Innovative R&D Offshoring in North-South Trade: Theory and Evidence*

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Abstract

This study proposes a general equilibrium model to describe innovative R&D location decisions by multinational firms. Using two countries, a developed North and a developing South, the model examines Northern firms employing researchers in the South in order to produce new varieties of a good. The Northern firms risk their product being imitated when offshoring research. Southern researchers may take information learned while employed by the Northern firm and start their own competing firm. The model's main predictions are supported empirically by a dataset constructed with US patent data. For high-tech industries, stronger IPR-protection in the South increases both industry-level and firm-level offshoring at a rate faster than low-tech industries. Southern import tariffs do not affect firm-level innovative R&D offshoring.

JEL Classification: F1, L1, L2, O3

Keyworks: R&D, Innovation, IPR-Protection, Multinational, Employee Mobility

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1 Introduction

The practice of offshoring research and development (R&D) to the developing world is becoming a more attractive option for multinational firms.[1] Usually, this research is adaptive and for the purpose of modifying an already established product for sale in a different market; however, the offshoring of new product design for global distribution is a rapidly growing strategy of multinational firms. For example, new product design, or innovative R&D, is the fastest growing offshoring segment in India (Lewin, Massini, and Peeters, 2009). Offshoring innovative R&D to the developing world provides employment opportunities in emerging economies while making firms in developed countries more competitive; however, offshored employees may take information gathered while researching the new product and join a competing firm. While there have been theoretical studies concerning offshoring from developed countries to developing countries (Dinopoulos and Tsoulouhas, 2015; Grossman and Helpman; 2005), there have been no models that explore the offshoring of innovative R&D to the developing world. I construct a general equilibrium model to show how innovative R&D offshoring is affected by IPR-protection, technology type, market size, and import tariffs. I also confirm the theoretical predictions using a new empirical method for measuring innovative R&D offshoring.

Previous studies have used R&D expenditures to examine innovative R&D offshoring (Todo and Shimizutani, 2009; Hedges and Hicks, 2008). By only using R&D spending, authors do not fully capture the determinants of innovative R&D. Other studies have used the existence of a patent (Berry, 2014) or the existence of an R&D lab (Ito and Wakasgui, 2007) to proxy innovative activity. To my knowledge, there is no paper that explores

[1]For example, between 1998-2004, the share of R&D personnel in FDI firms in China increased from 7 percent to 20 percent (Lundin and Serger, 2008). In their independent survey, Garcia-Canal and Martnez-Noya (2014) find 15.7% of industry-level firms outsourced the most representative R&D tasks to developing countries.

innovative R&D offshoring intensity decisions in the developing world. I also introduce a new method of defining innovation research offshoring that fully captures innovative R&D intensity. When conducting innovative R&D in developing countries, firms risk imitation through employee mobility. Since firm decisions are influenced by this risk, I use the employment of researchers in developing countries as a measure of innovative R&D.

I employ a North-South general equilibrium model where Northern firms innovate and Southern firms imitate. Northern firms invent a new product variety using R&D workers. A Northern firm can both conduct research in its own country and conduct research in the developing South. Southern researchers demand a much lower wage than Northern researchers; however, these Southern workers may also appropriate the designs for the new product. A Northern firm faces a probability of imitation related to its R&D intensity in both the North and the South. Successful imitation of a product shifts the production of that product to the Southern firm. After the product has been created, firms sell their specific varieties in both their domestic and the foreign market. The number of Northern and Southern firms, and therefore the number of product varieties available to consumers, is endogenous.

Using the general equilibrium model, I predict the determinants of firm-level and industry-level innovative R&D offshoring. The model predicts three empirically testable hypotheses. First (Hypothesis 1), high-tech (or large) firms increase their R&D employment in the South at a faster rate than low-tech (or small) firms when IPR-protection strengthens. This relationship is true at the industry-level as well. Intuitively, firms with large research needs have a large cost of research relative to small firms. That cost can be greatly reduced by using Southern laborers who demand a low wage; however, imitation of the product can be extremely costly. Thus, the strengthening of IPR-protection allows for the opportunity to greatly reduce labor cost without introducing additional risk of imitation.

Next (Hypothesis 2), Southern market size does not have an effect on firm-level innovative R&D offshoring but decreases industry-level R&D offshoring. Firms do not factor market size into their individual innovative R&D offshoring decisions. Firms make location decisions based on the probability of imitation. Market size does not affect the probability of imitation, as the channel for imitation is based around employees leaving the firm with knowledge of the product. However, an increase in the market size brings additional Southern firms into the market which increases competition for Northern firms. Northern firms are then forced to exit the market. Industry-level R&D offshoring decreases as a result. Finally (Hypothesis 3), Southern import tariffs do not have an effect on firm-level innovative R&D offshoring. Intuitively, the change in tariffs only affects the amount of the good being sold by each firm. The tariff makes the Northern good more expensive. However, Southern consumers have additional income from the tariff. These two effects result in an unchanged value of the final product to the firm.

Using two sets of data constructed from USPTO, NBER, BEA, and WDI data sources, I confirm some of the predictions of the theoretical model. The empirical results are not sensitive across a number of different specifications and estimation strategies. I confirm Hypothesis 1 using OLS, Tobit, and difference-in-difference regression models. Unexpectedly, the results of the regression analysis refutes Hypothesis 2. Firm-level innovative R&D offshoring decreases with Southern market size. The connection between firm-level innovative R&D offshoring and Southern market size implies that there is a market-size component embedded in the probability of imitation. Finally, I find evidence to support Hypothesis 3. Firm-level innovative R&D offshoring is not affected by import tariffs at an economically significant magnitude.

This paper contributes to a number of different strands of literature. Using a new North-

South model, I contribute to the global outsourcing and offshoring literature as a whole. Previous North-South models have explored the offshoring of tasks; however, no study has specifically modeled the offshoring of innovation to the South. Acemoglu, Gancia, and Zilibotti (2015) develop a model with offshoring of intermediate inputs in a global economy. Feenstra and Taylor (2011) show the relationship between the price of outsourced inputs and R&D affect the amount of outsourcing in equilibrium. Dinopoulos and Tsoulouhas (2015) model the offshoring of heterogenous tasks to the South while assuming Southern workers are less skillful than their Northern counterparts. I contribute to this strand of literature by introducing both the use of Southern researchers and a negative consequence of contracting such workers: product imitation. Following Lai, Riezman, and Wang (2009), I include the notion of information leakage when using Southern researchers. Using employee mobility as the channel of imitation, the probability of imitation of a firm's product then depends on how many employees are working on a single product.

This study also contributes to literature exploring the connection between multinational activities, high-tech industries, and IPR-protection. Javorcik (2004) finds weak IPR-protection deters FDI in high-tech industries. Bilir (2014) shows that countries with strong IPR-protection see high R&D intensity industries increasing activities in host countries more than their low R&D counterparts. Canals and Sener (2014) identify 16 countries which underwent an IPR-reform and examine the effect of the reform on offshoring to those countries. The authors find that high-tech industries in the US increase their intra-industry and broad offshoring following IPR-reform. Branstetter et al. (2006, 2011) also use the time of a major IPR-reform in a country. The authors find that these high patent firms increase intrafirm royalty payments, affiliate employee compensation, affiliate assets, and affiliate R&D spending for parent firms with high technology transfer rates when faced with a strengthening of IPR-protection. While Branstetter et al. examine affiliate R&D

expenditures, the authors do not separate adaptive R&D spending and innovative R&D spending. To add to this strand of literature, I examine the drivers of innovative R&D. As this aspect of multinational activity in developing countries is only recently becoming an increasing trend, past literature has yet to explore the connection between innovative R&D, technology type, and IPR-protection. Since innovative R&D is the earliest step of the creation and sale of a new product, there is a high penalty of imitation. Thus, it does not immediately follow from past studies that high-tech firms are willing to offshore innovative R&D even as IPR-protection strengthens.

The findings of this paper contribute to the literature concerning market size and multinational activity. Theoretical studies have shown the size of the South is positively related to the range of tasks offshored to the South (Dinopoulos and Tsoulouhas, 2015) and the amount of inputs outsourced (Grossman and Helpman, 2005). Empirical studies have found a positive relationship between the size of the host market and R&D offshoring.[2] Todo and Shimizutani (2009) uses survey data on Japanese firms to show the size of a host country's market positively affects both adaptive and innovative R&D offshoring. Hedge and Hicks (2007) find that a large host country size predicts U.S. multinational firm engagement of R&D in the host country. Berry (2014) finds that host market size increases the likelihood of using a foreign inventor for a patent. I focus only on developing countries and the number of inventors used in the creation of a patent. Previous studies on offshoring cannot predict how Southern researcher employment responds to market size.

Finally, the model presented in this paper connects innovative R&D offshoring and Southern import tariffs. While no empirical studies have previously connected industry

[2] Other authors have shown that the size of a host country positively influences other types of multinational activity. For example, Ivus, Park, and Saggi (2015) show that host country size is positively related to technology licensing to developing countries. Bilir (2014) finds that affiliate sales, assets, and employment increase with host country size. Javorcik (2004) finds that a large market size increases the likelihood of foreign direct investment. Branstetter et al (2011) show that market size is positively associated with multinational activity.

specific import tariffs and innovative R&D offshoring to the South, a number of authors have connected a host country's openness to trade with increases in multinational activity into a host country (Canals and Sener, 2014; Branstetter et al, 2011).

The paper is organized as follows. Section 2 presents the general equilibrium model. Section 3 outlines the estimation implementation. Section 4 discuses the data used in this study. Section 5 presents the econometric analysis and results. Section 6 concludes the paper.

2 Theoretical Framework

This section presents a general-equilibrium model analyzing the impact of firm size, technology type, IPR-protection, host country size, and tariffs on both firm-level and industry-level R&D offshoring from the developed world to developing countries. This model converts the symmetric two country model developed by Venables (1987) into a North-South trade model. Two countries populate the global economy: North (n) and South (s). The North has firms capable of creating new varieties of a differentiated product to sell in a monopolistically competitive market. Firms in the South cannot innovate and are forced to imitate. Imitation of a specific variety starts competition between the Northern firm that innovated the variety and the Southern firm that imitated that variety. When imitation of a variety occurs, the Southern firm prices the Northern firm out of both markets.[3]

[3] This assumption is a multinational firm's worst case scenario of imitation. The best case scenario is that imitation has no effect on operating profit. The best case scenario sees multinational firms fully investing in Southern labor. In reality, multinational firms may share the market after imitation has taken place. So, the results of this model may overstate the comparative statics magnitude while correctly predicting the direction of the changes. In Appendix B.6, I show the equilibrium does not change greatly as this assumption is weakened.

2.1 Demand Structure

Labor is the only factor of production. The South is endowed with L_s workers while the North has L_n workers. Both countries also have outside-good sectors producing products under perfect competition with constant returns to scale. The technologically advanced Northern firms produce each unit of the outside-good using one unit of labor. Southern firms must use $\frac{1}{c}$ units of labor to produce the outside-good, where $c < 1$. Workers are mobile between sectors but not countries. Setting the price of the outside-good equal to 1 allows the wage rate in the North to be fixed at unity and the wage rate in the South to be fixed at c. Consumer preferences in each country take the form of a Cobb-Douglas utility function for the representative consumer:

$$U_i = z_i^{1-\beta} X_i^{\beta} \qquad\qquad i = [n, s] \tag{1}$$

where z_i is the consumption of the outside-good in country i and X_i is the sub-utility function for differentiated goods.

Let the sub-utility X_i function be defined as:

$$X_n = \left[M_n (a_{nn} x_{nn})^{\frac{\epsilon-1}{\epsilon}} + M_s (a_{sn} x_{sn})^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \tag{2}$$

$$X_s = \left[M_n (a_{ns} x_{ns})^{\frac{\epsilon-1}{\epsilon}} + M_s (a_{ss} x_{ss})^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \tag{3}$$

where M_n is the number of firms operating in the North and M_s is the number of Southern firms. Let a_{ji} describe consumer preferences from country i for goods sold by firms from country j. Likewise, a_{ii} describes consumer preferences from country i for goods sold by firms from country i. These parameters allow the market shares for Northern firms to differ from the market shares of Southern firms through a factor other than price.[4] Thus, Northern firms can still capture a majority of the Northern market despite offering products at a higher price than the Southern firms. Also, let the elasticity of substitution between products, ϵ, be greater than 1. Corresponding price indexes to equations (2) and (3) can now be defined as:

$$P_n = \left[M_n (\frac{p_{nn}}{a_{nn}})^{1-\epsilon} + M_s (\frac{p_{sn}}{a_{sn}})^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \quad (4)$$

$$P_s = \left[M_n (\frac{p_{ns}}{a_{ns}})^{1-\epsilon} + M_s (\frac{p_{ss}}{a_{ss}})^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \quad (5)$$

where p_{ji} and p_{ii} are the prices for goods in country i produced by j firms and i firms, respectfully. The price indexes (4) and (5) represent the cost of living in the North and South, respectively.[5] Each firm produces a different variety of the good. Thus, M_n represents the number of varieties sold by Northern firms, and M_s represents the number of varieties sold by Southern firms. All firms export, so all consumers have the same variety of goods available; however, the prices of the goods vary across countries.

Every Northern firm sets price p_{nn} in the North while each Southern firm sets a lower price p_{sn} in the North. These prices are set proportionally to marginal cost.[6] Likewise, in the South, consumers can purchase Northern products for p_{ns} and Southern goods for p_{ss}. Consumers in the North then face a different cost of living than consumers in the South based on the price difference between the two types of goods. Finally, the price of each product also depends on the consumer preferences for goods from each country. Consumers are willing to pay higher prices for products with a perceived higher quality.

[4]These parameters may also be product quality parameters (Feenstra and Romalis, 2014). Given that the firms must adapt their products to each specific market, quality of a product may vary from market to market. These parameters lead to Home consumers purchasing more of Home goods than foreign goods.

[5]Welfare in each country is then inversely related to the price index in that country.

[6]I calculate the equilibrium prices in Appendix B.2.

The North may have a much lower price index due to the greater perceived quality of the products, more Northern varieties available in equilibrium, and low transport costs for Southern firms.

Consumer demands for the differentiated sector are:

$$P_n X_n = \beta L_n \tag{6}$$

$$P_s X_s = \beta(cL_s + TR) \tag{7}$$

where TR is Southern import tariff revenue dispersed to each consumer. Until Subsection 2.5, I assume there is no import tariff. In other words, $TR = 0$. Within sector budgeting results in consumers allocating total spending on differentiated goods between the individual products taking into account each product's price. This budgeting yields the product demands.[7]

2.2 Expected Profit Structure

Northern firms must pay a fixed cost of entering the global market. This fixed cost takes the form of research and development (R&D).[8] Firms must pay workers in order to research the new product. All firms must hire a certain number of researchers, $\overline{R}$, in order to create a new product. Finally, firms can offshore and employ some Southern researchers. Northern fixed cost of entry can then be written as:

$$\begin{aligned} f_e &= w_n(R^n) + w_s(R^s) \\ &= R^n + c(R^s) \end{aligned}$$

[7]The formal structure of these demands and their derivations can be found in Appendix A

[8]International trade literature has previously interpreted the fixed cost of entry with R&D (Melitz, 2003).

where R^n denotes the number of Northern researchers, and R^s denotes the number of Southern researchers employed by the firm. While the Northern firm can reduce their costs by using Southern labor for research, weak IPR-protection in the South can result in imitation from a Southern competitor with a probability ϕ. The probability of imitation from an information leak is positively related to the number of Southern R&D workers. More specifically, I define the probabilities as:

$$\phi = \left(\frac{\zeta R^s}{R^n + \zeta R^s}\right) \qquad 0 < \zeta < 1 \tag{8}$$

$$1 - \phi = \left(\frac{R^n}{R^n + \zeta R^s}\right) \tag{9}$$

Using the functional form of a Tullock lottery, the amount of Northern researchers can be seen as the Northern firm's effort to retain the patent.[9] Likewise, the number of Southern researchers working for the Northern firm is the effort extended by the Southern firm to successfully copy the new product. Southern researchers can leave to work at the Southern firm after internalizing knowledge used in the creation of the new product; however, government IPR-protection barriers and the lack of other R&D knowledge prevent this worker from fully threatening the Northern firm's claim on the patent. Southern researchers do not have full access to the work done by Northern researchers; therefore, having more Northern researchers on a patent reduces the probability that the Southern firm successfully imitates the product.

The IPR parameter ζ captures the barriers and complications associated with imitation.[10] A ζ near zero indicates strong Southern IPR-protection, while a ζ near 1 indicates

[9]Tulluck contests have often been applied to R&D races in previous studies (Baye and Hoppe, 2003). Leininger (1993) includes a scaling parameter on the effort of one player in order to reflect differential advantages. Baik (1994) and Fonseca (2009) explore the properties of asymmetric Tullock lotteries. This model uses a single player choosing both effort levels, or the number of researchers in each region.

[10]Rosen (1986) uses a Tullock lottery to model the probability of receiving a promotion. The author uses coefficients before each effort level to denote innate player ability. In the same manner, ζ can be thought

weak IPR-protection. Once the fixed cost of entry has been paid, firms must produce and sell products. Northern and Southern firms have the same technology of production. Producing a unit requires κ laborers. Therefore, the marginal cost of production for Northern firms is the Northern wage multiplied by the number of workers needed to make one product: κ. The marginal cost of production for the Southern firm is then $c\kappa$. Northern exporting firms face iceberg trade costs τ_n when exporting the differentiated good to the South. The Northern firm also faces the possibility of losing the market to a Southern imitator. The Northern firm faces a probability of imitation of ϕ. Northern expected profit can then be defined as:

$$E(\pi_n) = (1-\phi)[x_{nn}(p_{nn}-\kappa) + x_{ns}(p_{ns}-\kappa-\tau_n-t)] - R^n - c(R^s) \tag{10}$$

The Northern firm must pay a tariff of amount t to the South when exporting its product. Until Subsection 2.5, the tariff is set to zero. Southern firms are only able to enter the market by attempting to copy a variety. Exporting Southern firms must pay a trade cost of τ_s.[11] Finally, Southern firms hire a number of additional workers, f_s, to research aspects of the product that were not appropriated by mobile Southern researchers:

$$E(\pi_s) = \phi[x_{sn}(p_{sn}-c\kappa-\tau_s) + x_{ss}(p_{ss}-c\kappa)] - cf_s \tag{11}$$

Filling in equations (8) and (9) and replacing R^s with $\overline{R} - R^n$, the expected profit

of as the relative Southern ability to Northern IPR-protection.

[11]Trade costs can vary vastly between countries. Different trade costs faced by the North and the South help facilitate an equilibrium where both countries trade. This difference in trade costs may be due to a difference in infrastructure (Behar and Venables, 2011).

functions can be redefined:

$$E(\pi_n) = \left(\frac{R^n}{R^n(1-\zeta) + \zeta\overline{R}} \right) [\pi_n^o] - R^n - c(\overline{R} - R^n) \tag{12}$$

$$E(\pi_s) = \left(\frac{\zeta(\overline{R} - R^n)}{R^N(1-\zeta) + \zeta\overline{R}} \right) [\pi_s^o] - cf_s \tag{13}$$

where π_n^o and π_s^o denote operating profit for Northern and Southern firms, respectively. Formally, these equations are:

$$\pi_n^o = x_{nn}(p_{nn} - \kappa) + x_{ns}(p_{ns} - \kappa - \tau_n) \tag{14}$$

$$\pi_s^o = x_{sn}(p_{sn} - c\kappa - \tau_s) + x_{ss}(p_{ss} - c\kappa) \tag{15}$$

2.3 Industry Equilibrium

In this subsection, I explore the industry equilibrium. Each Northern firm must decide how much research to offshore to the South. Southern firms decide on entry into the market. Any firm in the market must also set prices. I only examine the case where each Northern firm splits research and development between the North and the South. The Northern firm solves the following maximization problem taking operating profits as given:

$$\max_{R^n} E(\pi_n)$$

Southern firms only decide whether to enter the market or to not enter in this stage. The Northern firm does not hire more researchers than is necessary to complete the innovation. Likewise, the firm cannot hire a negative amount of researchers. So, R^n is bounded by 0 and $\overline{R}$. With $0 < \zeta < 1$, a first-order condition yields a maximum value of Northern research. That is, the expected profit function (12) is concave for $R^n \in \{0, \overline{R}\}$.[12] The type

[12] The second order conditions are established in the Appendix B.

of solution, interior or corner, can be determined by examining the relationship between total research, operating profit, IPR-protection, and the wage gap. An interior solution exists iff:

$$\frac{\zeta[\pi_n^*]}{(1-c)} < \overline{R} < \frac{[\pi_n^*]}{\zeta(1-c)} \tag{16}$$

The value of equilibrium Northern operating profit π_n^* is determined in Section 5. I assume that condition (16) holds in equilibrium; therefore, every Northern firm employs both Northern and Southern researchers.[13] Taking the FOC and rearranging yields the optimal Northern research level:

$$R^{n*} = (\frac{1}{1-\zeta})\left(\frac{[\pi_n^*]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta})\overline{R} \tag{17}$$

After firms pay fixed costs, they must choose the price of the product to maximize operating profit. Maximization of operating profit equations (14) and (15) yield equilibrium prices.[14] The Southern firm must be able to set a low enough price that the Northern firm cannot compete in either market. I assume the highest price charged by the Southern firm is lower than the Northern firm's marginal cost.[15]

Just as in Venables (1987), I define the convenient parameters, s_{nn}, s_{sn}, s_{ns}, and s_{ss}, to simplify the discussion of the equilibrium:

$$s_{nn} = (p_{nn}/a_{nn})^{1-\epsilon} \qquad s_{ns} = (p_{ns}/a_{ns})^{1-\epsilon} \tag{18}$$

$$s_{ss} = (p_{ss}/a_{ss})^{1-\epsilon} \qquad s_{sn} = (p_{sn}/a_{sn})^{1-\epsilon} \tag{19}$$

[13]Appendix B.3 defines this condition in just the parameters of the model.
[14]These prices can be seen in Appendix B.2
[15]Note that $p_{sn} < \kappa$ ensures that the Northern firm must drop out of the market after imitation occurs. This assumption holds under the following condition: $\frac{c\kappa+\tau_s}{\kappa} < \frac{\epsilon-1}{\epsilon}$

These values can be used to show the market shares that a given firm has in a given market relative to a firm in the same market from the other country.[16] I make two assumptions that imply a relationship between the market shares. First, I assume that consumers in the North slightly prefer products made by firms from their own country. Second, consumers in the South prefer products from Southern firms. That is, $a_{sn} < a_{nn}$ and $a_{ns} < a_{ss}$. These assumptions imply that each firm's domestic market share is larger than its foreign market share.[17] It proves convenient to define this implication as:

Assumption 1. $s_{ns}s_{sn} < s_{nn}s_{ss}$

2.4 General Equilibrium

The equilibrium of this economy can now be defined using free-entry conditions. With the optimal Northern research level and the expected profit functions (12) and (13), two free-entry conditions can be defined as:

$$E(\pi_n)^* = \pi_n^* - 2\left(\zeta\overline{R}(1-c)\pi_n^*\right)^{\frac{1}{2}} - \overline{R}(c-\zeta) = 0 \tag{20}$$

$$E(\pi_s)^* = \pi_s^* - (1-\zeta)cf_s(\pi_n^*)^{\frac{1}{2}}\left[(\zeta\overline{R}(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}\right]^{-1} = 0 \tag{21}$$

These two equations determine the equilibrium level of π_n^* and π_s^*. The level of Northern

[16]These values do not immediate resemble market shares. Using the individual differentiated product demands, these values can be rewritten as: $s_{ij} = \frac{p_{ij}x_{ij}}{P_j^{\epsilon}X_j}$. So, $\frac{s_{ij}}{s_{jj}} = \frac{p_{ij}x_{ij}}{p_{jj}x_{jj}}$. Thus, this ratio expresses the market share a firm from country i has in market j relative to the market share of a firm from country j in the same market.

[17]In trade literature, this implication is referred to as a "home bias" in consumption. Many authors have documented individual cases of home bias (Balta and Delgado, 2009; Obstfeld and Rogoff, 2000). Generally, the home bias in consumption is explained by trade costs and a preference for domestic products. Friberg, Paterson, and Richardson (2011) show strong preference for U.S. wine in the U.S. market drives the home bias. In the model presented in this paper, strong preferences for domestic goods would be described as $a_{ii} > a_{ji}$. Evans (2001) finds evidence that trade tariffs explain a large amount of the home bias. In this case, a_{ii} and a_{ji} would be relatively similar.

operating profit in terms of the model's parameters is:

$$\pi_n^* = \overline{R}\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^2 \tag{22}$$

Using equations (6) and (7), the individual demands for differentiated goods, and equations (18) and (19), equations (20) and (21) can be used to define the operating profit of a given firm in equilibrium:

$$\pi_n^* = \frac{1}{\epsilon}(s_{nn}P_n^{\epsilon-1}\beta L_n + s_{ns}P_s^{\epsilon-1}\beta c L_s) \tag{23}$$
$$\pi_s^* = \frac{1}{\epsilon}(s_{sn}P_n^{\epsilon-1}\beta L_n + s_{ss}P_s^{\epsilon-1}\beta c L_s) \tag{24}$$

Note that equilibrium profit levels must be positive. If one of the values were negative, then one or both of the price indexes would have to be negative, implying a negative number of firms in at least one region. I use two sufficient conditions to guarantee a unique interior solution:[18]

Assumption 2. $\zeta < c$

Assumption 3. $c + \zeta < 1$

Assumption 2 states that the the IPR-environment must be sufficiently strong in order to attract any investment into the South. Assumption 3 indicates that Southern research requires both a small enough wage and a sufficiently strong IPR-environment to be profitable.[19] Given these assumptions, firms are willingly to risk imitation by using Southern

[18] I derive these conditions and the explicit form for Northern operating profit (22) in Appendix B.3.

[19] Assumptions 2 and 3 have some empirical support. Other authors have shown that these conditions facilitate R&D offshoring. For example, Demirbag and Glaister (2010) show that low wage attracts multinational R&D investment in the developing world. Ito and Wakasugi (2007) find that IPR-protection has a strong positive effect on the location of R&D research labs. I use a dataset that includes an IPR-protection index that ranks IPR-regimes. In the sample, 14% of the patents with at least one Southern inventor are in extremely weak (below 2) IPR-protection countries. 60% of the patents are in average (2.95) or stronger than average IPR-protection developing countries.

researchers. In other words, Assumptions 2 and 3 guarantee that condition (16) holds and that the equilibrium operating profits for Northern and Southern firms are positive; however, this does not guarantee positive price indexes. Equations (23), (24), and the known values of operating profit in equilibrium determine the price indexes. Both indexes must be positive. This can be ensured if the following condition holds:

$$\frac{s_{sn}\pi_n^*}{s_{nn}} < \pi_s^* < \frac{s_{ss}\pi_n^*}{s_{ns}} \tag{25}$$

Condition (25) guarantees that both price indexes are positive; however, the condition does not imply that the equilibrium values of M_n and M_s are positive. A necessary and sufficient condition for both regions to have active firms in the differentiated goods sector is:

$$\frac{s_{sn}}{s_{ss}} < \left(\frac{P_s}{P_n}\right)^{\epsilon-1} < \frac{s_{nn}}{s_{ns}} \tag{26}$$

Using equations (4) and (5) with the optimal price indexes, the equilibrium number of active firms in the North can be found:

$$M_n^* = \frac{s_{ss}P_n^{1-\epsilon} - s_{sn}P_s^{1-\epsilon}}{s_{nn}s_{ss} - s_{ns}s_{sn}} \tag{27}$$

$$M_s^* = \frac{s_{nn}P_s^{1-\epsilon} - s_{ns}P_n^{1-\epsilon}}{s_{nn}s_{ss} - s_{ns}s_{sn}} \tag{28}$$

Condition (26) identifies several factors that influence the existence of both countries having active firms in the differentiated goods sector. First, a high Southern consumer preference for Southern goods facilitates Southern entry. Second, a low Southern production cost relative to the Northern production cost and transport cost make Southern entry more likely. Finally, a large population in the South relative to the North facilitates the existence of Southern firms. Conditions (25) and (26) are assumed to hold throughout the ensuing analysis.

Figure 1 graphically shows this case. The intersection of the two equilibrium operating profit lines determine the equilibrium price indexes and expected number of firms. The $M_n = 0$ and $M_s = 0$ lines show the combination of Northern and Southern price indexes that yield zero firms in the North and South, respectively. Any combination of price indexes that fall below the $M_n = 0$ line yields a positive number of Northern firms. Likewise, any combination of price indexes that lie above the $M_s = 0$ line yields a positive number of Southern firms.[20]

2.5 Comparative Statics

Assuming an equilibrium where both countries have firms engaged in producing and selling differentiated goods, the two free-entry conditions can be used to analyze the comparative statics from any exogenous change. This section examines the effect of a number of exogenous changes on two empirically measurable parameters: firm-level offshoring, industry-level offshoring. Firm-level offshoring is denoted R^{s*}. Let the total number of Southern researchers employed be O_s. This variable captures the industry amount of offshoring in the South. I define O_s as the number of Northern firms multiplied by each firm's Southern R&D intensity, or $O_s = M_n^* * R^{s*}$.

Proposition 1. *A strengthening of IPR-protection ($\zeta \downarrow$) increases firm-level offshoring to the South ($R^{s*} \uparrow$). The magnitude of this effect increases with $\overline{R}$. For industries with large $\overline{R}$, industry-level offshoring increases ($O_s \uparrow$) as IPR-protection strengthens.*

Proof. See Appendix C.1. □

[20] Appendix B.5 shows the cases where only one country has a positive number of firms in the differentiated goods sector.

Tighter IPR laws in the South can encourage investment and innovation in the North; however, these laws could hinder the growth of industries in the South by preventing firms from entering the market. Similar to Helpman's (1993) model presenting stronger IPR-protection as a decrease in the rate of imitation, Southern IPR-protection affects the probability of imitation in the model presented in this paper. A strengthening of the Southern IPR environment, or a decrease in the Southern firm's effectiveness at imitating (a decrease in ζ), places more legal barriers preventing employee mobility and product imitation. Northern firms respond to this increase in IPR-protection by employing more researchers in the South. This shift of researcher allocation decreases the fixed cost of entry for Northern firms but increases the probability of imitation. Northern firms with large research costs, or high-tech firms, increase their research tasks in the South more than firms with small research costs when Southern IPR-protection strengthens. These high-tech firms have large fixed costs of entry and use the exogenous change in IPR-protection to greatly decrease these fixed costs of production. For high-tech industries, the increase in IPR-protection also increases industry-level offshoring.[21] Each firm increases offshoring while extra Northern firms are able to enter the market. Low-tech industries may see a reduction in Northern firms as Southern firms have more opportunities to imitate the product and enter the market.

Proposition 2. *An increase in the Southern labor force ($L_s \uparrow$) does not affect firm-level offshoring to the South ($R^{s*} \leftrightarrow$) and decreases industry-level offshoring ($O_s \downarrow$).*

Proof. See Appendix C.2. □

Proposition 2 reflects the following considerations. An increase in the size of the South

[21] A number of empirical studies find that strong IPR-protection in a host country increases innovation offshoring to that country (Demirbag and Glaister, 2010; Ito and Wakasugi, 2007; Moncada-Paterno-Castello et al, 2011). High-tech industries, like computers and electronics, engage in more R&D offshoring than low-tech industries (Hedge and Hicks, 2007). Canals and Sener (2014) show high-tech industries increase outsourcing due to the strengthening of IPR-protection.

increases the amount of income in the South. A large Southern host country has a large amount of Southern firms to meet the high demand for goods by Southern consumers. For a Northern parent firm, the threat of imitation comes from individual employees who may leak information or move to a competing firm. The probability of imitation is then similar if there is only one potential imitator or many potential imitating firms. Individual parent firm's offshoring decisions are not affected by the host country size. Successful imitation forces some Northern companies out of the market entirely. Thus, one would expect industry-level R&D offshoring to decrease as host country market size expands. There are fewer Northern firms in the market to offshore.

Proposition 3. *An increase in the Southern import tariff ($t \uparrow$) does not change firm-level offshoring to the South ($R^{s*} \leftrightarrow$). Industry-level offshoring decreases ($O_s \downarrow$) if Southern income increases as a result of the tariff.*

Proof. See Appendix C.3. □

An increase in the Southern tariff on the Northern good in the South increases the marginal cost of the Northern home firms, who are the competition of the Southern host country's firms. Some Northern firms are not able to stay in the market.[22] The offshoring decision of each firm left in the market is unaffected by the change in tariff. Firms only change their R&D intensity if they believe that the tariff will change the value of the product when it becomes available on the market. The additional marginal cost in the host market decreases the return on each unit sold; however, firms sell more units in their domestic market. Fewer Northern parent firms exist allowing the remaining Northern firms to expand sales in the North. Furthermore, the Southern consumers have more income from

[22]This result has been found in other monopolistic competition models. While examining a large country with a monopolistically competitive sector, Felbermayr, Jung, and Larch (2013) show import tariffs increase the amount of home varieties and decrease the amount of imported varieties. Demidova and Rodrguez-Clare (2009) show that an import tariff in a small country on a monopolistically competitive industry can raise the number of active firms.

the tariff and can thus buy more goods from each firm. These countervailing effects result in the value of the product remaining relatively unchanged despite the level of the tariff placed by the host country. Industry-level innovative R&D offshoring then decreases as a result of less firms engaging in offshoring.

3 Estimation Implementation

Testing the theoretical predictions of this model requires a number of considerations. The factors that influence Northern firms' R&D decisions are not easily observed. The use of inventors to capture the number of Southern researchers working on a patent allows for a tractable way to examine the factors that affect innovative offshoring empirically. Given the inability to measure marginal costs for a variety of industries and firms, the functional forms of the model cannot easily be estimated using empirical methods; however, the implications of the model in terms of the factors that influence innovative R&D offshoring can be explored using a reduced form approach.

The main variables of interest in this study are IPR-protection, technology type, tariff levels, and host country size. The comparative statics properties of the model yield the following empirical implications for the effects of these variables of interest. For firm-level innovative R&D offshoring, Proposition 1 implies that both high-tech or large firms and high-tech industries are more reactive to changes in Southern IPR-protection than low-tech firms and industries. Proposition 1 yields the following empirically testable hypothesis:

Hypothesis 1: *Southern IPR-protection positively increases high-tech or large firms' innovative R&D offshoring at a higher rate than low-tech or small firms. Southern IPR-protection also positively affects innovative R&D offshoring of high-tech industries at a higher rate than low-tech industries.*

Hypothesis 1 can also be stated in context of the model:

$$\frac{\partial^2 R^{s*}}{\partial(-\zeta)\partial\overline{R}} > 0 \qquad\qquad \frac{\partial^2 O_s}{\partial(-\zeta)\partial\overline{R}} > 0$$

where ζ captures the weakness of an IPR-regime. Thus, as $(-\zeta)$ increases, the IPR-protection in the South decreases. The two variables of interest in Hypothesis 1 are not easily estimated. One possible way of estimating the total amount of researchers working on a patent, or $\overline{R}$, is counting the total number of inventors listed on that patent. With a dependent variable of the number of Southern researchers, including the total amount of researchers as an independent variable creates an endogeneity concern. Instead, I measure $\overline{R}$ by noting that larger firms are more likely to have more researchers. Furthermore, firms working on high-tech patents have more total researchers. I identify large firms as those who have hired an above average amount of inventors previous to the current patent. High-tech firms are those who operate in the high-tech industries, or industries with a significantly greater than average R&D spending.[23]

Measuring IPR-protection can be difficult. IPR-protection refers to the level of protection a country provides to each patent. IPR-protection has been treated in two different ways throughout the previous literature. First, an IPR-protection index that ranks IPR-regimes using a number of different dimensions has been used in the past. Second, authors have used periods of major IPR-reform in a country in order to determine how firms act after the reform (Branstetter et al., 2006; Branstetter et al., 2011; Canals and Sener, 2014; Park, Ivus, and Saggi, 2015). I use both of these method to examine the effect of IPR-protection. I interact the IPR-protection index variable with the large firm and high-tech indicator variables in order to test this aspect of Hypothesis 1. I also use an IPR-reform dummy with a difference-in-difference model testing whether larger firms increased R&D

[23]High-tech industries include Chemistry, Computers, Transport, and Wholesale.

offshoring after a reform.

Proposition 2 connects market size and innovative R&D offshoring. For firm-level innovative R&D offshoring, Proposition 2 implies that firms base innovation decisions on host country market size. For industry-level offshoring, Proposition 2 implies Southern market size negatively affects innovative R&D offshoring. These implications yield the following hypothesis:

Hypothesis 2: *Southern market size does not affect firm-level innovative R&D offshoring and reduces industry-level innovative R&D offshoring.*

Instead of using population to measure the number of Southern workers (L_s), I use GDP per capita to better measure the working population's purchasing power. The use of GDP or GDP per capita has been used by previous authors to estimate market size (Todo and Shimizutani, 2009; Berry, 2014; Naghavi, Spies, and Toubal; 2015).

Finally, Proposition 3 implies that firm-level innovative R&D offshoring is unaffected by import tariffs. Proposition 3 also implies that an increase in import tariffs decreases industry-level innovative R&D offshoring in a host country for cases where the Southern host country's tariff increases Southern income; however, this is difficult to determine empirically. Therefore, I only predict the firm-level response to import tariffs.

Hypothesis 3: *Southern import tariffs do not affect firm-level innovative R&D offshoring.*

Import tariff levels, or t, are approximated as the average tariff faced by a product in each industry.

4 Data

4.1 Dependent Variables

Three main databases are used to construct the dataset for this study. First, both the USPTO and the NBER databases provide firm-level data on patents filed and inventors used to create those patents. The WDI tables provide country specific information. Finally, the BEA's database on U.S. multinational enterprises is used for both industry specific controls and the industry R&D spending in a particular host country per year. Industries are defined using two digit NAICS codes. Ten industries are used with individual patents matched to their corresponding industry.

The dependent variables are industry-level and firm-level innovative R&D offshoring to developing countries. For firm-level statistics, this study uses a proxy that is commonly used in previous literature: patents.[24] Patents indicate that researchers have created a new and valuable product or component. As argued by Hedge and Hicks (2008), inventions for the purpose of adapting products for foreign markets are unlikely to warrant the expense of protection in the US market. Thus, patents represent the completion of innovative research and not adaptive research.

This approach has three major problems. First, the patent may only be a part of a larger product. Therefore, firms might need to patent a number of innovations just for one product. This possibility should not change firm behavior greatly. This study supposes that firms risk information leaks when conducting research abroad. Information leaks for individual components of a product still damages the firm. Second, patents may be acquired by multinationals firms as a way of suppressing an innovation to protect a

[24] Some authors that use patents as a proxy for innovative R&D include Hedge and Hicks (2008), Zhao (2006), Berry (2014), D′Agostino, Laursen, and Santangelo (2013), and Qian (2007). Ito and Wakasugi (2007) examine innovation by looking at the odds of multinationals choosing 3 types of foreign affiliates: no R&D, R&D with no lab, R&D with a lab. Demirbag and Glaister (2010) use R&D lab location announcements instead of patent data.

previous invention.[25] Thus, the patent may not be intended for the sale of a new product; however, firms should still fear imitation as a threat to an existing product. Factors such as tariffs and market size that affect the sale of a finished product do not influence firm's R&D location decisions; however, my theory predicts that these factors do not influence firm's R&D decisions regardless. Third, some patents are assigned for process innovation and not product innovations.

Keeping these concerns under consideration, the use of inventors for individual patents still sufficiently capture innovative R&D. This model supposes that innovative R&D offshoring at the firm-level is influenced by the probability of imitation. With any of the concerns raised above, the probability of imitation still motivates R&D location decisions to an extent. Thus, I have no reason to believe that firms conducting R&D overseas for purposes other than innovative R&D react differently to changes in IPR-protection, market size, and import tariff than firms conducting innovative R&D.

In order to create the dataset, I take inventor records for each patent application from the USPTO database and eliminate any application that does not have at least one foreign inventor from a developing country. The remaining patents are then matched with the patent data in the NBER database. The number of foreign inventors in a host country is used as the dependent variable. I also use the R&D intensity as a dependent variable. To construct this variable, I divide the number of inventors in a host country by the total amount of inventors listed on the patent. For example, a patent assigned to the US based company Nalco Chemical Company in 1988 has two inventors listed on the patent cover page. One inventor is based in the United States. The other inventor is based out of Brazil. In my data set, this observation reads that there is one Southern inventor. The dependent variable for the regression analysis is then equal to 1. For the R&D intensity variable, the

[25] Saunders (2002) discusses the nonuse patents. Also, the author provides a discussion on patent acquisition for the purpose of licensing.

value is 1/2. For this observation, country specific data is for Brazil, and industry specific data is for the chemical industry in the US.

Each foreign inventor listed on a US multinational's patent application is evidence that R&D has been offshored to a foreign country. Therefore, a large amount of offshoring takes place on an invention if many foreign inventors were listed on the patent application. Patent application data is found in the USPTO database. First, the inventors for each invention are categorized and matched with the eventual patent grant number. Applications that do not yield a successful patent are thrown out of the sample. Patents are assigned for inventions that have a certain level of novelty. Therefore, the invention represents a profitable technological advance. Patents help separate the adaptive research that multinationals often assign to their foreign subsidiaries from the innovative research. The NBER Database takes information from the USPTO database and matches patents with both the industry and the type of assignee: i.e. US corporation, foreign corporation, US individual, etc. Limiting the sample to only patents being assigned to multinational US corporations, I link the two databases via patent number. Once linked, the sample contains data from 1970-2006 with 6,501 unique patents that use at least one inventor from the developing world. Of those observations, 6,416 patents only used inventors from a single developing country. 87 of these patents had inventors from more than one developing country. These patents were split into multiple observations to create unique country, firm, industry observations. The final sample contains 6,590 unique observations.

Industry-level offshoring is captured by a BEA statistic on dollars spent by multinationals on R&D in developing countries. For example, in 2007, affiliates of US multinational chemical firms in Brazil spent 147 million dollars in R&D expenditures. Thus, the dependent variable for this observation is 147. R&D expenditures have been used in the past as a proxy variable for innovation (Qian, 2007; Hedge and Hicks, 2008). One flaw with using

R&D expenditures by multinational firms in a host country includes the inability to fully distinguish between adaptive research and innovative research. Using 35 different developing countries as possible hosts for R&D, there are 4,308 observations spanning between 1999 and 2013.

4.2 Independent Variables

This study examines the effect IPR-protection has on high-tech or large firms' innovative R&D offshoring decisions. Additionally, this study examines the effect of host country size and tariff levels on innovative R&D offshoring.

IPR-protection data from each country during specific times is found using the Park (2008) index, which is an updated version of the Ginarte and Park (1997) index.[26] Differentiating from past literature, I propose a new proxy for firm size: the total number of researchers previously employed by each firm.[27] That is, large firms conduct more research than smaller firms. Using the USPTO database, I determine the amount of inventors employed by the firm before the current patent. Firms with a greater than average amount of researchers employed are designated as large. R&D expenditures for US parent companies approximates industry research needs in the industry regressions.

Host country size is measured by GDP per capita collected for the WDI. The level of import tariffs faced by U.S. multinational firms selling a product into a country can be observed. Following Keller and Yeaple (2013), industry and country specific tariffs are found from the UNCTAD's Trade Analysis and Information System (TRAINS) dataset. Tariff levels are not given by industry. Instead, the tariff data uses broad product categories

[26] This updated index has been used in a number of previous studies such as Keller and Yeaple (2013), Berry (2014), Naghavi, Spies, and Toubal (2015), and Bilir (2014).

[27] In previous studies, the sales of the firm have been used as a way of estimating firm size. The number of firm employees has also been used to measure firm size (Buss and Peukert, 2015). Since this data was not available, I propose a new proxy for firm size based on the established connection between firm size and research and development spending. See Symeonidis (1996).

to describe tariff levels. Import tariff levels in a country for each of the 10 industries are determined using an average of the ad valorem tariffs placed on final products within an industry. Table 1 presents the summary statistics for the firm-level dataset. Table 2 presents the summary statistics for the industry-level dataset.

5 Empirical Specifications and Results

In order to test each hypothesis put forth in this paper, I need to use both sets of data. First, I look at the firm-level data to examine how firms react to IPR-protection, Southern market size, and import tariffs. Next, I use the industry-level dataset to examine the reaction of all US firms in the industry. Together, the regression analyses in Subsection 5.1 and Subsection 5.2 confirms Hypothesis 1, refutes Hypothesis 2, and finds some support for Hypothesis 3. Subsection 5.3 confirms that these results are not sensitive to a number of different specifications including a difference-in-difference analysis.

5.1 Firm-Level R&D Offshoring

I use the statistical model for the firm-level number of researchers in the South employed by the Northern parent firm specified as follows:

$$Y^i_{jkt} = \beta_0 + \beta_1 \text{Tariff}_{jkt} + \beta_2 \text{Host Size}_{jt} + \beta_3 \text{IPR}_{jkt} + \beta_4 \text{High-Tech}_k +$$

$$\beta_5 \text{High-Tech}_k * \text{IPR}_{jkt} + \beta_6 X_{jt} + \beta_7 X_{kt} + \epsilon^i_{jkt} \qquad (29)$$

where Y^i_{jkt} is the number of Southern inventors working on firm i's patent in host country j in industry k at time t. I also use Y^i_{jkt} as the ratio of Southern researchers to total researchers working on firm i's patent. Tariffs_{jkt} is the average ad valorem tariff in industry k for imports into country j at time t. Likewise, IPR_{jkt} is the level of IPR-protection in country j for industry k at time t. Host Size_{jt} is the size of the market in country j at time t. Finally, High-Tech_{k} is a dummy variable indicating whether or not industry k is high-tech. ϵ^{i}_{jkt} is the error term for each individual project. X_{jt} is a vector of country specific controls while X_{kt} is a vector of industry specific controls. Both sets of controls vary with time. Each observation measures a specific patent. Thus, there can be multiple observations for a firm in a single year and country. The estimation method for the number of foreign inventors is OLS. Also, I examine the effect that firm size has on R&D offshoring:

$$Y^{i}_{jkt} = \beta_0 + \beta_1 \text{Tariffs}_{jkt} + \beta_2 \text{Host Size}_{jt} + \beta_3 \text{IPR}_{jkt} + \beta_4 \text{Large Firm}_{ikt} +$$

$$\beta_5 \text{Large Firm}_{ikt} * \text{IPR}_{jkt} + \beta_6 X_{jt} + \beta_7 X_{kt} + \epsilon^{i}_{jkt} \tag{30}$$

where Large Firm_{jkt} is the size of firm i in industry k at time t. Large Firm is a dummy variable indicating whether or not a firm has employed a more than average amount of inventors before the time of the patent.

Tables 3 and 4 present the results of the regression analysis with the number of inventors as the dependent variable. Table 3 reports the set of regressions that use the high-tech indicator. There is little evidence that firms in high-tech industries offshore more than firms in low-tech industries. The coefficient on the high-tech and IPR interaction variable is also not statistically significant. There is then no evidence to support that firms in high-tech industries respond differently to IPR-protection in host countries. The lack of evidence in Table 3 is explained by the variance in project size for firms in high-tech industries.

This study only measures product complexity for an industry and not the specific project complexity.[28]

Table 4 includes the large firm dummy variable; however, the coefficient on the dummy variable is only statistically significant in column (5) and column (7). Likewise, the coefficient for the large firm and IPR interaction variable is only statistically significant in these columns as well. The coefficient for the large firm dummy variable is negative while the coefficient on the IPR and large firm interaction variable is positive.[29] The sign of the coefficient on the interaction variable implies that large firms are more reactive to changes in IPR-protection than small firms. This provides support for Hypothesis 1.

Throughout all sets of regressions in Tables 3 and 4, the coefficient on GDP per capita is negative and often statistically significant. A single standard deviation increase in the host country size yields a decrease of up to 0.39 researchers. This provides evidence against Hypothesis 2.[30] This finding suggests that there is a connection between employee mobility and the market size. A large market size means there are more opportunities for employees to migrate. Thus, the probability of imitation increases with market size. There is also some evidence to suggest that IPR-protection positively affects firm-level innovative R&D decisions.

The coefficient on a host countries tariff level is positive and occasionally statistically significant. The effect of tariffs is often very small. An increase of one standard deviation of the tariff level increases the amount of people offshored by only 0.26 inventors at the

[28]The regressions with R&D intensity control for this inability to measure the project complexity by dividing the number of Southern researchers by the total number of researchers working on the patent.

[29]When the interaction term is taken into account with the mean IPR value, large firms tend to offshore more than small firms as long as the IPR-environment is stronger than average for developing countries.

[30]This result contradicts many previous findings on host country size and multinational activities. For example, Ivus, Park, and Saggi (2015) show that host country size is positively related to technology licensing to developing countries. Bilir (2014) finds that affiliate sales, assets, and employment increase with host country size. Hedge and Hicks (2007) find that host country size positively influences US multinational firm engagement of R&D in the host country.

most. A possible explanation for this is the relationship between import tariffs and the preferences of consumers in the host market. A high import tariff may signal that a certain industry is thriving in the host country. Therefore, the product is valued in the market place. Furthermore, qualified researchers in a specific industry would then already exist in the host country. Given the small magnitude of the coefficient, there is some support for Hypothesis 3. Also, supporting the findings of Demirbag and Glaister (2010), the previous experience variable is a positive predictor of R&D offshoring.

For the level of R&D intensity as a dependent variable, I use a Tobit model. Given that the R&D intensity is by nature between 0 and 1, a Tobit model is appropriate. The Tobit model can be useful as many firms may be willing to locate more than 100% of their research in their host country. Thus, the data is censored at 1.[31]

Tables 5 and 6 present the results of regressions with R&D intensity as the dependent variable. Table 5 provides additional support for Hypothesis 1. The coefficient for the high-tech and IPR interaction variable is positive and statistically significant. High-tech firms are more likely to increase offshoring activity during a strengthening of IPR-protection than low-tech firms. Table 6 does not yield any statistically significant results regarding firm size. The coefficients on the tariff and GDP per capita variables are never statistically significant in either Table 5 or Table 6. Thus, this set of regressions does not yield support for or against Hypotheses 2 and 3.

5.2 Industry-Level R&D Offshoring

Finally, this study presents an OLS model with the industry-level of R&D spending in a host country from US multinational firms as the dependent variable. Equation (34) outlines the statistical model for industry-level offshoring:

[31] The data also does not show any heteroskedasticity; therefore, the Tobit model will not present any biased coefficients.

$$Y_{jkt} = \beta_0 + \beta_1 \text{Tariff}_{jkt} + \beta_2 \text{Host Size}_{jt} + \beta_3 \text{IPR}_{jkt} + \beta_4 \text{High-Tech}_{kt} +$$

$$\beta_5 \text{High-Tech}_{kt} * \text{IPR}_{jkt} + \beta_6 X_{jt} + \beta_7 X_{kt} + \epsilon_{jkt} \tag{31}$$

where Y_{jkt} is innovative R&D spending for host country j in industry k at time t. ϵ_{jkt} is the error term for each industry k operating in country j at time t. I measure the variable High-Tech$_{kt}$ in two ways. First, I use a dummy variable to indicate whether or not an industry is high-tech. Second, I use the industry R&D expenditures by US multinational firms. Industries with larger R&D expenditures in the home country have higher research needs than other industries. Thus, industry R&D expenditures acts as a proxy for the technological level of an industry at a given time.

Tables 7 and 8 use the industry-level of multinational R&D expenditures in a host country as the dependent variable. Table 7 again uses a binary variable to indicate whether an industry is high-tech. High-tech industries are determined by having a higher than average parent R&D expenditure. The coefficient on the interaction term between the high-tech dummy and the IPR-protection variable is positive, statistically significant, and large. These high-tech industries respond to a strengthening of IPR-protection with more investment than low-tech industries. Table 8 tests Hypothesis 1 using an examination of the interaction variable constructed from the IPR variable and the R&D expenditures of US parent firms. The coefficient for parent R&D expenditures is negative and statistically significant. The coefficient on the interaction term is statistically significant and positive in all regressions. Industries with large amounts of research are reluctant to locate in a host country with extremely weak IPR-protection; however, these industries begin moving research to the South as IPR-protection strengthens at a greater rate than industries with small research needs. Along with the results of the previous subsection, these two tables provide strong evidence for Hypothesis 1.

Tables 7 and 8 also tests Hypothesis 2. GDP per capita, which captures the host country size, is not statistically significant. There is no evidence to either confirm or refute Hypothesis 2. Also, the coefficient on the tariff level is often not statistically significant. When the coefficient is statistically significant, the value is positive and economically significant. Import tariffs may then be a signal of a market that highly values that industry. Thus, parent firms would want to expand into the market with adaptive research as a way of both entering the market and adapting an existing product to fit the unique preferences and tastes of consumers in that market. By using R&D expenditures as a dependent variable, adaptive and innovative research are tied together. High import tariffs may also indicate that qualified researchers already exist in the host country for that industry. Also, high import tariffs may decrease Southern consumer income and unintentionally force Southern firms to close. More Northern firms could then enter the market.

5.3 Sensitivity Tests

In order to determine the robustness of the results presented above, a number of sensitivity tests are performed. First, two industries, Chemicals and Wholesale, are removed from the sample. This removal of these industries ensures that the results are not driven by specific industries in which patents are found to be especially effective. In an additional test, I remove the 5 countries that are the largest recipients of R&D tasks from US multinational firms. Again, this test is to determine whether the results can be applied in general or are driven by these unobserved characteristics of these five countries. In both of these tests, the results of this paper remain largely the same. This study uses industry fixed effects and country fixed effects. Controlling for the possibility of significant changes in the size or technology of industries throughout the year, I add sector-year fixed effects. Country-year fixed effects are added to the regressions to control for similar reasons. The inclusion of these fixed effects does not significantly change any of the results.

Testing the stability of the results to the IPR index, the IPR variable is removed in favor of difference-in-difference method used by Branstetter et al. (2006, 2011), Canals and Sener (2014), and Park, Ivus, and Saggi (2015). Using the year of major IPR-reform as the time of treatment and firms from high-tech industries as the treatment group, I estimate the effect IPR-reform has on innovative R&D offshoring. The specific time of reform from each country comes from the previous literature mentioned above. Table 9 uses this diff-in-diff method with the treatment group being high-tech firms and the dependent variable being the number of foreign inventors. The results are similar to the ones presented in Table 3. Table 10 also presents results similar to Table 4. Using large firms as the treatment group, the coefficient for the interaction term between the treatment group and the IPR-reform dummy variable is statistically significant and positive. Large firms tend to offshore less than small firms before the IPR-reform; however, large firms offshore more after the reform. Table 11 displays results of regressions using the IPR reform dummy variable, high-tech dummy variable, and industry-level data. The interaction term between the two dummy variables is statistically significant and positive. The high-tech dummy variable is no longer statistically significant. The results of the difference-in-difference regressions is not drastically different from the regressions using the IPR index; therefore, the results of this paper are not sensitive to the IPR index used in this study.

There is a common concern among previous literature that the IPR variable is endogenous (Branstetter et al., 2006; Canals and Sener, 2014; Bilir, 2014; Park, Ivus, and Saggi, 2015). So far in this study, IPR-protection is treated as exogenous; however, there may be omitted variables correlated with the IPR environment and the inflow of R&D offshoring. Furthermore, countries may feel obligated to strengthen IPR-protection if a large number of US multinational firms already locate R&D in the country. In an attempt to rule out these concern, this paper tests whether there has been a clear upward trend in the offshoring of innovative R&D. In order to test whether there was an upward trend, I create a series of dummy variables for the pre- and post-reform years. Pre5 equals 1 for 5 years or more before the reform takes place. Post5 equals 1 for 5 years or more after the reform. Pre4 equals 1 for 4 years before the reform while Post4 equals 1 for 4 years after the reform. Pre3, Pre2, Post3, Post2, and Post1 are defined in similar ways. Pre 1 is left out as a baseline. RO is a dummy variable indicating the year of reform. Table 11 shows the results of these regressions. Columns (1) and (2) use the firm-level dependent variable of the number of foreign inventors. Columns (3) and (4) use the industry-level dependent variable of R&D expenditures in a host country. There is no statistically significant trend in R&D offshoring before each reform; therefore, I conclude that the IPR reform is not endogenous.

5.4 Discussion

The results of the regression analysis imply that the theoretical structure correctly models multinational firms' innovative R&D offshoring decisions as it relates to IPR-protection and import tariffs. The model does not correctly predict a Northern firm's response to changes in the Southern market size. Multinational firms employ less Southern researchers from larger Southern markets.

The theoretical model supposes a number of assumptions. Violation of those assumptions may explain the model's inability to predict the firm-level offshoring response to Southern market size. First, the model assumes a significantly strong IPR-environment.

IPR-protection is weak in a number of the countries used in this dataset. Firms locating in these areas may be resigned to imitation. I also assume the worst case scenario of imitation. Imitation of a product forces the Northern firm out of the market. Thus, the theoretical model may overstate the reaction to exogenous changes. Also, I assume that both Northern firms and Southern firms are active. Imitation may not force the Northern firm out of the market. If a country has no Southern firms in the market during the time that a Northern firm is making its offshoring decision, imitation will not be a concern. Without competing firms to absorb employees of Northern firms, the threat of imitation decreases greatly. These concerns do not explain the evidence against Hypothesis 2 and strengthen the evidence supporting Hypotheses 1 and 3.

The result that multinational firms decrease their innovative R&D offshoring as Southern market size increases is explained by a connection between the probability of imitation and market size. Larger markets might have a larger amount of active Southern firms. These Southern firms provide employment for Southern researchers looking to leave the multinational firm. A large number of Southern firms means more opportunities for Southern researchers to find employment elsewhere. The theoretical model can be improved upon by including the host country size in the probability of imitation. As an alternate structure for the probability of imitation, the Southern firm's ability to successfully imitate the product could also depend on L_s. As L_s increases, the probability of imitation increases. In other words,

$$\phi = \left(\frac{\omega(\zeta, L_s) R^s}{R^n + \omega(\zeta, L_s) R^s} \right) \qquad 0 < \omega(\zeta, L_s) < 1 \tag{32}$$

where $\frac{\partial \omega}{\partial \zeta} > 0$ and $\frac{\partial L_s}{\partial \zeta} > 0$. Including this factor into the Southern imitator's ability function corrects the model's prediction for the firm-level response to changes in the Southern market size.[32]

Introducing Southern market size into the probability of imitation weakens the models predictive power for industry-level innovative offshoring during Southern market size changes. The model no longer predicts an unambiguous fall in industry-level innovative R&D offshoring as Southern market size increases. The empirical section of this paper finds no evidence regarding the Southern market size effect on industry-level R&D offshoring. Additional empirical evidence is needed.

6 Conclusion

This paper examines a global economy where Northern firms innovate using Northern and Southern researchers while Southern firms imitate. To match the growing trend in R&D offshoring, this paper assumes that firms are able to split research tasks between multiple research sites. I confirm the main predictions of the model using U.S. patent data and a number of publicly available datasets. High-tech firms and large firms increase innovative R&D offshoring more than their low-tech counterparts when IPR-protection strengthens. High-tech industries also increase innovative R&D offshoring more than low-tech industries when IPR-protection strengthens. Firm-level innovative R&D offshoring is not significantly affected by import tariffs. This study also finds empirical evidence that conflicts with the predictions of the theoretical model. Firm-level innovative R&D offshoring decreases with market size.

The results of this paper confirm and add to previous findings in the empirical literature concerning multinational activity, high-tech firms, and IPR-protection (Canals and Sener, 2014; Branstetter et al, 2006; Branstetter et al, 2011; Bilir, 2014). The study in this paper furthers the evidence that US high-tech industries increase their operations abroad

[32] I prove this case in Appendix D.

as Southern countries strengthen their IPR-protection laws. A main result of this paper is that high-tech firms are willing to locate more R&D tasks in the South as IPR-protection strengthens. The findings of this paper also contribute to the understanding of multinational activity and market size by showing that firms tend to offshore less research to larger countries. This paper also establishes the connection between multinational activity and industry specific tariffs. Furthermore, this paper adds to the North-South offshoring literature by introducing employee mobility as a channel of imitation.

The results of this paper imply a number of policy decisions may have unintended consequences for innovative R&D offshoring and thus R&D employment. First, decreasing an import tariff in a developing country could result in firms withdrawing innovative R&D from the country. A country may be stifling innovation within its borders by setting low import tariffs. Free trade agreements, like the TPP, may have unintended consequences on R&D employment. Second, enacting IPR-reform attracts high-tech firms to locate innovative R&D within the host country. By providing employment opportunities, IPR-protection laws can then be used as a way of preventing highly skilled researchers from leaving the country.

This study raises further questions on the subject of innovative R&D offshoring. While this paper examines the response of high-tech firms and large firms to IPR-protection changes, it does not separate into industry specific IPR-protection changes. One possible avenue for further research is to narrow the scope to the pharmaceutical industry after the TRIPS agreement. TRIPS promoted IPR reform in a number of developing nations in the pharmaceutical industry. The model may also be adapted to examine other R&D types such as quality increasing R&D. Finally, higher ability employees are more likely to leave firms than low ability employees. This model could be expanded to include heterogenous labor with higher ability researchers producing more research while being more likely to move to a competing firm.

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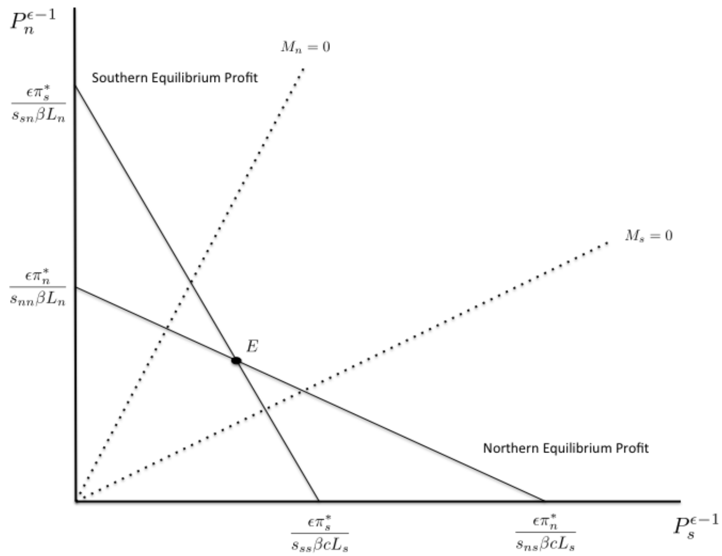

Figure 1: Trading Equilibrium

Table 1: Summary Statistics For Firm-Level Regressions

Variable	Mean	Std. Dev.	Min.	Max.
Number of Foreign Inventors	1.8	1.4	1	23
US Firm R&D Intensity in Host Country	0.6	0.3	0.02	1
High-tech Industry	0.5	0.49	0	1
Large Firm	0.5	0.5	0	1
IPR Index	2.9	0.8	0	4.88
Tariff	13.2	10.5	0	100
Previous Experience	0.5	0.5	0	1
GDP per capita	2681.9	3810.6	153	58884
Industry Employment	1415.9	2064.8	0	8808.1
Industry Assets	410729.5	264711.4	0	1741805
Product Life	9.3	0.57	8.4	10.4
Host Trade	58.1	44.1	11.5	220.4
Host Science Publications	17305.7	22456.4	0	181690
Host Country Population	4.59e+08	5.11e+08	55930	1.31e+09
Host GDP growth	4.5	4.8	-22.9	88.9

Note: Host country specific data is found using WDI tables. Industry specific data is found using BEA data and only concerns the industry in the U.S. The number of foreign inventors, firm size, and firm R&D intensity in a host country are determined using the USPTO database. Tariff data is found using the TRAINS database. The IPR index is from Park (2008). Product life data is from Bilir (2014).

Table 2: Summary Statistics For Industry-Level Regressions

Variable	Mean	Std. Dev.	Min.	Max.
R&D Expenditures in Host Country	8.7	46.4	0	822
IPR	3.4	0.6416347	1.72	4.68
GDP per capita	9535.3	14954.9	299.4	93605.75
High-tech Industry	0.31	0.47	0	1
Tariff	8.7	8	0	98.8
Industry Employment	1287.9	2046.6	0	8808.1
Industry Assets	371051.2	415370.9	0	1741805
Industry Sales	404120.9	333240.5	0	1493181
Industry R&D expenditures	13415.5	17264.72	0	58859
Host Science Publications	13556.2	41844	5.5	401434.5
Host GDP per capita Growth	2.9	4.1	-15.1	30.3
Host Trade	78	42.8	21	430.4

Note: Host country specific data is found using WDI tables. Industry specific data is found using BEA data and only concerns the industry in the U.S. Tariff data is found using the TRAINS database. The IPR index is from Park (2008).

Table 3: High-Tech Firms, Host Country Patents Laws, and Number of Inventors Offshored, Firm-Level

	Number of Foreign Inventors for US Firm's Patent						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariff	0.00133	0.00167	0.0145*	0.0202**	-0.00563	0.0245***	-0.00670
	(0.00508)	(0.00510)	(0.00816)	(0.00834)	(0.00839)	(0.00851)	(0.00763)
High-tech Industry	0.128**	-0.132	-0.278	-0.316	-0.0766	0.383	0.956
	(0.0622)	(0.247)	(0.657)	(0.642)	(0.656)	(0.997)	(1.004)
IPR	0.192***	0.145**	0.225	0.254	0.0114	0.253*	0.0348
	(0.0654)	(0.0627)	(0.179)	(0.162)	(0.261)	(0.146)	(0.279)
Previous Experience	0.276***	0.278***	0.269***	0.265***	0.221**	0.298***	0.259***
	(0.0615)	(0.0607)	(0.0789)	(0.0729)	(0.0858)	(0.0801)	(0.0889)
GDP per capita	-7.32e-05***	-7.38e-05***	-9.09e-05***	-9.53e-05***	-8.01e-05	-9.24e-05***	-5.77e-05
	(1.70e-05)	(1.69e-05)	(1.95e-05)	(2.71e-05)	(6.44e-05)	(2.67e-05)	(6.62e-05)
IPRxHigh-tech		0.0844	0.108	0.121	0.0304	0.151	0.0824
		(0.0812)	(0.201)	(0.194)	(0.192)	(0.172)	(0.168)
Constant	1.140***	1.284***	0.713	0.417	1.681	0.480	0.975
	(0.225)	(0.220)	(0.854)	(0.873)	(1.676)	(1.112)	(1.559)
Industry Controls	No	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	No	Yes	Yes
Observations	4,740	4,740	2,378	2,378	2,378	2,378	2,378
R-squared	0.030	0.030	0.042	0.046	0.077	0.057	0.088

Note: Standard errors in parentheses and are clustered by firm. Stars indicate significance with *** $p<0.01$, ** $p<0.05$, * $p<0.1$. High-tech is a dummy variable indicating if a firm is in a high-tech industry (Chemistry, Computers, Transport, and Wholesale). The number of foreign inventors on each patent is determined using the USPTO database. Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR index is from Park (2008). Product life, from Bilir (2014), controls for product complexity in each industry.

Table 4: Large Firm, Host Country Patents Laws, and Number of Inventors Offshored, Firm-Level

	Number of Foreign Inventors for US Firm's Patent						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariff	0.00202	0.00263	0.0153*	0.0209**	-0.00801	0.0251***	-0.00910
	(0.00510)	(0.00524)	(0.00839)	(0.00841)	(0.00778)	(0.00848)	(0.00739)
Large Firm	4.81e-05	-0.468	-0.892	-0.937	-1.485**	-0.869	-1.351**
	(0.114)	(0.360)	(0.683)	(0.662)	(0.691)	(0.630)	(0.640)
IPR	0.188***	0.121	0.165	0.206	-0.228	0.244	-0.154
	(0.0666)	(0.0815)	(0.165)	(0.182)	(0.199)	(0.181)	(0.218)
Previous Experience	0.274***	0.274***	0.279***	0.277***	0.236**	0.298***	0.252**
	(0.0816)	(0.0807)	(0.100)	(0.0967)	(0.101)	(0.0960)	(0.0982)
GDP per capita	-7.69e-05***	-7.81e-05***	-9.25e-05***	-0.000103***	-9.49e-05	-9.80e-05***	-7.43e-05
	(1.72e-05)	(1.73e-05)	(1.98e-05)	(2.68e-05)	(6.03e-05)	(2.65e-05)	(6.56e-05)
IPRxLarge Firm		0.154	0.280	0.295	0.473**	0.282	0.443**
		(0.108)	(0.205)	(0.196)	(0.208)	(0.190)	(0.197)
Constant	1.223***	1.423***	1.012	0.731	2.660**	0.835	2.662**
	(0.232)	(0.262)	(0.777)	(0.838)	(1.228)	(0.982)	(1.248)
Industry Controls	No	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	No	Yes	Yes
Observations	4,740	4,740	2,378	2,378	2,378	2,378	2,378
R-squared	0.028	0.029	0.045	0.049	0.085	0.060	0.094

Note: Standard errors in parentheses and are clustered by firm. Stars indicate significance with *** $p<0.01$, ** $p<0.05$, * $p<0.1$. Large firm is a dummy variable indicating if firms have more than average inventors employed previously as seen from the USPTO data. The number of foreign inventors on each patent is determined using the USPTO database. Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR index is from Park (2008). Product life, from Bilir (2014), controls for product complexity in each industry.

Table 5: High-Tech Firms, Host Country Patents Laws, and R&D Intensity in Host Country, Firm-Level, Tobit Regression

	US Firm R&D Intensity in Host Country						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariff	-0.000843	-0.000537	-0.000240	0.00220	0.000221	0.00289	0.00222
	(0.00182)	(0.00181)	(0.00309)	(0.00334)	(0.00424)	(0.00334)	(0.00405)
High Tech Industry	-0.0657*	-0.311***	-0.514**	-0.495**	-0.340	-0.820***	-0.692***
	(0.0368)	(0.106)	(0.233)	(0.229)	(0.220)	(0.238)	(0.226)
IPR	-0.00745	-0.0527	-0.132*	-0.117	-0.186	-0.119	-0.163
	(0.0258)	(0.0346)	(0.0770)	(0.0846)	(0.129)	(0.0810)	(0.131)
Previous Experience	0.131***	0.134***	0.170***	0.158***	0.162***	0.153***	0.155***
	(0.0383)	(0.0386)	(0.0553)	(0.0565)	(0.0444)	(0.0536)	(0.0417)
GDP per capita	8.60e-07	2.67e-07	-2.30e-06	-2.27e-06	-9.91e-06	4.04e-07	-6.06e-07
	(1.10e-05)	(1.09e-05)	(1.28e-05)	(1.67e-05)	(2.73e-05)	(1.66e-05)	(2.80e-05)
IPRxhigh_tech		0.0798**	0.127**	0.123**	0.0715	0.136**	0.0926
		(0.0330)	(0.0633)	(0.0624)	(0.0614)	(0.0614)	(0.0603)
Constant	0.750***	0.889***	1.378***	1.209***	1.831***	1.536***	1.914***
	(0.102)	(0.122)	(0.389)	(0.447)	(0.602)	(0.435)	(0.572)
Industry Controls	No	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	No	Yes	Yes
_sigma	0.481	0.48	0.493	0.491	0.477	0.488	0.474
	(0.007)***	(0.007)***	(0.010)***	(0.010)***	(0.010)***	(0.010)***	(0.010)***
Observations	4740	4740	2378	2378	2378	2378	2378

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Standard errors in parentheses and are clustered by firm. Stars indicate significance with *** p<0.01, ** p<0.05, * p<0.1. High-tech is a dummy variable indicating if a firm is in a high-tech industry (Chemistry, Computers, Transport, and Wholesale). R&D intensity is defined as the number of foreign inventors divided by the number of total inventors on a patent and is constructed with the USPTO database. Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR index is from Park (2008). Product life, from Bilir (2014), controls for product complexity in each industry.

Table 6: Large Firms, Host Country Patents Laws, and R&D Intensity in Host Country, Firm-Level, Tobit Regression

	US Firm R&D Intensity in Host Country						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariff	-0.00117	-0.00121	-0.000520	0.00197	0.000879	0.000378	0.00217
	(0.00184)	(0.00188)	(0.00170)	(0.00341)	(0.00395)	(0.00285)	(0.00397)
Large Firm	-0.00470	0.0256	0.0862	0.0839	0.0828	0.129	0.0291
	(0.0419)	(0.126)	(0.123)	(0.230)	(0.215)	(0.174)	(0.211)
IPR	-0.00518	-0.000881	-0.0113	0.00115	-0.0910	-0.000663	-0.0971
	(0.0264)	(0.0249)	(0.0308)	(0.0514)	(0.111)	(0.0410)	(0.117)
Previous Experience	0.134***	0.134***	0.164***	0.151***	0.152***	0.149***	0.160***
	(0.0347)	(0.0347)	(0.0256)	(0.0502)	(0.0403)	(0.0376)	(0.0393)
GDP per capita	2.77e-06	2.85e-06	-8.53e-07	1.66e-06	-4.50e-06	1.11e-05	-1.72e-06
	(1.07e-05)	(1.07e-05)	(5.89e-06)	(1.62e-05)	(2.65e-05)	(1.52e-05)	(2.77e-05)
IPRxLarge Firm		-0.00996	-0.0207	-0.0209	-0.0205	-0.0454	-0.0137
		(0.0442)	(0.0383)	(0.0737)	(0.0672)	(0.0568)	(0.0669)
Constant	0.708***	0.695***	0.813***	0.639**	1.246**	0.530***	1.337**
	(0.0982)	(0.0903)	(0.216)	(0.317)	(0.496)	(0.184)	(0.534)
Industry Controls	No	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	No	Yes	Yes
_sigma	0.481	0.481	0.492	0.491	0.476	0.48	0.472
	(0.007)***	(0.007)***	(0.010)***	(0.010)***	(0.010)***	(0.008)***	(0.010)***
Observations	4740	4740	2378	2378	2378	4084	2378

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Note: Standard errors in parentheses and are clustered by firm. Stars indicate significance with *** p<0.01, ** p<0.05, * p<0.1. Large firm is a dummy variable indicating if firms have more than average inventors employed previously as seen from the USPTO data. R&D intensity is defined as the number of foreign inventors divided by the number of total inventors on a patent and is constructed with the USPTO database. Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR index is from Park (2008). Product life, from Bilir (2014), controls for product complexity in each industry.

Table 7: High-Tech Industry, Host Country Patents Laws, and R&D Intensity in Host Country, Industry-Level

	R&D Expenditures in Host Country					
	(1)	(2)	(3)	(4)	(5)	(6)
IPR	1.618	2.313	-5.893**	-3.977	-6.002**	-4.136
	(2.245)	(2.369)	(2.379)	(4.933)	(2.384)	(5.200)
High-tech Industry	-46.82***	-56.95***	-50.46***	-49.41***		
	(11.76)	(14.31)	(13.49)	(13.31)		
IPRxHigh-tech	20.32***	18.91***	18.81***	19.78***	18.69***	19.73***
	(3.543)	(3.703)	(3.485)	(3.436)	(3.482)	(3.431)
GDP per capita	6.16e-05	-0.000273	0.000521	0.000762	0.000493	0.000837
	(0.000341)	(0.000371)	(0.000358)	(0.000706)	(0.000361)	(0.000760)
Tariff	0.204	0.296*	0.176	0.122	0.163	0.117
	(0.143)	(0.154)	(0.151)	(0.178)	(0.163)	(0.199)
Constant	-5.938	-5.529	10.45	10.85	13.85	14.93
	(7.495)	(8.219)	(8.725)	(16.45)	(12.88)	(19.52)
Industry Controls	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	Yes	Yes
Observations	1,819	1,715	1,715	1,715	1,715	1,715
R-squared	0.072	0.083	0.190	0.241	0.200	0.252

Note: Standard errors in parentheses. Stars indicate significance with *** p<0.01, ** p<0.05, * p<0.1. R&D expenditures from U.S. multinationals in a host country data is from the BEA. High-tech is a dummy variable indicating if a firm is in a high-tech industry (Chemistry, Computers, Transport, and Wholesale). Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR index is from Park (2008). Product life, from Bilir (2014), controls for product complexity in each industry.

Table 8: Parent R&D Expenditures, Host Country Patents Laws, and R&D Intensity in Host Country, Industry-Level

	R&D Expenditures in Host Country					
	(1)	(2)	(3)	(4)	(5)	(6)
IPR	-0.216	0.0946	-6.891***	-5.002	-7.440***	-4.727
	(2.420)	(2.530)	(2.511)	(4.945)	(2.527)	(5.220)
IPRxIndustry R&D Expenditures	0.000634***	0.000625***	0.000552***	0.000574***	0.000573***	0.000605***
	(0.000106)	(0.000111)	(0.000105)	(0.000104)	(0.000105)	(0.000104)
GDP per capita	-3.97e-05	-0.000291	0.000481	0.000497	0.000465	0.000730
	(0.000341)	(0.000370)	(0.000358)	(0.000700)	(0.000361)	(0.000759)
Tariff	0.264*	0.284*	0.190	0.166	0.142	0.0949
	(0.145)	(0.152)	(0.149)	(0.174)	(0.163)	(0.199)
Industry R&D Expenditures	-0.00148***	-0.00138***	-0.00118***	-0.00126***	-0.00135***	-0.00158***
	(0.000358)	(0.000375)	(0.000354)	(0.000351)	(0.000478)	(0.000475)
Constant	-1.939	1.630	13.09	13.37	19.17	17.75
	(8.160)	(8.645)	(9.052)	(16.56)	(13.18)	(19.59)
Industry Controls	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	Yes	Yes
Observations	1,804	1,715	1,715	1,715	1,715	1,715
R-squared	0.080	0.086	0.189	0.239	0.200	0.253

Note: Standard errors in parentheses. Stars indicate significance with *** $p<0.01$, ** $p<0.05$, * $p<0.1$. R&D expenditures from U.S. multinationals in a host country data is from the BEA. U.S. R&D expenditures in the U.S. are used as a proxy for the research needs of the industry. This data also comes from the BEA. Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, and assets for US parent companies. Tariff data is found using the TRAINS database. The IPR index is from Park (2008). Product life, from Bilir (2014), controls for product complexity in each industry.

Table 9: Diff-in-Diff: High-Tech Industry, Patents Reform Year, and R&D Intensity in Host Country, Firm-Level

	Number of Foreign Inventors for US Firm's Patent						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariff	-0.00512	-0.00512	0.00298	0.0103	-0.00508	0.0139*	-0.00571
	(0.00452)	(0.00452)	(0.00657)	(0.00716)	(0.00897)	(0.00747)	(0.00803)
High-tech Industry	0.117*	0.130	0.485	0.410	0.642		
	(0.0633)	(0.155)	(0.438)	(0.448)	(0.439)		
IPR Dummy	0.0411	0.0501	0.513**	0.443**	0.120	0.432**	0.0687
	(0.0965)	(0.127)	(0.214)	(0.221)	(0.343)	(0.212)	(0.336)
Previous Experience	0.292***	0.292***	0.279***	0.284***	0.247***	0.313***	0.278***
	(0.0598)	(0.0597)	(0.0796)	(0.0740)	(0.0853)	(0.0826)	(0.0892)
GDP per capita	-7.40e-05***	-7.40e-05***	-8.89e-05***	-0.000102***	-9.78e-05	-9.43e-05***	-7.66e-05
	(1.71e-05)	(1.71e-05)	(1.94e-05)	(2.67e-05)	(6.05e-05)	(2.50e-05)	(6.20e-05)
IPR DummyxHigh-tech		-0.0152	-0.481	-0.401	-0.659	-0.319	-0.529
		(0.169)	(0.451)	(0.460)	(0.461)	(0.459)	(0.465)
Constant	1.776***	1.767***	1.321**	1.300**	-5.651	1.613	-6.147
	(0.139)	(0.153)	(0.566)	(0.641)	(5.824)	(1.190)	(5.726)
Industry Controls	No	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	No	Yes	Yes
Observations	4,629	4,629	2,329	2,329	2,329	2,329	2,329
R-squared	0.024	0.024	0.036	0.040	0.074	0.051	0.084

Note: Standard errors in parentheses and are clustered by firm. Stars indicate significance with *** p<0.01, ** p<0.05, * p<0.1. High-tech is a dummy variable indicating if a firm is in a high-tech industry (Chemistry, Computers, Transport, and Wholesale). The number of foreign inventors on each patent is determined using the USPTO database. Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR reform dummy indicates the time of a major strengthening of IPR-protection in a host country. Product life, from Bilir (2014), controls for product complexity in each industry.

Table 10: Diff-in-Diff: Large Firm, Patents Reform Year, and Number of Inventors Offshored, Firm-Level

	Number of Foreign Inventors for US Firm's Patent						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Tariff	-0.00427	-0.00362	0.00376	0.0113	-0.00346	0.0150**	-0.00404
	(0.00461)	(0.00454)	(0.00662)	(0.00729)	(0.00902)	(0.00759)	(0.00821)
Large Firm	-0.00876	-0.442**	-1.181**	-1.185*	-1.422**	-1.315**	-1.472**
	(0.118)	(0.193)	(0.600)	(0.609)	(0.686)	(0.581)	(0.654)
IPR Dummy	0.0421	-0.147	-0.417	-0.429	-1.180*	-0.420	-1.146*
	(0.0964)	(0.133)	(0.528)	(0.536)	(0.655)	(0.523)	(0.636)
Previous Experience	0.294***	0.287***	0.292***	0.289***	0.247**	0.317***	0.267***
	(0.0806)	(0.0792)	(0.101)	(0.0966)	(0.0979)	(0.0967)	(0.0954)
GDP per capita	-7.71e-05***	-7.64e-05***	-8.92e-05***	-0.000102***	-9.51e-05	-9.37e-05***	-7.40e-05
	(1.73e-05)	(1.73e-05)	(1.91e-05)	(2.68e-05)	(5.96e-05)	(2.46e-05)	(6.21e-05)
IPR DummyxLarge Firm		0.483***	1.179**	1.197**	1.448**	1.340**	1.531**
		(0.161)	(0.576)	(0.585)	(0.662)	(0.572)	(0.646)
Constant	1.838***	1.994***	2.241***	2.153***	-4.420	2.625**	-4.654
	(0.135)	(0.155)	(0.716)	(0.769)	(5.829)	(1.238)	(5.837)
Industry Controls	No	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	No	Yes	Yes
Observations	4,629	4,629	2,329	2,329	2,329	2,329	2,329
R-squared	0.023	0.025	0.040	0.045	0.080	0.057	0.090

Note: Standard errors in parentheses and are clustered by firm. Stars indicate significance with *** p<0.01, ** p<0.05, * p<0.1. Large firm is a dummy variable indicating if firms have more than average inventors employed previously as seen from the USPTO data. The number of foreign inventors on each patent is determined using the USPTO database. Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR reform dummy indicates the time of a major strengthening of IPR-protection in a host country. Product life, from Bilir (2014), controls for product complexity in each industry.

Table 11: Diff-in-Diff: Parent R&D Expenditures, Patents Reform Year, and R&D Intensity in Host Country, Industry-Level

	R&D Expenditures in Host Country					
	(1)	(2)	(3)	(4)	(5)	(6)
IPR Dummy	3.422	2.764	-4.230	-19.44**	-4.055	-20.99***
	(5.505)	(5.718)	(5.483)	(8.093)	(5.467)	(8.094)
High-tech Industry	1.039	-14.65	-7.801	-2.091	2.262	3.164
	(8.757)	(13.77)	(13.20)	(12.82)	(18.88)	(18.15)
IPR DummyxHigh-tech	32.78***	26.44***	26.93***	27.74***	26.85***	27.81***
	(9.251)	(9.559)	(9.116)	(8.744)	(9.116)	(8.732)
GDP per capita	0.000170	-0.000181	5.93e-05	0.00175**	-3.62e-05	0.00151**
	(0.000226)	(0.000263)	(0.000261)	(0.000716)	(0.000269)	(0.000752)
Tariff	0.349*	0.460**	0.337	0.0496	0.387*	0.0599
	(0.205)	(0.218)	(0.211)	(0.254)	(0.226)	(0.281)
Constant	-5.034	-2.209	-4.778	1.251	5.245	18.28
	(5.883)	(6.798)	(6.967)	(16.26)	(15.02)	(20.41)
Industry Controls	No	Yes	Yes	Yes	Yes	Yes
Country Controls	No	No	Yes	Yes	Yes	Yes
Country Fixed Effects	No	No	No	Yes	No	Yes
Industry Fixed Effects	No	No	No	No	Yes	Yes
Observations	1,746	1,589	1,586	1,586	1,586	1,586
R-squared	0.071	0.085	0.172	0.250	0.184	0.264

Note: Standard errors in parentheses. Stars indicate significance with *** p<0.01, ** p<0.05, * p<0.1. R&D expenditures from U.S. multinationals in a host country data is from the BEA. High-tech is a dummy variable indicating if a firm is in a high-tech industry (Chemistry, Computers, Transport, and Wholesale). Host country specific data is found using WDI tables. Host country control variables include GDP growth, number of science publications, and the amount of trade as defined by exports and imports divided by GDP. Industry specific data, from the BEA database, includes U.S. industry-level parents sales, number of employees, assets, and R&D expenditures for US parent companies. Tariff data is found using the TRAINS database. The IPR reform dummy indicates the time of a major strengthening of IPR-protection in a host country. Product life, from Bilir (2014), controls for product complexity in each industry.

Table 12: Parent R&D Offshoring with Pre and Post Reform Dummies, Industry-Level

	Number of Foreign Inventors for US Firm's Patent		R&D Expenditures in Host Country	
	(1)	(2)	(3)	(4)
pre5	-0.159	0.441	5.287	4.823
	(1.809)	(2.317)	(11.93)	(13.91)
pre4	-0.114	0.456	4.756	5.091
	(1.972)	(2.311)	(14.15)	(16.64)
pre3	0.0635	0.155	3.921	4.467
	(0.884)	(1.725)	(14.15)	(16.63)
pre2	0.544*	0.160	3.050	3.234
	(0.318)	(0.803)	(13.82)	(16.37)
RO	0.0206	0.688	-1.819	-1.554
	(0.262)	(0.700)	(10.50)	(12.22)
post1	-0.115	0.538	-8.975	-15.46
	(0.272)	(0.601)	(8.926)	(10.13)
post2	-0.119	0.556	-8.596	-10.41
	(0.286)	(0.597)	(9.588)	(11.10)
post3	-0.200	0.119	-6.310	-8.218
	(0.303)	(0.602)	(9.664)	(11.13)
post4	-0.0760	0.510	-8.650	-10.93
	(0.315)	(0.602)	(10.24)	(11.85)
post5	-0.00553	0.351	-3.107	-2.669
	(0.319)	(0.595)	(10.67)	(12.42)
pre5xHigh_tech		-0.529		-0.281
		(1.721)		(22.45)
pre4xHigh_tech		-0.513		2.556
		(2.122)		(24.17)
pre3xHigh_tech		0.00986		2.179
		(1.858)		(29.17)
pre2xHigh_tech		0.456		0.976
		(0.872)		(29.17)
ROxHigh_tech		-0.743		3.190
		(0.743)		(29.15)
post1xHigh_tech		-0.737		27.39
		(0.630)		(17.82)
post2xHigh_tech		-0.787		10.35
		(0.622)		(19.94)
post3xHigh_tech		-0.297		8.089
		(0.622)		(20.31)
post4xHigh_tech		-0.689		8.829
		(0.618)		(21.90)
post5xHigh_tech		-0.316		0.491
		(0.598)		(22.73)
Constant	0.862	0.315	4.864	8.132
	(2.453)	(2.558)	(14.22)	(14.93)
Observations	2,688	2,688	2,234	2,234
R-squared	0.084	0.088	0.267	0.273

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

This Appendix is not intended for publication.

Appendix

A Consumers

Consumers maximize utility function (1) in two stages. First, I solve the within sector consumer optimization. That is, consumers decide what quantities of x_{ii} and x_{ji} to consume in order to maximize the CES sub-utility function, X_i. The consumer must determine how much of each variety to consumer:

$$\max_{x_{ii},\, x_{ji}} \quad X_i = \left[M_i(a_{ii} * x_{ii})^{\frac{\epsilon-1}{\epsilon}} + M_j(a_{ji} * x_{ji})^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} \qquad s.t. \quad M_i p_{ii} x_{ii} + M_j p_{ji} x_{ji} = E_{X_i} \tag{A.1}$$

where $i \neq j \in (n, s)$ and E_{X_i} is the expenditure spent on differentiated goods. The Lagrangian can be defined as:

$$\mathcal{L} = \left[M_i(a_{ii} * x_{ii})^{\frac{\epsilon-1}{\epsilon}} + M_j(a_{ji} * x_{ji})^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}} - \lambda[M_i p_{ii} x_{ii} + M_j p_{ji} x_{ji} - E_{X_i}] \tag{A.2}$$

Taking first order conditions:

$$\frac{\partial \mathcal{L}}{\partial x_{ii}} = X_i^{\frac{1}{\epsilon}} a_{ii} M_i (a_{ii} x_{ii})^{\frac{-1}{\epsilon}} - \lambda p_{ii} M_i = 0 \tag{A.3}$$

$$\frac{\partial \mathcal{L}}{\partial x_{ji}} = X_i^{\frac{1}{\epsilon}} a_{ji} M_j (a_{ji} x_{ji})^{\frac{-1}{\epsilon}} - \lambda p_{ji} M_j = 0 \tag{A.4}$$

$$\frac{\partial \mathcal{L}}{\partial \lambda} = -[M_i p_{ii} x_{ii} + M_j p_{ji} x_{ji} - E_{X_i}] = 0 \tag{A.5}$$

Note that:

$$\left[M_i (a_{ii} * x_{ii})^{\frac{\epsilon-1}{\epsilon}} + M_j (a_{ji} * x_{ji})^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{1}{\epsilon-1}} = \left[X_i^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{1}{\epsilon-1}} = X_i^{\frac{1}{\epsilon}}$$

Combining (A.3) and (A.4) yields:

$$\frac{a_{ji} X_i^{\frac{1}{\epsilon}} (a_{ji} x_{ji})^{\frac{-1}{\epsilon}}}{p_{ji}} = \frac{a_{ii} X_i^{\frac{1}{\epsilon}} (a_{ii} x_{ii})^{\frac{-1}{\epsilon}}}{p_{ii}} \tag{A.6}$$

$$(a_{ji} x_{ji})^{\frac{-1}{\epsilon}} = \frac{p_{ji}}{p_{ii}} (a_{ii} x_{ii})^{\frac{-1}{\epsilon}} a_{ji}^{-1} a_{ii} \tag{A.7}$$

$$p_{ji} * x_{ji} = p_{ii}^{\epsilon} x_{ii} a_{ji}^{\epsilon-1} a_{ii}^{1-\epsilon} p_{ji}^{1-\epsilon} \tag{A.8}$$

Likewise,

$$p_{ii} * x_{ii} = p_{ji}^{\epsilon} x_{ji} a_{ii}^{\epsilon-1} a_{ji}^{1-\epsilon} p_{ii}^{1-\epsilon} \tag{A.9}$$

Using equation (A.5) with (A.8), (A.9) and the definition of the price index from equations (4) and (5), the individual demands for x_{ii} and x_{ji} can be found:

$$x_{ji} = a_{ji}^{\epsilon-1} p_{ji}^{-\epsilon} P_i^{\epsilon-1} E_{X_i} \tag{A.10}$$

$$x_{ii} = a_{ii}^{\epsilon-1} p_{ii}^{-\epsilon} P_i^{\epsilon-1} E_{X_i} \tag{A.11}$$

Plugging equations (A.10) and (A.11) back into the the sub-utility function yields:

$$\begin{aligned}
X_i &= \left[M_i (a_{ii} * x_{ii})^{\frac{\epsilon-1}{\epsilon}} + M_j (a_{ji} * x_{ji})^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \\
&= \left[M_i a_{ii}^{\frac{\epsilon-1}{\epsilon}} a_{ii}^{\frac{(\epsilon-1)^2}{\epsilon}} p_{ii}^{-\epsilon+1} P_i^{\frac{(\epsilon-1)^2}{\epsilon}} E_{X_i}^{\frac{\epsilon-1}{\epsilon}} + M_j a_{ji}^{\frac{\epsilon-1}{\epsilon}} a_{ji}^{\frac{(\epsilon-1)^2}{\epsilon}} p_{ji}^{-\epsilon+1} P_i^{\frac{(\epsilon-1)^2}{\epsilon}} E_{X_i}^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}} \\
&= E_{X_i} P_i^{\epsilon-1} \left[M_i a_{ii}^{\frac{\epsilon-1}{\epsilon}} a_{ii}^{\frac{(\epsilon-1)^2}{\epsilon}} p_{ii}^{-\epsilon+1} + M_j a_{ji}^{\frac{\epsilon-1}{\epsilon}} a_{ji}^{\frac{(\epsilon-1)^2}{\epsilon}} p_{ji}^{-\epsilon+1} \right]^{\frac{\epsilon}{\epsilon-1}}
\end{aligned}$$

Using the definition of the price index, the sub-utility function simplifies to:

$$X_i = E_{X_i} P_i^{\epsilon-1} P_i^{-\epsilon} = \frac{E_{X_i}}{P_i} \tag{A.12}$$

So, the expenditures on differentiated goods in country i equals the price index multiplied by the quality index: $X_i P_i = E_{X_i}$. The demands for each variety can be further simplified:

$$x_{ji} = a_{ji}^{\epsilon-1} p_{ji}^{-\epsilon} P_i^{\epsilon} X_i \tag{A.13}$$

$$x_{ii} = a_{ii}^{\epsilon-1} p_{ii}^{-\epsilon} P_i^{\epsilon} X_i \tag{A.14}$$

Specifically,

$$x_{nn} = p_{nn}^{-\epsilon} a_{nn}^{\epsilon-1} P_n^{\epsilon} X_n \tag{A.15}$$

$$x_{sn} = p_{sn}^{-\epsilon} a_{sn}^{\epsilon-1} P_n^{\epsilon} X_n \tag{A.16}$$

$$x_{ns} = p_{ns}^{-\epsilon} a_{ns}^{\epsilon-1} P_s^{\epsilon} X_s \tag{A.17}$$

$$x_{ss} = p_{ss}^{-\epsilon} a_{ss}^{\epsilon-1} P_s^{\epsilon} X_s \tag{A.18}$$

This completes the within sector consumer optimization. Note that the expenditure on the outside-good good is just z_i. The price of the outside-good good is set equal to 1. Consumer then face the across sector maximization problem:

$$\max_{z_i,\ X_i} \quad z_i^{1-\beta} X_i^{\beta} \qquad s.t. \quad z_i + P_i X_i = w_i L_i \tag{A.19}$$

where w_i is the wage in country i. Assuming free entry in the differentiated good sector, consumer income is equal to the wage multiplied by the number of workers. The Lagrangian associated with this problem can then be defined:

$$\mathcal{L} = z_i^{1-\beta} X_i^{\beta} - \lambda[z_i + P_i X_i - w_i L_i] \tag{A.20}$$

Taking first order conditions:

$$\frac{\partial \mathcal{L}}{\partial z_i} = (1-\beta) z_i^{-\beta} X_i^{\beta} - \lambda = 0 \tag{A.21}$$
$$\frac{\partial \mathcal{L}}{\partial X_i} = (\beta) z_i^{1-\beta} X_i^{\beta-1} - \lambda P_i = 0 \tag{A.22}$$
$$\frac{\partial \mathcal{L}}{\partial \lambda} = -[z_i + P_i X_i - w_i L_i] = 0 \tag{A.23}$$

Combining equations (A.21) and (A.22):

$$X_i = (\frac{z_i \beta}{P_i(1-\beta)}) \tag{A.24}$$

Plugging equation (A.24) into (A.23) yields:

$$z_i + z_i(\frac{\beta}{1-\beta}) = w_i L_i$$
$$z_i(\frac{1}{1-\beta}) = w_i L_i$$

$$z_i = (1-\beta) w_i L_i \tag{A.25}$$

Equation (A.25) represents the share of income that the representative consumer spends on the outside-good good. Likewise, combining (A.25) and (A.24) shows the share of income devoted to differentiated goods:

$$X_i P_i = \beta w_i L_i \tag{A.26}$$

Using (A.19), (A.25), and (A.26), the indirect utility function can easily be found:

$$V(P_i) = [(1-\beta)I_i]^{1-\beta}[\frac{\beta w_i L_i}{P_i}]^{\beta} \tag{A.27}$$

$$= \frac{(1-\beta)^{1-\beta}\beta^{\beta} w_i L_i}{P_i^{\beta}} = \boxed{\frac{B w_i L_i}{P_i^{\beta}}} \tag{A.28}$$

Dividing (A.28) by the total population in country i yields the welfare per worker in country i:

$$W_i = \boxed{\frac{B w_i}{P_i^{\beta}}} \tag{A.29}$$

B Producers

B.1 First Stage

In the first stage, Northern firms must decide on the level of research task to assign to Northern and Southern researchers. A Northern firm faces the expected profit function:

$$E(\pi_n) = \left(\frac{R^n}{R^n(1-\zeta)+\zeta\overline{R}}\right)[\pi_n^o] - R^n - c(\overline{R} - R^n) \tag{B.1}$$

Taking the first derivative:

$$\frac{\partial E(\pi_n)}{\partial R^n} = \left(\frac{\zeta\overline{R}}{(R^n(1-\zeta)+\zeta\overline{R})^2}\right)[\pi_n^o] - (1-c) \tag{B.2}$$

Setting (B.2) equal to zero yields the optimal research level iff $\frac{\partial^2 E(\pi_n)}{(R^n)^2} < 0$. Note:

$$\frac{\partial^2 E(\pi_n)}{(R^n)^2} = \left(\frac{-(1-\zeta)\zeta\overline{R}}{(R^n(1-\zeta)+\zeta\overline{R})^3}\right)[\pi_n^o] \tag{B.3}$$

Given the restriction on the IPR parameter, ζ, the second order condition hold. Therefore, the FOC yields:

$$R^n = (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta})\overline{R} \tag{B.4}$$

This number of Northern researchers then implies that the number of Southern researchers is equal to $\overline{R} - R^n$:

$$R^s = (\frac{1}{1-\zeta})\overline{R} - (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} \tag{B.5}$$

The probability of imitation is then:

$$\phi = (\frac{1}{1-\zeta})\left(\frac{\zeta\overline{R}(1-c)}{\pi_n^o}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta}) \tag{B.6}$$

Note that for both levels to be positive, R^n cannot be greater than the total research level, $\overline{R}$ or:

$$\begin{aligned}
\overline{R} &> R^n \\
\overline{R} &> (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta})\overline{R} \\
(\frac{1}{1-\zeta})\overline{R} &> (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} \\
\overline{R} &> \left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}}
\end{aligned}$$

$$\implies \overline{R} > \frac{[\pi_n^o]\zeta}{1-c} \tag{B.7}$$

Condition (B.7) also guarantees that R^s is positive. Finally, the level of Northern research must also be positive:

$$\begin{aligned}
0 &< R^n \\
0 &< (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta})\overline{R} \\
(\frac{\zeta}{1-\zeta})\overline{R} &< (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} \\
\zeta\overline{R} &< \left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}}
\end{aligned}$$

$$\implies \overline{R} < \frac{[\pi_n^o]}{\zeta(1-c)} \tag{B.8}$$

These two conditions together imply the necessary and sufficient condition (16) for an interior solution.

B.2 Second Stage

In the second stage, firms chooses the optimal price levels to maximize operating profit. A firm from the North maximizes the following operating profit function:

$$\pi_n = [x_{nn}(p_{nn} - \kappa) + x_{ns}(p_{ns} - \kappa - \tau_n)] \tag{B.9}$$

Firms must set p_{nn} and p_{ns} to maximize profit. Using the demands (A.15) and (A.17), the profit function can be rewritten:

$$\pi_n = [p_{nn}^{-\epsilon} a_{nn}^{\epsilon-1} P_n^{\epsilon} X_n(p_{nn} - \kappa) + p_{ns}^{-\epsilon} a_{ns}^{\epsilon-1} P_s^{\epsilon} X_s(p_{ns} - \kappa - \tau_n)] \tag{B.10}$$

Taking the derivative wrt p_{nn} and p_{ns} yields two first order conditions:

$$\frac{\partial \pi_n}{\partial p_{nn}} = -\epsilon[p_{nn}^{-\epsilon-1} a_{nn}^{\epsilon-1} P_n^{\epsilon} X_n(p_{nn} - \kappa) - p_{nn}^{-\epsilon} a_{nn}^{\epsilon-1} P_n^{\epsilon} X_n] = 0 \tag{B.11}$$

$$\frac{\partial \pi_n}{\partial p_{ns}} = -\epsilon[p_{ns}^{-\epsilon-1} a_{ns}^{\epsilon-1} P_s^{\epsilon} X_s(p_{ns} - \kappa - \tau_n) - p_{ns}^{-\epsilon} a_{ns}^{\epsilon-1} P_s^{\epsilon} X_s] = 0 \tag{B.12}$$

Rearranging the FOC's yields:

$$\frac{\partial \pi_n}{\partial p_{nn}} = -\epsilon[p_{nn}^{-\epsilon-1} a_{nn}^{\epsilon-1} P_n^{\epsilon} X_n (p_{nn} - \kappa) - p_{nn}^{-\epsilon} a_{nn}^{\epsilon-1} P_n^{\epsilon} X_n] = 0 \tag{B.13}$$

$$\frac{\partial \pi_n}{\partial p_{ns}} = -\epsilon[p_{ns}^{-\epsilon-1} a_{ns}^{\epsilon-1} P_s^{\epsilon} X_s (p_{ns} - \kappa - \tau_n) - p_{ns}^{-\epsilon} a_{ns}^{\epsilon-1} P_s^{\epsilon} X_s] = 0 \tag{B.14}$$

The FOC's yield:

$$p_{nn} = \frac{\epsilon \kappa}{\epsilon - 1} \tag{B.15}$$

$$p_{ns} = \frac{\epsilon(\kappa + \tau_n)}{\epsilon - 1} \tag{B.16}$$

A similar process can be used to show the optimal price levels set by a Southern firm.

$$p_{ss} = \frac{\epsilon c \kappa}{\epsilon - 1} \tag{B.17}$$

$$p_{sn} = \frac{\epsilon(c\kappa + \tau_s)}{\epsilon - 1} \tag{B.18}$$

B.3 Free Entry Conditions

Using equations (12) and (B.4), I find the equilibrium Northern expected profit:

$$
\begin{aligned}
E(\pi_n) &= \pi_n^o R^n \left(\frac{(1-c)}{\pi_n^o \zeta \overline{R}}\right)^{\frac{1}{2}} - c\overline{R} - (1-c)R^n \\
&= (\frac{1}{1-\zeta}) \left(\frac{[\pi_n^o]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} \left(\frac{(1-c)\pi_n^o}{\zeta\overline{R}}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta})\overline{R} \left(\frac{(1-c)\pi_n^o}{\zeta\overline{R}}\right)^{\frac{1}{2}} - c\overline{R} - (1-c)R^n \\
&= (\frac{1}{1-\zeta})\pi_n^o - (\frac{\zeta}{1-\zeta}) \left(\frac{(1-c)\pi_n^o\overline{R}}{\zeta}\right)^{\frac{1}{2}} - c\overline{R} - (\frac{1}{1-\zeta}) \left((1-c)\pi_n^o\zeta\overline{R}\right)^{\frac{1}{2}} + (\frac{\zeta(1-c)}{1-\zeta})\overline{R} \\
&= (\frac{1}{1-\zeta})\pi_n^o - (\frac{\zeta}{1-\zeta}) \left(\frac{(1-c)\pi_n^o\overline{R}}{\zeta}\right)^{\frac{1}{2}} - (\frac{1}{1-\zeta}) \left((1-c)\pi_n^o\zeta\overline{R}\right)^{\frac{1}{2}} + (\frac{\zeta-c}{1-\zeta})\overline{R}
\end{aligned}
$$

Taking this equation and setting it equal to zero yields the Northern free-entry condition:

$$
E(\pi_n) = \pi_n^* - 2\left((1-c)\zeta\pi_n^*\overline{R}\right)^{\frac{1}{2}} + (\zeta - c)\overline{R} = 0 \tag{B.19}
$$

Using equation (13), the Southern free entry condition can be found in a similar manner:

$$
\begin{aligned}
E(\pi_s) &= \pi_s^o\zeta(\overline{R} - R^n)(\frac{(1-c)}{\pi_n^o\zeta\overline{R}})^{\frac{1}{2}} - cf_s \\
&= \pi_s^o(\frac{\zeta(1-c)}{\pi_n^o\overline{R}})^{\frac{1}{2}} \left(\overline{R} - (\frac{1}{1-\zeta}) \left(\frac{\pi_n^o\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} + (\frac{\zeta}{1-\zeta})\overline{R}\right) - cf_s \\
&= \pi_s^o(\frac{\zeta(1-c)}{\pi_n^o\overline{R}})^{\frac{1}{2}} \left(\frac{\overline{R}}{1-\zeta} - (\frac{1}{1-\zeta}) \left(\frac{\pi_n^o\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}}\right) - cf_s \\
&= \pi_s^o(\frac{1}{1-\zeta}) \left(\left(\frac{\overline{R}\zeta(1-c)}{\pi_n^o}\right)^{\frac{1}{2}} - \zeta\right) - cf_s \\
&= \pi_s^o(\frac{\zeta(1-c)}{\pi_n^o\overline{R}})^{\frac{1}{2}} \left(\frac{\overline{R}}{1-\zeta} - (\frac{1}{1-\zeta}) \left(\frac{\pi_n^o\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}}\right) - cf_s \\
&= \pi_s^o(\frac{1}{1-\zeta}) \left(\frac{(\overline{R}\zeta(1-c))^{\frac{1}{2}} - \zeta(\pi_n^o)^{\frac{1}{2}}}{(\pi_n^o)^{\frac{1}{2}}}\right) - cf_s
\end{aligned}
$$

Taking this equation and setting it equal to zero yields the Northern free-entry condition:

$$
E(\pi_s) = \pi_s^*(\frac{1}{1-\zeta}) \left(\frac{(\overline{R}\zeta(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}}{(\pi_n^*)^{\frac{1}{2}}}\right) - cf_s = 0 \tag{B.20}
$$

Next, I find the optimal Northern operating profit level in terms of the model's parameters in order to fully solve for the interior condition (16). Letting $x = (\pi_n^*)^{\frac{1}{2}}$ and rearranging (B.19):

$$
x^2 - 2(\zeta(1-c)\overline{R})^{\frac{1}{2}}x - (c-\zeta)\overline{R} = 0
$$

Using the quadratic formula:

$$x = \frac{1}{2}\left[2(\zeta(1-c)\overline{R})^{\frac{1}{2}} \pm \sqrt{4\zeta(1-c)\overline{R} + 4(c-\zeta)\overline{R}}\right]$$
$$= (\zeta(1-c)\overline{R})^{\frac{1}{2}} \pm \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c) + (c-\zeta)}$$

There are two possible solutions for x. For x to be both positive and unique, I assume $c > \zeta$. Thats is, the following equation does not yield a possible solution:

$$x = (\zeta(1-c)\overline{R})^{\frac{1}{2}} - \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c) + (c-\zeta)} \tag{B.21}$$

Note that (B.21) yields a negative x:

$$x < 0$$
$$(\zeta(1-c)\overline{R})^{\frac{1}{2}} < \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c) + (c-\zeta)}$$
$$\zeta < c$$

Thus, the only solution for x is:

$$x = (\zeta(1-c)\overline{R})^{\frac{1}{2}} + \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c) + (c-\zeta)} \tag{B.22}$$

Therefore,

$$\pi_n^* = \overline{R}\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^2 \tag{B.23}$$

Condition (16) can then be rewritten as:

$$\zeta < (1-c)\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^{-2} < \frac{1}{\zeta} \tag{B.24}$$

The upper bound for (B.24) holds.

$$\begin{aligned}
(1-c)\zeta &< \left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^2 \\
(1-c)^{\frac{1}{2}}\zeta^{\frac{1}{2}} &< \zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}} \\
0 &< c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}
\end{aligned}$$

The lower bound holds only given current restrictions:

$$\begin{aligned}
\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^2 &< \left(\frac{1-c}{\zeta}\right) \\
\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}} &< \left(\frac{1-c}{\zeta}\right)^{\frac{1}{2}} \\
\zeta^{\frac{1}{2}}c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}} &< (1-\zeta)(1-c)^{\frac{1}{2}} \\
\zeta^{\frac{1}{2}}c^{\frac{1}{2}} &< (1-\zeta)^{\frac{1}{2}}(1-c)^{\frac{1}{2}} \\
\zeta c &< (1-\zeta)(1-c)
\end{aligned}$$

$$\implies \boxed{c + \zeta < 1} \tag{B.25}$$

B.4 Price Index and Number of Firms

Solving for the equilibrium price indexes uses the operating profit equations (23) and (24). Rearranging equation (23) yields:

$$P_n^{\epsilon-1}\beta L_n = \frac{\epsilon\pi_n^* - s_{ns}P_s^{\epsilon-1}\beta c L_s}{s_{nn}} \tag{B.26}$$

Filling (B.26) into the Southern operating profit in equilibrium:

$$\beta c L_s P_s^{\epsilon-1} = \left(s_{ss} - \frac{s_{sn}s_{ns}}{s_{nn}}\right)^{-1}\left[\epsilon\pi_s^* - \frac{s_{sn}\epsilon\pi_n^*}{s_{nn}}\right] \tag{B.27}$$

Since the $\left(s_{ss} - \frac{s_{sn}s_{ns}}{s_{nn}}\right) > 0$ by assumption, $P_s^{\epsilon-1}$ is positive iff:

$$\left[\epsilon\pi_s^* - \frac{s_{sn}\epsilon\pi_n^*}{s_{nn}}\right] > 0 \tag{B.28}$$

Likewise, $P_n^{\epsilon-1}$ is positive iff:

$$\beta c L_s P_s^{\epsilon-1} < \frac{\epsilon\pi_n^*}{s_{ns}} \tag{B.29}$$

Using equation (B.27), this condition can be rewritten as:

$$\pi_s^* < \frac{\pi_n^* s_{ss}}{s_{ns}} \tag{B.30}$$

This condition, taken with a rearranged condition (B.28) yields a sufficient and necessary condition for $P_n^{\epsilon-1}, P_s^{\epsilon-1} > 0$. The equilibrium number of firms will be positive from both nations given equations (27) and (28) are positive. Since $s_{nn}s_{ss} - s_{ns}s_{sn} > 0$ by assumption, $M_n > 0$ iff:

$$\frac{s_{ss}}{s_{sn}} > \left(\frac{P_n}{P_s}\right)^{\epsilon-1} \tag{B.31}$$

Likewise, $M_s > 0$ iff:

$$\frac{s_{nn}}{s_{ns}} > \left(\frac{P_s}{P_n}\right)^{\epsilon-1} \tag{B.32}$$

Taking these two conditions together yields:

$$\frac{s_{sn}}{s_{ss}} < \left(\frac{P_s}{P_n}\right)^{\epsilon-1} < \frac{s_{nn}}{s_{ns}} \tag{B.33}$$

Finally, note that

$$\left(\frac{P_s}{P_n}\right)^{\epsilon-1} = \frac{L_n s_{nn}}{cL_s}\left(\frac{\epsilon\pi_s^* s_{nn} - s_{sn}\epsilon\pi_n^*}{\epsilon\pi_n^* s_{ss}s_{nn} - \epsilon\pi_s^* s_{ns}s_{nn}}\right) \tag{B.34}$$

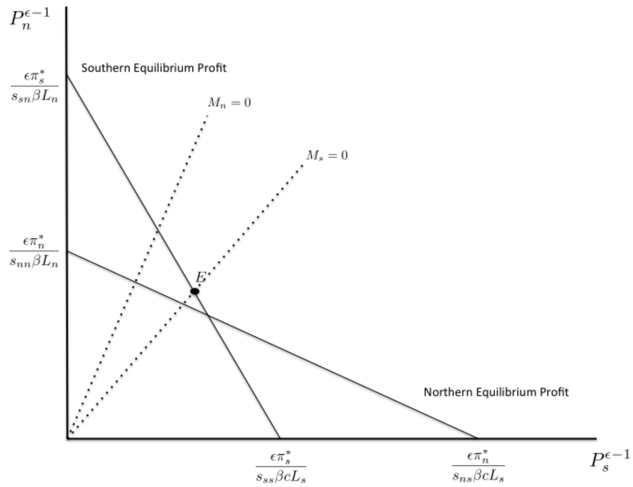

Figure 2: No Southern Firms

So, the plausibility of an equilibrium where firms exist in both countries then depends on the relative incomes of both regions.

B.5 Alternative Equilibria

Figure 2 shows the case where the free entry conditions intersect above the $M_s = 0$ line. The equilibrium point in this case is the point of intersection of the $M_s = 0$ line and the Northern free entry line. In this case, Southern firms never enter the market as Northern firms are able to capture a high enough share of both markets to make any entry by Southern firms yield operating profit that does not cover the fixed cost of entry. A small number of workers in the South and a large workforce in the North makes this case more likely to occur. Northern firms can then earn a high operating profit from the North, where the firms are able to capture more of market place based on preference for Northern goods. A high fixed cost of entry in the South coupled with a low $\overline{R}$ in the North also facilitate an equilibrium without Southern firms.

Figure 3 shows the case in which this intersection is above the $M_n = 0$ line. In this

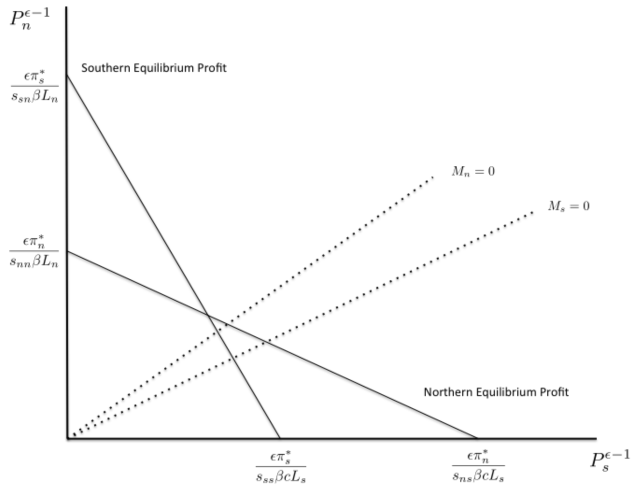

Figure 3: No Differentiated Goods

case, no Northern firms will exist in the market in equilibrium. Northern firms do not enter the market due to the expectation of a negative profit. Since these firms do not innovate any new products, the Southern firms do not have a change to imitate any of the products. Therefore, the differentiated goods sector will not exist. Low values of f_s and L_n and high values of $\overline{R}$ and L_s increase the likelihood of this case. Northern firms that have a high fixed cost of entry are not able to cover the fixed cost of entry from the small amount of Northern consumers and the large amount of Southern consumers who prefer the Southern product more. Furthermore, low fixed costs in the South mean many Southern firms are able to enter and thus capture a large amount of the Souther market. Thus, Northern firms are not able to cover the fixed costs and refuse to enter the market. In the following section, I assume both countries have active firms in equilibrium.

B.6 Robustness of Equilibrium

As a way of testing the robustness of the results, I relax one of the simplifying assumptions and show that the results of the comparative statics are unaffected. Instead of having

Northern firms exit the market when their product is imitated, I assume that the imitation leads to a drop in operating profit. I rewrite equation (B.1):

$$E(\pi_n) = \left(\frac{R^n}{R^n(1-\zeta)+\zeta\overline{R}}\right)[\pi_n^o] - \left(1 - \left(\frac{R^n}{R^n(1-\zeta)+\zeta\overline{R}}\right)\right)\gamma + R^n - c(\overline{R} - R^n) \tag{B.35}$$

So, there is a penalty associated with having a product imitated, and the Northern firm only earns a fraction of the operating profit when imitated. Imitation leads to competition between the Northern firm and it's imitator. The value of γ depends on the market structure and can vary with the amount of firms in the market; however, I assume that γ is fixed for simplicity. FOC using (B.35) yields:

$$R^n = (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o+\gamma]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta})\overline{R} \tag{B.36}$$

This number of Northern researchers then implies that the number of Southern researchers is equal to $\overline{R} - R^n$:

$$R^s = (\frac{1}{1-\zeta})\overline{R} - (\frac{1}{1-\zeta})\left(\frac{[\pi_n^o+\gamma]\zeta\overline{R}}{1-c}\right)^{\frac{1}{2}} \tag{B.37}$$

The probability of imitation is then:

$$\phi = (\frac{1}{1-\zeta})\left(\frac{\zeta\overline{R}(1-c)}{\pi_n^o+\gamma}\right)^{\frac{1}{2}} - (\frac{\zeta}{1-\zeta}) \tag{B.38}$$

The second stage choices are unaffected. The free-entry conditions can be now be found.

Note that (B.19) is now:

$$E(\pi_n) = \pi_n^* - 2\left((1-c)(\pi_n^* + \gamma)\zeta\overline{R}\right)^{\frac{1}{2}} + (\zeta - c)\overline{R} = 0 \tag{B.39}$$

The Southern free-entry condition can also be found:

$$E(\pi_s) = \pi_s^*(\frac{1}{1-\zeta})\left(\frac{(\overline{R}\zeta(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}}{(\pi_n^*)^{\frac{1}{2}}}\right) - cf_s = 0 \tag{B.40}$$

Letting $x = (\pi_n^* + \gamma)^{\frac{1}{2}}$ and rearranging (B.39):

$$x^2 - 2(\zeta(1-c)\overline{R})^{\frac{1}{2}}x - (c-\zeta)\overline{R} - \gamma = 0$$

Using the quadratic formula:

$$\begin{aligned} x &= \frac{1}{2}\left[2(\zeta(1-c)\overline{R})^{\frac{1}{2}} \pm \sqrt{4\zeta(1-c)\overline{R} + 4(c-\zeta)\overline{R} + 4\gamma}\right] \\ &= (\zeta(1-c)\overline{R})^{\frac{1}{2}} \pm \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c) + (c-\zeta) + 4\gamma} \end{aligned}$$

There are two possible solutions for x. For x to be both positive and unique, I assume $c > \zeta$. Thats is, the following equation does not yield a possible solution:

$$x = (\zeta(1-c)\overline{R})^{\frac{1}{2}} - \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c) + (c-\zeta) + 4\gamma} \tag{B.41}$$

Note that (B.41) yields a negative x:

$$x < 0$$

$$(\zeta(1-c)\overline{R})^{\frac{1}{2}} < \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c)+(c-\zeta)+4\gamma}$$

$$\zeta < c + 4\gamma$$

Thus, the only solution for x is:

$$x = (\zeta(1-c)\overline{R})^{\frac{1}{2}} + \overline{R}^{\frac{1}{2}}\sqrt{\zeta(1-c)+(c-\zeta)+4\gamma} \tag{B.42}$$

Therefore,

$$\pi_n^* = \overline{R}\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + (c(1-\zeta)+4\gamma)^{\frac{1}{2}}\right]^2 - \gamma \tag{B.43}$$

A recreation of the comparative statics in section C shows that the directional changes to both firm-level and industry-level offshoring are unaffected by the inclusion of γ. Therefore, the results of this paper are unchanged by relaxing one of the major assumptions of this model. Note that:

$$\frac{\partial \pi_n^*}{\partial \overline{R}} = \left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + (c(1-\zeta)+4\gamma)^{\frac{1}{2}}\right]^2 = \frac{\pi_n^* + \gamma}{\overline{R}} \tag{B.44}$$

$$\frac{\partial \pi_n^*}{\partial \zeta} = 2\overline{R}\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]\left[\frac{1}{2}(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}} - \frac{1}{2} - c(c(1-\zeta)+4\gamma)^{\frac{1}{2}}\right] \tag{B.45}$$

$$\frac{\partial \pi_n^*}{\partial L_s} = 0 \tag{B.46}$$

$$\frac{\partial \pi_n^*}{\partial t} = 0 \tag{B.47}$$

$$\frac{\partial R^s}{\partial \zeta} = (\frac{1}{1-\zeta})^2\left[\overline{R} - \left(\frac{\overline{R}(\pi_n^*+\gamma)\zeta}{(1-c)}\right)^{\frac{1}{2}}\right] - (\frac{1}{1-\zeta})(\frac{1}{2})\left[\frac{\partial \pi_n^*}{\partial \zeta}\left(\frac{\overline{R}\zeta}{(1-c)(\pi_n^*+\gamma)}\right)^{\frac{1}{2}} + \left(\frac{\overline{R}(\pi_n^*+\gamma)}{\zeta(1-c)}\right)^{\frac{1}{2}}\right] \tag{B.48}$$

$$\frac{\partial R^s}{\partial L_s} = -\left[\frac{1}{1-\zeta}\right]\left(\frac{1}{2}\right)\left[\frac{\zeta(\pi_n^*+\gamma)\overline{R}}{(1-c))(\pi_n^*)}\right]^{\frac{1}{2}}\frac{\partial \pi_n^*}{\partial L_s} = 0 \tag{B.49}$$

$$\frac{\partial R^s}{\partial t} = -\left[\frac{1}{1-\zeta}\right]\left(\frac{1}{2}\right)\left[\frac{\zeta(\pi_n^*+\gamma)\overline{R}}{(1-c)(\pi_n^*)}\right]^{\frac{1}{2}}\frac{\partial \pi_n^*}{\partial t} = 0 \tag{B.50}$$

Comparison with the values determined in section C shows that the inclusion of γ has not change the signs of equations (C.1), (C.8), (C.19), (C.25), (C.29). So, γ does not change the reaction of firm-level offshoring to exogenous parameter shifts. The reaction of industry-level offshoring depends on the number of Northern firms as well as the firm-level reaction. Since the second stage decisions are unaffected, the comparative statics for industry-level offshoring regarding market size is unaffected. The change in IPR-protection's effect on industry-level offshoring for high-tech industries is trivial to calculate. The firm-level effect also does not change. Using (B.44) and taking the derivative of (B.48) wrt to

$$\frac{\partial^2 R^s}{\partial\zeta\partial\overline{R}} = (\frac{1}{1-\zeta})^{\frac{1}{2}} - (\frac{1}{1-\zeta})(\frac{1}{2})\left[\frac{\partial^2\pi_n^*}{\partial\zeta\partial\overline{R}}\left(\frac{\overline{R}\zeta}{(1-c)(\pi_n^*+\gamma)}\right)^{\frac{1}{2}} + \frac{1}{2}\left(\frac{\zeta}{\overline{R}(1-c)(\pi_n^*+\gamma)}\right)^{\frac{1}{2}}\right] \tag{B.51}$$

Using similar steps from subsection C.1, equation (B.51) can be shown to be negative.

C Comparative Statics

Before proving Propositions 1, 2, and 3, it is useful to explore how the Northern operating profit changes as $\overline{R}$ increases. Differentiating equation (22) wrt $\overline{R}$ yields the change in Northern operating profit as total necessary research changes:

$$\frac{\partial\pi_n^*}{\partial\overline{R}} = \left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^2 \tag{C.1}$$

Also, note that equation (C.1) can be simplified to:

$$\frac{\partial\pi_n^*}{\partial\overline{R}} = \frac{\pi_n^*}{\overline{R}} \tag{C.2}$$

I also look at Southern operating profit as it changes with $\overline{R}$. Partially differentiating free-entry condition (21) wrt $\overline{R}$:

$$\frac{\partial \pi_s^*}{\partial \overline{R}} = \frac{1}{2}\frac{\pi_s^*}{\pi_n^*}\frac{\partial \pi_n^*}{\partial \overline{R}} - \pi_s^*[(\zeta\overline{R}(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}]^{-1}[\frac{1}{2}(\frac{\zeta(1-c)}{\overline{R}})^{\frac{1}{2}} - \frac{1}{2}\zeta(\pi_n^*)^{\frac{-1}{2}}\frac{\partial \pi_n^*}{\partial \overline{R}}] \quad \text{(C.3)}$$

Note that $\frac{\partial \pi_s^*}{\partial \overline{R}} = 0$. To prove this, I assume the case:

$$\begin{aligned}
\frac{\partial \pi_s^*}{\partial \overline{R}} &= 0 \\
0 &= \frac{1}{2}\frac{\pi_s^*}{\pi_n^*}\frac{\partial \pi_n^*}{\partial \overline{R}} - \pi_s^*[(\zeta\overline{R}(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}]^{-1}[\frac{1}{2}(\frac{\zeta(1-c)}{\overline{R}})^{\frac{1}{2}} - \frac{1}{2}\zeta(\pi_n^*)^{\frac{-1}{2}}\frac{\partial \pi_n^*}{\partial \overline{R}}] \\
\frac{1}{2}\frac{\pi_s^*}{\pi_n^*}\frac{\partial \pi_n^*}{\partial \overline{R}} &= \pi_s^*[(\zeta\overline{R}(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}]^{-1}[\frac{1}{2}(\frac{\zeta(1-c)}{\overline{R}})^{\frac{1}{2}} - \frac{1}{2}\zeta(\pi_n^*)^{\frac{-1}{2}}\frac{\partial \pi_n^*}{\partial \overline{R}}]
\end{aligned}$$

Using equation (C.2):

$$\begin{aligned}
\frac{1}{2}\frac{\pi_s^*}{\overline{R}} &= \pi_s^*[(\zeta\overline{R}(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}]^{-1}[\frac{1}{2}(\frac{\zeta(1-c)}{\overline{R}})^{\frac{1}{2}} - \frac{1}{2}\zeta(\pi_n^*)^{\frac{1}{2}}(\frac{1}{\overline{R}})] \\
\frac{1}{2}\frac{1}{\overline{R}}[(\zeta\overline{R}(1-c))^{\frac{1}{2}} - \zeta(\pi_n^*)^{\frac{1}{2}}] &= [\frac{1}{2}(\frac{\zeta(1-c)}{\overline{R}})^{\frac{1}{2}} - \frac{1}{2}\zeta(\pi_n^*)^{\frac{1}{2}}(\frac{1}{\overline{R}})] \\
\frac{1}{2}\frac{(\zeta(1-c))^{\frac{1}{2}}}{\overline{R}} - \frac{1}{2}\frac{\zeta}{\overline{R}}(\pi_n^*)^{\frac{1}{2}}] &= [\frac{1}{2}(\frac{\zeta(1-c)}{\overline{R}})^{\frac{1}{2}} - \frac{1}{2}\frac{\zeta}{\overline{R}}(\pi_n^*)^{\frac{1}{2}}] \\
0 &= 0
\end{aligned}$$

Therefore, $\frac{\partial \pi_s^*}{\partial \overline{R}} = 0$. It also proves beneficial to systematically determine how the equilibrium number of firms changes with the price indexes. In order to examine the effect on the number of firms, I partially differentiate equations (27) and (28) wrt P_n and P_s.

$$\frac{\partial M_n}{\partial P_n} = \left[\frac{-(\epsilon-1)s_{ss}P_n^{-\epsilon}}{s_{nn}s_{ss}-s_{sn}s_{ns}}\right] < 0 \tag{C.4}$$
$$\frac{\partial M_n}{\partial P_s} = \left[\frac{(\epsilon-1)s_{sn}P_s^{-\epsilon}}{s_{nn}s_{ss}-s_{sn}s_{ns}}\right] > 0 \tag{C.5}$$
$$\frac{\partial M_s}{\partial P_n} = \left[\frac{(\epsilon-1)s_{ns}P_n^{-\epsilon}}{s_{nn}s_{ss}-s_{sn}s_{ns}}\right] > 0 \tag{C.6}$$
$$\frac{\partial M_s}{\partial P_s} = \left[\frac{-(\epsilon-1)s_{nn}P_s^{-\epsilon}}{s_{nn}s_{ss}-s_{sn}s_{ns}}\right] < 0 \tag{C.7}$$

C.1 Proof of Proposition 1

Partially differentiating equation (22) wrt ζ yields the change in Northern operating profit as IPR-protection laws change:

$$\frac{\partial \pi_n^*}{\partial \zeta} = 2\overline{R}\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]\left[\frac{1}{2}(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}} - \frac{1}{2}(1-\zeta)^{\frac{-1}{2}}c^{\frac{1}{2}}\right] \tag{C.8}$$

Note that $\frac{\partial \pi_n^*}{\partial \zeta} > 0$:

$$\begin{aligned}
\frac{\partial \pi_n^*}{\partial \zeta} &> 0 \\
\frac{1}{2}(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}} &> \frac{1}{2}(1-\zeta)^{\frac{-1}{2}}c^{\frac{1}{2}} \\
(1-c)^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}} &> c^{\frac{1}{2}}\zeta^{\frac{1}{2}} \\
(1-c)(1-\zeta) &> c\zeta \\
1-\zeta-c+\zeta c &> c\zeta \\
1 &> \zeta + c
\end{aligned}$$

By assumption 3, $\frac{\partial \pi_n^*}{\partial \zeta} > 0$. Now to determine the change in Southern operating profit, I differentiate the probability of imitation (B.6) wrt ζ:

$$\frac{\partial \phi}{\partial \zeta} = \frac{1}{1-\zeta}\phi - \frac{1}{1-\zeta} + \frac{1}{2}\frac{1}{1-\zeta}\left(\frac{\zeta \overline{R}(1-c)}{\pi_n^*}\right)^{\frac{1}{2}}\left[\zeta^{-1} - (\pi_n^*)^{-1}\frac{\partial \pi_n^*}{\partial \zeta}\right] \tag{C.9}$$

Note that $\frac{\partial \phi}{\partial \zeta} > 0$ iff:

$$\phi - 1 > -\frac{1}{2}(1-\zeta)\left(\frac{\zeta \overline{R}(1-c)}{\pi_n^*}\right)^{\frac{1}{2}}\left[\zeta^{-1} - (\pi_n^*)^{-1}\frac{\partial \pi_n^*}{\partial \zeta}\right]$$

$$\left(\frac{\zeta \overline{R}(1-c)}{\pi_n^*}\right)^{\frac{1}{2}} - \zeta > (1-\zeta) - \frac{1}{2}(1-\zeta)\left(\frac{\zeta \overline{R}(1-c)}{\pi_n^*}\right)^{\frac{1}{2}}\left[\zeta^{-1} - (\pi_n^*)^{-1}\frac{\partial \pi_n^*}{\partial \zeta}\right]$$

$$(1-\zeta)\left[\zeta^{-1} - (\pi_n^*)^{-1}\frac{\partial \pi_n^*}{\partial \zeta}\right] > 2\left(\frac{\zeta \overline{R}(1-c)}{\pi_n^*}\right)^{\frac{-1}{2}} - 2 \tag{C.10}$$

Note that $(\pi_n^*)^{-1}\frac{\partial \pi_n^*}{\partial \zeta} = \left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^{-1}\left[(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}} - (1-\zeta)^{\frac{-1}{2}}c^{\frac{1}{2}}\right]$. Also,

$$\frac{\zeta \overline{R}(1-c)}{\pi_n^*} = \zeta(1-c)\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^2$$

Therefore, ϕ and $\frac{\partial \phi}{\partial \zeta}$ are independent of $\overline{R}$. Therefore, $\frac{\partial^2 \pi_s^*}{\partial \zeta \partial \overline{R}} = 0$. This can also be verified by partially differentiating (C.3) wrt $\overline{R}$. Now, inequality (C.10) can be rewritten:

$$(1-\zeta)\left[\zeta^{-1} - \left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^{-1}\left[(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}} - (1-\zeta)^{\frac{-1}{2}}c^{\frac{1}{2}}\right]\right]\left[(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}} - c^{\frac{1}{2}}(1-\zeta)^{\frac{-1}{2}}\right]$$
$$> 2\zeta^{\frac{-1}{2}}(1-c)^{\frac{-1}{2}}[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}]^{-1} - 2$$

$$2+\frac{1-\zeta}{\zeta} > \left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}}+c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right]^{-1}\left[(1-\zeta)(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}}-(1-\zeta)^{\frac{1}{2}}c^{\frac{1}{2}}+2\zeta^{\frac{-1}{2}}(1-c)^{\frac{-1}{2}}\right]$$

$$\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}}+c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right](\frac{1+\zeta}{\zeta}) > (1-\zeta)(1-c)^{\frac{1}{2}}\zeta^{\frac{-1}{2}}-(1-\zeta)^{\frac{1}{2}}c^{\frac{1}{2}}+2\zeta^{\frac{-1}{2}}(1-c)^{\frac{-1}{2}}$$

$$(1+\zeta)\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}}+(1+\zeta)c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}} > (1-\zeta)(1-c)^{\frac{1}{2}}\zeta^{\frac{1}{2}}-\zeta(1-\zeta)^{\frac{1}{2}}c^{\frac{1}{2}}+2\zeta^{\frac{1}{2}}(1-c)^{\frac{-1}{2}}$$

$$(1+\zeta-1+\zeta)\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}}+c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}[1+2\zeta] > 2\zeta^{\frac{1}{2}}(1-c)^{\frac{-1}{2}}$$

$$2\zeta\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}}+c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}[1+2\zeta] > 2\zeta^{\frac{1}{2}}(1-c)^{\frac{-1}{2}}$$

$$2\zeta[\zeta(1-c)^{\frac{1}{2}}-(1-c)^{\frac{-1}{2}}]+c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}(1+2\zeta) > 0$$

$$\implies c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}(1+2\zeta) > 2\zeta^{\frac{1}{2}}[(1-c)^{\frac{-1}{2}}-\zeta(1-c)^{\frac{1}{2}}] \tag{C.11}$$

Condition (C.11) is the necessary and sufficient condition for $\frac{\partial \pi_s^*}{\partial \zeta} < 0$. The change in price indexes is ambiguous as well. Totally differentiating equations (23) and (24) to examine the change of ζ:

$$\begin{bmatrix}(\epsilon-1)s_{nn}P_n^{\epsilon-2}\beta L_n & (\epsilon-1)s_{ns}P_s^{\epsilon-2}\beta c L_s \\ (\epsilon-1)s_{sn}P_n^{\epsilon-2}\beta L_n & (\epsilon-1)s_{ss}P_s^{\epsilon-2}\beta c L_s\end{bmatrix}\begin{bmatrix}\partial P_n \\ \partial P_s\end{bmatrix} = \begin{bmatrix}\epsilon\frac{\partial \pi_n^*}{\partial \zeta} \\ \epsilon\frac{\partial \pi_s^*}{\partial \zeta}\end{bmatrix}\partial\zeta$$

Let the determinant of the left hand side be $|D|$. Note that $|D| > 0$:

$$(\epsilon-1)s_{nn}P_n^{\epsilon-2}\beta L_n*(\epsilon-1)s_{ss}P_s^{\epsilon-2}\beta c L_s-(\epsilon-1)s_{ns}P_s^{\epsilon-2}\beta c L_s*(\epsilon-1)s_{sn}P_n^{\epsilon-2}\beta L_n > 0$$

$$s_{nn}P_n^{\epsilon-2}\beta L_n*s_{ss}P_s^{\epsilon-2}\beta c L_s > s_{ns}P_s^{\epsilon-2}\beta c L_s*s_{sn}P_n^{\epsilon-2}\beta L_n$$

$$s_{nn}s_{ss} > s_{sn}s_{ns} \tag{C.12}$$

Inequality (C.12) holds by assumption 1. Using Cramer's rule, the change in P_n and

P_s due to increases in ζ can be found:

$$\frac{\partial P_n}{\partial \zeta} = \left[\frac{\epsilon(\epsilon-1)\frac{\partial \pi_n^*}{\partial \zeta} s_{ss} P_s^{\epsilon-2}\beta c L_s - \epsilon(\epsilon-1)\frac{\partial \pi_s^*}{\partial \zeta} s_{ns} P_s^{\epsilon-2}\beta c L_s}{|D|}\right] \tag{C.13}$$

$$\frac{\partial P_s}{\partial \zeta} = \left[\frac{\epsilon(\epsilon-1)\frac{\partial \pi_s^*}{\partial \zeta} s_{nn} P_n^{\epsilon-2}\beta L_n - \frac{\partial \pi_n^*}{\partial \zeta}\epsilon(\epsilon-1) s_{sn} P_n^{\epsilon-2}\beta L_n}{|D|}\right] \tag{C.14}$$

The directional change of the price indexes then depends on the relative market shares and the degree of change in the operating profit. $\frac{\partial P_n}{\partial \zeta} > 0$ iff:

$$\frac{\partial \pi_n^*}{\partial \zeta}\frac{s_{ss}}{s_{ns}} > \frac{\partial \pi_s^*}{\partial \zeta} \tag{C.15}$$

Likewise, $\frac{\partial P_s}{\partial \zeta} < 0$ iff:

$$\frac{\partial \pi_n^*}{\partial \zeta} > \frac{\partial \pi_s^*}{\partial \zeta}\frac{s_{nn}}{s_{sn}} \tag{C.16}$$

Since $\overline{R}$ only affects $\frac{\partial \pi_n^*}{\partial \zeta}$ and not $\frac{\partial \pi_s^*}{\partial \zeta}$, a large $\overline{R}$ increase the likelihood of (C.15) and (C.16) holding. Likewise, a large $\frac{s_{ss}}{s_{ns}}$ and small $\frac{s_{nn}}{s_{sn}}$ increase the likelihood of the above conditions holding.

From equations (C.4), (C.5), (C.6), and (C.7), an increasing Northern price index coupled with a decreasing Southern price index implies $\frac{\partial M_n}{\partial \zeta} < 0$ and $\frac{\partial M_s}{\partial \zeta} > 0$. The change in the number of firms can be written as:

$$\frac{\partial M_n}{\partial \zeta} = \frac{\partial M_n}{\partial P_n}\frac{\partial P_n}{\partial \zeta} + \frac{\partial M_n}{\partial P_s}\frac{\partial P_s}{\partial \zeta} \tag{C.17}$$

$$\frac{\partial M_s}{\partial \zeta} = \frac{\partial M_s}{\partial P_n}\frac{\partial P_n}{\partial \zeta} + \frac{\partial M_n}{\partial P_s}\frac{\partial P_s}{\partial \zeta} \tag{C.18}$$

Figure 4 shows the result of a decrease in ζ. The equilibrium point shifts down causing a decrease in the Northern price index while the Southern price index increases. More

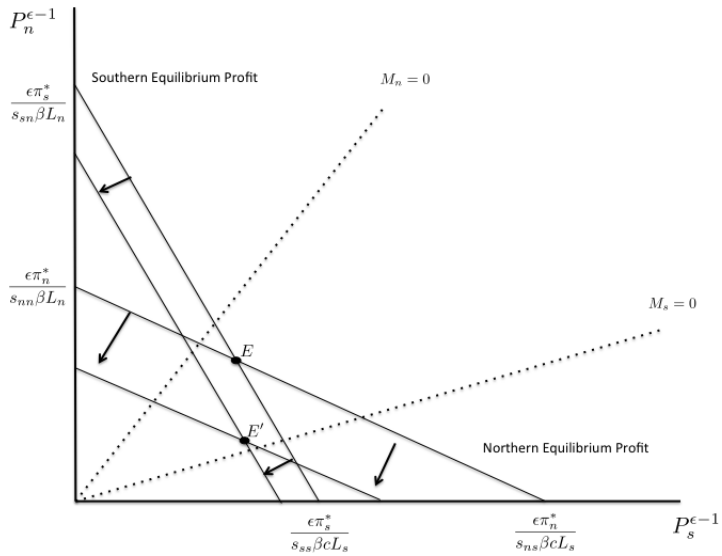

Figure 4: A Strengthening of IPR-Protection with a Large $\overline{R}$

Northern firms enter the market, and Southern firms are forced to exit.

Now that the change in Northern firms as IPR-protection has been found, I use the firm-level decision on R&D to determine the direction of offshoring as IPR-protection changes. As IPR-protection changes, the research allocations change as well. The research employment changes in one region must equal the opposite of the change in the other region. That is, $\frac{\partial R^s}{\partial \zeta} = -\frac{\partial R^n}{\partial \zeta}$. I only examine the change in Southern research as a result. From (B.5), differentiating R^s wrt ζ:

$$\frac{\partial R^s}{\partial \zeta} = (\frac{1}{1-\zeta})^2 \left[\overline{R} - \left(\frac{\overline{R}\pi_n^*\zeta}{(1-c)}\right)^{\frac{1}{2}}\right] - (\frac{1}{1-\zeta})(\frac{1}{2}) \left[\frac{\partial \pi_n^*}{\partial \zeta}\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}} + \left(\frac{\overline{R}\pi_n^*}{\zeta(1-c)}\right)^{\frac{1}{2}}\right] \tag{C.19}$$

So, $\frac{\partial R^s}{\partial \zeta} > 0$ iff:

$$
\begin{aligned}
2R^s &> \frac{\partial \pi_n^*}{\partial \zeta}\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}} + \left(\frac{\overline{R}\pi_n^*}{\zeta(1-c)}\right)^{\frac{1}{2}} \\
2\overline{R} &> \left(\frac{\overline{R}\pi_n^*}{(1-c)}\right)^{\frac{1}{2}}\left[\zeta^{\frac{1}{2}} + \zeta^{\frac{-1}{2}}\right] + \frac{\partial \pi_n^*}{\partial \zeta}\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}} \\
2(\overline{R}\pi_n^*(1-c))^{\frac{1}{2}} &> \pi_n^*\left[\zeta^{\frac{1}{2}} + \zeta^{\frac{-1}{2}}\right] + \frac{\partial \pi_n^*}{\partial \zeta}\zeta^{\frac{1}{2}} \\
\pi_n^* - \overline{R}(c-\zeta) &> \pi_n^*(1+\zeta) + \zeta\frac{\partial \pi_n^*}{\partial \zeta}
\end{aligned}
$$

$$
\boxed{-\left(\frac{c-\zeta}{\zeta}\right)\overline{R} > \pi_n^* + \frac{\partial \pi_n^*}{\partial \zeta}} \tag{C.20}
$$

From previous assumptions, the LHS is negative while the RHS is positive. So, (C.20) will never hold. Therefore, $\frac{\partial R^s}{\partial \zeta} < 0$ and $\frac{\partial R^n}{\partial \zeta} > 0$. Finally, when IPR-protection strengthens, firms with larger research costs increase their Southern research tasks more than firms with smaller research needs. That is, $\frac{\partial^2 R^s}{\partial \zeta \partial \overline{R}} < 0$. Differentiating (C.19) wrt $\overline{R}$ yields:

$$
\begin{aligned}
\frac{\partial^2 R^s}{\partial \zeta \partial \overline{R}} = (\frac{1}{1-\zeta})^2\left[\overline{R} - \left(\frac{\overline{R}\pi_n^*\zeta}{(1-c)}\right)^{\frac{1}{2}}\right]\overline{R}^{-1} - \frac{1}{2}(\frac{1}{1-\zeta})^2\left[\left(\frac{\overline{R}\pi_n^*\zeta}{(1-c)}\right)^{\frac{1}{2}}\right]\frac{\partial \pi}{\partial \overline{R}} \\
- (\frac{1}{1-\zeta})(\frac{1}{2})\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}}\left[\overline{R}^{-1} - (\pi_n^*)^{-1}\frac{\partial \pi_n^*}{\partial \overline{R}}\right] \\
- (\frac{1}{1-\zeta})(\frac{1}{2})\left[\frac{1}{2}\left(\frac{\overline{R}\pi_n^*}{\zeta(1-c)}\right)^{\frac{1}{2}}\left(\overline{R}^{-1} + (\pi_n^*)^{-1}\frac{\partial \pi_n^*}{\partial \overline{R}}\right) + \left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}}\frac{\partial^2 \pi_n^*}{\partial \overline{R}\partial \zeta}\right]
\end{aligned}
$$

Since $\frac{\pi_n^*}{\overline{R}} = \frac{\partial \pi_n^*}{\partial \overline{R}}$ by (C.2), $\frac{\partial^2 R^s}{\partial \zeta \partial \overline{R}}$ can be simplified as:

$$\frac{\partial^2 R^s}{\partial\zeta\partial\overline{R}} = (\frac{1}{1-\zeta})^2 \left[\overline{R} - \left(\frac{\overline{R}\pi_n^*\zeta}{(1-c)}\right)^{\frac{1}{2}}\right]\overline{R}^{-1} - \frac{1}{2}(\frac{1}{1-\zeta})^2 \left[\left(\frac{\overline{R}\pi_n^*\zeta}{(1-c)}\right)^{\frac{1}{2}}\right]\frac{\partial\pi_n^*}{\partial\overline{R}}$$
$$-(\frac{1}{1-\zeta})(\frac{1}{2})\left[\frac{1}{2}\left(\frac{\overline{R}\pi_n^*}{\zeta(1-c)}\right)^{\frac{1}{2}}\left(\overline{R}^{-1} + (\pi_n^*)^{-1}\frac{\partial\pi_n^*}{\partial\overline{R}}\right) + \left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}}\frac{\partial^2\pi_n^*}{\partial\overline{R}\partial\zeta}\right]$$

So, $\frac{\partial^2 R^s}{\partial\zeta\partial\overline{R}} < 0$ iff

$$2(\frac{1}{1-\zeta})\left[\overline{R} - \left(\frac{\overline{R}\pi_n^*\zeta}{(1-c)}\right)^{\frac{1}{2}}\right]\overline{R}^{-1} < (\frac{1}{1-\zeta})\frac{\partial\pi}{\partial\overline{R}}\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}} + \frac{\partial^2\pi_n^*}{\partial\overline{R}\partial\zeta}\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}}$$
$$+\frac{1}{2}\left(\frac{\overline{R}\pi_n^*}{\zeta(1-c)}\right)^{\frac{1}{2}}\left(\overline{R}^{-1} + (\pi_n^*)^{-1}\frac{\partial\pi_n^*}{\partial\overline{R}}\right)$$

Again, using (C.2) and simplifying:

$$2(\frac{1}{1-\zeta}) - (\frac{1}{1-\zeta})\left(\frac{\pi_n^*\zeta}{\overline{\overline{R}}(1-c)}\right)^{\frac{1}{2}} < \left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}}\left[\frac{1}{1-\zeta}\frac{\partial\pi_n^*}{\partial\overline{R}} + \frac{\partial^2\pi_n^*}{\partial\overline{R}\partial\zeta}\right] + \frac{\partial\pi}{\partial\overline{R}}\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}}$$
$$2(\frac{1}{1-\zeta}) < 2(\frac{1}{1-\zeta})\left(\frac{\pi_n^*\zeta}{\overline{\overline{R}}(1-c)}\right)^{\frac{1}{2}} + \left(\frac{\pi_n^*}{\zeta\overline{R}(1-c)}\right)^{\frac{1}{2}} + \frac{\partial^2\pi_n^*}{\partial\overline{R}\partial\zeta}\left(\frac{\overline{R}\zeta}{\pi_n^*(1-c)}\right)^{\frac{1}{2}}$$

Now, the inequality above can be determined to hold if the following holds:

$$2(\frac{1}{1-\zeta}) < 2(\frac{1}{1-\zeta})\left(\frac{\pi_n^*\zeta}{\overline{R}(1-c)}\right)^{\frac{1}{2}} + \left(\frac{\pi_n^*}{\zeta\overline{R}(1-c)}\right)^{\frac{1}{2}} \qquad \text{(C.21)}$$

Inequality (C.21) holds. To prove this, I use Northern operating profit equation (22):

$$
\begin{aligned}
1 &< \left(\frac{\pi_n^* \zeta}{\overline{R}(1-c)}\right)^{\frac{1}{2}} + \frac{1}{2}(1-\zeta)\left(\frac{\pi_n^*}{\zeta\overline{R}(1-c)}\right)^{\frac{1}{2}} \\
1 &< (\frac{\zeta}{1-c})^{\frac{1}{2}}\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right] + \frac{1}{2}(1-\zeta)\zeta^{\frac{-1}{2}}(1-c)^{\frac{-1}{2}}\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right] \\
1 &< \left(\frac{1}{2}\zeta^{\frac{1}{2}}(1-c)^{\frac{-1}{2}} + \frac{1}{2}\zeta^{\frac{-1}{2}}(1-c)^{\frac{-1}{2}}\right)\left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right] \\
2 &< \left[\zeta^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\right](1-c)^{\frac{-1}{2}}(\zeta^{\frac{1}{2}} + \zeta^{\frac{-1}{2}}) \\
2(1-c)^{\frac{1}{2}} &< \zeta(1-c)^{\frac{1}{2}} + \zeta^{\frac{1}{2}}c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}} + (1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\zeta)^{\frac{1}{2}}\zeta^{\frac{-1}{2}} \\
(1-c)^{\frac{1}{2}}(1-\zeta) &< (1-\zeta)^{\frac{-1}{2}}(\zeta^{\frac{1}{2}}c^{\frac{1}{2}} + c^{\frac{1}{2}}\zeta^{\frac{-1}{2}} \\
(1-\zeta)(1-c) &< c(\zeta + 2 + \zeta^{-1}) \\
1 &< \zeta + c + 2c + c\zeta^{-1}
\end{aligned}
$$

$$
\implies \qquad 1 < c(3 + \zeta^{-1}) + \zeta \tag{C.22}
$$

Given $\zeta < c$ by assumption 2, clearly inequality (C.22) holds:

$$
1 < \zeta(3 + \zeta^{-1}) + \zeta < c(3 + \zeta^{-1}) + \zeta
$$

Therefore, $\frac{\partial^2 R^s}{\partial\zeta\partial\overline{R}} < 0$. In other words, firms with large $\overline{R}$ increase R^s more when IPR-protection strengthens.

In order to examine the industry-level response, note that industries with larger $\overline{R}$ values per firm see more firms enter the market as a result of Southern IPR-protection strengthening. This can be seen by the previous argument concerning inequalities (C.15) and (C.16). A larger $\overline{R}$ strengthens both of those conditions and thus increases the reactiveness of the number of Northern firms to IPR changes. Therefore, as IPR-protection strengthens, both firm-level offshoring and the number of Northern firms increases more for firms and industries with large $\overline{R}$ values. Industry-level offshoring then must increase faster for high-tech industries than low-tech industries as IPR-protection strengthens.

C.2 Proof of Proposition 2

From equations (20) and (21), a change in L_s has no effect on π_n^* and π_s^*. Totally differentiating equations (23) and (24) to examine an exogenous change in Southern size:

$$\begin{bmatrix} (\epsilon-1)s_{nn}P_n^{\epsilon-2}\beta L_n & (\epsilon-1)s_{ns}P_s^{\epsilon-2}\beta c L_s \\ (\epsilon-1)s_{sn}P_n^{\epsilon-2}\beta L_n & (\epsilon-1)s_{ss}P_s^{\epsilon-2}\beta c L_s \end{bmatrix} \begin{bmatrix} \partial P_n \\ \partial P_s \end{bmatrix} = \begin{bmatrix} -\, s_{ns}P_s^{\epsilon-1}\beta c \\ -s_{ss}P_s^{\epsilon-1}\beta c \end{bmatrix} \partial L_s$$

Using Cramer's rule, the change in P_n and P_s due to increases in L_s can be found:

$$\frac{\partial P_n}{\partial L_s} = \left[\frac{-s_{ns}P_s^{\epsilon-1}\beta^2(\epsilon-1)s_{ss}P_s^{\epsilon-2}c^2L_s + s_{ss}P_s^{\epsilon-1}\beta^2c^2(\epsilon-1)s_{ns}P_s^{\epsilon-2}L_s}{|D|}\right] = 0 \quad \text{(C.23)}$$

$$\frac{\partial P_s}{\partial L_s} = \left[\frac{-(\epsilon-1)s_{nn}P_n^{\epsilon-2}\beta^2L_n c s_{ss}P_s^{\epsilon-1} + s_{ns}P_s^{\epsilon-1}\beta c(\epsilon-1)s_{sn}P_n^{\epsilon-2}\beta L_n}{|D|}\right] < 0 \quad \text{(C.24)}$$

From equation (C.23), the change in size in the South has no effect on the price index in the North. The price index in the South decreases. Using equations (C4), (C.5), (C.6), and (C.7), the effects on the number of firms can be seen. M_n decreases while M_s increases when the Southern market grows in size. The results can be summarized as:

$$\frac{\partial \pi_n^*}{\partial L_s} = 0 \qquad \frac{\partial \pi_s^*}{\partial L_s} = 0$$

$$\frac{\partial P_n}{\partial L_s} = 0 \qquad \frac{\partial P_s}{\partial L_s} < 0$$

$$\frac{\partial M_n}{\partial L_s} < 0 \qquad \frac{\partial M_s}{\partial L_s} > 0$$

I now a show that research location decisions do not depend on market size. From (B.5), differentiating R^s wrt L_s:

$$\frac{\partial R^s}{\partial L_s} = -\left[\frac{1}{1-\zeta}\right]\left(\frac{1}{2}\right)\left[\frac{\zeta \overline{R}}{(1-c)\pi_n^*}\right]^{\frac{1}{2}} \frac{\partial \pi_n^*}{\partial L_s} = 0 \tag{C.25}$$

Since $\frac{\partial \pi_n^*}{\partial L_s} = 0$, $\frac{\partial R^s}{\partial L_s}$ equals zero. Therefore, $\frac{\partial R^n}{\partial L_s} = 0$ as well. Industry-level offshoring decreases as L_s increases. Firm-level offshoring does not change; however, less Northern firms exist in the market to offshore research.

Figure 5 graphically shows this case. An increase in Southern income does not affect the research intensities of each Northern firm; however, the increase in the Southern market affects the number of Northern firms in equilibrium. The x-intercept of each equilibrium operating profit line shifts down. The Southern price index must decrease as additional Southern firms enter the market.

C.3 Proof of Proposition 3

For this proof, I compare the the levels of P_n, P_s, M_n, and M_s when $t = 0$ and when $t > 0$. First, the inclusion of a tariff changes consumer demands in the South as the tariff adds to Southern consumer income. Thus, Southern consumer income becomes $cL_s + M_n x_{ns}^* t$.

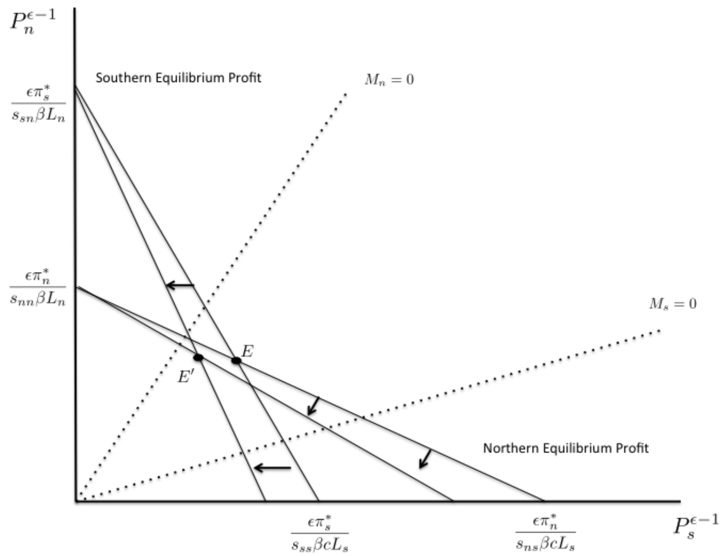

Figure 5: An Increase in the Southern Labor Force

Consumer demands (A.17) and (A.18) can be rewritten:

$$x_{ns} = p_{ns}^{-\epsilon} a_{ns}^{\epsilon-1} \beta (cL_s + M_n x_{ns}^* t) \tag{C.26}$$

$$x_{ss} = p_{ss}^{-\epsilon} a_{ss}^{\epsilon-1} \beta c L_s + M_n x_{ns}^* t \tag{C.27}$$

The price set by the Northern firm in the Southern market increases to include the cost of the tariff.

$$p_{ns} = \frac{\epsilon(\kappa + \tau_n + t)}{\epsilon - 1} \tag{C.28}$$

Inspection of the two free-entry conditions (20) and (21), show that the inclusion of a tariff does not change the π_n^* and π_s^*. Notice that a positive import tariff does not affect each firm's research intensity. From (B.5), differentiating R^s wrt t:

$$\frac{\partial R^s}{\partial t} = -\left[\frac{1}{1-\zeta}\right]\left(\frac{1}{2}\right)\left[\frac{\zeta \overline{R}}{(1-c)\pi_n^*}\right]^{\frac{1}{2}} \frac{\partial \pi_n^*}{\partial t} = 0 \tag{C.29}$$

So, the research allocation decision is not affect by the tariff amount. The equilibrium profit equations (23) and (24) become:

$$\pi_n^* = \frac{1}{\epsilon}[s_{nn}P_n^{\epsilon-1}\beta L_n + s_{ns}P_s^{\epsilon-1}\beta(cL_s + M_n x_{ns}^* t)] \tag{C.30}$$

$$\pi_s^* = \frac{1}{\epsilon}[s_{sn}P_n^{\epsilon-1}\beta L_n + s_{ss}P_s^{\epsilon-1}\beta(cL_s + M_n x_{ns}^* t)] \tag{C.31}$$

Combining (C.30) and (C.31) to find P_n rearranging terms yields:

$$s_{ss}\epsilon\pi_n^* - s_{ss}s_{nn}P_n^{\epsilon-1}\beta L_n = s_{ns}\epsilon\pi_s^* - s_{ns}s_{sn}P_n^{\epsilon-1}\beta L_n \tag{C.32}$$

$$s_{ss}\epsilon\pi_n^* - s_{ns}\epsilon\pi_s^* = P_n^{\epsilon-1}\beta L_n(s_{ss}s_{nn} - s_{ns}s_{sn}) \tag{C.33}$$

$$\implies P_n^{\epsilon-1} = (\beta L_n)^{-1}(s_{ss}\epsilon\pi_n^* - s_{ns}\epsilon\pi_s^*)(s_{ss}s_{nn} - s_{ns}s_{sn})^{-1} \tag{C.34}$$

The introduction of t only affects s_{ns} in equation (C.34). Introducing a tariff decreases s_{ns}:

$$\frac{\partial s_{ns}}{\partial t} = \frac{1-\epsilon}{\kappa + \tau_n + t}\left[\frac{\epsilon(\kappa + \tau_n + t)}{(\epsilon-1)a_{ns}}\right]^{1-\epsilon} \tag{C.35}$$

Thus, the effect the tariff has on the Northern price index can be found by differentiating

(C.34) wrt to s_{ns}:

$$\frac{\partial P_n^{\epsilon-1}}{\partial s_{ns}} = \frac{(s_{sn})(s_{ss}\epsilon\pi_n^* - s_{ns}\epsilon\pi_s^*)}{(\beta L_n)(s_{ss}s_{nn} - s_{ns}s_{sn})^2} + \frac{-\epsilon\pi_s^*}{(\beta L_n)(s_{ss}s_{nn} - s_{ns}s_{sn})} \tag{C.36}$$

$$= \frac{s_{sn}s_{ss}\epsilon\pi_n^* - s_{sn}s_{ns}\epsilon\pi_s^* - s_{ss}s_{nn}\epsilon\pi_s^* + s_{ns}s_{sn}\epsilon\pi_s^*}{(\beta L_n)(s_{ss}s_{nn} - s_{ns}s_{sn})^2} \tag{C.37}$$

$$= \frac{s_{sn}s_{ss}\epsilon\pi_n^* - s_{ss}s_{nn}\epsilon\pi_s^*}{(\beta L_n)(s_{ss}s_{nn} - s_{ns}s_{sn})^2} \tag{C.38}$$

$$= \frac{(s_{sn}\pi_n^* - s_{nn}\pi_s^*)s_{ss}\epsilon}{(\beta L_n)(s_{ss}s_{nn} - s_{ns}s_{sn})^2} \tag{C.39}$$

By condition (25), $\frac{\partial P_n^{\epsilon-1}}{\partial s_{ns}} < 0$. So, introducing the tariff increases the Northern price index and decreases Northern welfare. As the tariff increases, the Northern price index will unambiguously increase as well. Rearranging equation (C.31) yields:

$$P_s^{\epsilon-1} = \frac{\epsilon\pi_s^* - s_{sn}P_n^{\epsilon-1}\beta L_n}{s_{ss}(cL_s + M_n x_{ns}^* t)} \tag{C.40}$$

The inclusion of a tariff increases Southern income and Northern price index. Therefore, the Southern price index must decrease. As the tariff increases, the change in the Southern price index is ambiguous. Increases in the tariff can conceivably reduce tariff revenue as Northern firms sell less of their product in the Southern market. The decrease in Southern income could then force out some Southern firms and allow extra Northern firms to enter. The Southern price index decreases if Southern income increases as the tariff increases. Differentiating equations (27) and (28) wrt s_{ns}:

$$\frac{\partial M_n}{\partial s_{ns}} = \frac{s_{sn}(s_{ss}P_n^{1-\epsilon} - s_{sn}P_s^{1-\epsilon})}{(s_{nn}s_{ss} - s_{ns}s_{sn})^2} \tag{C.41}$$

$$\frac{\partial M_s}{\partial s_{ns}} = \frac{s_{sn}(s_{nn}P_s^{1-\epsilon} - s_{ns}P_n^{1-\epsilon})}{(s_{nn}s_{ss} - s_{ns}s_{sn})^2} - \frac{P_n^{1-\epsilon}}{s_{nn}s_{ss} - s_{ns}s_{sn}} \tag{C.42}$$

Inspecting of (C.41) shows that the number of Northern firms decrease as s_{ns} decreases.

Since M_n decreases from both the price index changes and the market share changes, the increase in t unambiguously decreases the number of Northern firms. Equation (C.42) can be simplified:

$$\frac{\partial M_s}{\partial s_{ns}} = \frac{s_{sn}s_{nn}P_s^{1-\epsilon} - s_{ss}s_{nn}P_n^{1-\epsilon}}{(s_{nn}s_{ss} - s_{ns}s_{sn})^2} \tag{C.43}$$

$$= \frac{s_{nn}(s_{sn}P_s^{1-\epsilon} - s_{ss}P_n^{1-\epsilon})}{(s_{nn}s_{ss} - s_{ns}s_{sn})^2} < 0 \tag{C.44}$$

Note that equation (C.44) is negative from the assumption that $M_n > 0$. Using equations (C.4)-(C.7), the number of firms in the North decreases while the number of Southern firms increases as the tariff is introduced. As the tariff increases, the Northern firms will exit the market if Southern income increases with the tariff. This outcome depends on the preferences of Southern consumers for Northern goods. Firm-level offshoring does not change with increases in the tariff. So, industry-level offshoring decreases as tariffs increase if Southern income increases as well.

Figure 5 shows Proposition 4 graphically. When the South places a tariff on Northern imports, the Northern equilibrium profit line shifts out due to the increase the price set by Northern firms in the South. The Northern equilibrium profit line shifts down as well due to the increase in Southern income; however, the shift in income also shifts the Southern equilibrium profit line down. More Southern firms enter the market as a result while Northern firms exit. The increase in the Southern market place is not enough to offset the forced increase in price that Northern firms must endure from the tariff.

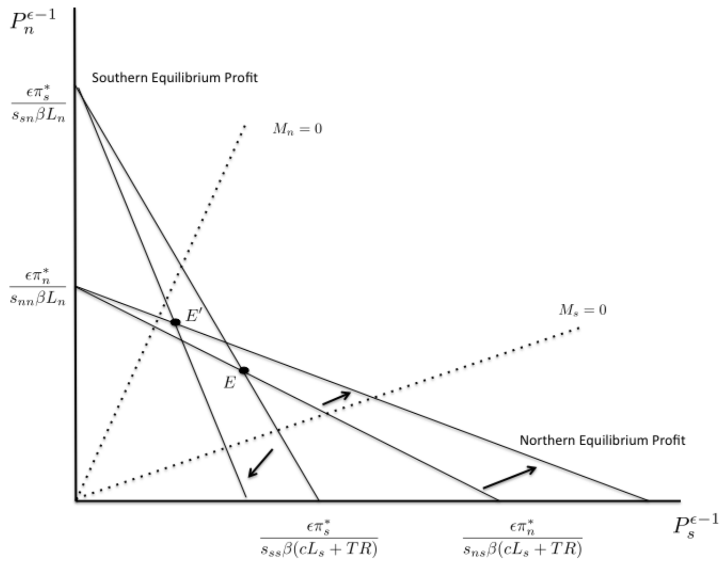

Figure 6: Introducing a Southern Import Tariff

D Including Southern Market Size in the Probability of Imitation

The model can be improved in light of the empirical evidence on firm-level reaction to Southern market size. I include Southern market size in equation (8).

$$\phi = \left(\frac{\omega(\zeta, L_s)R^s}{R^n + \omega(\zeta, L_s)R^s} \right) \qquad 0 < \omega(\zeta, L_s) < 1 \qquad \text{(D.1)}$$

Note that the ability for Southern firms to win the imitation contest now depends on both IPR-protection and L_s. Southern ability, or $\omega(\zeta, L_s)$, increases with ζ and also increases with L_s. Now, I show an increase in Southern market size decreases the amount of firm-level offshoring. Using the Northern free-entry condition, it can easily be verified that the new Northern operating profit in equilibrium is:

$$\pi_n^* = \overline{R}\left[\omega^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\omega)^{\frac{1}{2}}\right]^2 \tag{D.2}$$

Likewise, equation (17) slightly changes to:

$$R^{n*} = (\frac{1}{1-\omega})\left(\frac{[\pi_n^*]\omega\overline{R}}{1-c}\right)^{\frac{1}{2}} - (\frac{\omega}{1-\omega})\overline{R} \tag{D.3}$$

The equilibrium probability of imitation is then:

$$\phi = (\frac{1}{1-\omega})\left(\frac{\omega\overline{R}(1-c)}{\pi_n^*}\right)^{\frac{1}{2}} - (\frac{\omega}{1-\omega}) \tag{D.4}$$

Partially differentiating equation (D.2) wrt L_s yields the change in Northern operating profit as Southern market size changes:

$$\frac{\partial\pi_n^*}{\partial L_s} = 2\overline{R}\left[\omega^{\frac{1}{2}}(1-c)^{\frac{1}{2}} + c^{\frac{1}{2}}(1-\omega)^{\frac{1}{2}}\right]\left[\frac{1}{2}(1-c)^{\frac{1}{2}}\frac{\partial\omega}{\partial L_s}\omega^{\frac{-1}{2}} - \frac{1}{2}\frac{\partial\omega}{\partial L_s}(1-\omega)^{\frac{-1}{2}}c^{\frac{1}{2}}\right] \tag{D.5}$$

Now to determine the change in Southern operating profit, I differentiate the probability of imitation (D.4) wrt L_s:

$$\frac{\partial\phi}{\partial L_s} = \frac{1}{1-\omega}\phi\frac{\partial\omega}{\partial L_s} - \frac{1}{1-\omega}\frac{\partial\omega}{\partial L_s} + \frac{1}{2}\frac{1}{1-\omega}\left(\frac{\omega\overline{R}(1-c)}{\pi_n^*}\right)^{\frac{1}{2}}\left[\omega^{-1} - (\pi_n^*)^{-1}\frac{\partial\pi_n^*}{\partial\omega}\right]\frac{\partial\omega}{\partial L_s} \tag{D.6}$$

In a similar manner to the proof in subsection C.1, the probability of imitation may increase or decrease. Totally differentiating equations (23) and (24) to examine the change of L_s:

$$\begin{bmatrix} (\epsilon-1)s_{nn}P_n^{\epsilon-2}\beta L_n & (\epsilon-1)s_{ns}P_s^{\epsilon-2}\beta cL_s \\ (\epsilon-1)s_{sn}P_n^{\epsilon-2}\beta L_n & (\epsilon-1)s_{ss}P_s^{\epsilon-2}\beta cL_s \end{bmatrix} \begin{bmatrix} \partial P_n \\ \partial P_s \end{bmatrix} = \begin{bmatrix} \epsilon\frac{\partial\pi_n^*}{\partial\omega}\frac{\partial\omega}{\partial L_s} - s_{ns}P_s^{\epsilon-1}\beta c \\ \epsilon\frac{\partial\pi_s^*}{\partial\omega}\frac{\partial\omega}{\partial L_s} - s_{ss}P_s^{\epsilon-1}\beta c \end{bmatrix} \partial L_s$$

Using Cramer's rule, the change in P_n and P_s due to increases in L_s can be found:

$$\frac{\partial P_n}{\partial L_s} = (\frac{1}{|D|})\left[(\epsilon\frac{\partial\pi_n^*}{\partial a}\frac{\partial a}{\partial L_s} - s_{ns}P_s^{\epsilon-1}\beta c)(\epsilon-1)s_{ss}P_s^{\epsilon-2}\beta cL_s - (\epsilon\frac{\partial\pi_s^*}{\partial\omega}\frac{\partial\omega}{\partial L_s} - s_{ss}P_s^{\epsilon-1}\beta c)(\epsilon-1)s_{ns}P_s^{\epsilon-2}\beta cL_s\right] \tag{D.7}$$

$$\frac{\partial P_s}{\partial L_s} = (\frac{1}{|D|})\left[(\epsilon-1)s_{nn}P_n^{\epsilon-2}\beta L_n(\epsilon\frac{\partial\pi_s^*}{\partial a}\frac{\partial a}{\partial L_s} - s_{ss}P_s^{\epsilon-1}\beta c) - (\epsilon\frac{\partial\pi_n^*}{\partial\omega}\frac{\partial\omega}{\partial L_s} - s_{ns}P_s^{\epsilon-1}\beta c)(\epsilon-1)s_{sn}P_n^{\epsilon-2}\beta L_n\right] \tag{D.8}$$

Using (C.23), equation (D.7) can be simplified to:

$$\frac{\partial P_n}{\partial L_s} = (\frac{1}{|D|})\left[(\epsilon\frac{\partial\pi_n^*}{\partial\omega}\frac{\partial\omega}{\partial L_s})(\epsilon-1)s_{ss}P_s^{\epsilon-2}\beta cL_s - (\epsilon\frac{\partial\pi_s^*}{\partial\omega}\frac{\partial\omega}{\partial L_s})(\epsilon-1)s_{ns}P_s^{\epsilon-2}\beta cL_s\right] \tag{D.9}$$

Thus, $\frac{\partial P_n}{\partial L_s}$ is positive iff:

$$\frac{\partial\pi_n^*}{\partial\omega}\frac{s_{ss}}{s_{ns}} > \frac{\partial\pi_s^*}{\partial\omega} \tag{D.10}$$

Likewise, $\frac{\partial P_s}{\partial L_s} < 0$ iff:

$$\frac{\partial\pi_n^*}{\partial\omega}\frac{\partial\omega}{\partial L_s} > \frac{\partial\pi_s^*}{\partial\omega}\frac{s_{nn}}{s_{sn}}\frac{\partial\omega}{\partial L_s} + \frac{P_s^{\epsilon-1}}{\epsilon P_n^{\epsilon}}\frac{s_{sn}s_{ns} - s_{ss}s_{nn}}{s_{sn}} \tag{D.11}$$

Note that $s_{sn}s_{ns} - s_{ss}s_{nn} < 0$ by previous assumption. Unlike subsection (C.1), increases in $\overline{R}$ do not necessarily increase the likelihood of inequality (D.11) holding. Changes in $\overline{R}$ affect the price indexes as well. Also, the value of ϵ determines . Thus, I can make no prediction on the effect changes of Southern market size has on industry-level offshoring.

Finally, the effect on firm-level offshoring can be determined. From equation (D.3):

$$R^{s*} = (\frac{1}{1-\omega})\overline{R} - (\frac{1}{1-\omega})\left(\frac{[\pi_n^*]\omega\overline{R}}{1-c}\right)^{\frac{1}{2}} \tag{D.12}$$

Differentiating equation (D.12) wrt L_s:

$$\frac{\partial R^s}{\partial L_s} = (\frac{1}{1-\omega})^2\left[\overline{R} - \left(\frac{\overline{R}\pi_n^*\omega}{(1-c)}\right)^{\frac{1}{2}}\right]\frac{\partial\omega}{\partial L_s} - (\frac{1}{1-\omega})(\frac{1}{2})\left[\frac{\partial\pi_n^*}{\partial\omega}\left(\frac{\overline{R}\omega}{\pi_n^*(1-c)}\right)^{\frac{1}{2}} + \left(\frac{\overline{R}\pi_n^*}{\omega(1-c)}\right)^{\frac{1}{2}}\right]\frac{\partial\omega}{\partial L_s} \tag{D.13}$$

So, $\frac{\partial R^s}{\partial L_s} < 0$ iff:

$$\begin{aligned}
2R^s &< \frac{\partial\pi_n^*}{\partial\omega}\left(\frac{\overline{R}\omega}{\pi_n^*(1-c)}\right)^{\frac{1}{2}} + \left(\frac{\overline{R}\pi_n^*}{\omega(1-c)}\right)^{\frac{1}{2}} \\
2\overline{R} &< \left(\frac{\overline{R}\pi_n^*}{(1-c)}\right)^{\frac{1}{2}}\left[\omega^{\frac{1}{2}} + \omega^{\frac{-1}{2}}\right] + \frac{\partial\pi_n^*}{\partial\omega}\left(\frac{\overline{R}\omega}{\pi_n^*(1-c)}\right)^{\frac{1}{2}} \\
2(\overline{R}\pi_n^*(1-c))^{\frac{1}{2}} &< \pi_n^*\left[\omega^{\frac{1}{2}} + \omega^{\frac{-1}{2}}\right] + \frac{\partial\pi_n^*}{\partial\omega}\omega^{\frac{1}{2}} \\
\pi_n^* - \overline{R}(c-\omega) &< \pi_n^*(1+\omega) + \omega\frac{\partial\pi_n^*}{\partial\omega}
\end{aligned}$$

$$\boxed{-\left(\frac{c-\omega}{\omega}\right)\overline{R} < \pi_n^* + \frac{\partial\pi_n^*}{\partial\omega}} \tag{D.14}$$

By previous assumption, inequality (D.14) holds. Therefore, firm-level innovative R&D offshoring decreases as Southern market size increases.