Rules versus Discretion in the Protection of Intellectual Property*

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Abstract

I study the effect of government patent policy on innovation, profits, and welfare. The framework is a multi-country dynamic model where governments strategically choose their patent policy each period and the strategic interactions between countries are regulated by international trade. Differences in country patent policies can be explained by variation in education, wages, market size, and bilateral trade. I find the inability of government to commit to its patent policy results in less innovation, profits, and welfare. Trade can help government commit, but it also leads to weaker protection as countries do not internalize the effects of their policy on others.

Keywords: Innovation, Intellectual Property Rights, International Trade, Government Commitment.

JEL Codes: E61, F10, O31

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1 Introduction

In their 1977 paper, Kydland and Prescott show that discretionary government policies may not maximize the social objective function even though they provide governments the flexibility to choose the best policy each period. The degree to which government discretion may negatively affect equilibrium outcomes, how these effects differ across countries, or how strategic interactions among countries may mitigate or amplify them are important open questions. This paper represents a step at filling that void.

In particular, I study the effect of discretionary government patent policy – a motivating example in Kydland and Prescott (1977) – on entrepreneurial effort, firm profits, and consumer welfare. The framework is a multi-country dynamic model of endogenous intellectual property right (IPR) protection. At the beginning of each period, welfare-maximizing governments choose the imitation risk facing all goods sold within their borders. Strong patent protection (*i.e.*, low imitation risk) increases the return to investment leading to entry of monopolistically competitive firms and more goods available for consumption, but these goods are also expensive so quantity consumed of each variety is low. Weak protection, on the other hand, enables imitation and marginal cost pricing leading to greater quantities consumed of the available varieties, but these varieties are few as the returns to innovation are small. Further, a government may choose strong IPR protection today to increase the incentive for firms to create new varieties. Tomorrow, however, it may choose weak IPR protection to lower the prices of these goods.

International trade plays a large role in the above trade-off as it introduces both export markets and foreign imports. The former may increase the return to innovation and encourage a country to increase IPR protection while the latter may encourage a country to decrease its level of IPR protection to decrease consumer prices. These effects are both captured in the open economy recursive equilibrium where the endogenous IPR policy in one country must not only be consistent with domestic firm investment but also the IPR policies and firm investment rates in other countries.

The paper delivers several contributions. First, I show that differences in educational attainment (*i.e.*, innovative ability), wages, GDP, and calibrated trade frictions generate country IPR decisions consistent with the data. Second, I find the inability of governments to commit to their IPR policies leads to weaker protection than optimal and, consequently, less innovation, firm profits, and welfare. Third, opening to trade leads all governments to weaken their IPR policies to take advantage of innovations abroad. This is particularly true for developing countries who tend to decrease their level of protection more than developed countries, suggesting a larger free-riding incentive. This strategic use of IPR policy by countries also leads to lower gains from trade as governments adjust their IPR policies to extract rents from the rest-of-the-world. Fourth, I show that trade can act as a commitment device as export markets decrease governments' ability to influence innovation through their patent policy, thereby decreasing their incentive to defect from past IPR policy. Finally, the paper is a methodological contribution as it introduces a dynamic, multinational model of strategic policy-setting sufficiently tractable to tackle a variety of quantitative questions related to international competition amongst governments but out of the scope of this paper (*e.g.*, taxation, tariffs, export subsidies).

The paper proceeds as follows: Section 2 discusses the relevant literature. Section 3 outlines the model and illustrates the key mechanics. Section 4 discusses the empirical strategy while Section 5 presents the results. Section 6 provides concluding remarks.

2 Related Literature

This paper is related to the literature on government commitment, patent protection, and international trade. In addition to Kydland and Prescott (1977), Stokey (1989) considers an environment in which households produce and consume inventions while government may not be able to commit to its patent policy. She shows the commitment and no commitment equilibria are in general different, though there exist trigger strategies to induce the commitment equilibrium provided households are sufficiently patient and the trigger strategy is sufficiently long.

Other papers explore the role of government commitment in setting strategic trade policy. Spencer and Brander (1983) assume governments can commit and examine the optimal strategic innovation and trade policies when international trade connects country pay-offs. Maskin and Newbery (1990) explore the choice of an optimal tariff in a two period, two country model in which issues of dynamic consistency and commitment naturally impact government and firm decisions. Leahy and Neary (1996) combine these papers to assess how firm innovation decisions are impacted when countries set R&D subsidies today but may not be able to commit to these policies in the future. They find that governments inability to commit results in lower export subsidies, R&D subsidies, and welfare.

In the patent protection literature, previous research has been primarily concerned with understanding why different countries choose different levels of IPR protection.[1] Grossman and Lai (2004) study how international trade affects the incentives of governments to protect intellectual property. They use a two-country, North-South model to show that equilibrium IPR protection is increasing in education and market size, both consistent with the data. Helpman (1993) studies the welfare implications from strengthening IPR protection in developing countries. He finds theoretical evidence that the South is generally worse off but the general equilibrium effects on the North are difficult to pin down. Consequently, quantifying the general equilibrium interactions between the North and the South "cannot be answered by theoretical arguments alone."

This paper complements these works in two ways. First, incorporating sequential choice into the government's problem allows me to address how government's inability to commit affects its choice of IPR policy as well as entrepreneurial effort, firm profits, and consumer welfare across different countries. Further, I can quantify the degree to which international trade mitigates this issue. Second, the framework is sufficiently tractable that I can extend theory to data which enables me to quantify the general equilibrium effects among different countries.

The connection between patent protection and bilateral trade is also a large area of interest. Eaton and Kortum (1999) use data on patenting and trade flows to estimate the direction and magnitude of technological diffusion across countries. Maskus and Penubarti (1995) and Co (2004) use gravity regressions to show countries are more willing to export to countries with strong levels of patent protection. This suggests that countries choose stronger levels of patent protection to encourage foreign imports so international trade would have a positive effect on IPR protection. My results indicate just the opposite as countries in the structural model choose weaker levels of IPR protection when introduced to trade.

[1] There is also a large literature on the optimal level of IPR protection. Boldrin and Levine (2008, 2009) argue that countries are choosing levels of patent protection which are too strong as a firm's first-mover advantage is sufficient to encourage innovation. This suggests that a government's objective function may not be based on solely maximizing welfare. Identifying political economy issues that could potentially distort government patent policy and quantifying their impact is out of the scope of this paper, however, but is a topic for further research.

Conditional on these IPR choices, however, trade does flow to countries with stronger levels of IPR protection.

Finally, the paper is related to the large literature on quantifying the gains from trade.[2] Here, international trade leads to welfare gains through the introduction of new varieties from abroad and via innovation (by increasing firm profits via export markets) as well as through lower prices via imitation (by revealing new products to copy). Therefore, the degree to which a country gains from trade depends on its level of openness and the IPR policy chosen by its government. While the former is common in the literature, the latter is novel to this paper.

In order to ensure my results are comparable to the literature, I model trade flows using a simple Armington trade structure as in Anderson (1979). This approach lacks the micro-foundation of more complicated trade models such as Melitz (2003) or Eaton and Kortum (2002), but generates similar gains from trade.[3] I find that countries use their patent policies strategically and choose weaker levels of patent protection when exposed to trade, resulting in lower gains from trade. This suggests the estimated gains from trade found in the trade literature are an upper-bound and the benefits from coordinating national patent policies may be significant – an issue I explore in Thurk (2013). More generally, this suggests that governments use national policies strategically to extract rents from the rest-of-the-world and that these actions, though individually rational, are collectively suboptimal.[4]

3 Model

The model is a multi-country, non-cooperative model of endogenous IPR protection. Entrepreneurs in each country develop new goods each period. All goods are initially unique but face some risk of imitation according to the governments' choices of IPR protection which they choose each period where a "government" is all institutions within a country

[2] See Costinot and Rodriguez-Clare (2013) for a comprehensive review.

[3] See Arkolakis, Costinot, and Rodriguez-Clare (2012).

[4] This appears to be consistent with the data as countries have becoming increasingly interested in coordinating national policies. Baier, Bergstrand, Egger, and McLaughlin (2008) show that approximately half of the 250 international economic integration agreements notified to the WTO and General Agreement on Tariffs and Trade (GATT) between 1947 and 2002 occurred since 1980.

tasked with creating and enforcing patent-related laws.[5] Government policy can, therefore, change across time due to changes in written laws (*e.g.*, patent length or breadth) as well as the effectiveness, interest, or intensity in which the courts enforce written laws. Strong protection encourages the creation of new, expensive goods while weak protection generates less goods but at lower prices.

International trade affects this trade-off by introducing (a) export markets which increases the return to innovation thereby encouraging more protection, and (b) expensive imports which encourages imitation via less protection. Consistent with the data, I consider an environment with "national treatment" in which each government chooses the level of IPR protection afforded to all goods sold inside its borders regardless of country of origin.[6]

3.1 Timing

Agents (governments, consumers, entrepreneurs, firms) enter period t with an endogenous distribution of firms around the world. Events occur in the following sequence in period t:

1. Governments choose their IPR protection rates simultaneously.
2. Firms are imitated stochastically conditional on the level of IPR protection chosen in each country.
3. Firms choose price and realize profit.
4. Firms die at a stochastic rate and entrepreneurs create new firms.
5. Agents move to period $t + 1$

[5] This distinction will be useful when calibrating the baseline model to be consistent with IPR policies observed in the data.

[6] The natural question is whether foreign firms do actually receive the same degree of IPR protection as their domestic counterparts. The doctrine of "national treatment" is a fundamental component of international patent law and is outlined specifically in Article 2 of the 1883 *Paris Convention for the Protection of Industrial Property*:

> Nationals of any country of the Union shall, as regards the protection of industrial property, enjoy in all the other countries of the Union the advantages that their respective laws now grant, or may hereafter grant, to nationals; all without prejudice to the rights specially provided for by this Convention.

There is anecdotal evidence, however, to suggest that this is not always the case. Lerner (2002) notes some of these differences across countries, although it is unclear whether these differences are quantitatively important.

3.2 Households

Time is discrete and the horizon is infinite. To simplify notation, I suppress time subscripts and note when inter-temporal issues exist. There are N countries indexed by $i = 1, \dots, N$. Each country is endowed with a level of innovative ability E_i and L_i consumers. Each consumer is endowed with a unit of time and supplies labor inelastically. Agents in all countries consume a final, non-traded good constructed with the following production function:

$$Q_i = Z_i^{1-\eta} \left[\sum_{n=1}^{N} M_n^{-\lambda} a_{ni} \int_{\omega \in \Omega_n} q_{ni}(\omega)^{\frac{\epsilon-1}{\epsilon}} d\omega \right]^{\frac{\eta\epsilon}{\epsilon-1}} \qquad (1)$$

The first component is a homogeneous, non-traded good Z_i produced with a country-specific constant returns to scale production technology that uses labor as its only input.

The second component is a composite good produced with a set of differentiated goods. Define ω as the product variety, Ω_{ni} is the set of all product varieties exported from country n to country i where $M_n = \int_{\omega \in \Omega_n} d\omega$ is the mass of country n goods. The parameter $\eta \in (0, 1)$ pins down the expenditure share of composite good while $\epsilon > 1$ is the elasticity of substitution between differentiated goods. Both parameters are common to all countries. The "Armington" parameter a_{ni} determines the weight of country n products in country i consumption.

Labor is mobile between the homogeneous and heterogeneous good sectors. In equilibrium, wages are pinned down by each country's production technology in the non-traded sector. Hence, wages are insensitive to changes in government IPR policy or changes in bilateral trade. This simplification focuses my analysis on the interaction of international trade and government IPR decisions independent of changing wage differentials.

The typical Dixit-Stiglitz framework exhibits a "love of variety" effect in which the benefit of consuming small amounts of many varieties is preferred to consuming large amounts of few varieties. Here, government IPR policy will amount to trading off variety and quantity to maximize welfare. In order to guarantee concavity of this trade-off, I follow Benassy (1996) and Alessandria and Choi (2007) and introduce the term $M_n^{-\lambda}$ where $\lambda \in [0, 1]$ attenuates the variety effect. A λ equal to zero emits the standard Dixit-Stiglitz love of variety effect while a λ equal to one generates preferences where consumers hate variety.

This set-up implies the demand for good ω produced in country n and sold in country i is:

$$q_{ni}(\omega) \;=\; \left(M_n^{-\lambda} a_{ni}\right)^{\epsilon} \times \frac{p_{ni}(\omega)^{-\epsilon}}{P_i^{1-\epsilon}} \cdot \eta Y_i \tag{2}$$

where ηY_i is aggregate spending on differentiated goods in country i. P_i is the price index for country i defined as:

$$P_i = \left[\sum_{n=1}^{N} \left(M_n^{-\lambda} a_{ni}\right)^{\epsilon} \times \int_{\omega \in \Omega_{ni}} p_{ni}(\omega)^{1-\epsilon} d\omega\right]^{\frac{1}{1-\epsilon}} \tag{3}$$

3.3 Firms

Firms supply goods according to the linear production function $q_{ni}(\omega) = l_{ni}(\omega)$. All production for a firm from country i occurs in country i, though the firm may choose to sell goods in other countries. There are no trade costs.

Profits in the country n differentiated good sector occur in a spot market at the end of each period. Firm ω from country n solves the following static pricing problem in country i:

$$\max_{p_{ni}(\omega)} \left[p_{ni}(\omega) - w_n\right] \times \left(M_n^{-\lambda} a_{ni}\right)^{\epsilon} \times \frac{p_{ni}(\omega)^{-\epsilon}}{P_i^{1-\epsilon}} \cdot \eta Y_i \tag{4}$$

I assume that firms are sufficiently small such that $\frac{\partial P_i}{\partial p_{ni}(\omega)} = 0$. Optimal pricing is then the constant markup we often see in this class of models.

$$p_{ni}(\omega) \;=\; \frac{\epsilon}{\epsilon - 1} \times w_n$$

where $\frac{\epsilon}{\epsilon-1} > 1$ defines the constant mark-up applied by all differentiated goods firms. Profit for a firm from country n trading in country i is

$$\pi_{ni} = \left(M_n^{-\lambda} a_{ni}\right) \times \left[\frac{w_n}{P_i}\right]^{1-\epsilon} \left[\frac{(\epsilon - 1)^{\epsilon-1}}{\epsilon^{\epsilon}}\right] \eta Y_i \tag{5}$$

and we see that profit is increasing in competitor prices and market size but decreasing in the wage rate.

3.4 Imitation

Each period, goods sold in country i receive an idiosyncratic imitation shock and are imitated by country i firms at rate $1-\gamma_{i,t} \in [0,1]$ where $\gamma_{i,t}$ is the IPR policy chosen by government i in period t. A $\gamma_{i,t}$ choice close to one (zero) is said to have strong (weak) IPR protection. Once imitated, the good is no longer unique and firms compete in prices. Bertrand competition drives price down to marginal cost and quantity demanded increases. If a country n firm is imitated in country n (*i.e.*, it is imitated domestically), the firm cannot export to country i. To simplify the state space, I assume that goods imitated today regain their profitability tomorrow at rate $\gamma_{i,t+1}$ (*i.e.*, imitation occurs every period but is not permanent).

Suppose a country n good is imitated in country i. There are three possible cases:

Case 1: The wage in country i (w_i) is less than the country n wage (w_n). Bertrand competition implies the equilibrium price is w_i and a country i firm produces the good.

Case 2: The wage in country i (w_i) is greater than the country n wage (w_n) but less than $p_{ni} = \frac{\epsilon}{\epsilon-1} \times w_n$. Bertrand competition implies the equilibrium price is w_i. I assume that the country n firm still produces the good so imitation just limits its markup.

Case 3: The wage in country i (w_i) is greater than $\frac{\epsilon}{\epsilon-1} \times w_n$. Imitation has no effect. The country n firm produces the good and sells it in country i at price $p_{ni} = \frac{\epsilon}{\epsilon-1} \times w_n$.

Imitation necessarily implies that markups (and profits) are an endogenous function of government IPR policy.

3.5 Innovation

Country n entrepreneurs create new firms employing labor $L_{R,n}$ using the following production function

$$F(E_n, L_{R,n}) = L_{R,n}^{\alpha E_n} \tag{6}$$

where E_n is the time-invariant stock of innovative ability in country n. Define M_n^e as the mass of new firms in country n and $M = [M_1, M_2, ..., M_N]$ as the vector of firms around the world. Also define the government decision rule for country n as $\gamma_n = \Psi_n(M)$ and the vector of government decision rules as $\Psi = [\Psi_1, ..., \Psi_N]$. A γ_n choice close to one (zero) is said to have strong (weak) IPR protection. Define $\gamma = [\gamma_1, ..., \gamma_N]$ as the vector of IPR decisions around the world. Define γ_{-n} as the vector of all the government IPR choices other than country n. For now, consider the case where Ψ is exogenous. I assume firms exit at an exogenous rate δ, which is common to firms in all countries. The total value of a country n firm is the sum of discounted domestic and export profits:

$$\begin{aligned} V_n(M) &= \sum_{i=1}^{N} \pi_{ni}(M, \gamma) + (1-\delta) \times V_n(M') \\ \text{s.t. } \gamma_n &= \Psi_n(M) \\ M' &= \Upsilon(M, \gamma) \end{aligned} \tag{7}$$

where the law of motion for $M \in \mathcal{M}$ is $\Upsilon : \mathcal{M} \to \mathcal{M}$, and firms in all countries exit at an exogenous rate δ. A country n firm trading in country i earns profit $\pi_{ni}(M, \gamma)$ where profit depends on both the vector of firms around the world (via the price index) and the vector of IPR policies around the world (due to imitation risk).

Entrepreneurs in country n create new firms until the marginal return is equal to the marginal cost:

$$V_n(M) \cdot F_2(E_n, L_{R,n}) = w_n \tag{8}$$

and $F_2(E_n, L_{R,n}) \equiv \frac{\partial F(\cdot)}{\partial L_R}$.

3.6 Governments

Now endogenize the level of IPR protection chosen by governments (Ψ). Governments simultaneously choose their level of IPR protection $\gamma_n \in [0, 1]$ each period to maximize the indirect utility of their consumers.

$$\begin{aligned} W_n(M) &= \max_{\gamma_n} U_n(M, \gamma) + \beta W_n(M') \\ \text{s.t. } \gamma_{-n} &= \Psi_{-n}(M) \\ M' &= \Upsilon(M, \gamma_n, \gamma_{-n}) \end{aligned} \tag{9}$$

where $U_n(M)$ is the indirect utility function of the country n consumer facing aggregate state M (Equation 1) and $\beta \in (0,1)$ is the discount factor common to all countries. Feasibility in the labor market requires

$$L_n \geq L_{Z,n} + L_{R,n}(M) + L_{P,n}(M) \tag{10}$$

where $L_{Z,n}$ denotes total employment in production of the homogeneous good Z, $L_{R,n}$ is the labor employed in establishing differentiated firms, and $L_{P,n}$ is total labor employed in the production in the country n differentiated good sector.

As noted in Kydland and Prescott (1977), the ability of government to deviate from past patent protection decisions has potentially large implications for both firm investment and welfare. Consider as an example the restricted model without international trade. A country i government choosing high IPR protection today may induce entrepreneurs to innovate and increase the mass of firms (a state variable). In the next period, the government may optimally choose a low level of protection to generate imitation and drive prices down (quantities up) increasing consumer utility. Incorporating trade complicates this trade-off as the presence of export markets influences the degree to which IPR policy affects innovation.

Providing this level of flexibility introduces a great deal of complexity to solving the model. Following Krusell, Quadrini, and Rios-Rull (1997) and Corbae, D'Erasmo, and Kuruscu (2009), I solve the government's problem by considering one-shot deviations from the prescribed policy choice of country n, holding the IPR policies of the other countries fixed. Consider the value of a country n firm:

$$\begin{aligned} \tilde{V}_n(M) &= \sum_{i=1}^{N} \pi_{ni}(M, \tilde{\gamma}_n, \gamma_{-n}) + (1-\delta) \times V_n(\tilde{M}') \\ \text{s.t. } \tilde{\gamma}_n &= \tilde{\Psi}_n(M); \;\; \gamma_{-n} = \Psi_{-n}(M) \\ \tilde{M}' &= \Upsilon(M, \tilde{\gamma}_n, \gamma_{-n}) \end{aligned} \tag{11}$$

where a tilde superscript corresponds to the value under the one-shot deviation in IPR policy of country n and $V_n(\cdot)$ is from the solution to the incumbent firm's problem (Equation 7). As before, entrepreneurs choose their research effort ($\tilde{L}_{R,n}$) such that

$$\tilde{V}_n(M) \times F_2(E_n, \tilde{L}_{R,n}) = w_n \tag{12}$$

The government in country n chooses its one-shot deviation IPR policy to solve

$$\begin{aligned} \tilde{W}_n(M) &= \max_{\tilde{\gamma}_n} U_n(M, \tilde{\gamma}_n, \gamma_{-n}) + \beta W_n(\tilde{M}') \\ \text{s.t. } \gamma_{-n} &= \Psi_{-n}(M) \\ \tilde{M}' &= \Upsilon(M, \tilde{\gamma}_n, \gamma_{-n}) \end{aligned} \tag{13}$$

And $W_n(\cdot)$ shows that government n follows $\Psi_n(\cdot)$ for all future periods. From Equation 13, we see that if government n enters period t with few varieties (*i.e.*, low M) it will be tempted to choose stronger IPR in period t (*i.e.*, high γ) to encourage the entry of new firms/ varieties and then return to weak IPR protection in period $t+1$ to decrease prices and increase quantity consumed. Of course, the converse is also true.

3.7 Equilibrium Definition

Given state M, a *spot market equilibrium* in country n is a set of

1. demand functions:

$$q_{ni} = \left(M_n^{-\lambda} a_{ni}\right)^{\epsilon} \times \frac{p_{ni}(\omega)^{-\epsilon}}{P_i^{1-\epsilon}} \cdot \eta Y_i$$

2. price functions:

$$p_{ni} = \begin{cases} \frac{\epsilon}{\epsilon-1} \times w_n & \text{if the good was not imitated or } w_n \times \frac{\epsilon}{\epsilon-1} < w_i \\ w_i, & \text{if the good was imitated but } w_n < w_i \ \& \ w_i < w_n \times \frac{\epsilon}{\epsilon-1} \end{cases}$$

3. profit functions:

$$\pi_{nn}(M, \gamma) = \gamma_n \times \left[\frac{w_n}{P_n}\right]^{1-\epsilon} \left[\frac{M_n^{-\lambda}(\epsilon-1)^{\epsilon-1}}{\epsilon^{\epsilon}}\right] \eta Y_n$$

$$\pi_{ni,i\neq n}(M, \gamma) = \begin{cases} \gamma_n \times \left[\frac{w_n}{P_i}\right]^{1-\epsilon} \left[\frac{a_{ni} M_n^{-\lambda}(\epsilon-1)^{\epsilon-1}}{\epsilon^{\epsilon}}\right] \eta Y_i, & \text{if } \frac{\epsilon w_n}{\epsilon-1} < w_i \\ \gamma_n \times (1-\gamma_i)(w_i - w_n) \times \frac{\left(M_n^{-\lambda} a_{ni}\right)^{\epsilon} w_i^{-\epsilon}}{P_i^{1-\epsilon}} \cdot \eta Y_i, & \text{if } w_n < w_i < \frac{\epsilon w_n}{\epsilon-1} \\ \gamma_n \gamma_i \times \left[\frac{w_n}{P_i}\right]^{1-\epsilon} \left[\frac{a_{ni} M_n^{-\lambda}(\epsilon-1)^{\epsilon-1}}{\epsilon^{\epsilon}}\right] \eta Y_i, & \text{otherwise.} \end{cases}$$

4. and price indeces consistent with Equation 3

such that aggregate spending equals aggregate income ($\eta Y_n = w_n L_n + \Pi_n$) in all countries where aggregate profit of country n firms is defined as Π_n.

As a dynamic model of government and firm behavior, I focus on pure strategy Markov Perfect Equilibrium (MPE) in the sense of Maskin and Tirole (1988) which restricts strategies to be pay-off relevant and history-independent. An **Open Economy Markov Perfect Equilibrium (OEMPE)** is, therefore, a set of government decision rules $\{\Psi_n\}$ such that for all M:

i. each M induces a *spot market equilibrium*;

ii. the discounted profit for incumbent firms is defined by Equation 11 $\forall n$;

iii. entrepreneurs generate M_n^e new firms such that Equation 12 holds $\forall n$;

iv. the IPR decision rule Ψ_n solves the government's problem (Equation 13) $\forall n$;

v. The law of motion for country n (Υ_n) is

$$M_n' = (1-\delta)M_n + M_n^e;$$

vii. And the homogeneous goods generate country wage rates $\{w_n\}$.

As the cross-section of country IPR choices is stable in the data, I restrict my analysis to the set of equilibria in which each country's IPR policy is constant ($\gamma = \gamma' = \gamma''$) which also implies the mass of firm is constant ($M = M' = M''$).[7] The proof for existence of a steady-state OEMPE is located in the Appendix. Proving uniqueness, however, in this class of models is difficult, if not impossible.[8]

3.7.1 *An Alternative Government Policy Mechanism* I also consider a model where governments choose and commit to a single IPR policy at the beginning of time. Under this "commitment" model, the welfare-maximizing IPR policy for country n is defined as Ψ_n^{com} where commitment necessarily constrains future policy choices: $\gamma_n'' = \Psi_n^{com} = \gamma_n'$.[9] This

[7] See the appendix for a discussion on the evolution of national IPR policies over time.

[8] The numerical algorithm I use appears resilient to different initial conditions. That is, starting from different starting values results in the same equilibrium.

[9] Since I'm restricting attention to the set of steady-state equilibria, this definition of commitment necessarily does not allow governments to commit to a menu of different policies conditional on the state.

exercise is useful as the contrast between the equilibrium generated by the benchmark "sequential" choice model outlined above and the equilibrium generated by the "commitment" model identifies the effect of discretionary government patent policy on innovation, firm profits, and consumer welfare.

3.8 Education and IPR Choice

The firm entry condition (8) is at the core of the model since it connects government IPR policy, firm profits, and the mass of entering firms. Rearranging (8) yields the following equilibrium expression:

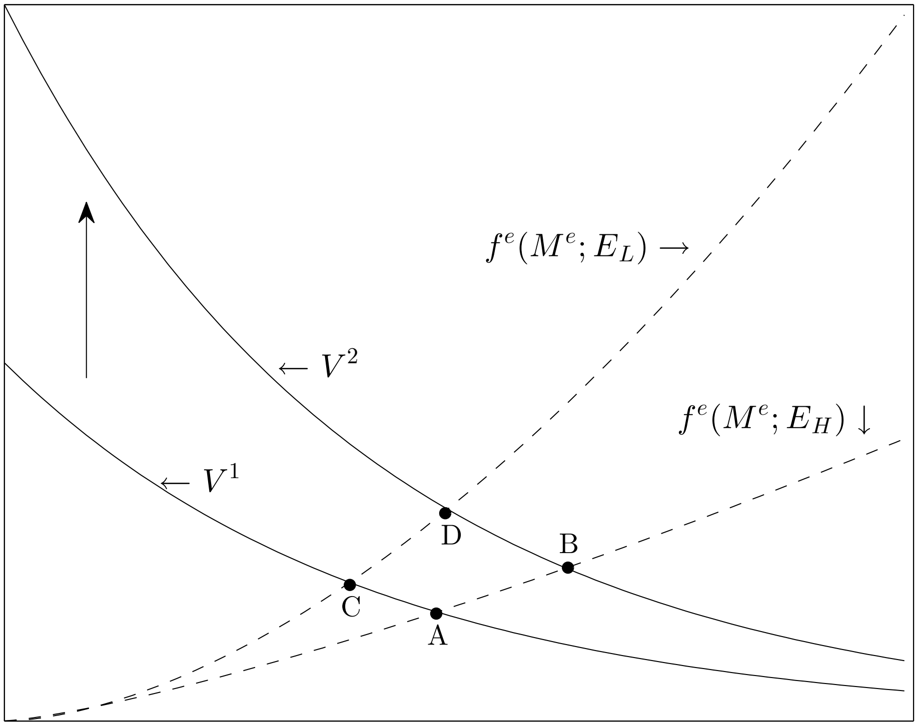
$$V_n(M) = f_n^e \tag{14}$$

where $f_n^e = \frac{w_n}{F_2(E_n, M_n^e)}$. Since firm profit is monotonically decreasing in the number of firms, discounted profits (V) are also monotonically decreasing in the number firms. Hence, we know the left-hand side of (14) is decreasing in the number of entering firms (M_n^e). Further, the "fixed entry cost" f_n^e is monotonically increasing in M_n^e when we constrain $\alpha \times E_n > 0$. Therefore, we know there exists a unique solution (point A) as Figure 1 demonstrates.

Consider two countries H and L facing identical firm value functions V^1 but endowed with different levels of education. Country H is endowed with a higher level of education and therefore faces less decreasing returns to innovative effort since $L_R^{\alpha E_H} > L_R^{\alpha E_L}$ for all values of L_R. This translates to a flatter innovation cost curve f^e. Therefore, there is more entry in Country H than in Country L as we see by comparing points A and C.

Now consider an exogenous shift up in firm profits from V^1 to V^2 due to an increase in government IPR protection. The shift results in an increase in firm entry which increases the number of varieties available for consumption. The increase in firms depends on the slope of the f^e curve which depends on the education endowment in Country n (E_n). In Country H, the increase in protection moves equilibrium entry from point A to point B while in Country L equilibrium entry moves from point C to point D. Since the more innovative Country (H) has a flatter cost curve, the increase in IPR protection leads to a larger increase in entry and relatively more varieties for consumers to purchase. Hence, the marginal benefit of increasing IPR is higher in the more educated country and we would expect IPR protection to be positively correlated with education in the full model.

Figure 1: Connecting Firm Entry and Profits



3.9 Patent Protection as a Non-Cooperative Game

Consider two symmetric countries. The fundamental trade-off facing governments is still the same, but now international trade affects country pay-offs. Namely, a country can choose low IPR protection to take advantage of the varieties created abroad, or increase its protection to accommodate the increased responsiveness of its entrepreneurs due to the presence of export markets. Consider the price index for Country 1:

$$
\begin{aligned}
P_1(M)^{1-\epsilon} \quad = \quad & M_1^{-\lambda\epsilon}\left[\gamma_1 M_1 \times \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\epsilon} + (1-\gamma_1)M_1\right] + \\
& M_{21}^{-\lambda\epsilon} a_{21}^{\epsilon} \times \left[\gamma_1 M_{21} \times \left(\frac{\epsilon}{\epsilon-1}\right)^{1-\epsilon} + (1-\gamma_1)M_{21}\right] \qquad (15)
\end{aligned}
$$

where $a_{11} = 1$, $M_{21} \equiv \gamma_2 M_2$, and I assume $w_1 = w_2 = 1$ for simplicity. Conditional on $M = [M_1, M_2]$, Country 1 has additional incentive to choose a low level of IPR since foreign goods can be imitated by domestic firms. As foreign goods become increasingly important, the marginal benefit from weaker IPR protection increases since countries do not internalize the effects of their IPR protection on others but rather see inventions from other countries as an opportunity to capture rents. This results in countries decreasing their level of IPR protection as they open to trade, ceteris paribus. I call this the "imitation effect."

But there is also an "innovation effect" as trade affects firm profits and therefore the returns to increasing patent protection. Consider the value of a Country 1 idea:

$$V_1 = \Bigg[\underbrace{\gamma_1 \pi_{11}}_{\text{Domestic Profit}} + \underbrace{\gamma_1 \gamma_2 \pi_{12}}_{\text{Export Profit}} \Bigg] \times \frac{1}{\delta} \tag{16}$$

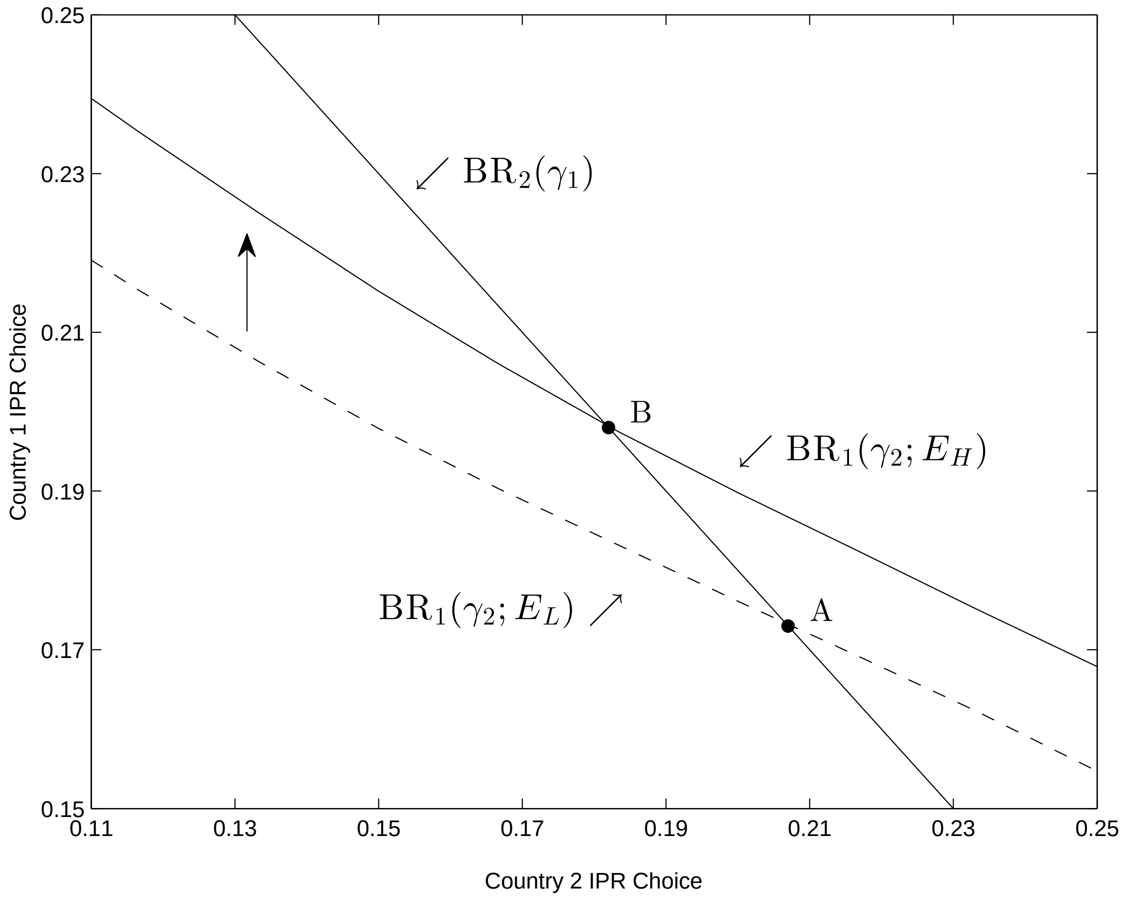
The free entry condition (8) implies that Country 1 research effort is

$$\begin{aligned} L_{R,1} &= (\alpha E_1 V_1)^{1/(1-\alpha E_1)} \\ \Rightarrow \frac{\partial L_{R,1}}{\partial \gamma_1} &= \left[\frac{\alpha E_1}{1-\alpha E_1} \times (\alpha E_1 V_1)^{\frac{\alpha E_1}{1-\alpha E_1}} \right] \times \frac{\partial V_1}{\partial \gamma_1} \end{aligned}$$

The responsiveness of innovation to changes in IPR $\left(\frac{\partial L_{R,1}}{\partial \gamma_1}\right)$ is again greater in more educated countries. With international trade, however, profits are based on both the domestic and export markets – the size of the latter depending on both π_{12} and the IPR protection choice of Country 2. Domestic research effort, therefore, depends not only on the domestic IPR choice but also the IPR choice abroad. Hence, the "innovation effect" depends on the responsiveness of firm profits (domestic and foreign) to increases in IPR protection $\frac{\partial V_1}{\partial \gamma_1}$. If this effect is large (small), then the "innovation effect" ("imitation effect") will dominate and the country will choose to strengthen (weaken) its IPR protection when it opens to trade. Interestingly, both the Country 1 imitation and innovation effects depend on the IPR choice of Country 2 and the converse, of course, is also true. The result is a non-cooperative game in which one country's IPR choice affects the pay-offs and IPR choice of the other countries and international trade acts as the intermediary.

Figure 2 presents the best response curves of each country: $\text{BR}_n(\gamma_{-n}; E)$. Both best response curves are downward sloping regardless of the level of innovative ability indicating that government IPR choices are strategic substitutes. Therefore, an upward shift in the best response curve for Country 1 due to an exogenous increase in innovative ability (E) moves the equilibrium from point A to point B reflecting an increase in the level of IPR

Figure 2: Best Response Curves



protection chosen by Country 1 and a decrease in the level of protection chosen by Country 2. This suggests that increasing the innovative ability of some countries (or just introducing innovative countries) leads other countries to reduce their level of protection in order to extract rents.

3.10 International Trade, Government Commitment, and IPR Choice

The model also provides framework to think about the effect of trade on government commitment. Without trade, a government may be tempted to deviate from a policy of weak IPR protection and choose strong IPR protection today in order to encourage innovation and firm entry. Tomorrow, however, it could return to its weak level of IPR protection to increase consumer welfare via imitation and price competition. This particular strategy has a clear negative effect on firm profit. In the steady-state equilibrium, entrepreneurs acknowledge this possibility and adjust their innovation decisions accordingly.

In order to make this analysis more concrete, consider a two-period restricted version of the model in which two symmetric countries (A and B) choose their patent policies each period. For simplicity, assume there is no discounting ($\beta = 1$) and hold the patent choice of Country B fixed. The government in Country A solves

$$\max_{\gamma_1,\gamma_2} U(M_1) + U(M_2) \tag{17}$$

$$\text{s.t. } M_1 = \Upsilon_1(\gamma_1, \gamma_2) \tag{18}$$

$$M_2 = \Upsilon_2(M_1, \gamma_1, \gamma_2) \tag{19}$$

where subscripts denote the time period. In the sequential model, the Country A government cannot commit to its IPR policy so it chooses its IPR policy in period two (γ_2) to maximize (17) subject to (19) and state (γ_1, M_1). This yields the following first-order equation:

$$\frac{\partial U_2}{\partial \Upsilon_2} \times \frac{\partial \Upsilon_2}{\partial \gamma_2} = 0 \tag{20}$$

When the government can commit to its IPR policy, however, the government chooses γ_2 to maximize (17) subject to both (18) and (19) – it internalizes how its choice of IPR protection in period two affects the innovative effort of entrepreneurs in period one. This yields the following first-order condition:

$$\underbrace{\frac{\partial U_2}{\partial \Upsilon_2} \times \frac{\partial \Upsilon_2}{\partial \gamma_2}}_{\substack{\text{Effect on period}\\ \text{two utility}}} + \underbrace{\frac{\partial U_1}{\partial \Upsilon_1} \times \frac{\partial \Upsilon_1}{\partial \gamma_2}}_{\substack{\text{Effect on period}\\ \text{one utility}}} + \underbrace{\frac{\partial U_2}{\partial \Upsilon_2} \times \frac{\partial \Upsilon_2}{\partial M_1} \times \frac{\partial \Upsilon_1}{\partial \gamma_2}}_{\substack{\text{Effect on period two}\\ \text{utility due change in}\\ \text{period one entry}}} = 0 \tag{21}$$

From the above conditions we see that the government's IPR choice without commitment converges to its IPR choice with commitment as $\frac{\partial \Upsilon_1}{\partial \gamma_2}$ converges to zero – when the IPR choice in period two has no effect on period one entry. In the closed economy model, firm profit depends on the imitation hazard rate in each period, therefore, period one firm entry also depends on period two IPR policy (via 8). Consequently, this condition is never met and the government's choice of IPR policy in the sequential model is always different than the IPR choice in the model with commitment. Further, since I'm restricting attention to steady-state equilibria, we know the IPR choice under commitment is optimal and, therefore, the government's IPR choice when it cannot commit is suboptimal.

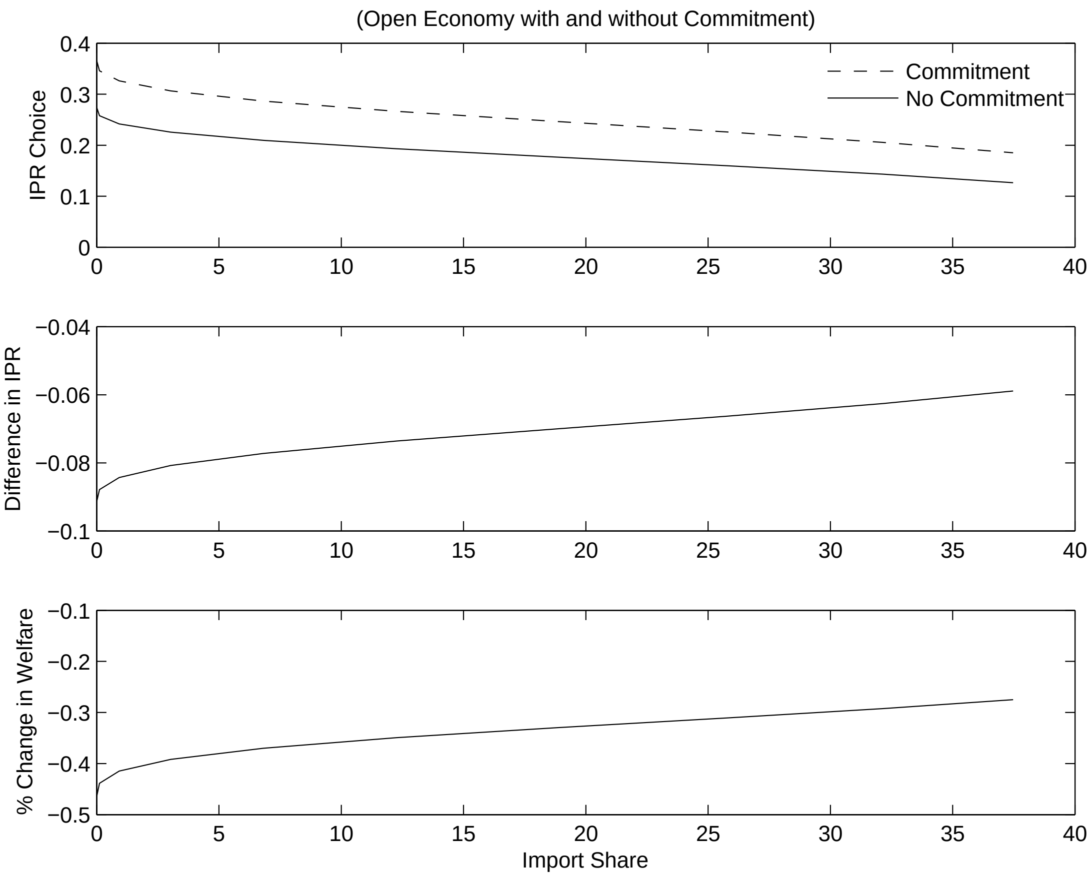
Now introduce export markets and imported goods via international trade. The impact of trade on $\frac{\partial \Upsilon_1}{\partial \gamma_2}$ on IPR choice, firm profits, and entrepreneurial effort is not analytically clear. If the "imitation effect" is dominant, then innovation is less responsive to changes in IPR policy when there are imported varieties (competition) and export markets. Hence, trade would decrease the effectiveness of domestic IPR policy and decrease the ability of governments to generate firm innovation by choosing strong IPR protection today. Trade, therefore, weakens the effectiveness of the deviation strategy ($\frac{\partial \Upsilon_1}{\partial \gamma_2} \downarrow 0$). This is equivalent to a commitment device in the steady-state equilibrium as firms are less concerned about the possibility of policy deviations from the equilibrium path by their government which leads to commitment on the equilibrium path. This scenario is more likely to occur in countries with greater openness to trade since firm profits become more dependent upon export markets.

Figure 3 plots the government IPR choices of Country A when we hold the actions of the Country B fixed and vary the degree to which the countries trade.

The top panel compares Country A's IPR choice both when it can and when it cannot commit to a single level of IPR protection. First, opening to trade leads to a reduction in the level of IPR protection chosen by the government. Second, Country A's inability to commit to an IPR policy results in uniformly lower levels of IPR protection across different degrees of openness. The middle panel shows, however, that this difference between the sequential and commitment equilibria is declining as the country is more open to trade. The bottom panel shows that Country A's inability to commit has a negative effect on welfare but the difference is declining as the country opens to trade.

Of course, the "innovation effect" could dominate and introducing trade would make Country A firms more responsive to changes in IPR policy and $\frac{\partial \Upsilon_1}{\partial \gamma_2}$ would be big. Trade would, therefore, amplify the difference in IPR choices implied by equations (20) and (21). Understanding how trade influences not only IPR decisions but also the degree to which it impacts government commitment is a quantitative issue and the goal of the remaining sections.

Figure 3: Trade and Government Commitment



4 Empirical Strategy

The results from Sections 3.8, 3.9, and 3.10 suggest that patent protection will be positively correlated with innovative ability (E) and that trade introduces strategic interactions amongst countries that will have significant effects on the equilibrium. Understanding the extent to which these effects are true and quantitatively important in the data is the objective of the remaining sections. In order to do this, I first establish a benchmark model which replicates both the national IPR policies and bilateral trade flows observed in the data. I use the benchmark model as a laboratory to explore the quantitative importance of the above effects.

4.1 Calibration

Matching the model to the data requires choosing parameters $\{\beta, \epsilon, \eta, \delta, \lambda, \alpha\}$, a set of countries N, GDP $\{Y_n\}$, wages $\{w_n\}$, bilateral trade weights $\{a_{ni}\}$, and levels of innovative ability $\{E_n\}$. I use a sample of 35 countries representing about 90 percent of world GDP in 1990,[10] and average number of years of education from Barro and Lee (2000) is used as a proxy for innovative ability $\{E_n\}$. From Section 3.8, government IPR choice is positively correlated with innovative ability (*i.e.*, education) so the rank-ordering of $\{E_n\}$ provides discipline on the rank-ordering of country IPR choices. An increase in α increases the return to protecting IPRs (the "innovative effect") leading to all countries choosing stronger levels of protection so I chose α such that the equilibrium IPR choice by the US government implies an imitation hazard rate of 15% based on Mansfield, Schwartz, and Wagner (1981).[11]

The trade weights a_{ni} are pinned down with trade flows. Denote the total trade from country n to country i as T_{ni}, then the model implies the following trade equation:

$$T_{ni} = \begin{cases} \gamma_n \gamma_i X_{ni} \times \left(\frac{\epsilon w_n}{\epsilon-1}\right)^{1-\epsilon} & \text{if } w_i < w_n \\ \gamma_n \gamma_i X_{ni} \left(\frac{\epsilon w_n}{\epsilon-1}\right)^{1-\epsilon} + \gamma_n (1-\gamma_i) X_{ni} w_i^{1-\epsilon} & \text{if } w_i \in [w_n, w_n \times \frac{\epsilon}{\epsilon-1}] \\ \gamma_n X_{ni} \times \left(\frac{\epsilon w_n}{\epsilon-1}\right)^{1-\epsilon} & \text{if } w_n \times \frac{\epsilon}{\epsilon-1} < w_i \end{cases}$$

where $X_{ni} \equiv \left(M_n^{-\lambda} a_{ni}\right)^{\epsilon} P_i^{\epsilon-1} \eta Y_i$. I assume the trade weights are symmetric and take the following log-linear form:

$$\ln(a_{ni}) = a_{const} + a_{dist} \ln(dist_{ni}) + a_{col} colony_{ni} + a_{lang} lang_{ni} + a_{legal} legal_{ni} + u_{ni} \qquad (22)$$

The variable $dist_{ni}$ is the bilateral distance between countries n and i, $colony_{ni}$ is a colony dummy equal to one when country n and i share a colonial history, $lang_{ni}$ is a language dummy equal to one when country n and i share an official language, $legal_{ni}$ is a legal dummy equal to one when country n and i have a common legal system, and u_{ni} is an

[10] The countries included in the sample are Argentina, Australia, Austria, Belgium, Brazil, Canada, Chile, China, Colombia, Germany, Denmark, Ecuador, Egypt, Spain, Finland, France, Great Britain, Greece, Indonesia, India, Italy, Japan, Korea, Malaysia, Mexico, Netherlands, Norway, Peru, Portugal, South Africa, Sweden, Thailand, Turkey, United States, and Venezuela.

[11] The authors document that 60% of patented goods in their study were imitated within four years of introduction. In the context of this model, I interpret this to mean 60% of firms experienced imitation at some point during the first four years after introduction.

i.i.d. error term. I identify the parameters $\{a_{colony}, a_{dist}, a_{lang}, a_{legal}\}$ by the corresponding coefficients from a standard log-linear gravity model:

$$\begin{aligned}\log(T_{ni}) &= \text{constant} + \beta_{dist}\ln(dist_{ni}) + \beta_{col}colony_{ni} + \beta_{lang}lang_{ni} + \\ &\quad \beta_{legal}legal_{ni} + I_i + E_n + u_{ni} \end{aligned} \tag{23}$$

where E_n and I_i are exporter and importer fixed effects, respectively. The constant term a_{const} attenuates the weight applied to all foreign goods independent of location and is identified by average import share.

For the other parameters, I set the elasticity of substitution (ϵ) to 3 which pins down the markup for non-imitated goods. Recall that markups in this model are also a function of the IPR choices of governments. In Section 5, I show that the model generates markups consistent with those found in Broda and Weinstein (2006). International wage data $\{w_i\}$ is from Bureau of Labor Statistics (2012). I follow Eaton and Kortum (2002) in using gross manufacturing output as my input for market expenditure (Y_n) and set the share parameter for the differentiated goods (η) to 0.15 using the average manufacturing expenditure share from United Nations Statistics Division (2007). The firm death rate is set at 10% in line with Bartelsman, Haltiwanger, and Scarpetta (2013) and the time discount factor β is 0.945 given a 7% return on US bonds. The final parameter is the love of variety factor λ which generates concavity in the government's objective function. I use the IPR decisions in the data to reveal the value of λ consistent with these choices.[12]

4.2 Solving the Model

Solving the benchmark model requires finding optimal IPR decisions on and off the equilibrium path. As noted by many authors, solving this class of models is computationally intensive (or impossible) for even moderately-sized state spaces. This is referred to as the *curse of dimensionality* in the Industrial Organization literature since the size of the aggregate state space increases exponentially in the number of agents and possible agent states. I remedy this issue by assuming government and firm decision rules take the aggregate state (M) as given, though still endogenous. Weintraub, Benkard, and Van Roy (2008) show

[12]Specific details regarding the calibration are located in the Appendix.

that this approach provides a good approximation to a Markov Perfect Equilibrium when the number of agents is greater than three or four and no agent has a dominant position.

This approach is appropriate here. First, CES preferences imply that firms make all their decisions (*i.e.*, innovation, pricing, production, and trade) taking the aggregate state and related laws of motion as given. Second, "national treatment" limits strategic interactions between individual countries, thereby reducing the problem to a series of small open economy problems. Regarding dominance, governments choose their IPR policies simultaneously by construction so there is no inherent first mover advantage that might cause concern. The fact that the model involves a large number of countries, all of which each comprise a relatively minor share of total world exports provides further reassurance that this approach is appropriate.[13]

5 Results

I use the model to address the quantitative importance of government commitment and international trade on equilibrium IPR policies, innovation, firm profits, and welfare. In Section 5.1, I present the results from the open economy model in which governments choose IPR policy each period and cannot commit. In Section 5.2, I show that countries use their IPR policy strategically to extract rents from the rest-of-the-world and this is particularly true for developing countries. In Section 5.3, I show that the inability to commit to their IPR policy leads to weaker levels of patent protection, lower innovation rates, lower profits, and less welfare in all countries. In Section 5.4, I show that international trade does indeed narrow the gap between the equilibrium IPR levels chosen with and without commitment – evidence that trade can act as a commitment device.

5.1 Benchmark Results

I evaluate the model's ability to replicate the IPR decisions in the data using an index developed by Ginarte and Park (1997) (hereafter GP). The GP index measures the strength of a country's patent regime according to its (1) extent of coverage, (2) membership in

[13]United States, Japan, and Germany are the largest exporters in the sample and account for 13.5%, 15.8%, and 14.8% of world exports, respectively.

international patent agreements, (3) provisions for loss of protection, (4) enforcement mechanisms, and (5) duration of protection.[14] While the GP index provides a simple and effective way of mapping the abstract notion of IPR protection into a numerical index, replicating these values is not meaningful. For example, if two countries have GP scores of 2 and 1, respectively, does the first country have a level of protection twice as strong as the first? Not necessarily, but it does imply that Country One chooses a stronger level of IPR protection than Country Two. Accordingly, I evaluate the model by its ability to replicate the ordinal ranking of countries observed in the data.

Table 5.1 presents cross-country statistics from the benchmark model, as well as the correlations between these statistics and patent protection. Using the Spearman rank-order correlation (ρ) as a measure for goodness of fit, the benchmark model generates heterogeneous IPR decisions consistent with the data ($\hat{\rho} = 0.76$). The correlation is high and statistically significant at one percent so I can reject the null hypothesis that the model's results are uncorrelated with the data. Developed, research-intensive countries such as the US, Germany, and Japan choose strong levels of protection, while developing, imitative countries like India, Brazil, and China choose weak levels of protection.

The model seems to do a better job at replicating the ordinal ranking of IPR choices amongst smaller, developing countries. Since countries in the model are heterogeneous only in their level of education, wage, market size, and bilateral trade weights, this result indicates that additional factors may drive developed country IPR decisions. For example, while I choose parameters based broadly on observed trade for all manufacturing goods, developed countries may concentrate production and trade within specific manufacturing sub-sectors. The research intensity and IPR sensitivity of these sub-sectors would likely impact the IPR choices of the country.

Markups are 31% on average, consistent with Broda and Weinstein (2006), but they vary as more innovative countries choose stronger IPR protection generating larger markups. The correlation between discounted firm profits (V) and IPR protection is positive and significant (0.69) – consistent with the prediction from Section 3.8. The right-most column indicates that entrepreneurs in countries that choose a high level of patent protection are very responsive to changes in policy reflecting the greater level of innovative ability and higher returns to innovation in these countries – again consistent with Section 3.8. Finally, import

[14] Further specifics are located in the Appendix.

Table 5.1: Open Economy with Sequential IPR Choice (Benchmark)

Country	Market Size	Innovative Ability	Wage	Import Share	IPR	Avg Markup	V	Innovation Elasticity
United States	28.27	1.00	1.00	10.19	0.85	1.43	100.00	1.71
Belgium	0.22	0.70	1.56	77.76	0.31	1.33	20.27	0.66
Great Britain	4.29	0.73	1.02	29.43	0.49	1.26	61.35	0.91
Netherlands	1.63	0.72	1.19	42.28	0.43	1.31	42.06	0.86
Italy	3.75	0.51	1.22	21.99	0.32	1.28	34.51	0.56
Germany	9.03	0.75	1.51	20.07	0.56	1.38	100.54	1.01
Denmark	0.52	0.84	1.15	33.35	0.47	1.30	41.20	1.04
France	4.94	0.63	1.41	26.81	0.43	1.40	56.83	0.76
Japan	19.76	0.77	1.13	3.81	0.59	1.34	118.58	1.04
Sweden	1.10	0.80	1.26	30.95	0.54	1.37	48.03	1.06
Korea	2.26	0.77	0.47	15.22	0.45	1.35	42.84	0.76
Austria	0.92	0.68	1.36	34.61	0.37	1.37	30.20	0.77
Spain	2.65	0.51	1.47	18.31	0.33	1.42	25.18	0.56
Norway	0.55	0.90	1.20	26.85	0.59	1.36	51.49	1.30
Finland	0.70	0.79	1.13	21.69	0.54	1.32	38.79	1.04
Australia	1.43	0.84	0.92	16.97	0.65	1.34	50.89	1.20
Canada	2.90	0.88	0.88	27.21	0.66	1.34	63.38	1.26
South Africa	0.70	0.43	0.42	13.98	0.19	1.28	15.18	0.31
Greece	0.35	0.64	0.65	29.99	0.28	1.31	28.95	0.50
Chile	0.21	0.59	0.39	19.42	0.26	1.30	18.01	0.45
Malaysia	0.38	0.46	0.46	40.21	0.20	1.28	13.72	0.33
Argentina	1.02	0.65	0.42	1.90	0.35	1.32	25.36	0.59
Portugal	0.45	0.36	0.44	32.67	0.13	1.26	29.26	0.21
Indonesia	0.40	0.27	0.20	26.05	0.10	1.26	25.30	0.16
Egypt	0.25	0.30	0.23	21.54	0.10	1.25	41.39	0.17
Mexico	0.52	0.49	0.22	34.11	0.19	1.27	45.49	0.31
China	7.33	0.44	0.14	2.29	0.17	1.27	60.35	0.27
Brazil	0.00	0.31	0.50	2.19	0.11	1.26	7.35	0.19
Thailand	0.80	0.45	0.34	22.02	0.19	1.27	19.69	0.31
Turkey	0.72	0.33	0.58	12.62	0.13	1.28	12.32	0.22
Ecuador	0.05	0.49	0.35	21.94	0.19	1.27	18.55	0.33
Colombia	0.21	0.36	0.38	8.52	0.13	1.26	14.05	0.23
India	1.31	0.31	0.12	5.15	0.11	1.25	64.19	0.17
Venezuela	0.25	0.41	0.62	14.59	0.17	1.28	9.04	0.28
Peru	0.13	0.49	0.30	7.87	0.19	1.28	21.66	0.33
Corr(IPR,X)	0.58***	0.95***	0.67***	0.08	1.00	0.75***	0.69***	0.99***

Notes: Countries presented in descending order according to GP Index. "Market Size" (Y) is share of total expenditure in the sample. "Innovative Ability" (E) is the educational attainment from Barro and Lee (2000) relative to the United States. Average Markup" is the average markup for goods sold in the country after accounting for imitation. All values for the discounted value of a firm (V) are relative to the US value. "Innovation Elasticity" is defined as $\%\Delta M_n^e/\%\Delta\gamma$. Correlation significance indicated by * $p < 0.10$, ** $p < 0.05$, and *** $p < 0.01$.

share is not significantly correlated with IPR protection indicating that general openness to trade is not a good predictor of IPR policy.

5.2 IPR Policy as a Strategic Choice for Governments

In this section, I compare the benchmark equilibrium to one without international trade to further explore how trade influences the IPR policies chosen by different countries. Without trade, the pay-off for country i is independent of the IPR choice of country n so countries choose their level of patent protection based solely on market size (Y), wage rate (w), and innovative ability (E). Table 5.2 presents the equilibrium imitation hazard rates, firm profits, and welfare effects of moving from autarky to the benchmark open economy model.

Table 5.2: Open Versus Closed Economy Results

		Hazard Rate $(1-\gamma)$			Firm Profit (V)			Welfare
	IM/Y	Open	Closed	Δ	Open	Closed	Δ	%Δ
All Countries:								
-Mean	22.13	66.43	56.09	10.34	39.89	35.13	4.75	4.60
-Std Dev	14.67	19.80	18.36	1.43	26.54	35.57	-9.03	2.41
Developed:								
-Mean	27.31	54.15	45.21	8.93	50.35	57.56	-7.21	3.94
-Std Dev	15.34	17.84	15.91	1.93	28.48	33.89	-5.41	2.35
Developing:								
-Mean	15.98	81.02	69.00	12.02	27.46	8.50	18.96	5.38
-Std Dev	11.43	9.41	11.54	-2.13	17.89	9.77	8.12	2.30

Notes: "IM/Y" is the share of total expenditure dedicated to imports. All values for the firm profits (V) are relative to the US value in the open economy model. $\Delta(1-\gamma)$, ΔV, and %Δ welfare are the change from the closed economy to the open economy equilibrium.

Introducing trade generates four primary results. First, it increases the model's fit from 0.73 to 0.76 indicating that trade is an important determinant to understanding country IPR choices. Since import share is not a significant indicator for IPR policy, this result indicates that who a country trades with is more important than its general openness to trade. Second, all countries choose to reduce their level of IPR protection leading to a 10.34% increase in the imitation hazard rate; hence the *imitation effect* dominates the *innovation effect* (Section 3.9). This suggests that all countries use their national IPR policy as a strategic mechanism to extract rents from the rest-of-the-world. This effect is greater in developing, imitative countries as trade leads to a 12.02% increase in the hazard rate for these countries (*e.g.*, Brazil, China, Mexico) compared to a 8.93% increase for developed, more innovative economies (*e.g.*, United States, Germany, Japan).

Third, opening to trade has significant effects on firm profitability, which is not obvious since trade introduces foreign competition as well as export markets. Introducing trade increases the value of a firm in most countries (4.75%, on average), though firms in developed countries generally see their profits decrease while average profits for firms in developing countries increase. Hence, trade liberalization appears to have a disproportionately large benefit for entrepreneurs in developing countries as trade gives them access to large foreign markets. Firms in developed countries, in contrast, are already located in relatively large markets so a reduction in trade barriers introduces more competition than it does market potential.

Fourth, international trade increases average welfare by 4.60%, on average. Developing countries generally benefit more from trade (5.38%) than developed countries (3.94%). Large countries with relatively low openness to trade like the US experience smaller increases in welfare while smaller countries that trade a lot such as Austria, Belgium, Denmark, and Mexico generally experience large increases in welfare.

Moving from autarky to an open economy introduces strategic incentives between countries. The degree to which different countries adjust their IPR policy in the equilibrium identifies the extent to which they use their domestic IPR policy as a strategic lever to potentially extract rents from their neighbors. Understanding how strategic play amongst the countries may hinder or enhance the gains from trade is difficult, however, since there are several forces at play in the general equilibrium. For example, given the IPR choices of the rest-of-the-world and the implied distribution of firms (M) in the closed economy equilibrium, country i may modify its IPR choice to maximize welfare. Other countries, however, can respond to this modification and change their own IPR policies. In the equilibrium, each country's IPR decision maximizes welfare conditional on the actions of the rest-of-the-world. Consequently, the strategic play and the resulting welfare of country i may be confounded if we just compare the closed economy and open economy equilibria. To address this issue I compare the change in welfare of opening economies to trade (using the calibrated trade weights) when (a) country IPR policies are fixed at their closed economy level and when (b) countries are allowed to change their IPR policies in response to trade.

The first column of Table 5.3, shows that opening to trade conditional on the IPR choices in the closed economy model (*i.e.*, "IPR Fixed") generates welfare gains of 5.17%, on average. This exercise is the analog to the standard "gains from trade" experiment in the international trade literature and yields results consistent with that literature.[15] In the second column are the equilibrium results from Table 5.2 when countries can change their IPR policies (*i.e.*, "IPR Flexible").

Table 5.3: Decomposing the Gains from Trade

		%Δ Welfare from Closed Economy Model		
	IM/Y	IPR Fixed	IPR Flexible	Difference
All Countries:				
- Mean	22.13	5.17	4.60	-0.57
- Std Dev	14.67	2.52	2.41	0.11
Developed:				
- Mean	27.31	4.93	3.94	-0.98
- Std Dev	15.34	2.75	2.35	0.40
Developing:				
- Mean	15.98	5.46	5.38	-0.08
- Std Dev	11.43	2.26	2.30	-0.04

Notes: "IM/Y" is the share of total expenditure dedicated to imports. Country-specific results located in the Appendix.

The third column of Table 5.3 compares the first two and reveals that opening to trade and allowing countries to re-optimize their IPR policy yields lower average welfare gains (4.60% versus 5.17%). This provides further evidence that countries do indeed use IPR policy as a strategic mechanism to extract rents and these actions lead to a sub-optimal aggregate outcome. This is analogous to the classic "Prisoner's Dilemma" game where individual profit-maximizing players generate an outcome which is collectively sub-optimal.[16]

Not all countries are worse off, however, as 8 of the 35 countries experience net welfare increases. Most of these are developing countries (7) which provides evidence that developing countries use domestic IPR policy for, in the words of Adam Smith, "beggaring all their neighbours" from the North. This finding appears consistent with recent efforts

[15]For example, see Eaton and Kortum (2002) and Arkolakis, Costinot, and Rodriguez-Clare (2012).

[16]Deardorff (1996) makes a similar conclusion when analyzing national trade policies.

to harmonize international IPR standards[17] and suggests there may be significant gains to coordinating national patent policies – an issue I address in Thurk (2013).

5.3 The Effects of Government Commitment

In this section, I quantify the equilibrium effects of governments' inability to commit to their IPR policies. Table 5.4 presents the open economy equilibrium when we assume governments can commit to their IPR policy ("C") and when we assume that governments choose their IPR policy each period ("S"). Whether or not we assume governments can commit has significant effect on their equilibrium IPR choice, as well as on firm profits and innovative effort but not on the rank-order correlation ($\hat{\rho} = 0.77$). I find that a commitment technology enables governments to choose stronger levels of IPR protection which reduces the imitation hazard rate 7.04% on average. The lower risk of imitation leads to a 7.56% increase in market entry (*i.e.*, innovation) and a 6.86% increase in profits.

Table 5.4: Open Economy Sequential and Commitment Equilibria

		Hazard Rate $(1-\gamma)$			Firm Profit (V)			Innovation (M_n^e)		
	IM/Y	S	C	%Δ	S	C	%Δ	S	C	%Δ
All Countries:										
-Mean	22.13	66.43	59.39	-7.04	39.89	42.62	6.86	15.61	16.79	7.56
-Std Dev	14.67	19.80	20.77	1.82	26.54	27.57	3.88	18.86	20.20	7.09
Developed:										
-Mean	27.31	54.15	46.38	-7.77	50.35	53.02	5.30	12.14	13.24	9.02
-Std Dev	15.34	17.84	18.03	1.72	28.48	29.34	3.01	22.26	23.98	7.71
Developing:										
-Mean	15.98	81.02	74.85	-6.17	27.46	30.27	10.26	19.72	21.00	6.49
-Std Dev	11.43	9.41	10.87	1.57	17.89	19.77	10.50	13.36	14.14	5.84

Notes: "IM/Y" is the share of total expenditure dedicated to imports. All values for the firm profits (V) are relative to the US value in the sequential, open economy model. $\Delta(1-\gamma)$, $\%\Delta V$, and %Δ welfare are the average change from the sequential to the commitment equilibria.

[17] During the Uruguay Round of World Trade Organization negotiations in the early 1990s, negotiators from the United States and Europe emphasized the need for stronger patent protection in developing countries. The result was the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) which introduced the regulation of intellectual property rights (IPRs) into the WTO for the first time and remains the most comprehensive international agreement on IPRs to date. The general purpose of TRIPS was to define a minimum level of IPR protection across member countries and to harmonize the definition and enforcement of patent regulation.

The benefit of a government commitment technology appears to be larger for richer, more innovative countries presumably due to the increased responsiveness of entrepreneurs to changes in government IPR policy in these countries. The introduction of a commitment technology has a larger effect on the IPR policies of developed countries (7.77% decrease in imitation risk) than in developing countries (6.17% decrease in imitation risk). Firms in developed countries experience a 5.30% increase in profits and entrepreneurs respond by generating 9.02% more firms. Firms in developing countries experience a similar profit increase in levels but this reflects a substantial percentage change (10.26%) due to a lower base. The response by entrepreneurs is more muted in these countries (6.49%) though still substantial.

Table 5.4 demonstrates that introducing a commitment technology has significant equilibrium effects but how much of this results directly from commitment and how much is due to the strategic interactions among countries in the equilibrium is unclear. In order to isolate the effect of commitment without these strategic interactions, Table 5.5 presents the results when I take the benchmark equilibrium and introduce a commitment technology in each country but hold the aggregate state fixed. Consequently, this a partial equilibrium analysis in which I prevent other countries from responding to a deviation in country n's IPR choice resulting from its exposure to a commitment technology.

Table 5.5: The Effect of Commitment on Equilibrium Outcomes

		%Δ			
	IM/Y	Imitation	Profits	Innovation	Welfare
All Countries:					
- Mean	22.13	-7.75	12.80	13.83	0.05
- Std Dev	14.67	2.07	5.39	5.07	0.01
Developed:					
- Mean	27.31	-8.93	10.57	17.21	0.04
- Std Dev	15.34	1.65	5.57	3.81	0.01
Developing:					
- Mean	15.98	-6.35	15.46	9.82	0.05
- Std Dev	11.43	5.57	3.84	3.04	0.01

Notes: "IM/Y" is the share of total expenditure dedicated to imports. "Imitation" is the change in imitation hazard rate. "Profits" is the change in firm profits (V). "Innovation" is the change in firm entry (M_n^e). "Welfare" is the change in utility (consumption). Country-specific results located in the Appendix.

The results from Table 5.5 are consistent with the equilibrium comparison in Table 5.4. All countries choose to increase their IPR protection and the risk of imitation falls 7.75%. The stronger protection increases profits 12.80% and incentivizes entrepreneurs to create 13.83% more firms – both of which are substantially greater than in the equilibrium from Table 5.4. The overall welfare effect (0.05%) is small, however, as lower imitation increases prices and decreases the quantity consumed of each product. Incorporating technological spillovers would likely amplify these effects as shown by Atkeson and Burstein (2011), though modeling these spillovers is difficult since there exists little data to discipline their role.

Introducing government commitment is again more important in developed countries as the change in IPR policy is larger in these countries. While the change in profits is greater in developing countries (15.46% versus 10.57%), this is largely due to the fact that entrepreneurs in developed countries are more responsive (17.21% versus 9.82%) to the change in protection.

5.4 Trade as a Commitment Device

In this section, I combine the above analyses to explore the interaction of international trade and governments' inability to commit on IPR policy. Specifically, Table 5.6 shows that the combination of these forces has significant impact on the equilibrium IPR policy of all countries. These results also provide an opportunity to address whether the presence of international trade brings countries closer to the IPR policies chosen when a commitment device does exist. If trade does act as a commitment device, we should observe the gap between the IPR policies chosen under sequential and commitment models shrink when trade is present (*i.e.*, $\Delta^{ce} - \Delta^{o} < 0$).

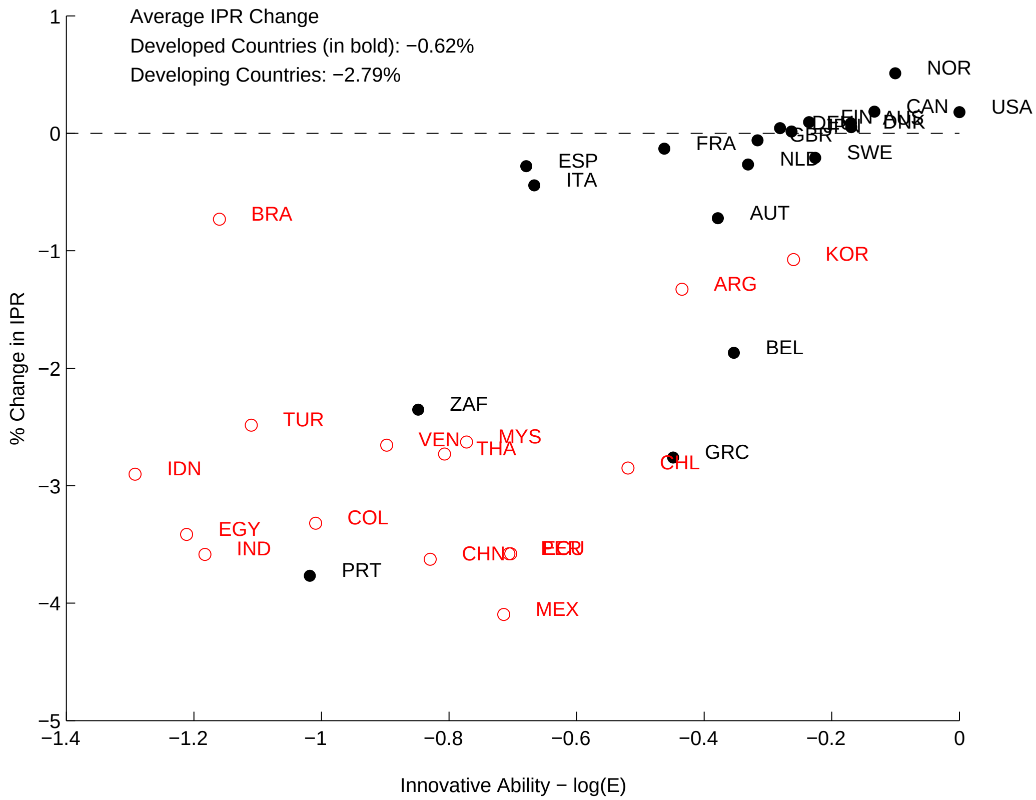
Table 5.6: IPR Policies Under Different Environments

		Open Economy $(1-\gamma)$			Closed Economy $(1-\gamma)$			
	IM/Y	S	C	Δ^o	S	C	Δ^{ce}	$\Delta^{ce}-\Delta^o$
All Countries:								
-Mean	22.13	66.43	58.68	-7.75	56.09	46.73	-9.36	-1.61
-Std Dev	14.67	19.80	21.10	2.07	18.36	18.47	1.47	1.54
Developed:								
-Mean	27.31	54.15	45.22	-8.93	45.21	35.67	-9.55	-0.62
-Std Dev	15.34	17.84	17.99	1.65	15.91	15.10	1.44	1.18
Developing:								
-Mean	15.98	81.02	74.67	-6.35	69.00	59.86	-9.14	-2.79
-Std Dev	11.43	9.41	10.88	1.60	11.54	12.69	1.51	0.98

Notes: "IM/Y" is the share of total expenditure dedicated to imports. Δ is the average change in imitation hazard rate. I hold the aggregate state fixed in order to isolate the effect of commitment from general equilibrium effects incorporated in the aggregate state. Hence, the IPR choices in the "open economy, commit" column are different than those presented in Table 5.4. Country-specific results located in the Appendix.

Table 5.6 indicates that both trade and the inability to commit has significant effects on IPR policy and, therefore, also on firm profits, entrepreneurial effort, and welfare. First, introducing a commitment technology in the open economy model leads all governments to choose stronger levels of protection and decrease the imitation rate 7.75%, on average, and the effect is larger in the closed economy model as imitation rates fall 9.36% on average. Second, opening the model to trade reduces the IPR protection choices of all countries regardless of whether we assume commitment or not. Third, introducing trade does, on average, narrow the gap between equilibrium IPR policies in the sequential and commitment models. Further, this effect is more pronounced in developing countries where introducing trade leads to a 2.79% decrease in the effect of commitment on IPR policy.

Figure 4: Trade as a Commitment Device (by Country)



The descriptive statistics presented in Table 5.6 mask an interesting level of heterogeneity in the model – not all countries can use trade as a commitment device. Figure 4 demonstrates that trade can also amplify the gap between the sequential and commitment equilibria ($i.e.$, $\Delta^{ce} - \Delta^{o} > 0$), particularly for developed countries (in bold). In Table 5.7, I project these gaps on country characteristics to identify possible explanations.

Table 5.7: **Trade, Commitment, and Country Characteristics**

Gap ($\Delta^{ce} - \Delta^{o}$)	(i)	(ii)	(iii)	(iv)
Constant	-1.7986***	-3.6084***	-2.6354***	-2.7711***
	(0.4805)	(0.2610)	(0.3189)	(0.4702)
Import Share (IM/Y)	0.8612	-	-	-4.8570***
	(1.8180)			(2.2827)
Innovation Elasticity	-	3.2008***	-	1.8698***
		(0.3517)		(0.7140)
Interaction	-	-	7.0181***	7.3051***
			(1.6326)	(3.3939)
R^2	0.0068	0.7151	0.3590	0.7533
N	35	35	35	35

Model (i) demonstrates that failing to account for other country characteristics may leads us to conclude that openness to trade (*i.e.*, import share) actually amplifies the difference between the IPR policies chosen in the sequential and commitment equilibria. We may therefore incorrectly conclude that trade exacerbates the negative effects (*e.g.*, lower profits, entrepreneurial effort, and welfare) associated with a government's inability to commit. Model (iv), however, shows us that controlling domestic firms' sensitivity to changes in government IPR protection is a more important component to explaining the increasing gap between the sequential and commitment equilibria, and that trade actually decreases the gap. Consequently, it appears that trade does indeed act as a commitment device for most countries and, therefore, mitigates some of the negative effects of suboptimal IPR policy to entrepreneurs, firms, and consumers.

6 Conclusion

The inability of governments to commit to a particular IPR policy choice can have significant implications when agents are forward-looking, but there exists little evidence to indicate how big these effects are, how they differ across countries, or how strategic interactions among countries may mitigate or amplify them. This goal of this paper was to begin filling that void. At the core of the analysis is a multi-country, non-cooperative model in which governments choose their level of patent protection each period and international trade acts as the intermediary connecting country pay-offs via both export markets and foreign imports. I use differences in educational attainment, GDP, and calibrated trade frictions to generate country IPR decisions and trade flows consistent with the data. I then use this as a benchmark to quantify the effects of government commitment.

The inability of governments to commit to their IPR policies leads to suboptimal levels of patent protection and decreases innovation, firm profits, and welfare. I find that opening to trade leads all governments to weaken their IPR policies to take advantage of innovations abroad and developing countries tend to decrease their level of protection more than developed countries. The strategic use of national patent policies ultimately reduces the grains from trade as countries choose their IPR policies to extract rents from the rest-of-the-world but fail to internalize the effects on the aggregate state. This suggests the potential gains from coordinating national IPR policies may be large and is a topic for further research. I also find that trade acts as a commitment device as export markets decrease government's ability to influence innovation through its patent policy, thereby decreasing its incentive to defect from past IPR policy.

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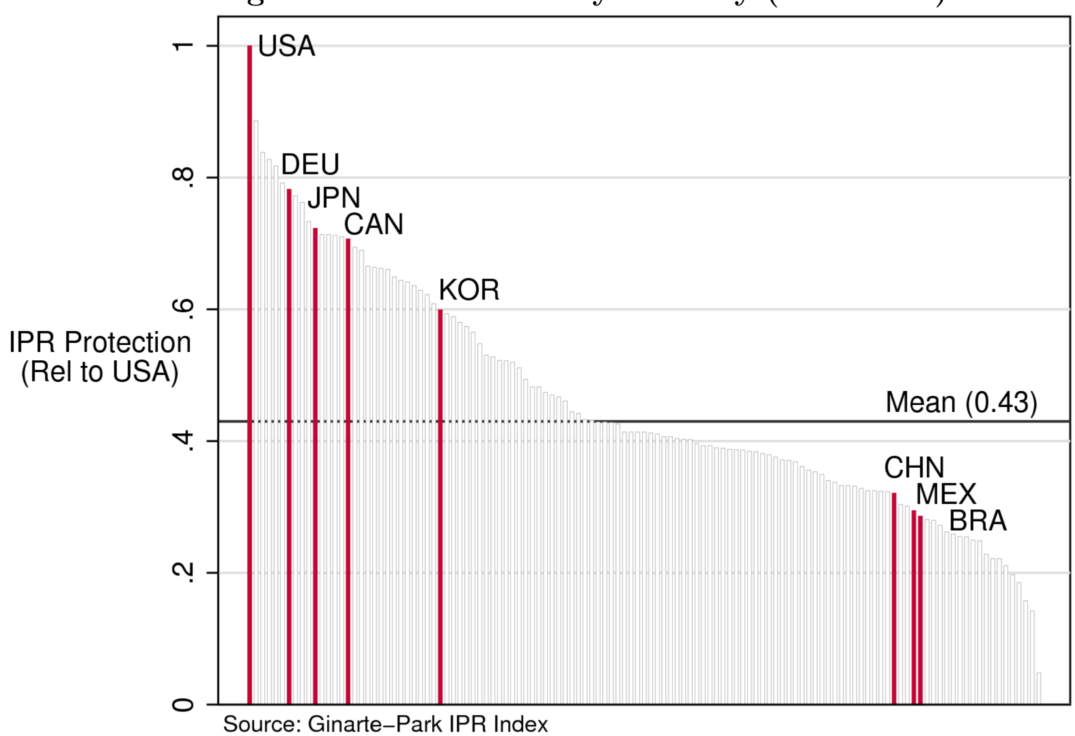
Appendix

A Intellectual Property Rights

In contrast to tariffs, IPR protection is a national policy that applies to all goods sold in that country, regardless of origin, and it refers to any protection afforded to the creator of an idea. In this paper I am interested primarily in the protection of technology (i.e, utility patents), but IPR protection can also refer to copyrights, trademarks, or even trade secrets. How these ideas are protected is equally broad, encompassing fundamental issues such as the definition of a patent right, the duration of that right, breadth of patentability, viability of enforcement institutions, and penalties for infringement. Further, a firm choosing not to patent an idea can also gain from increased IPR protection. For example, non-disclosure agreements are a form of protection intended to prevent the employees of one firm from divulging trade secrets to other firms. Therefore, a firm in one country has to file for a patent in each country it desires protection. The inability of countries to discriminate their level of IPR protection based on national origin also limits the strategic interactions between two specific countries but strategic incentives between one country and the rest-of-the-world still exist.

Figure A.1 demonstrates that countries choose very different levels of IPR protection.

Figure A.1: GP Index by Country (1960-1990)



Developed countries such as the US, Germany, and Japan choose high levels of IPR protection, while developing countries like China, Brazil, and Mexico have lower levels of IPR protection. Table A.1 demonstrates that the cross-section of government IPR protection is relatively stable across time, though the average GP index does increase.

Table A.1: The GP Index Across Time

Year	Mean	Median	Std Dev
1960	0.46	0.41	0.17
1965	0.47	0.42	0.18
1970	0.48	0.44	0.19
1975	0.49	0.44	0.19
1980	0.46	0.41	0.19
1985	0.44	0.41	0.19
1990	0.46	0.41	0.20
1995	0.55	0.50	0.21
2000	0.63	0.63	0.20
2005	0.69	0.69	0.18

Source: Ginarte and Park (1997) where I normalize the GP index by the US. Special thanks to Walter Park for providing updated scores for 2000 and 2005.

The sharp increase in IPR protection after 1990 is due to the implementation of the TRIPS agreement.[18] The creation of TRIPS and its inclusion in the WTO suggests the existence of large externalities between countries. In particular, weak levels of IPR protection chosen by developing countries may have significant negative effects on the returns to innovation for firms in developed countries.

A.1 IPR Policy Across Time The analysis in the paper focused on comparative statics in the steady-state but the results also have dynamic implications – particularly related to the tension between openness to trade and innovative ability. The model predicts that the increase in world trade since 1960 will encourage countries to decrease their level of patent protection while the observed increase in education attainment (*i.e.*, innovative ability) for both developed and developing countries will encourage countries to strengthen protection.[19] The fact that patent protection (as measured by the GP index) has increased over time for most countries (though the cross-section is stable) indicates that the increase in innovative

[18] While developed countries weren't required to adhere to the new IPR standards until 1996, the increase in IPR protection in 1995 suggests that countries began modifying their IPR policies in preparation. Most developing countries were required to adhere by 2001.

[19] See Barro and Lee (2000).

Table A.2: Breaking Down the GP IPR Index

Category / Criteria		
(1) Coverage (COV)	Available	Not Available
Patentability of pharmaceuticals	1/7	0
Patentability of chemicals	1/7	0
Patentability of food	1/7	0
Patentability of plant and animal varieties	1/7	0
Patentability of surgical products	1/7	0
Patentability of microorganisms	1/7	0
Patentability of utility models	1/7	0
(2) Duration of Protection (DUR)	Full	Partial or No Protection
where full duration is 20 years from the date of application (or 17 years from the date of grant, for grant-based patent systems) and f equals the duration of protection as a fraction of the full duration.	1	$0 < f < 1$
(3) Enforcement (ENF)	Available	Not Available
Preliminary Injunctions	1/3	0
Contributory Infringement	1/3	0
Burden-of-Proof Reversal	1/3	0
(4) Membership in International Treaties (MEM)	Available	Not Available
Paris Convention and Revisions	1/3	0
Patent Cooperation Treaty	1/3	0
Protection of New Varieties (UPOV)	1/3	0
(5) Restrictions on Patent Rights (RIG)	Does Not Exist	Exists
Working Requirements	1/3	0
Compulsory Licensing	1/3	0
Revocation of Patents	1/3	0
Total Points Possible	5	0

ability is the dominant force.[20] This result is consistent with Kortum and Lerner (1998) who show that improvements in the management of research & design resources over time are responsible for the observed increase in firm patenting since the late 1980s.

[20]Lerner (2002) documents this increase but also notes that some developing countries chose to decrease their level of patent protection during the 1960s and 1970s.

B Data Sources

Table B.1: Data Sources

Variable	Description	Source
IPR_n	Patent regime strength	Ginarte and Park (1997)
w_n	Wage	US Bureau of Labor Statistics
E_n	Innovative ability (avg yrs of education)	Barro and Lee (2000)
Y_n	Manufacturing expenditure	INDSTAT (2010)
T_{ni}	Bilateral trade flows	Feenstra, Lipsey, Deng, Ma, and Mo (2005)
colony_{ni}	Colonial heritage dummy	Helpman, Melitz, and Rubinstein (2008)
dist_{ni}	Distance (capitals)	Helpman, Melitz, and Rubinstein (2008)
lang_{ni}	Common language dummy	Helpman, Melitz, and Rubinstein (2008)
legal_{ni}	Common legal system dummy	Helpman, Melitz, and Rubinstein (2008)

A special thanks to Walter Park for sharing the updated GP index scores. The education data in Barro and Lee (2000) is based on average years of education completed for individuals greater than 25 years of age. I computed quality-adjusted wages following Eaton and Kortum (2002) and adjusted the wages to account for differences in worker quality using $w_n = \text{comp}_n \times e^{\phi E_n}$ where comp_n is manufacturing hourly compensation from the US Bureau of Labor Statistics and E_n is average years of schooling from Barro and Lee (2000). I set $\phi = 0.06$ following Bils and Klenow (2000).

C Calibration- The Nitty Gritty

Define the set of remaining parameters as $\Theta = \{\lambda, \alpha, a_{const}\}$ which I pin-down by jointly estimating Θ using via a method of moments approach. Specifically, I solve the model for a given Θ and compute a set of moments M_Θ. The optimal set of parameters $\hat{\Theta}$ is defined as:

$$\hat{\Theta} = \underset{\Theta}{\text{argmin}}[M'_\Theta M_\Theta] \tag{C.1}$$

where

$$M_\Theta = \begin{bmatrix} 1 - \rho(\hat{\Theta}) \\ (1 - \gamma^d_{USA}) - (1 - \gamma_{USA}(\hat{\Theta})) \\ \text{Imp. Share}^d - \text{Imp. Share}(\hat{\Theta}) \end{bmatrix}$$

The moment ρ is the Spearman rank order correlation discussed in Section 5 and is identified by λ. The parameter α increases scales the innovative ability of all countries, increasing the returns to protecting intellectual property. It is identified by the imitation hazard rate generated by US patent law $(1 - \gamma_{USA})$. The final parameter is the trade weight constant a_{const} which changes the attractiveness of foreign goods to domestic consumers independent of the location of the exporting country. Hence, it's identified by the average import share in the country sample. Since the model is just- identified and the identification is strong, I can choose the parameters the exactly match the moments. That said, equation C.1 is non-linear which makes finding a global minimum difficult. I mitigate this issue by searching for $\hat{\Theta}$ using a simulated annealing minimization algorithm to limit the risk of falling into local minima. Table C.1 presents the results of the calibration.

Table C.1: Calibration Strategy

Variable	Description	Identification Rationale	Value
N	Number of Countries	Selected share of world GDP	35
ϵ	Elasticity of substitution	Broda and Weinstein (2006)	3
η	Average Mfg share of GDP	United Nations Statistics Division (2007)	0.15
δ	Firm death rate	Bartelsman, et al (2013)	0.10
β	Discount factor	7% return on US Bonds	0.96
a_{colony}	Trade weight – colonial history dummy	$\beta_{colony} = 0.376$ from gravity model (23)	1.1318
a_{dist}	Trade weight – bilateral distance	$\beta_{dist} = -1.03$ from gravity model (23)	-0.3248
a_{lang}	Trade weight – language dummy	$\beta_{lang} = 0.300$ from gravity model (23)	1.1225
a_{legal}	Trade weight – legal dummy	$\beta_{legal} = 0.347$ from gravity model (23)	1.1068
λ	Love of variety preference parameter	Spearman rank-order statistic (ρ)	0.1448
α	Scaling factor for innovative ability	US imitation hazard rate $(1-\gamma_{USA}) = 0.15$	1.7813
a_{const}	Average import share	24%. Author calculation using Y_n and T_{ni}	0.5723

D Existence Proof

Proposition 1 *(Existence) There exists an equilibrium.*

Proof

Given the IPR decision rules of governments Ψ, standard techniques show the value functions exist conditional on M. As for entry, the left-hand side of Equation (8) is continuous, monotonically decreasing, and takes a value of infinity when $L_{R,n} = 0$ and zero when $L_{R,n} = \infty$. Since the right-hand side is fixed, there exists a unique solution $L^{\star}_{R,n}(M)$.

Define the function $f_n : [0,1]^{N-1} \rightarrow [0,1]$ as the country n best response function and f as the corresponding vector-valued function. Without loss of generality, look at the problem for country n and consider a small change in protection choices for the other countries. Firm innovation decisions are clearly continuous in the protection level, hence the distributions (M) are also continuous. The small change leads to a continuous change in country n's IPR policy and the function is continuous.

The set $[0,1]^N$ is a closed ball by construction. Therefore, we have a continuous function f on a closed ball, and there exists at least one fixed point by Brouwer's Fixed Point Theorem. ■

E Algorithm for the Open Economy

In this section I outline the algorithm to solve the equilibrium where agents (governments, firms, consumers) make decisions taking the aggregate state given following Weintraub, Benkard, and Van Roy (2008). The loop terminates when policy, trade, and innovation decisions and the set of country firm distributions (M) are consistent.

1. Given a guess for the aggregate state $\{\gamma_n, M_n\}$
   (a) Solve for the steady-state IPR choices around the world $\{\gamma'_n, M'_n\}$. All agents in country n take M as given. Each government chooses the utility maximizing level of IPR protection. In the commitment model, this amounts to searching for the γ_n that maximizes steady-state welfare. For the sequential model, the solution method is more complex and is detailed below. In either case, the result is the steady-state IPR choice and mass of firms in country n (γ'_n, M'_n).
2. Compute the distance between the old and new aggregate states: $\| M - M' \|_\infty$. Note that M is a monotonically increasing, continuous function of γ so checking $\| \gamma - \gamma' \|_\infty$ is also small is redundant.
3. If the new aggregate state is sufficiently close to the old guess then we've found the equilibrium. If not, update the guess for the aggregate state and return to (1a).

F Algorithm for the Sequential Model

I solve the sequential model by restricting off-the-equilibrium path beliefs to ones in which the government commits to its level of IPR protection, similar to Aiyagari and Peled (1995). For simplicity, the following algorithm is for the closed economy. Solving the open economy model involves nesting this algorithm in an outer loop to account for the effects of country IPR decisions as well as firm innovation and trade decisions around the world (see E).

1. Solve for the equilibrium given government commitment.
2. Compute the sequential equilibrium via simulation, starting from the commitment equilibrium.

3. Given the state of firms (M_s). Consider a one-shot government IPR policy (γ') where I restrict of-the-equilibrium path beliefs to ones in which the government commits to γ'.
   (a) Solve for welfare by computing the transition from $M_{s,t=1}$ to the steady-state mass of firms $M_{s,t=T}$ where T is large.
   (b) Given $M_{s,t}$, firms enter until Equation 12 is satisfied for all t.
   (c) Solve for welfare $W_s(M_s, \gamma')$ using the set $\{M_{s,t}\}$. Call this $W_s(M_s, \gamma')$.
   (d) Government chooses the one-shot deviation γ_s that solves

$$\gamma_s = \underset{\gamma' \in [0,1]}{\operatorname{argmax}} W_s(M_s, \gamma')$$

   (e) This yields a new mass of firms M_{s+1}. Continue iterating to find the steady-state $\{M_{s=S}, \gamma_{s=S}\}$ where S is large.

Appendix - For Online Publication Only

G Detailed Results

Table G.1: Open Versus Closed Economy Results by Country

		Hazard Rate $(1-\gamma)$			Firm Profit (V)			Welfare
Country	IM/Y	Open	Closed	Δ	Open	Closed	Δ	$\%\Delta$
United States	10.19	15.00	14.34	0.66	100.00	101.54	-1.54	0.55
Belgium	77.76	68.96	46.97	22.00	20.27	29.22	-8.94	10.89
Great Britain	29.43	50.82	44.37	6.45	61.35	71.32	-9.96	2.25
Netherlands	42.28	56.82	45.44	11.38	42.06	54.80	-12.74	3.88
Italy	21.99	68.24	63.97	4.28	34.51	46.03	-11.53	3.08
Germany	20.07	44.39	41.75	2.64	100.54	122.69	-22.15	2.82
Denmark	33.35	53.43	32.43	21.00	41.20	52.24	-11.04	5.53
France	26.81	57.42	53.79	3.63	56.83	77.11	-20.28	3.48
Japan	3.81	40.72	40.35	0.37	118.58	130.12	-11.54	1.39
Sweden	30.95	45.74	37.31	8.43	48.03	60.53	-12.50	3.86
Korea	15.22	55.32	40.11	15.21	42.84	36.28	6.56	3.25
Austria	34.61	63.10	48.63	14.47	30.20	43.59	-13.39	5.59
Spain	18.31	67.45	64.50	2.95	25.18	40.64	-15.46	5.27
Norway	26.85	41.10	25.71	15.40	51.49	63.57	-12.08	4.79
Finland	21.69	45.96	38.16	7.81	38.79	48.10	-9.31	3.66
Australia	16.97	35.05	32.46	2.59	50.89	56.58	-5.69	2.08
Canada	27.21	34.24	28.98	5.27	63.38	66.96	-3.58	1.21
South Africa	13.98	81.01	70.91	10.10	15.18	8.05	7.13	2.78
Greece	29.99	71.86	52.99	18.87	28.95	16.21	12.75	6.50
Chile	19.42	73.99	56.94	17.05	18.01	8.15	9.86	5.78
Malaysia	40.21	79.93	68.22	11.71	13.72	6.71	7.00	4.00
Argentina	1.90	65.28	52.17	13.11	25.36	20.49	4.88	2.77
Portugal	32.67	87.46	76.05	11.41	29.26	4.38	24.88	5.30
Indonesia	26.05	90.26	82.35	7.90	25.30	1.90	23.40	4.41
Egypt	21.54	89.94	80.71	9.23	41.39	1.57	39.82	6.16
Mexico	34.11	81.44	65.96	15.48	45.49	6.62	38.87	7.93
China	2.29	82.62	70.27	12.35	60.35	22.84	37.51	3.51
Brazil	2.19	88.79	79.73	9.05	7.35	0.05	7.30	10.12
Thailand	22.02	80.92	69.48	11.44	19.69	8.67	11.01	3.68
Turkey	12.62	86.82	78.40	8.42	12.32	5.43	6.89	3.13
Ecuador	21.94	80.93	65.53	15.40	18.55	2.18	16.37	9.34
Colombia	8.52	86.75	75.81	10.94	14.05	2.48	11.57	5.12
India	5.15	89.48	80.08	9.40	64.19	4.74	59.45	5.01
Venezuela	14.59	83.03	72.52	10.51	9.04	4.33	4.71	4.04
Peru	7.87	80.78	65.64	15.13	21.66	3.57	18.10	7.82

Notes: Countries in descending order according to Ginarte-Park Index. "IM/Y" is the share of total expenditure dedicated to imports. All values for the firm profits (V) are relative to the US value in the open economy model. $\Delta(1-\gamma)$, ΔV, and $\%\Delta$ welfare are the change from the closed economy to the open economy equilibrium.

Table G.2: Decomposing the Gains from Trade by Country

		%Δ Welfare from Closed Economy Model		
Country	IM/Y	IPR Fixed	IPR Flexible	Difference
United States	10.19	0.81	0.55	-0.26
Belgium	77.76	13.11	10.89	-2.22
Great Britain	29.43	3.02	2.25	-0.78
Netherlands	42.28	5.10	3.88	-1.22
Italy	21.99	4.16	3.08	-1.08
Germany	20.07	3.89	2.82	-1.07
Denmark	33.35	6.95	5.53	-1.42
France	26.81	4.74	3.48	-1.25
Japan	3.81	1.95	1.39	-0.57
Sweden	30.95	5.19	3.86	-1.33
Korea	15.22	3.30	3.25	-0.05
Austria	34.61	7.10	5.59	-1.51
Spain	18.31	7.02	5.27	-1.75
Norway	26.85	6.30	4.79	-1.51
Finland	21.69	4.94	3.66	-1.28
Australia	16.97	2.89	2.08	-0.81
Canada	27.21	1.56	1.21	-0.36
South Africa	13.98	2.84	2.78	-0.06
Greece	29.99	6.77	6.50	-0.27
Chile	19.42	5.75	5.78	0.04
Malaysia	40.21	4.28	4.00	-0.28
Argentina	1.90	2.85	2.77	-0.08
Portugal	32.67	5.24	5.30	0.06
Indonesia	26.05	4.39	4.41	0.02
Egypt	21.54	6.12	6.16	0.04
Mexico	34.11	7.83	7.93	0.10
China	2.29	3.44	3.51	0.07
Brazil	2.19	10.32	10.12	-0.20
Thailand	22.02	3.79	3.68	-0.11
Turkey	12.62	3.45	3.13	-0.32
Ecuador	21.94	9.36	9.34	-0.01
Colombia	8.52	5.24	5.12	-0.13
India	5.15	4.96	5.01	0.06
Venezuela	14.59	4.50	4.04	-0.47
Peru	7.87	7.76	7.82	0.06

Notes: Countries in descending order according to Ginarte-Park Index. “IM/Y” is the share of total expenditure dedicated to imports.

Table G.3: Comparing Sequential and Commitment Equilibria by Country

		Hazard Rate $(1-\gamma)$			Firm Profit (V)			Innovation (M_n^e)			
	IM/Y	S	C	%Δ	S	C	%Δ	S	C	%Δ	%ΔW
United States	10.19	15.00	9.95	-5.05	100.00	100.90	0.90	100.00	107.55	7.55	0.13
Belgium	77.76	68.96	62.79	-6.18	20.27	22.16	1.88	0.75	0.87	15.98	1.25
Great Britain	29.43	50.82	41.51	-9.31	61.35	65.68	4.33	9.13	10.36	13.44	0.46
Netherlands	42.28	56.82	48.70	-8.12	42.06	44.67	2.61	3.62	4.03	11.28	0.72
Italy	21.99	68.24	59.02	-9.22	34.51	39.51	5.00	7.17	8.04	12.09	0.61
Germany	20.07	44.39	34.75	-9.63	100.54	105.38	4.84	10.49	11.55	10.13	0.58
Denmark	33.35	53.43	47.85	-5.58	41.20	42.34	1.14	1.31	1.43	8.66	0.90
France	26.81	57.42	47.51	-9.91	56.83	61.70	4.87	6.72	7.46	11.06	0.68
Japan	3.81	40.72	30.78	-9.94	118.58	125.68	7.10	27.58	31.29	13.47	0.34
Sweden	30.95	45.74	37.49	-8.24	48.03	49.58	1.55	2.47	2.67	8.11	0.72
Korea	15.22	55.32	46.49	-8.82	42.84	45.02	2.18	20.08	22.39	11.48	0.06
Austria	34.61	63.10	55.69	-7.41	30.20	32.31	2.10	2.12	2.36	11.10	0.91
Spain	18.31	67.45	57.99	-9.46	25.18	28.19	3.01	4.84	5.32	9.75	0.89
Norway	26.85	41.10	36.02	-5.08	51.49	51.69	0.19	1.13	1.15	1.58	0.85
Finland	21.69	45.96	37.58	-8.39	38.79	40.21	1.42	2.04	2.22	8.91	0.70
Australia	16.97	35.05	26.42	-8.63	50.89	52.42	1.53	4.92	5.38	9.37	0.45
Canada	27.21	34.24	26.22	-8.02	63.38	65.59	2.21	10.42	11.77	12.90	0.22
South Africa	13.98	81.01	73.76	-7.25	15.18	17.27	2.09	11.16	12.08	8.28	0.07
Greece	29.99	71.86	64.43	-7.44	28.95	30.31	1.35	7.35	7.81	6.21	0.22
Chile	19.42	73.99	66.49	-7.50	18.01	19.24	1.23	8.82	9.50	7.73	0.05
Malaysia	40.21	79.93	72.72	-7.21	13.72	15.32	1.60	8.90	9.62	8.03	0.19
Argentina	1.90	65.28	55.99	-9.29	25.36	27.53	2.17	10.80	12.08	11.83	0.07
Portugal	32.67	87.46	82.68	-4.78	29.26	31.86	2.59	17.52	18.24	4.11	0.06
Indonesia	26.05	90.26	86.13	-4.13	25.30	28.74	3.44	23.88	24.89	4.22	0.03
Egypt	21.54	89.94	85.89	-4.05	41.39	45.93	4.54	27.31	28.35	3.83	0.03
Mexico	34.11	81.44	75.45	-5.99	45.49	49.79	4.31	36.72	39.38	7.25	0.03
China	2.29	82.62	76.42	-6.20	60.35	67.15	6.80	52.75	56.45	7.02	0.01
Brazil	2.19	88.79	84.21	-4.58	7.35	8.24	0.89	10.35	10.82	4.52	0.13
Thailand	22.02	80.92	73.93	-6.99	19.69	22.06	2.37	14.45	15.57	7.79	0.10
Turkey	12.62	86.82	81.26	-5.56	12.32	14.09	1.77	11.38	12.04	5.73	0.19
Ecuador	21.94	80.93	74.71	-6.22	18.55	20.06	1.51	12.58	13.37	6.35	0.08
Colombia	8.52	86.75	81.62	-5.12	14.05	15.71	1.67	13.25	13.98	5.53	0.11
India	5.15	89.48	85.28	-4.20	64.19	71.79	7.60	41.07	42.84	4.29	0.01
Venezuela	14.59	83.03	76.49	-6.54	9.04	10.23	1.20	7.02	7.54	7.34	0.26
Peru	7.87	80.78	74.47	-6.30	21.66	23.45	1.78	16.15	17.18	6.40	0.04

Notes: Countries in descending order according to Ginarte-Park Index. "IM/Y" is the share of total expenditure dedicated to imports. All values for the firm profits (V) are relative to the US value in the sequential, open economy model. $\Delta(1-\gamma)$, ΔV, and %ΔW are the change from the sequential to the commitment equilibria.

Table G.4: Trade as a Commitment Device by Country

Country	IM/Y	Open Economy $(1-\gamma)$			Closed Economy $(1-\gamma)$			Deviation
		S	C	Δ	S	C	Δ	
United States	10.19	15.00	9.88	-5.12	14.34	9.40	-4.94	0.18
Belgium	77.76	68.96	60.26	-8.70	46.97	36.40	-10.57	-1.87
Great Britain	29.43	50.82	40.50	-10.32	44.37	33.99	-10.38	-0.06
Netherlands	42.28	56.82	46.62	-10.20	45.44	34.98	-10.46	-0.27
Italy	21.99	68.24	58.22	-10.02	63.97	53.50	-10.47	-0.44
Germany	20.07	44.39	34.21	-10.18	41.75	31.61	-10.14	0.04
Denmark	33.35	53.43	44.50	-8.94	32.43	23.55	-8.88	0.05
France	26.81	57.42	46.73	-10.69	53.79	42.97	-10.82	-0.13
Japan	3.81	40.72	30.72	-10.00	40.35	30.36	-9.99	0.02
Sweden	30.95	45.74	36.00	-9.74	37.31	27.36	-9.95	-0.21
Korea	15.22	55.32	46.43	-8.88	40.11	30.15	-9.96	-1.07
Austria	34.61	63.10	53.16	-9.94	48.63	37.97	-10.66	-0.72
Spain	18.31	67.45	57.31	-10.14	64.50	54.08	-10.42	-0.28
Norway	26.85	41.10	32.96	-8.15	25.71	18.07	-7.64	0.51
Finland	21.69	45.96	36.15	-9.82	38.16	28.43	-9.72	0.09
Australia	16.97	35.05	26.07	-8.97	32.46	23.57	-8.89	0.08
Canada	27.21	34.24	25.78	-8.46	28.98	20.70	-8.28	0.18
South Africa	13.98	81.01	73.72	-7.29	70.91	61.26	-9.65	-2.35
Greece	29.99	71.86	63.82	-8.04	52.99	42.19	-10.80	-2.76
Chile	19.42	73.99	66.05	-7.94	56.94	46.15	-10.79	-2.85
Malaysia	40.21	79.93	72.55	-7.38	68.22	58.22	-10.01	-2.63
Argentina	1.90	65.28	55.82	-9.46	52.17	41.39	-10.79	-1.33
Portugal	32.67	87.46	82.51	-4.95	76.05	67.34	-8.71	-3.77
Indonesia	26.05	90.26	86.02	-4.24	82.35	75.22	-7.14	-2.90
Egypt	21.54	89.94	85.78	-4.17	80.71	73.13	-7.58	-3.41
Mexico	34.11	81.44	75.28	-6.16	65.96	55.70	-10.26	-4.10
China	2.29	82.62	76.49	-6.13	70.27	60.51	-9.75	-3.63
Brazil	2.19	88.79	84.02	-4.76	79.73	74.24	-5.49	-0.73
Thailand	22.02	80.92	73.80	-7.12	69.48	59.63	-9.85	-2.73
Turkey	12.62	86.82	81.11	-5.71	78.40	70.21	-8.19	-2.48
Ecuador	21.94	80.93	74.27	-6.65	65.53	55.29	-10.23	-3.58
Colombia	8.52	86.75	81.32	-5.43	75.81	67.06	-8.75	-3.32
India	5.15	89.48	85.28	-4.20	80.08	72.30	-7.78	-3.58
Venezuela	14.59	83.03	76.32	-6.71	72.52	63.15	-9.37	-2.66
Peru	7.87	80.78	74.09	-6.68	65.64	55.38	-10.26	-3.58

Notes: Countries in descending order according to Ginarte-Park Index. "IM/Y" is the share of total expenditure dedicated to imports.

Table G.5: Decomposing the Gains from Trade by Country

		%Δ Welfare from Closed Economy Model		
Country	Import Share	IPR Fixed	IPR Flexible	Difference
United States	10.19	0.81	0.55	-0.26
Belgium	77.76	13.11	10.89	-2.22
Great Britain	29.43	3.02	2.25	-0.78
Netherlands	42.28	5.10	3.88	-1.22
Italy	21.99	4.16	3.08	-1.08
Germany	20.07	3.89	2.82	-1.07
Denmark	33.35	6.95	5.53	-1.42
France	26.81	4.74	3.48	-1.25
Japan	3.81	1.95	1.39	-0.57
Sweden	30.95	5.19	3.86	-1.33
Korea	15.22	3.30	3.25	-0.05
Austria	34.61	7.10	5.59	-1.51
Spain	18.31	7.02	5.27	-1.75
Norway	26.85	6.30	4.79	-1.51
Finland	21.69	4.94	3.66	-1.28
Australia	16.97	2.89	2.08	-0.81
Canada	27.21	1.56	1.21	-0.36
South Africa	13.98	2.84	2.78	-0.06
Greece	29.99	6.77	6.50	-0.27
Chile	19.42	5.75	5.78	0.04
Malaysia	40.21	4.28	4.00	-0.28
Argentina	1.90	2.85	2.77	-0.08
Portugal	32.67	5.24	5.30	0.06
Indonesia	26.05	4.39	4.41	0.02
Egypt	21.54	6.12	6.16	0.04
Mexico	34.11	7.83	7.93	0.10
China	2.29	3.44	3.51	0.07
Brazil	2.19	10.32	10.12	-0.20
Thailand	22.02	3.79	3.68	-0.11
Turkey	12.62	3.45	3.13	-0.32
Ecuador	21.94	9.36	9.34	-0.01
Colombia	8.52	5.24	5.12	-0.13
India	5.15	4.96	5.01	0.06
Venezuela	14.59	4.50	4.04	-0.47
Peru	7.87	7.76	7.82	0.06

Notes: Countries in descending order according to Ginarte-Park Index.