al. (1981). Further, I set the imitation learning parameter to $\phi = 0.2$ which says that learning from R&D is five times more efficient than learning from imitation. The parameterization fulfills the multiple equilibria condition (3.20), so that both the imitation and the innovation equilibrium exist. As utility grows constantly and at the same rate in both regions in equilibrium, the effects on a single equilibrium period utility can be interpreted as long-run welfare effects.[29]

Table 3.1 reports the effect of a marginal change in IPRs ($a_C$ changes by 1%) on long-run welfare in North and South as well as relative consumption between South and North $u_0/u_0^* = c/c^*$.

| | innovation equilibrium | | imitation equilibrium | |
|---|---|---|---|---|
| IPRs ($a_C$) | 1.5 | $a_C \uparrow$ by 1% | 1.5 | $a_C \uparrow$ by 1% |
| welfare South ($u_0$) | 11.083 | 11.788 | 8.947 | 8.471 |
| welfare North ($u_0^*$) | 17.141 | 18.393 | 13.813 | 13.180 |
| relative cons. ($c/c^*$) | 0.647 | 0.641 | 0.648 | 0.643 |

Table 3.1: Welfare effects of stronger IPRs.

First, notice that the northern long-run welfare is higher in the innovation than in the imitation equilibrium which is mainly driven by the increased number of varieties supplied in the innovation equilibrium due to a more efficient southern R&D sector (for the South, the higher welfare has been already established in the analytical part).

29 For a similar approach see, for example, Gustafsson and Segerstrom (2010, 2011). Note, however, that this approach does not take into account the short-run welfare effects for which a detailed dynamic analysis would be necessary which proved to be unfeasible for the given set-up.

How different levels of IPRs influence equilibrium utility depends on the type of equilibrium. In the innovation equilibrium, higher IPRs are accompanied by higher welfare for both regions. The North benefits slightly overproportionately compared to the South as relative consumption between South and North decreases. This happens because stronger IPRs let the North benefit from both, higher product variety and a lower risk of being imitated whilst the South only benefits from higher product variety.[30]

In the imitation equilibrium, welfare is lower if IPRs are stronger, and the South is hurt more than proportionately compared to the North in this case. While both regions suffer from the decrease in product variety, the North is at least partially compensated for this loss by a lower risk of imitation.[31] The results imply that stronger IPRs in developing countries without sufficiently developed research sector do not only hurt these developing countries, but can have negative welfare implications for developed countries as well.

## 3.7 Conclusion

This chapter endogenizes the southern research sector's development in a North-South increasing variety model of non-scale growth. It follows the evidence from East Asian countries that the development of a research sector can be positively affected by the imitation of foreign technologies, but also recognizes that, with a sufficiently developed research sector, own innovative efforts contribute more to the R&D efficiency in a country.

[30] Introducing imitation of southern goods could change this overcompensation of the North. With imitation of the South, stronger IPRs would benefit the South by both, increasing the number of available varieties and decreasing the risk of imitation.

[31] Again, this overproportional loss of the South could be changed by introducing southern imitation into the framework as the South would then be also compensated by a lower risk of imitation.

The presented model allows the efficiency of the southern research sector to depend positively on how intensively southern firms engage in imitation and innovation. I show that the model can yield multiple equilibria associated with positive imitative and innovative southern activity if the southern research costs surpass a critical threshold level.

In the imitation equilibrium, the southern research sector is small and inefficiently develops a small number of varieties, the southern welfare is low. In this equilibrium, the North faces a high risk of imitation, and the world research output is low. In contrast, the innovation equilibrium yields high product variety, a low imitation risk, a relatively large southern research sector which efficiently develops a large number of varieties, and high welfare in both regions.

Depending on the size of the southern innovation sector, stronger IPRs have different implications. If the southern R&D sector is small and its efficiency is thus mainly imitation driven, an increase in IPRs can dampen innovative activity and welfare in both, the developed and developing region. If the R&D sector is sufficiently large and its efficiency is therefore mainly driven by own innovative activity, then stronger IPRs are associated with higher innovation output and welfare in both regions.

# Chapter 4

# Intellectual Property Rights as Development Determinants*

## 4.1 Introduction

Development determinants have long been the focus of cross-country growth regressions, which are well known to be subject to substantial model uncertainty (Barro (1997); Durlauf et al. (2005). This model uncertainty manifests itself in the vast number of candidate regressors that have been suggested by competing strands of growth and development theories. Durlauf et al. (2005) survey no fewer than 140 growth determinants for the Handbook of Economic Growth. Therefore it is not surprising that prominent approaches to development regressions conduct robustness exercises that juxtapose literally dozens of theories and candidate regressors.[32] Conspicuously absent from this entire literature is, however, one approach that in-

* This chapter is based on joint work with Theo Eicher.

[32] Acemoglu et al. (2001) and Rodrik et al. (2004) alone introduce more than 50 candidate regressors.

cludes the strength of intellectual property rights (IPRs) as a potential development determinant.[33]

The omission is surprising, given that IPRs are the central driving force of economic performance in all R&D based growth models.[34] Property rights over innovations guarantee returns for investors, whose inventions constitute the ultimate engine for long term development. In sharp contrast, the protection of physical property (e.g., capital investment) has long been widely accepted as a core determinant regressor in development empirics (as measured by "Rule of Law" or "risk of expropriation").[35]

We follow the canonical development determinant approach of Hall and Jones (1999), Acemoglu et al. (2001), and Rodrik et al. (2004), and introduce IPRs as an additional candidate regressor into this well established line of development regressions. Conceptually we could simply add IPRs to each one of the regressions suggested by the previous literature and report the IPR significance levels. Raftery (1995) points out, however, that significance levels are inflated when coefficients are based on a single statistical model whenever the uncertainty surrounding the validity of the particular theory is ignored. Instead, we thus use a statistical methodology that allows us to introduce IPRs while simultaneously addressing the profound model uncertainty that has been highlighted by the vast number of development specifications in the previous literature.

We analyze the impact of IPRs on development using Bayesian Model Averaging (BMA), which is designed to resolve model uncertainty as part of the statistical

33 While the relationship between IPRs and growth is the subject of a voluminous literature (Gould and Gruben, 1996; Kim et al., 2011) the effect of IPRs is usually not studied in cross-country development regressions, and never before with explicit endogeneity controls, see, e.g., Maskus and Penubarti (1995), Ginarte and Park (1997), Maskus (2000), Chen and Puttitanun (2005).

34 Romer (1990) and Aghion and Howitt (1992) assume perfect IPRs; and it is easily shown that the canonical R&D based growth model produces reduced growth and welfare with imperfect IPRs (Eicher and García-Peñalosa, 2008).

35 An alternative strand of the literature focuses on the effect of political institutions, see, e.g., Persson and Tabellini (2002) and Besley et al. (2005).

methodology.[36] The added complication that development regressions posit is that their model uncertainty is not confined by development determinants, but it is also present at the instrument level. Instruments are used to address the endogeneity of development determinants and to identify their exact effects on income. Appropriate instruments have also been the subject of a voluminous literature comprised of a sizable set of alternative theories. Instead of juxtaposing particular instrument specifications in what Rodrik et al. (2004) call a "horse race" approach, we employ the Lenkoski et al. (forthcoming) Two-Stage Least Squares BMA (2SBMA) procedure to account for model uncertainty at the development determinant and instrument levels.

To explore the effects of IPRs, we use Acemoglu et al. (2001) and Rodrik et al. (2004)'s own data and augment it with the Park (2008b) patent index. Figure 1 plots the dependent variable in Acemoglu et al./Rodrik et al., per capita income, against Park's (2008b) patent index and reveals a clear positive relationship. We are not the first to highlight the correlation between the intellectual property rights index and development;[37] we are, however, the first to address causality and model uncertainty to clarify whether better IPRs foster high incomes or whether high levels of development produce excellent IPRs.[38]

The 2SBMA methodology addresses the issue of causality by introducing instruments that identify the particular effect of IPRs on development. To motivate potential instruments for IPRs we follow the law and economics literature, which suggests that a particular type of legal origin provides the necessary identification for legal institutions today (La Porta et al., 1998, 1999; Djankov et al., 2003).

[36] See, e.g., Fernandez et al. (2001), Sala-i-Martin et al. (2004) and Masanjala and Papageorgiou (2008).

[37] See, e.g., Maskus and Penubarti (1995), Maskus (2000), and Ginarte and Park (1997).

[38] Ginarte and Park (1997) tested the latter hypothesis, but do not control for endogeneity.

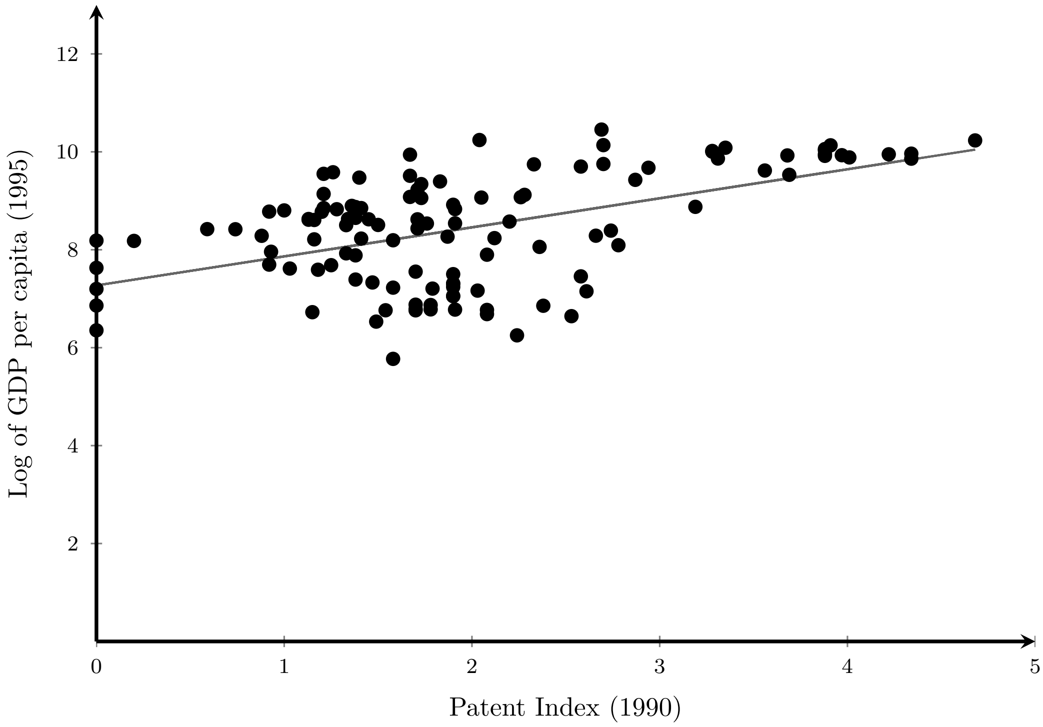


Figure 4.1: Development and Intellectual Property Rights

After addressing model uncertainty and causality, we find that IPR protection, specifically patent protection, exerts an important impact on development. This impact is separate and parallel to the impact of Rule of Law on development. The result highlights that both dimensions of property rights protection are crucial development determinants. We can also show that the impact of IPRs is causal, as our identification strategy posits that IPRs drive income, and our tests of instrument validity support this hypothesis.

In addition we show that the impact of patent rights on development depends crucially on the degree of intellectual property rights enforcement. As long as patent rights are simply "on the books" but not enforced, they are shown to exert no effect on development. It is the level of enforced patent rights that is positively correlated with development.[39] The magnitude of the impact of IPR enforcement on development is remarkable: increasing enforcement by one standard deviation causes a

[39] Enforcement is measured in terms of the stringency of preliminary injunctions, the existence of contributory infringement pleadings, and burden-of-proof reversals.

42% increase in long term development. Coincidentally this effect is just about the same in magnitude as the impact of Rule of Law on development. To illustrate the importance of the two dimensions of property rights protection, we can consider two countries at either end of the development spectrum in 1995: The US, with $27,806 per capita income and Brazil, with $6,820. Our results suggest that if Brazil adopted the same level of Rule of Law and IPR enforcement as the US, its predicted per capita income would more than triple to $24,323.

We are not the first to attempt to resolve endogeneity and identify proximate and fundamental development determinants. Alternative approaches to explain development include Mauro (1995), who first suggested ethnolinguistic fragmentation as a fundamental determinant of corruption although the subsequent literature focuses on "Rule of Law" as a more basic development determinant. Hall and Jones (1999) introduced latitude and common language as instruments for an institutional proxy that is a composite of trade, corruption and rule of law. We include these candidate instruments below and highlight the importance of the latter. La Porta et al. (2004) presented yet another "horse race" of theories, juxtaposing judicial independence vs. constitutional review; we employ their hypothesis that judicial characteristics matter in order to motivate candidate instruments in our analysis. Lenkoski et al. (forthcoming) apply 2SBMA to development determinants, but neglect IPRs.

We proceed as follows: section 4.2 outlines the statistical approach that underlies 2SBMA and discusses theoretical properties of the technique, section 4.3 describes the data, section 4.4 discusses the key results and highlights the importance of both determinant and instrument uncertainty in the recent development literature, and section 4.5 concludes.

## 4.2 Methodology

### 4.2.1 The Econometric Approach

Acemoglu et al. (2001) suggest a particular theory of development, namely that private property rights (as measured by government risk of expropriation) are a crucial development determinant, and that the security of such property rights is crucially dependent on the type of colonial history a country experienced. Rodrik et al. (2004) broaden the definition of development determinants and conduct an all out "horse race" of three potential determinants (private property rights, trade, and geography) against a host of alternative theories. Acemoglu et al. (2001) and Rodrik et al. (2004) constitute the most rigorous robustness tests that have been conducted; the studies employ the largest set of potential development theories to justify and juxtapose candidate regressors.

Both studies acknowledge that the effects of proximate development determinants are endogenous and apply the 2SLS instrumental variable technique to identify the specific effect that each determinant exerts on development. A complicating factor is, however, that competing theories suggest alternative sets of different instruments. Acemoglu et al. (2001) and Rodrik et al. (2004) approach this issue by juxtaposing not only theories of development determinants, but also theories that motivate alternative instruments against another. Profound model uncertainty thus contaminates coefficient estimates at both the instrument and the determinant level. To examine the effects of IPRs on development we adopt Acemoglu et al. and Rodrik et al.'s approach and data augmented by Park's IPR index.

### 4.2.2 Statistical Foundations

Instead of producing numerous robustness regressions, we resolve the model uncertainty using a statistical methodology that was specifically designed for that task, Two-Stage Least Squares Bayesian Model Averaging (2SBMA). 2SBMA combines the instrumental variable and BMA methodologies to process the data like a two stage estimator, while addressing model uncertainty in both stages. It is a nested approach that first determines the posterior model probabilities in the first stage via straight BMA to ascertain whether any instruments receive support from the data. Then 2SBMA model averages using the fitted values to derive second stage posterior model probabilities, means, and standard deviations. The weight of each model in the second stage depends not only on its performance, but also on the performance of the particular set of instruments that gave rise to the particular second stage model.

In addition to resolving model uncertainty, Bayesian model averaging minimizes the sum of Type I and Type II error, the mean squared error, and generates predictive distributions with optimal predictive performance (Raftery and Zheng, 2003). 2SBMA is also consistent and it reduces the many instrument bias that is especially relevant in approaches that juxtapose a number of alternative candidate regressors (Lenkoski et al., forthcoming). Below we provide a sketch of the 2SBMA methodology, limiting our discussion to the properties relevant to our application and refer the interested reader to the comprehensive tutorial and derivations by Raftery et al. (1997) and Lenkoski et al. (forthcoming) for further discussion.

The standard approach to addressing endogeneity of development determinants is to apply two-stage least squares (2SLS) and impose over-identification and instrument restrictions according to

$$Y = \alpha + \sum_{j=1}^{p} \beta_j X_j + \eta, \tag{4.1}$$

in which $Y$ is the dependent variable, $X$ is a vector of candidate regressors which is comprised of a vector of $W$ endogenous and $D$ exogenous variables. Reverse causality is of utmost interest in development regressions. Are countries rich because they have good institutions or property rights, or are property rights strong in countries that are sufficiently wealthy to maintain them? In the presence of endogeneity, the determination of $W$ leads to inconsistent estimates of the entire coefficient in (4.1). The 2SLS estimator solves the consistency problem, but relies on the existence of a set of instruments, $Z$, which are independent of $Y$, given the vector of covariates $X$. To identify the effect of $W$ on $Y$, the researcher must suggest a set of instruments, $Z$ such that

$$W = \delta + \theta_Z Z + \theta_D D + \varepsilon. \tag{4.2}$$

The IV estimates derived in a second stage by using the fitted values from the first stage (4.2) are consistent only if the conditional independence assumptions are valid. Theories seldom present clear-cut instruments that have both strong explanatory power on the endogenous variables and unquestionable conditional independence properties in relation to the dependent variable. Over-identification tests such as the one proposed by Sargan (1958) help verify the validity of the instrument assumptions.

The 2SBMA setup can be concisely summarized as follows. Let $\Delta$ be a quantity of interest and $M$ the set of potential models that is comprised of $I$ individual models in the first stage. The posterior distribution of $\Delta$ given the data, $D$, is given by the weighted average of the predictive distribution under each model,

$$\mathrm{pr}(\Delta \middle| \mathrm{D}) = \sum_{\mathrm{i}=1}^{\mathrm{I}} \mathrm{pr}(\Delta \middle| \mathrm{M_i}, \mathrm{D}) \pi_{\mathrm{i}} \tag{4.3}$$

in which $\text{pr}(\Delta \Big| \text{M}_\text{i}, \text{D})$ is the predictive distribution and the model weight is

$$\pi_i = \text{pr}(\text{M}_\text{i} \Big| \text{D}) \propto \int \text{pr}(\text{D} \Big| \theta_\text{i}, \text{M}_\text{i}) \mu(\theta_\text{i}) \text{d}\theta_\text{i} \gamma(\text{M}_\text{i}). \tag{4.4}$$

The model weight is thus comprised of the posterior probability for model $M_i$ and the prior densities for parameters and models, $\mu(\theta_i)$ and $\gamma(M_i)$, respectively. Intuitively, this implies that a model's weight is proportional to its relative efficiency in describing the data. Posterior model probabilities are also the weights used to establish the posterior means and variances

$$\hat{\theta}^{BMA} = \sum_{i \in M}^{I} \hat{\theta}_i \pi_i, \tag{4.5}$$

$$\hat{\sigma}^{2^{BMA}} = \sum_{i \in M}^{I} \pi_i \hat{\sigma_i}^2 + \sum_{I \in M}^{I} \pi_i \left( \hat{\theta}_i - \hat{\theta}_i^{BMA} \right)^2. \tag{4.6}$$

The BMA posterior mean is thus the weighted sum of all posterior means, where the weight is the quality of the model that generated a particular coefficient. The posterior variance is the sum of the weighted variances for each model plus a second term that indicates how much the estimates differ across models. To provide economically meaningful coefficient estimates we condition the posterior mean and variance on whether a regressor is included in the model. By summing the posterior model probabilities over all models that include a candidate regressor, we obtain the posterior inclusion probability

$$\text{pr}\left( \hat{\theta}_\text{i} \neq 0 \Big| \text{D} \right) = \sum_{\text{i} \in \text{M}} \pi_\text{i}. \tag{4.7}$$

The posterior inclusion probability of a regressor is the probability that a variable is included in the true model. It provides a probability statement regarding the importance of a regressor that directly addresses the researcher's prime concern: what is the probability that the coefficient has a non-zero effect on the dependent variable?

The posterior inclusion probability thus also carries an important interpretation that goes beyond the information contained in standard p-values.

General rules developed by Jeffreys (1961) and refined by Kass and Raftery (1995) stipulate effect-thresholds for posterior probabilities. Posterior probabilities $< 50\%$ are seen as evidence against an effect, and the evidence for an effect is either *weak*, *positive*, *strong*, or *decisive* for posterior probabilities ranging from 50-75%, 75-95%, 95-99%, and $> 99\%$, respectively. In our analysis, we refer to a regressor as "effective" if its posterior inclusion probability exceeds 50%.

To address endogeneity, 2SBMA first determines the posterior model probabilities as outlined above as well as the first stage fitted values, $\tilde{w}_i$, for each model $M_i$. Denoting the set of $j$ second stage models as $L$, 2SBMA then uses the fitted values to derive second stage posterior probabilities and estimates, $v_j(\tilde{w}_i)$ and $\hat{\beta}_j(\tilde{w}_i)$ to obtain the posterior mean

$$\hat{\beta}^{2SBMA} = \sum_{i \in M}^{I} \sum_{j \in L}^{J} v_j(\tilde{w}_i)\pi_i \hat{\beta}_j(\tilde{w}_i). \tag{4.8}$$

The posterior mean consists of the combination of weighted fitted values from the first stage models and the weighted posteriors means of the second stage models. The model weight, or the quality of the first stage instrumentation thus influences the overall model weight of a second stage coefficient. The posterior variance and inclusion probability are then

$$\hat{\sigma}^{2^{2SBMA}} = \sum_{i \in M}^{I} \pi_i \left( \sum_{j \in L}^{J} v_j \sigma_j^2 + \sum_{j \in L}^{J} v_j \left( \hat{\beta}_j - \bar{\beta} \right)^2 \right) + \sum_{i \in M}^{I} \pi_i \left( \bar{\beta}_i - \hat{\beta}_i^{2SBMA} \right)^2 \tag{4.9}$$

$$\text{pr}\left( \hat{\beta}_{\text{j}} \neq \middle| \text{D} \right) = \sum_{i \in M} \sum_{j \in L} v_j \pi_i, \tag{4.10}$$

in which $\bar{\beta}$ is the model averaged estimate for a given first stage model, $M_i$. The 2SBMA variance has a similar interpretation as the BMA variances. The first term is the average of BMA variances associated with the first stage models, and the second term represents the variation of a given first stage model's BMA estimates relative to the overall 2SBMA estimate.

## 4.3 Data

Our data was collected from four major sources. Acemoglu et al. (2001) provide data on settler mortality and religion, Park (2008b) provides the IPR index, which is in fact an index of patent protection, and La Porta et al. (1998) provide data on the legal origins of a country. All other variables suggested in the comprehensive robustness approach are obtained from Rodrik et al. (2004). Acemoglu et al. (2001)'s sample covers 64 countries, but the combination with IPR data limits our sample to 54 observations.

Table 4.1 provides the key descriptive statistics for all variables. For example, GDP per capita ranges from \$519 (Tanzania) to \$27,806 (US) with a mean of \$4,825, and Rule of Law ranges from 1.71 (New Zealand) to −1.49 (Angola), with a mean of −0.28. Park's patent index is the sum of five equally weighted sub-indices (patent length, scope, enforcement, the protection from loss of patent rights and membership in patent treaties).[40] It evaluates the strength of a country's patent system on a scale of 0 (poor patent system) to 5 (strong patent system) with US (4.48) being the strongest and Angola (0.0) the weakest. Patent enforcement is measured on a scale of 0 to 1 scale on which 1 is obtained if a country has all of the following enforcement mechanisms: preliminary injunctions, contributory infringement pleadings and burden-of-proof reversals.

[40] This index is an updated version of the Ginarte and Park (1997) index, see Park (2008b).

| Variable | Max | Min | Mean | StDev | Meaning, Source |
|---|---|---|---|---|---|
| lcgdp95 | 10.23 | 6.25 | 7.99 | 0.97 | natural log of GDP per capita in PPP in 1995, RST (2004), originally: PWT, Mark 6. |
| gdp95 | 27806.08 | 519.00 | 4824.67 | 5659.47 | GDP per capita in 1995, same as above |
| rule | 1.71 | -1.49 | -0.28 | 0.80 | Rule of Law, RST (2004), originally: Kaufmann et al. (2002) |
| logem4 | 7.99 | 2.15 | 4.79 | 1.19 | Settler Mortality, AJR (2001) |
| logfrankrom | 3.74 | 0.94 | 2.49 | 0.63 | natural log of predicted trade shares, RST (2004), originally: Frankel and Romer (1999) |
| engfrac | 0.95 | 0.00 | 0.08 | 0.22 | Fraction of population speaking English, RST (2004), originally: Hall and Jones (1999) |
| eurfrac | 1.00 | 0.00 | 0.32 | 0.41 | fraction of population speaking English, French, German, Portuguese or Spanish, RST (2004), orig.: Hall and Jones (1999) |
| legor_fr | 1.00 | 0.00 | 0.68 | 0.46 | 1 if origins of the legal system are French, La Porta et al. (1998) |
| disteq | 45.00 | 0.00 | 15.82 | 12.03 | Distance from Equator, RST (2004) |
| laam | 1.00 | 0.00 | 0.34 | 0.47 | 1 if country belongs to Latin America or the Caribbean, RST (2004) |
| safrica | 1.00 | 0.00 | 0.41 | 0.49 | 1 if country belongs to Sub-Saharan Africa, RST (2004) |
| catho80 | 96.60 | 0.10 | 44.23 | 37.42 | 1 if population is predominantly Catholic, AJR (2001) |
| muslim80 | 99.40 | 0.00 | 23.95 | 33.75 | 1 if population is predominantly Muslim, AJR (2001) |
| protmg80 | 58.40 | 0.00 | 11.04 | 13.99 | 1 if population is predominantly Protestant, AJR (2001) |
| tropics | 1.00 | 0.00 | 0.73 | 0.41 | percentage of tropical land area, RST (2004), originally: Gallup and Sachs (1998) |
| access | 1.00 | 0.00 | 0.18 | 0.37 | 1 for countries without access to the sea, RST (2004) |
| oil | 1.00 | 0.00 | 0.11 | 0.29 | 1 if country is major oil exporter, RST (2004) |
| frstarea | 1.00 | 0.00 | 0.17 | 0.29 | proportion of land with $>5$ frost-days/month in winter, RST (2004), originally: Masters and McMillan (2001) |
| frstdays | 29.68 | 0.02 | 3.42 | 5.91 | Average number of frost-days/month in winter, RST (2004), originally: Masters and McMillan (2001) |
| malfal94 | 1.00 | 0.00 | 0.44 | 0.44 | Malaria index for 1994, RST (2004), originally: Gallup and Sachs (1998) |
| meantemp | 29.30 | -0.20 | 22.70 | 5.09 | Average temperature in Celsius, RST (2004) |
| lcopen | 4.64 | 2.55 | 3.76 | 0.47 | natural log of nominal openness, RST (2004), originally: PWT, Mark 6. |
| asiae | 1.00 | 0.00 | 0.07 | 0.23 | 1 if country belongs to South-East Asia, RST (2004) |
| pat_1990 | 4.68 | 0.00 | 1.74 | 0.81 | Patent index (0-5 scale, 0 = weak, 1 = strong), Park (2008) |
| enf_1990 | 1.00 | 0.00 | 0.17 | 0.26 | Patent enforcement index (0 = weak, 1 = strong), Park (2008) |

Table 4.1: Descriptive Statistics and Data Sources.

To identify the effect of physical and intellectual property rights on development requires instruments that influence property rights directly but are unlikely to impact the income level in 1995 directly. To identify the security of physical property rights, Acemoglu et al. (2001) propose settler mortality, which indicates whether a country was a settlement or extraction colony. Countries with the latter history are presumed to have adopted weaker property rights institutions. Alternative instruments for physical property rights are the fractions of the English or European language speaking population in a country (Hall and Jones, 1999), which are hypothesized to serve as measures of the colonial powers' commitment to building good property rights institutions.

To introduce IPRs, we are required to propose additional instruments, and we rely on a country's type of legal origin. Specifically we follow the law and economics literature, which suggests either English common law or Roman (in particular French) civil law (La Porta et al., 1998, 1999) legal origins to have a profound impact on how intellectual property rights are considered by today's legal system. David and Brierley (1985) show that corporate law and commercial laws vary systematically by legal origin, and that French legal origins (civil law) are associated with greater formalism of judicial procedures (Djankov et al., 2003) and less judicial independence La Porta et al. (2004). The latter has been associated with better contract enforcement and greater security of property rights.

Since the legal traditions were typically introduced into various countries through conquest and colonization, they are considered largely exogenous, which qualifies them as strong candidate instruments. The remaining variables included in our estimation are candidate regressors that have been previously argued to exert an effect on development and that were included in Rodrik et al. (2004)'s robustness checks.

## 4.4 Quantifying the Effects of Intellectual Property Rights on Development

This section reports the results of the 2SBMA estimation that introduces IPRs to the canonical development regressions by Acemoglu et al. (2001) and Rodrik et al. (2004) and resolves model uncertainty as part of the statistical procedure. We commence with the results for the aggregate patent index.

Columns 2–4 and 5–6 in Table 2 reveal that our instrument strategy provides two effective instruments for patents (fraction of English speaking population in a country and French legal origin) and that physical property rights are also well identified. The Bayesian Sargan test (see Lenkoski et al. (forthcoming)) confirms that the exogeneity condition is fulfilled and the instruments are not correlated with the error term in the equation of interest. In other words, the legal and colonial history instrument regressors do exert an effect on development, but not directly, only indirectly through their impact on IPRs. We can thus be confident that the endogeneity of IPRs has been addressed successfully and are able to discuss causal effects of IPRs on development.

The impact of the aggregate patent index on development is, however, disappointing: The aggregate patent index does not surpass the effectiveness threshold. Instead, "Rule of Law" and geographic variables, such as tropics, malaria, and the South-East Asia dummy show inclusion probabilities that are significantly larger than 50%. One hypothesis could be that the weak effect of the aggregate patent index reflects the sizable number of developing countries that achieve high marks for the breadth of their patent laws, but whose intellectual property rights laws are not well enforced.

By disaggregating the patent index, we can find that the average patent duration is largely identical for developing and developed countries. In contrast, a number of developing countries exhibit a dismal score for the enforcement of their strin-

| | Patent Protection | | | Rule of Law | | | Income | | |
|---|---|---|---|---|---|---|---|---|---|
| | Incl. Prob. | Post. Mean | Post. StDev | Incl. Prob. | Post. Mean | Post. StDev | Incl. Prob. | Post. Mean | Post. StDev |
| **Instruments** | | | | | | | | | |
| **English Language Fraction** | **100.0** | **1.807** | **0.536** | 9.3 | 0.839 | 0.531 | | | |
| **French Legal Origin** | **55.6** | **−0.424** | **0.206** | 11.8 | 0.203 | 0.160 | | | |
| **European Language Fraction** | 1.7 | −0.633 | 0.458 | **98.7** | **1.298** | **0.294** | | | |
| Implied Trade Shares | 26.8 | 0.240 | 0.148 | 3.5 | 0.110 | 0.139 | | | |
| Settler Mortality | 8.4 | −0.144 | 0.118 | 8.1 | 0.095 | 0.077 | | | |
| **Development Determinants** | | | | | | | | | |
| **South-East Asia** | | | | | | | **84.9** | **1.043** | **0.472** |
| **Rule of Law** | | | | | | | **80.7** | **0.702** | **0.260** |
| **Malaria (1994)** | | | | | | | **75.9** | **−0.716** | **0.307** |
| **Oil** | | | | | | | **70.1** | **0.572** | **0.277** |
| **Tropics** | | | | | | | **58.0** | **−0.592** | **0.325** |
| **Muslim** | | | | | | | **56.3** | **−0.006** | **0.003** |
| **Sub-Saharan Africa** | | | | | | | **51.7** | **−0.585** | **0.318** |
| Catholic | | | | | | | 47.4 | 0.008 | 0.004 |
| Trade | | | | | | | 34.1 | 0.252 | 0.192 |
| Patent Protection | | | | | | | 29.4 | 0.285 | 0.390 |
| Latin America | | | | | | | 18.4 | 0.433 | 0.394 |
| No Sea Access | | | | | | | 13.3 | −0.233 | 0.210 |
| Distance to Equator | | | | | | | 12.2 | −0.016 | 0.016 |
| Mean Temperature | | | | | | | 8.8 | −0.012 | 0.034 |
| Frost Area | | | | | | | 6.9 | 0.351 | 0.417 |
| Frost Days | | | | | | | 4.0 | 0.006 | 0.026 |
| Protestant | | | | | | | 0.9 | −0.001 | 0.008 |
| Bayes Sargan P-value | | | | | | | | | 0.59 |

Table 4.2: Instrumented Effects of Property Rights on Development

gent patent rights. With an average patent enforcement index of 0.11, developing countries' enforcement mechanisms are almost *eight* times weaker than the average protection afforded by developed economies in our sample.

To test our hypothesis formally, we replace the aggregate patent index by the patent *enforcement* index and reestimate the above specification. With three valid instruments (settler mortality, fraction of population speaking English, and French legal origin), patent enforcement is well identified. The result of the Sargan test confirms the exogeneity of the instruments, which allows us to discuss causal results. Table 3 reports strong positive effects of the enforcement of intellectual property rights on development. Given the coefficient estimates in column 9, we find that a one standard deviation increase in patent enforcement increases income by 42.0%. This magnitude is impressive given that a one standard deviation increase in "Rule of Law", the key regressor in the previous literature, increases income by a similar magnitude (by 41.7%). This result strongly suggests that both dimensions of property protection, physical and intellectual, are crucial for development.[41]

To illustrate the impact of these two dimensions, consider two examples: 1995 per capita income in the US has been about 4.3 times higher than in Venezuela. Our results suggest that if Venezuela adopted the degree of intellectual property rights enforcement and the level of Rule of Law to match the levels in the US, the income difference between the two countries would only be about 11%. Our other example compares the US and India. In 1995 US per capita income was about 14 times greater than India's. If India adopted US intellectual and physical property rights, the predicted result would be a *tenfold* reduction in the income differences between the two countries.

41 Our results are robust to the inclusion of alternative measures of IPRs and IPR enforcement. In regressions that are available from the authors, we introduce sub-indices for duration, coverage and protection from loss of rights. None of these indices changed our results or surpassed effective thresholds.

| | Patent Enforcement | | | Rule of Law | | | Income | | |
|---|---|---|---|---|---|---|---|---|---|
| | Incl. Prob. | Post. Mean | Post. StDev | Incl. Prob. | Post. Mean | Post. StDev | Incl. Prob. | Post. Mean | Post. StDev |
| **Instruments** | | | | | | | | | |
| **Engl. Language Fraction** | **100.0** | **0.647** | **0.162** | 9.3 | 0.839 | 0.531 | | | |
| **Settler Mortality** | **89.5** | **−0.081** | **0.033** | 8.1 | −0.095 | 0.077 | | | |
| **French Legal Origin** | **51.5** | **−0.114** | **0.060** | 11.8 | −0.203 | 0.160 | | | |
| **Euro Language Fraction** | 21.5 | 0.143 | 0.088 | **98.7** | **1.298** | **0.294** | | | |
| Impl. Trade Share | 0.4 | −0.042 | 0.042 | 3.5 | −0.110 | 0.139 | | | |
| **Development Determinants** | | | | | | | | | |
| **South-East Asia** | | | | | | | **90.9** | **0.987** | **0.317** |
| **Oil** | | | | | | | **75.6** | **0.566** | **0.257** |
| **Patent Enforcement** | | | | | | | **78.9** | **1.600** | **0.704** |
| **Malaria 1994** | | | | | | | **75.1** | **−0.603** | **0.267** |
| **Tropics** | | | | | | | **65.5** | **−0.591** | **0.295** |
| **Rule of Law** | | | | | | | **61.2** | **0.524** | **0.284** |
| **Latin America** | | | | | | | **51.8** | **0.658** | **0.314** |
| Catholic | | | | | | | 38.2 | 0.008 | 0.003 |
| Trade | | | | | | | 31.8 | 0.257 | 0.170 |
| Sub-Saharan Africa | | | | | | | 22.2 | −0.544 | 0.345 |
| Mean Temperature | | | | | | | 18.9 | −0.026 | 0.029 |
| Muslim | | | | | | | 17.5 | −0.005 | 0.003 |
| No Sea Access | | | | | | | 13.5 | −0.237 | 0.186 |
| Frost Area | | | | | | | 7.8 | 0.490 | 0.389 |
| Distance Equator | | | | | | | 7.5 | −0.013 | 0.015 |
| Frost Days | | | | | | | 6.9 | 0.020 | 0.020 |
| Protestant | | | | | | | 0.5 | −0.003 | 0.007 |
| Bayes Sargan P-value | | | | | | | | | 0.55 |

Table 4.3: Instrumented Effects of Patent *Enforcement* on Development

Apart from highlighting the impact of the two dimensions of property protection on development, our results also emphasize the importance of accounting for model uncertainty at both the instrument and income stages. The approach allows us to augment the findings by Rodrik et al. (2004) and Acemoglu et al. (2001). Our approach discovers, for example, additional income determinants: While Rodrik et al. (2004) and Acemoglu et al. (2001) find at best weak direct evidence of geography on development, we find strong effects for geographic variables that influence the level of development (e.g., Latin America, East Asia, tropics, and malaria).[42] These results are consistent with the results obtained by Lenkoski et al. (forthcoming) who account for model uncertainty by using 2SBMA.

In line with the results by Rodrik et al. (2004), we also find that trade does not surpass the effectiveness threshold. Our first stage results confirm those of Lenkoski et al. (forthcoming) and Albouy (forthcoming) in that settler mortality is not an effective instrument for Rule of Law in contrast to the findings of Rodrik et al. (2004) and Acemoglu et al. (2001). However, we do find that settler mortality serves as a strong instrument for the *intellectual* property dimension of institutions as its inclusion probability for patent enforcement is almost 90%. All other results conform to Lenkoski et al. (forthcoming), Rodrik et al. (2004), and Hall and Jones (1999) in that common language variables are shown to be excellent instruments for institutions.

## 4.5 Concluding Remarks

The literature that attempts to isolate development determinants has long focused on the effects of physical property rights protection as a key determinant of the observed differences in per capita incomes. Rule of Law (Rodrik et al., 2004) or

[42] Kourtellos et al. (2010) previously challenged Rodrik et al. (2004)'s results on the basis of parameter heterogeneity.

Risk of Government Expropriation (Acemoglu et al., 2001) had previously been identified as crucial institutional development determinants. Theoretical models of development also highlight, however, the importance of intellectual property rights, which we introduce to the development empirics literature in this chapter.

Cross-country growth and development regressions are well known to suffer from substantial model uncertainty, and numerous candidate regressors and theories have been proposed by the voluminous literature in outright "horse races" (Rodrik et al., 2004; La Porta et al., 2004). Not only is the uncertainty about development determinants substantial, but theories which suggest instruments to resolve endogeneity are equally abundant. In this chapter, while introducing IPRs into the cross country development literature, we account for endogeneity of the development determinants and address model uncertainty at the income determinant and instrument levels using Two-Stage Least Square Bayesian Model Averaging (2SBMA).

We find that intellectual property rights exert a strong impact on development if they are properly enforced. The important insight is thus that both intellectual and physical property rights are crucial determinants of cross-country income differences. Interestingly, our results suggest that the two dimensions of property rights protection hold equally strong explanatory power: a one standard deviation increase in "Rule of Law" increases per capita income by 42%, and this effect is identical to the impact of a one standard deviation increase in patent enforcement, which is also estimated to raise per capita income by the same amount. In line with previous studies, we also find evidence for an effect of geographical variables (as malaria and tropics) on development. We conclude from the data that the effective protection of both physical and intellectual property rights, along with geography, are the key determinants of a country's economic development.

# Appendix A

# Appendix to chapter 2: The model in the narrow-gap case

In this section, we describe how the model in chapter 2 changes if it is solved for an equilibrium in which the wage gap is narrow, i.e. $\omega \geq \alpha$. The main change occurs through the fact that now imitators of northern products cannot charge the monopoly price, but charge the innovator's marginal cost to exclude him from the market. Equation (2.7a) becomes

$$p_{C_N} = w^*, \quad \pi_{C_N} = (w^* - w)\bar{x}_{C_N} L. \tag{2.7a$'$}$$

From this follows that the profits used in the cost-benefit equation (2.12c) change. Accordingly, the equations which are derived with the help of this cost-benefit condition also change. These are the equations for the rate at which northern varieties are copied, the wage gap, and the equation for the employment in the southern research sector:

$$\iota_N = \frac{(1-\omega)(\rho+\theta g)g}{\frac{\gamma}{1+\gamma}\Delta_1 d\phi_N(\rho+\theta g)\omega - (1-\omega)g} \tag{2.14b$'$}$$

$$\omega^{\varepsilon-1} - \omega^{\varepsilon}\left(1 + (1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}d\phi_N\right) = \frac{\gamma}{1+\gamma}\frac{d\phi_N}{\phi_S}\eta^* - (1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}\frac{d\phi_N}{\beta} \tag{2.18$'$}$$

$$\ell_R = \frac{(1-\alpha)(g+\iota_S)}{\Lambda_1 + \iota_S + \frac{1-\alpha}{\eta^*}\frac{1+\gamma}{\gamma}\frac{\phi_S}{\beta}\left(\frac{\iota_S}{g}\right)^2\Lambda_2}\left(\ell - \frac{1-\alpha}{1-\omega}d\phi_N\left(\frac{\iota_N}{g}\right)^2\frac{(1-\omega)g+\omega(\rho+\theta g)}{\Lambda_1+\iota_N}\right). \tag{2.17$'$}$$

The function $f(\omega) \equiv \omega^{\varepsilon-1} - \omega^{\varepsilon}(1 + (1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}d\phi_N)$ and the constant $W \equiv \frac{\gamma}{1+\gamma}\frac{d\phi_N}{\phi_S}\eta^* - (1-\alpha)\alpha^{\varepsilon-1}\frac{\rho+\theta g}{g}\frac{d\phi_N}{\beta}$ are illustrated in figure A.1. From differentiating $f(\omega)$ follows that $df(\omega)/d\omega < 0$ if $\alpha/(1+\frac{\gamma}{1+\gamma}\Delta_1 d\phi_N(\rho+\theta g)) < \omega$. As the denominator of the expression is greater than one the relation always holds in the narrow-gap case ($\alpha \leq \omega$). Consequently, the economy is on the downward sloping side of the wage parabola.

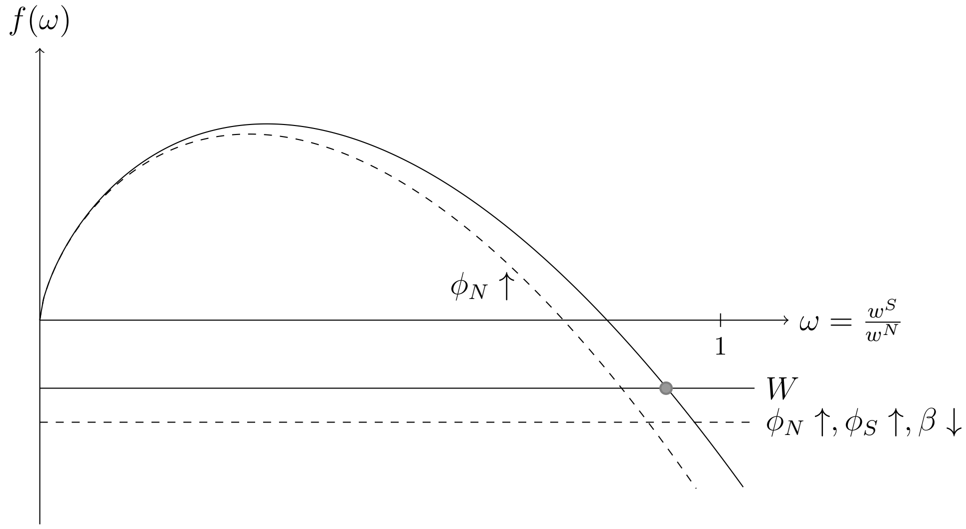


Figure A.1: Relative wage in the narrow-gap case.

Further we know that $W$ will be negative if the imitation rate of southern products is non-negative (compare equation (2.14a)). Figure A.1 also illustrates the effects of changes in the southern innovation productivity $\beta$ and the levels of IPR protection $\phi_N$ and $\phi_S$. The wage gap is higher the higher the southern disadvantage in innovation $\beta$ and the lower the protection of southern goods $\phi_S$: The higher $\beta$ (the lower $\phi_S$) the more attractive it is to imitate. When the imitation rates $\iota_N$ and $\iota_S$ rise, expected profits from innovation decline in both regions. At the same time, due to the higher imitation rates, imitation is also more costly. As a result, the southern wage declines more strongly than the northern one so that the wage gap increases.

Applying the implicit function theorem to the wage function, one can see that the relative wage is falling (wage gap is rising) with stronger IPRs for northern goods $\phi_N$.

While not all balanced growth path effects can be derived analytically, numerical analysis (available from the authors) showed that the remaining effects of changes in IPRs and research efficiency are qualitatively similar to the wide-gap case.

# Appendix B

# Appendix to chapter 2: The model without southern innovation

We turn to a short description of the model of chapter 2 (Lorenczik and Newiak, 2011) for the case in which condition (2.13) is not satisfied such that southern research employment $\ell_R$ is not positive in the general model. As research labor cannot be negative, we set it to zero for both cases which restricts southern activity to the imitation of the North and production. In this case, $\ell_R = \ell_{C_S} = \ell_P = 0$.

The only R&D functions are (2.4a) for northern innovation and (2.5a) for southern imitation of northern goods. Likewise, the no-arbitrage conditions for southern innovation and imitation of the South drop out. The labor market clearing condition for the South becomes $\ell = \ell_{C_N} + \ell_Y = \frac{a\phi_N \iota_N}{N^\theta}\dot{n}_{C_N} + n_{C_N}\bar{x}_{C_N}L$.

Employment in the imitation sector $\ell_{C_N}$ is still given by (2.16), but the imitation rate in that equation is now different. Combining (2.12c) with the variety share $\xi_R^*$ obtained from dividing the northern R&D function by $N$, using $\xi_{C_N} = \iota_N \xi_R^*/g$ and substituting for $\ell_R^*$ from (2.15) we can solve for $n_{C_N}\bar{x}_{C_N}$. To solve for the imitation rate we substitute $n_{C_N}\bar{x}_{C_N}$ and (2.16) in the above labor-market clearing condition.[43] The resulting quadratic equations for wide- and narrow-gap case have each only one positive solution which is given by:

$$\iota_N = \frac{\ell}{\ell^*}\frac{g^2}{2\Lambda_1 d\phi_N}\left(1+\sqrt{1+\frac{4\Lambda_1 d\phi_N}{g^2}\frac{\ell^*}{\ell}}\right), \qquad \omega \leq \alpha \qquad \text{(B.1)}$$

$$\iota_N = \frac{\frac{\ell}{\ell^*}g - \Lambda_3\sqrt{(\frac{\ell}{\ell^*}g-\Lambda_3)^2 + 4\frac{\ell}{\ell^*}g\Lambda_1(d\phi_N(1-\alpha)+\alpha^{1-\varepsilon})}}{2(d\phi_N(1-\alpha)+\alpha^{1-\varepsilon})}, \qquad \omega \geq \alpha \qquad \text{(B.1}'\text{)}$$

in which $\Lambda_3 = \alpha^{1-\varepsilon}(\rho+\theta g)$. The imitation rate is increasing in the relative size of the South $\ell/\ell^*$ and decreasing in the level of IPR protection $\phi_N$. The relative wage is calculated as

$$\omega = \left(\frac{\rho+\theta g+\iota_N}{\rho+\theta g}\frac{g}{d\phi_N\iota_N}\right)^{\frac{1}{\varepsilon}}, \qquad \omega \leq \alpha \qquad \text{(B.2)}$$

$$\omega = \frac{g(\rho+\theta g+\iota_N)\alpha^{1-\varepsilon}}{(1-\alpha)(\rho+\theta g)d\phi_N\iota_N + g(\rho+\theta g+\iota_N)\alpha^{1-\varepsilon}}, \qquad \omega \geq \alpha. \qquad \text{(B.2}'\text{)}$$

As in the case with southern innovation, the relative wage between South and North is decreasing in the strength of IPR protection for northern goods. However, compared to the case in which southern innovation is possible, the imitation rate $\iota_N$ can never be zero, because imitation and the production of imitated goods constitute the only southern activities. From this fact and from (B.2′) follows that $\omega < 1$ for all parameter values. Consequently, the South can never catch up to the North in wages in the no-innovation case.[44]

[43] For the narrow-gap case, we additionally divide (2.12a) by (2.12c) to be able to substitute for the relative wage $\omega$.

[44] If innovation is possible in the South, wages in the two regions can equalize if the southern research sector catches up in efficiency. Setting $\omega = 1$ in (2.18′) we obtain the parameter combination under which wages are equal: $\Delta_1(\rho+\theta g)(1/\beta-1) = g\eta^\star/\phi_S$. This condition says that the South can only catch up in wages if $\beta = 1$, i.e. if research in both regions is equally efficient. As northern products are not subject to imitation any longer in that case, equal wages require perfect IPR protection of southern innovations. This can be achieved by letting $\phi_S \to \infty$. Similarly $\beta = 1$ and $\eta^\star = 0$ lead to $\omega = 1$.

Finally, southern asset holdings and consumption expenditures change with the cease of innovation in the South to $A = \xi_{C_N} d\phi_N w a N^{1-\theta} \iota_N$ and $e = \left(1 + (\rho + g_L) \frac{\xi_{C_N}}{\ell} d\phi_N a \iota_N N^{1-\theta}\right) w$, and the price index reduces to $P = N^{\frac{1}{1-\varepsilon}} \left[\xi_R^* (p_R^*)^{1-\varepsilon} + (1 - \xi_R^*)(p_{C_N})^{1-\varepsilon}\right]^{1/(1-\varepsilon)}$.

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