DISCUSSION PAPERS IN ECONOMICS

Working Paper No. 13-07

Product Cycle Dynamics with Heterogenous Industries

Yuchen Shao
University of Colorado at Boulder

November 2013

Department of Economics

University of Colorado at Boulder
Boulder, Colorado 80309

Product Cycle Dynamics with Heterogenous Industries*

Yuchen Shao†

November 7, 2013

Abstract

This paper investigates a dynamic product-cycle model with industrial heterogeneity in R&D productivity when intellectual property rights are imperfectly protected. Northern firms might innovate to put forward quality frontier, or shift out relatively-old generations by the means of foreign direct investment (FDI). It is cheaper to manufacture in the South but entails a risk of imitation from local firms. Compared to the case without imitation, the measure of industries exhibiting product-cycle pattern gets narrowed. Stronger intellectual property protection in the South is likely to expand this range and increase the average technology levels of goods transferred abroad. A panel of U.S. imports data from 1989 to 2006 is utilized to examine the major theoretical predictions.

Keywords: Innovation, intellectual property rights, foreign direct investment, heterogeneity

JEL classification: F14; F23; O34

*I am indebted to Keith Maskus for his encouragement and invaluable guidance. I also thank Keith Maskus and Lei Yang for sharing their data with me. All remaining mistakes are my own.

†Department of Economics, University of Colorado at Boulder. *E-mail: yuchen.shao@colorado.edu.*

1 Introduction

Many manufacturing goods seem to go through a standard international product cycle, in which they are invented and initially produced in an advanced economy (the "North") and production of a standardized version is eventually shifted to lagging economies (the "South") via some form of technology transfer, whether foreign direct investment (FDI) or simple imitation of traded goods. In Vernon's (1966)[33] classic conception, all products are subject to these basic dynamics and a continuous cycle of birth, death and rebirth of new goods occurs. This assumption of homogeneity persists through many extensions of the product cycle model, including the dynamic, general-equilibrium versions begun by the seminal model of Grossman and Helpman (1991a)[11]. However, not all goods can be characterized as identical in this context. Some proceed rapidly through the process of technology transfer but remain in production in the South rather than expire. Others go through the standard dynamics as noted. Still others, generally very high-technology goods, seem resistant and both innovation and production remain in the advanced countries (Lu, 2007[23]).

Put in other terms, goods may broadly be placed into three categories in this context. First would be lower-technology products that, once transferred, remain relatively stagnant in terms of innovation and production remains permanently in developing nations. An obvious example would be labor-intensive, standardized goods, such as footwear, mass-produced apparel items, and toys. Second would be inherently high-technology products that are so complex it is effectively impossible to separate production from technology sources. Examples here would be final assembly of passenger aircraft and sophisticated capital goods. Third, and most interestingly, are goods that exhibit product-cycle characteristics of innovation, technology transfer, and subsequent newer innovation. Examples here would include semiconductors, cellular phones, and automobile parts.

This heterogeneity seems fundamental and it is important to develop a theory that explains it. In this paper I develop a model, based on concepts of quality-ladder improvements in technology (Grossman and Helpman, 1991c[12]). However, here the industries are differentiated by the step size of improvements, with larger steps indicating higher-technology sectors. In this regard, I build on the model set out by Lu (2007), which features continuous innovation and technology transfer through FDI and generates cutoff levels of technological sophistication that segment low-technology, medium-technology (product cycle), and high-technology industries. In particular, Lu solves for cutoffs determining industries that "move out" (i.e., goods that transfer permanently through FDI or become product-cycle goods) or "move up" (i.e., innovation and production remain in the advanced economies). In this context, a product that remains in the South is always produced within an FDI affiliate.

An important element of competition missing in her model is the possibility that local Southern firms may imitate goods transferred to their countries via FDI. Adding imitation, which is the objective of this paper, changes the results in significant ways. First, all products in low-technology industries ultimately are produced by firms owned in the South. Second, the fact that owners of multinational firms must concern themselves with this imitation threat means that in equilibrium fewer technologies are transferred from the North. In particular, the range of technological sophistication within which products remain always in the North expands.

One immediate implication is that stronger intellectual property protection in the South, which reduces the rate of imitation aimed at FDI, is likely to reduce this range and increase the average technology levels of goods transferred abroad. With the help of the U.S. trade panel, I confirm this promotion effect and find it most significant in industries with moderate technology levels.

The remainder of this paper is organized as follows. In the next section, I offer a brief literature review to help set up the problem. In Section 3, I describe the basic setup of the model. In Section 4, I analyze the model to figure out the relevant industry thresholds, and determine in steady-state equilibrium which industries are subject to product cycles and which are not. Since the analytical solution of the model is complex, I conduct comparative statics on such factors as labor endowment, quality increments, innovation costs, FDI adaptation costs and imitation intensities in the next section. In Section 6, I describe the datasets and provide empirical evidence of my major theoretical predictions. I offer concluding remarks in the last section.

2 Literature review

The role of technological change in international trade and FDI had been long neglected by economist. Vernon (1966)[33] is the first to mention the relocation of product manufacturing over time and its subsequent influence on the direction of trade. At the early stage of a commodity's life cycle, it is produced in the country where it is invented, usually the United States, since there is a large market over there. As technology becomes more and more standardized, production will migrate to less developed countries to exploit low marginal cost. This shifting process is called "product cycle". However, Vernon only mentions FDI as the only way to transfer technology. Besides, he elaborates his idea with examples. Facts and theories are anticipated.

Afterwards, a whole literature on " product cycle" has emerged to further address this issue. Basically, there are two dimensions of development, implying different theoretical results. One branch of framework depends on horizontal differentiation. Innovation takes the form of product expansion. New varieties come out and substitute the old one. The other branch considers vertical differentiated products. Innovation improves product quality continuously while keeping the number of varieties unchanged.

2.1 Horizontal Differentiated

As a precursor, Krugman (1979)[21] formalizes the leakage of technology to developing countries by building up a dynamic horizontally-differentiated model. Labor is assumed to be the only input[1]. There is a continuing process of innovation, in the form of creating new products. The North specializes in inventing, producing and exporting these new goods. Meanwhile, new goods gradually turn into old goods and their technology are learnt by the South. Then the North begins to import these goods from the South. Hence, the "imitation lag" gives rise to international trade. Note that both rates of innovation and transfer are taken as exogenous here. Although labor in the two countries is equally productive, wage in the North is relatively higher. Either a slow down in innovation or a speed up in transfer may narrow this differential.

Dollar (1986)[1] further takes factor-price equalization of the neoclassic model into account. Capital is introduced as the second factor and moves slowly across borders. The most important adjustment is to assume that there is a difference in production costs between the North and South, which determines the rate of transfer positively, while keeping the rate of innovation exogenous. Meanwhile, Jensen and Thursby (1986)[16] suppose that a Northern monopolist and a Southern

[1] Krugman (1979) also spends a short section to discuss the possibility of international mobile of capital, which leads to foreign investment. However, that is not the focus of his paper.

planner decide the rates of innovation and imitation respectively. Afterwards, they (1987)[17] modify the number of innovators to greater than one, but reverts to the exogeneity of imitation.

On the basis of Krugman (1979), Helpman (1993)[14] considers the welfare consequences of tighter intellectual property rights protection (IPP) in the South. Innovation is then endogenized. The strength in IPP is expressed by a decrease in the exogenous imitation intensity. It not only impedes the pace of Northern innovation, but also may hurt the South by reallocating production towards Northern firms. Krugman (1979) also considers a model with FDI; however, innovation in that case is exogenous.

Still with exogenous imitation, Lai (1998)[22] confirms Helpman (1993)'s positive feedback of the rate of imitation to the rate of innovation. However, he claims that this relationship only holds when imitation is the unique channel of technology transfer. When endogenous FDI decision is taken into consideration, the correlation turns out to be negative if the rate of multinationalization is high enough or the rate of pre-FDI imitation is tiny. Stronger IPP enhances the incentive to innovate in the North, and also promotes shifting production to the South. In addition, the Northern relative wage will be reduced.

Not only transfer method is important, but also the endogeneity of imitation is crucial. Intuitively to think, imitation is a costly activity. Firms will response to its cost and optimally allocate their resources between imitation and production. Taking imitation activity as given obviously misinterprets firms' behavior.

Grossman and Helpman (1991a)[10] endogenize both rates of innovation and transfer by setting up a general equilibrium model. The Northern oligopolist continuously faces a threat from the Southern imitators and may lose its market leadership after a random period of time. Faster imitation ultimately improves the incentives to innovate. If the wage gap is not too large, an increase in the relative size of Northern population retards the pace of imitation, and hence raises the share of varieties located in the North. Also, it raises the Northern relative wage, which is the opposite to Krugman's (1979) finding.

Branstetter and Saggi (2011) extends Grossman and Helpman (1991a) by adding endogenously-determined FDI. They also let the Northern firms to choose production location by themselves. In their paper, tighter IPP brings down the possibility of imitation, but encourages FDI. As a result, the share of Southern products in the global market gets increased. If the price of multinationals' products is higher than that of Southern imitators, the real wage of Southern workers will increase, while that of Northern workers will fall.

Further more, Gustafsson and Segerstrom (2011) modify previous work by treating transfer within multinational firms with a price. At first, new varieties are invented in the North and manufactured over there. Then Northern firms conduct adaptive R&D and later shift production to the low-wage South in order to get more profits. However, the foreign affiliates is exposed to imitation risk from Southern local firms. Once the imitation is successful, Southern imitators occupy the whole market share. Specifically, the strength in Southern IPR is modeled as a reduction in imitation rate. This change in IPP leads foreign affiliates to raise their R&D expenditures, making the speed of transfer to increase.

2.2 Vertical Improvement

In a partial equilibrium model, Gabszewicz et al. (1981)[4] begin to discuss the existence of trade in terms of different quality levels. However, the quality levels in his paper are all exogenously given.

Both Flam and Helpman (1987)[3] and Stokey (1988) [31] work on a framework with continuously introducing new high-quality goods and abandoning low-quality ones. In the former paper, the incentive to upgrade the product qualities stems from faster technology progress in the South and also consumer income differences. Gradually, relatively-low-quality goods shift their production to the South. However in Stokey (1988), learning-by-doing is the driving force behind the transfer.

Segerstrom et al. (1990) [29] assume that the time interval between two successive innovations is a deterministic decreasing function of resources devoted and R&D is conducted sequentially to a fixed number of industries. The portion of industries located in the South is exogenously given by the patent duration in the North. In Grossman and Helpman (1991c)[12], each product climbs up its own quality ladder simultaneously and stochastically. With Bertrand competition, the firm with the lowest quality-adjusted price controls the whole market. Both innovation and imitation are endogenous, and optimal resource allocation determines the split of production between the

North and South.

Glass and Saggi (2002)[8] add endogenous FDI into Grossman and Helpman's (1991c) framework and also consider the effect of strengthened intellectual property rights in the South. There are two possible targets for any Southern imitator: Northern firms and multinationals in the South. They find that stronger IPP impedes both innovation and FDI.

Could the difference in the type of innovation alter the consequences of IPP? Glass and Saggi (2002) cast doubt on whether stronger Southern IPP must always encourage FDI and innovation. They argue that stronger Southern IPP reduces the aggregate rate of innovation and the flow of FDI regardless of whether FDI or imitation targeting Northern production serves as the primary channel of international technology transfer. In their model, stronger IPP is an increase in the cost of imitation, which causes a reduction in the rate of imitation. They identify two effects of the increased cost of imitation: a labor wasting effect due to the increased amount of labor used for imitation and an imitation tax effect due to the decreased incentive for imitation. They show that each effect reduces FDI and innovation, and neither effect arose in previous analysis with exogenous and costless imitation. So the reason for the difference in results appears to be the difference in how IPP was modeled: as an increase in the cost of imitation rather than as an exogenous decrease in the imitation intensity.

By only allowing imitating from the multinationals, Glass and Wu (2007)[9] confirms Glass and Saggi's (2002) finding about tighter IPP on FDI and innovation in the case of quality improvements, but points out that it has a positive effect if the direction of innovation is horizontal.

Starting from Krugman (1979), the whole product cycle literature treats each variety identically. They enter consumer's utility function systematically and their R&D efforts are equally productive. However, Taylor (1993)[32] mentions that this theoretical assumption is inconsistent with stylized facts. R&D activities are discovered to be concentrated in a few sectors and related to 'demand pull' and 'technology push'. Hence, he calls back the Ricardian explanation of trade and introduces a model with different technologies and R&D opportunities across industries. Taylor does not make any specification in his paper, but provide a workable framework to the literature.

On account of Taylor (1993), Lu (2007)[23] generalizes a heterogenous industry model with endogenous innovation and FDI. Industries are ranked by their R&D productivity. All innovations take place in the North, by the form of improving product quality. When a Northern leader loses its market due to other firms' innovative endeavors, it may choose between further innovate (called "moving-up strategy") and invest in the South (called "moving-out strategy") according to the potential return. With the instinct heterogeneity, this ex-leader's decisions are different from industry to industry.

In particular, firms in high R&D productivity industries always prefer moving-up strategy and keep on inventing new generations of products. The Northern leader is the dominant exporter and the top-of-the-line blueprint owner. None of the product lines migrates to the South. To the contrary, in industries with medium or low R&D productivity, firms prefer moving-out strategy and reap cost savings in the South. These relocated firms control the whole market. It is worth noting that medium-technology industries continuously experience product cycle between the two countries. When manufacturing is directed by MNEs, the Northern inventors deploy resources in R&D and then win back their world demand. Afterwards, the followers invest in the South with a previous version. Finally, for low-technology industries, no firm is willing to innovate. Technology stagnates in the South.

My paper further extends Lu (2007) by allowing imitation, since it is a very common channel of international technology transfer. An important goal of this paper is to determine whether the Northern firms' moving-up and moving-out decisions are affected by the exposure to imitation, and how stronger IPP in the South affects the steady-state equilibrium. I find that the range of product cycle industries does get smaller with the risk of imitation; however, the tighter protection helps the multinationals regain confidence in the Southern market.

3 The model

This section makes a brief description of the model. There are two countries in the world, an industrialized North and an underdeveloped South. Labor is the only factor in the economy and is immobile between countries. Hence, the labor endowments in the North and South are fixed to be L and L^* respectively. The wage in the South is normalized to be 1. The wage in the North is supposed to be $\omega > 1$, which is also the relative wage between two countries. Following Lu (2007),

$\omega(t)$ is exogenously given and only can be changed by the relative labor endowment. Finally, trade is frictionless across borders.

There is a continuum of industries around the world, indexed by $z \in [0, 1]$. Within each industry, there is a continuum of varieties $y \in [0, 1]$, available at different quality levels. As a result, the product space is defined on a unit square indexed by $(z, y) \in [0, 1] \times [0, 1]$. The quality of version j of product (z, y) is denoted by $q(z, y, j) = \lambda(z, y)^j$, where $\lambda(z, y)$ is the step size of quality increment and also indicates its R&D productivity. Moreover, I assume that $\lambda(z, y) = \lambda(z)$, $\lambda(0) = 1$, and $\lambda(z)' > 0$. The quality increment within each industry is the same. The industries are ranked by their R&D productivities, which is increasing in z.

Similar to other product cycle works, the North and the South are thought to have different technology capacities. Supplied by highly-trained workers and equipped with advanced machines, the Northern firms can put forward the quality frontier through costly innovation. They also can choose to transfer existing blueprints to the South and become multinational enterprises (MNEs), in order to exploit the cost advantage over there. On the other side, the Southern firms are inefficient in innovation; therefore, imitative activities are undertook to copy the existing designs of multinationals. Once the Southern imitators succeed, the Northern firms will lose their dominance in the market.

3.1 Consumer's problem

The specification of the consumer's problem is similar to Lu (2007). Consumers around the world share identical and homothetic preference. For simplicity, I only show the utility function of the Northern consumers here. The Southern consumers follow the same rule to make their decision. In particular, a representative consumer seeks to maximize his/her intertemporal utility below

$$U = E_0[\int_0^\infty e^{-\rho t} \log u(t) dt] \tag{1}$$

where E_0 is expectation conditional on the information available at time 0, and ρ is the common subjective discount factor. The instantaneous utility $\log u(t)$ at time t over different generations of products is of the form:

$$\log u(t) = \int_0^1 \int_0^1 \log[\sum_{j=0}^{J(z,y,j)} q(z,y,j)X(z,y,j,t)]dydz \tag{2}$$

where $X(z,y,j,t)$ denotes the consumption for quality level j of product (z,y) at time t, and $J(z,y,t)$ denotes the highest quality level available of product (z,y) at time t.

The representative consumer maximizes his/her lifetime utility (1) subject to an intertemporal budget constraint $\int_0^\infty e^{-R(t)}E(t)dt \leq A(0)$. $E(t)$ is the aggregate expenditure of consumers at time t, and $A(0)$ is the present value of lifetime income plus initial asset holdings. In addition, $R(t) = \int_0^t r(s)ds$ is the cumulative interest rate up to time t, where $r(t)$ is the instantaneous interest rate. Accordingly, the optimal path for spending $E(t)$ is specified as

$$\dot{E}(t)/E(t) = r(t) - \rho \tag{3}$$

There are three stages of a consumer's maximization problem: firstly, how to allocate lifetime wealth over time; then at each instant, how to allocate expenditures across products in each industry; and lastly at each instant for each product, how to allocate spending across different quality levels. Actually, for all quality ladder structure, there is Bertrand competition around the world. Firms set prices to rule out their rivals, and then consumers pick up quantities. The provider with the lowest quality-adjusted price wins the whole market. For the situation here, only the version $\underline{j}(z,y,j,t) = \underset{j\in\{0,\cdots,J(z,y,t)\}}{\text{argmin}} \frac{p(z,y,j,t)}{q(z,y,j)}$ will be purchased, where $p(z,y,j,t)$ denotes its price at time t. Hence, the world demand functions are:

$$X(z,y,j,t) = \begin{cases} E^W(t)/p(z,y,j,t), & \text{if } j = \underline{j}(z,y,t) \\ 0, & \text{otherwise} \end{cases} \tag{4}$$

where $E^W(t) = LE(t) + L^*E(t)^*$ is the world aggregate expenditure at time t.

3.2 Firm's problem

There are three kinds of firms producing goods around the world: Northern firms (Firm N), multinationals set up by Northern firms in the South (Firm F), and Southern local firms (Firm S). I suppose that leapfrogging to a higher version is allowed, but further imitation is not immediately possible. Hence, Northern firms are exposed to innovation and adaptation risk, multinationals are exposed to innovation and imitation risk, and Southern firms are only exposed to innovation risk. Firm characteristics are summarized in Table 1, which will be explained one-by-one.

A firm needs one unit of labor to manufacture one unit of output. Since the relative wage is higher than 1, there exists a production cost advantage in the South. Further more, by assuming free entry to R&D, there is an infinite pool of potential competitors for all three kinds of firms. However, under Bertrand competition, each product is produced by exactly one manufacturer in equilibrium, likely to be any kind. Only the firm offering the lowest quality-adjusted price occupies the whole market of its specific variety. It limits the price to just keep its closest rival from earning a positive profit from production. Hence, the rest of firms either engage in R&D activity to strive for the leadership, or just quit the market.

3.2.1 Northern firms

I make a description of the Northern firms' behavior first. As discussed before, they are the only ones that can develop quality improvements. I name these firms devoted to introducing new generations of products as Firm N. In each product line, the one holds the state-of-the-art technology is the Northern leader, and I denote it by J. The rest of firms are Northern followers, and I denote them by $j \in \{0, 1, \cdots, J-1\}$ (subscripts suppressed). In equilibrium described later, only three most recent versions of a product may exist: the latest version J, the second-to-top version $J-1$, and the third-to-top version $J-2$. All out-of-date blueprints have been discarded.

Climbing up the quality ladder requires investment of resources and entails uncertainty of success. The labor requirement per unit of innovation is a_N, which is supposed to be constant across all industries for simplicity. An innovator engages in R&D intensity $\iota(z)$ for a time length of dt requests a total of $a_N\iota(z)dt$ units of Northern labor force, at a cost of $\omega a_N\iota(z)dt$. The probability of success is $\iota(z)dt$, which follows a Poisson process. This intensity is related to the industry rank as well, and can be different from industry to industry. A bigger endeavor of upgrading efforts leads to a higher possibility of success, but no level of investment will guarantee it. Note that the innovation intensity $\iota(z)$ might be different from industry to industry. Additionally, getting a new patent rewards the firm a value of $v_N dt$. In order to prevent unlimited R&D, the expected benefits should not exceed the relative costs. That is to say, for each industry,

$$v_N \leq \omega a_N \; with \; equality \; if \;\; \iota(z) > 0 \tag{5}$$

In fact, there are two pricing strategies for a producing Northern leader. On one hand, without competitors from the South, the most recent innovator can make a really high mark-up and charge at $p_N(z) = \lambda(z)^{J-J^*}\omega$ (or a tiny ϵ smaller). J^* is the highest level of quality that has been transferred to the South. Obviously, $J^* \leq J$. The unit production cost for Firm N is ω, which is the relative wage between the North and South. Hence, this specific price p_N reflects consumers' willingness to pay for a higher-quality version multiplied by the marginal cost. The expected instantaneous profits $\pi_N(z) = (p_N - \omega)X_N(z)$, where $X_N(z) = \frac{E^W}{\lambda(z)^{J-J^*}\omega}$ is the quantity sold globally. As a result, the profit function is presented as

$$\pi_N(z) = [1 - \frac{1}{\lambda(z)^{J-J^*}}]E^W \tag{6}$$

On the other hand, Firm N might compete with firms from the South, either imitators or multinationals. Since the manufacturing cost overseas is lower, the Northern leader is unable to set the price as high as before. The highest price possible is the maximal value between the quality difference between regions and its marginal cost. That is, $p_N(z) = \max\{\lambda(z)^{J-J^*}, \omega\}$ (or a tiny ϵ smaller). If $\lambda(z)^{J-J^*} < \omega$, which is more common in lower-technology industry, we have $p_N(z) = \omega$. Then instantaneous profits of the firm are $\pi_N(z) = [p_N(z) - \omega]X_N(z) = 0$, where $X_N(z)$ is the total sales. When further taking the initial R&D cost into account, no firm would like to conduct innovation since they lose money. However, if $\lambda(z)^{J-J^*} > \omega$, which is the case in higher-technology industries, $p_N(z) = \lambda(z)^{J-J^*}$. Making a sale of $X_N(z) = \frac{E^W}{\lambda(z)^{J-J^*}}$, the leader now earns instantaneous profits as follows

$$\pi_N(z) = [1 - \frac{\omega}{\lambda(z)^{J-J^*}}]E^W > 0 \qquad (6')$$

According to Lu (2007), the leader has no incentive to further innovate if it is currently producing. The incremental rewards to the recent innovator are less than those made by the non-producers, and hence are unable to justify the research cost. Moreover, its is unprofitable for any follower to engage in FDI. Since facing the same marginal adaptation cost, the previous leader $J-1$ can make more profits. Accordingly, it is always the previous leader $J-1$ to think how to regain its leadership. There are two different choices: it might conduct innovative R&D to seek for technology breakthrough (Lu (2007)[23] calls it the *moving-up strategy*) or transfer manufacturing to the South to exploit a lower cost (Lu (2007)[23] calls it the *moving-out strategy*).

3.2.2 Multinationals

Firm F refers to those multinational enterprises operated in the South by Northern patent holders. Among them, the company possessing the highest quality blueprint is called the multinational leader (with version J^*). Adaptation uses labor from the South. Its unit resource requirement is a_F, and its intensity $\phi(z)$ varying with industries. It is intuitive to assume that $a_F < a_N$; therefore, it costs less to FDI than improve product quality. Similar to innovation, a patent holder undertakes FDI at intensity $\phi(z)$ for a time interval dt has a probability of $\phi(z)dt$ of success. Since Southern labor is hired, $a_F\phi(z)dt$ units of labor will be consumed at a cost of $a_F\phi(z)dt$. The unit labor requirement for multinational production is 1. The Northern followers will invest in the foreign country only if the expected gains are no less than costs. Hence, free entry condition requires

$$v_F \leq a_F \ with\ equality\ if\ \phi(z) > 0 \qquad (7)$$

The multinationals charge a price of $p_F(z) = max\{\frac{\omega}{\lambda(z)^{J-J^*}}, 1\}$ (or a tiny ϵ smaller) to undercut their Northern rivals. The price is the maximum between cost premium discounted by their quality disadvantage and the marginal cost. When $\frac{\omega}{\lambda(z)^{J-J^*}} > \omega$, the price $p_F(z) = \frac{\omega}{\lambda(z)^{J-J^*}}$ yields the multinationals one hundred percent of the global and a flow of sales $X_F(z) = E^W/p_F(z) =$

$\frac{\lambda(z)^{J-J^*}E^W}{\omega}$. Correspondingly, the instantaneous profits are

$$\pi_F(z) = [p_F(z) - 1]X_F(z) = [1 - \frac{\lambda(z)^{J-J^*}}{\omega}]E^W \tag{8}$$

Otherwise, the instantaneous profits are zero and no firm is interested in FDI since it needs to bear the research cost at the beginning.

Note that the quality level in Firm F is at least one step behind Firm N, i.e. $J^* \leq J - 1$. The no quality gap situation $J = J^*$ is unfeasible in equilibrium. In that case, the price for Firm N is $p_N(z) = max\{\lambda(z)^0, \omega\} = \omega$, while the production cost is ω. Hence, $\pi_N(z) = (\omega - \omega)\frac{E^W}{\omega} = 0$. Because of the initial innovation cost, the gains are not sufficient to cover the costs. All firms would like to migrate to the South. Then the technology stagnates over there. This strong specialization contradicts what really happens in the world. So I need to rule out the possibility of $J = J^*$.

3.2.3 Southern firms

Then I look at the indigenous firms in the South. After the multinationals bring the blueprints to the South, the local firms can hire away skilled labor or visit the factories and hence learn the know-how and reverse engineering. I refer this group of firms as Firm S.

Following a few product cycle literature[2], I denote with Mdt probability of imitation success during time interval dt for Firm S. This imitation intensity $M \geq 0$ is exogenously given and can be interpreted as the level of IPP in the South. When the Southern government takes stricter legal and administrative regulations, the pace of imitation turns slower. Hence, stronger IPP brings down the values of M. Moreover, I also suppose that once imitation succeeds, technology becomes available to all Firm S. With perfect competition among Southern firms, the price set is $p_S(z) = 1$, which equals the marginal cost. With a total sale of $X_S(z) = E^W/p_S(z) = E^W$, they make instantaneous profits $\pi_S(z) = 0$. The quality level of their products is the same as previous multinational leader, that is, J^*.

Finally, the Southern firms might be the target of Northern R&D efforts. Each success by Firm N migrates production back to the North and reignites a new product cycle.

[2] Helpman (1993)[14], Lai (1998)[22], Glass (2004)[7], Sayek and Sener (2006)[27], Sener and Zhao (2009)[30].

3.3 Predictions in Lu (2007)

To facilitate comparing my work to Lu (2007), this subsection briefly introduces some basics of her model. Notations are altered a little bit to fit my setup. First of all, Assumption 1 needs to hold in order to arrive at her major predictions[3]. By assuming this, the cutoff functions will intersect with the relative wage within the reasonable range of z between 0 and 1. Hence, it ensures the existence of the cutoff points and their uniqueness. T The detailed proof is shown in Lu (2007). To save space, I do not repeat it here.

Assumption 1 (Single Crossing Property) $\lambda(0) < \omega_{t_0} < \omega(1)$, *where* ω_{t_0} *denotes the initial relative Northern wage when FDI is prohibited.*

In fact, the framework of Lu (2007) is almost the same as the descriptions in the last two subsections of my paper, except that there is no role of Southern imitation. In her paper, the only way to transfer technology to the South is by means of FDI. Sorted by R&D productivity, industries are categorized into three groups: high-technology, medium-technology, and low-technology. The first cutoff point $\bar{z}$ is to separate high-technology and medium-technology industries. Its solution is now $f(z) \equiv \frac{a_F}{a_N}(1-\frac{1}{\lambda(z)})+\lambda(z) = \omega$. The second cutoff $\underline{z}$ is to distinguish low-technology industries from medium-technology industries. It is the solution to $g(z) \equiv \lambda(z)^2 = \omega$. A similar process of finding out these cutoff functions is elaborated in the next section.

In high-technology industries, Northern firms engaged in innovation continuously and keeps production within the Northern border. In industries with relatively-lower technology, Northern followers shift production to the cheaper South. The difference is that in low-technology industries, production remains there and technology never gets improved. However, in medium-tech industries, there is still incentive for Northern firms to innovate and return production to the North. As a result, medium-technology industries are product-cycle industries.

4 The steady state

My model extends Lu (2007) by allowing Southern imitation. In this section, I introduce my new cutoff points, and compare them with Lu (2007)'s results. Actually, only the first cutoff has

[3] See Lu (2007) for proof.

changed and moves to the left. The second cutoff is the same as Lu (2007). It means that with the risk of imitation in the South, more Northern firms take "moving-up strategy" and the measure of product-cycle industries shrinks. I am also interested in possible influences on these cutoffs, especially the strengthened IPP in the South.

4.1 The cutoffs

Proposition 1 *Let* $F(z) \equiv \frac{-B+\sqrt{B^2-4AC}}{2A}$, *where* $A = a_N L$, $B = a_N L^* - \lambda(z) a_N L - a_N a_F M - (1 - \frac{1}{\lambda(z)}) a_F L$, *and* $C = -\lambda(z) a_N L^* - (1 - \frac{1}{\lambda(z)}) a_F L^*$. *Suppose Assumption 1 holds. Given that the industry leader* J *currently occupies the whole market, there exists an industry* $\bar{z}' \in (0, 1)$ *which satisfies* $F(\bar{z}') = \omega$, *such that: i) the nearest follower* $J(\bar{z}') - 1$ *is indifferent to the moving-up and the moving-out strategies. ii) For any industry* $z_H \in (\bar{z}', 1]$, *the moving-up strategy is preferred to the moving-out strategy. iii) For any* $z_{\bar{H}} \in [0, \bar{z}')$, *the moving-out strategy is preferred to the moving-up strategy, and* $J(z_{\bar{H}}) - 1$ *participate in FDI. When overseas factories are set up, the Southern indigenous firms begin to imitate from these MNEs.*

Proof: The first cutoff is to distinguish high-technology industries and the rest (including low-technology and medium-technology). It is denoted as $\bar{z}$ in Lu (2007). To make a distinction, I denote my first cutoff as $\bar{z}'$.

I call any industry $z_H \in [\bar{z}', 1]$ as the high-technology industries. In these industries, technology advantage defeats cost advantage; therefore, the nearest follower $J - 1$ deploys resources in innovation. There is no risk of FDI in all these industries since that would generate negative profits. When investment in R&D is successful, the new industry leader $J + 1$ takes over production and obtains instantaneous profits $\pi_N(z_H) = [1 - 1/\lambda(z)]E^W$, at a price of $p_N(z_H) = \lambda(z)\omega$. Note that there is no competition from the South.

From Taylor (1993)[32] and Lu (2007)[23], we know that in steady state, the expected market value equal to $v_N(z_H) = \pi_N(z_H)dt + (1 - r_N(z_H)dt)[(1 - \iota(z_H)dt)v_N(z_H) + \iota(z_H)dt \cdot 0]$, where $r_N(z_H)$ is the instantaneous rate of return of the extant Northern leader. $\iota(z_H)$ is the probability of displacement by a even superior generation. Reorganizing the above function, I solve out $r_N(z_H)$:

$$r_N(z_H) = \frac{\pi_N(z_H)}{v_N(z_H)} - \iota(z_H) \tag{9}$$

While, in the rest of industries $z_{\bar{H}} \in [0, \bar{z})$, moving-out strategy is preferred to moving-up strategy. Cheap labor force in the South attracts the followers to invest overseas. The quality level of the active MNE leader J^* is one step behind the Northern leader. In Lu (2007)'s paper, the expected market value for J^* in steady state is $v_F(z_{\bar{H}}) = \pi_F(z_{\bar{H}})dt + (1 - r_F(z_{\bar{H}})dt)[(1 - \iota(z_{\bar{H}})dt)v_F(z_{\bar{H}}) + \iota(z_{\bar{H}})dt \cdot 0]$, where $r_F(z_{\bar{H}})$ is the instantaneous rate of return of the MNE leader. $\iota(z_{\bar{H}})$ is the probability of displacement by a superior version faced by J^*. However, by permitting imitation, the $v_F(z_{\bar{H}})$ function is altered to be $v_F(z_{\bar{H}}) = \pi_F(z_{\bar{H}})dt + (1 - r_F(z_{\bar{H}})dt)[(1 - \iota(z_{\bar{H}})dt - M_F(z_{\bar{H}})dt)v_F(z_{\bar{H}}) + \iota(z_{\bar{H}})dt \cdot 0 + M_F(z_{\bar{H}})dt \cdot 0]$. The possibility of displacement by successful imitation of Firm S is added. Solving $r_F(z_{\bar{H}})$ out, I obtain a function different from Lu (2007):

$$r_F(z_{\bar{H}}) = \frac{\pi_F(z_{\bar{H}})}{v_F(z_{\bar{H}})} - \iota(z_{\bar{H}}) - M \tag{10}$$

In particular, from Section 3, it is calculated out that $\pi_N(z_H) = [1 - \frac{1}{\lambda(z)}]E^W$, and $\pi_F(z_H) = [1 - \frac{\lambda(z)}{\omega}]E^W$. It is obvious that $\pi_N(z_H)$ is increasing in z_H, and $\pi_F(z_{\bar{H}})$ is decreasing in $z_{\bar{H}}$. In the cutoff industry $\bar{z}'$, the nearest follower is indifferent between the moving-out strategy and the moving-up strategy. That is to say, the FDI venture and the R&D venture are equally profitable, i.e. $r_N(z_H) = r_F(z_{\bar{H}})$ at $\bar{z}$. The equal-profit equation for innovation and FDI for the follower $J - 1$ at the cutoff industry $\bar{z}'$ is:

$$\frac{\pi_N(\bar{z}')}{v_N(\bar{z}')} - \iota(\bar{z}') = \frac{\pi_F(\bar{z}')}{v_F(\bar{z}')} - \iota(\bar{z}') - M \tag{11}$$

$\iota(\bar{z}')$ on both sides cancel out. Then, since the imitation intensity M is taken as given, plugging the profit and value functions (6), (8), (5) and (7) into (11), it is

$$\frac{[1 - \frac{1}{\lambda(\bar{z}')}]E^W}{\omega a_N} - \iota(\bar{z}') = \frac{[1 - \frac{\xi\lambda(\bar{z}')}{\omega}]E^W}{a_F} - \iota(\bar{z}') - M \tag{ 11'}$$

Further substituting $E^W(t) = LE(t) + L^*E(t)^* = \omega L + L^*$ into the above function and arranging it into a quadratic function of ω, I derive

$$a_N L\omega^2 + [a_N L^* - \lambda(z)a_N L - a_N a_F M - (1 - \frac{1}{\lambda(z)})a_F L]\omega - \lambda(z)a_N L^* - (1 - \frac{1}{\lambda(z)})a_F L^* = 0 \tag{12}$$

By solving out equation (12), there are two possible results. The first cutoff function is

$$F(z) \equiv \frac{-B \pm \sqrt{B^2 - 4AC}}{2A} \tag{13}$$

where $A = a_N L$, $B = a_N L^* - \lambda(z) a_N L - a_N a_F M - (1 - 1/\lambda(z)) a_F L$, and $C = -\lambda(z) a_N L^* - (1 - 1/\lambda(z)) a_F L^*$.

It is difficult to prove the existence of solutions and decide which solution to drop. Also, it is very complicated to think the comparative statics here. More discussion will be elaborated in the calibration part.

Proposition 2 *Let* $G(\underline{z}) = \lambda(z)^2$. *Suppose Assumption 1 holds. Given that the MNE leader currently captures the world market, there exists an industry* $\underline{z}' \in (0, \bar{z}')$ *which satisfies* $G(\underline{z}') = \omega$, *such that: i) for any* $z_L \in [0, \underline{z}']$, *non-producing Northern firms exit the market, the dominant MNE leader has no incentive to undertake R&D, and thus the industry stagnates in the South. Southern imitators gradually substitute MNEs to occupy the market. At last, all these industries will be dominated by imitators. ii) for any* $z_M \in (\underline{z}', \bar{z}')$, *Southern indigenous firms engage in imitation. Non-producing Northern firms engage in innovation, targeting both MNEs and Southern imitators. After successful R&D, these industries return to the North.*

Proof: The second cutoff $\underline{z}$ is used to distinguish the low-technology and medium-technology industries. It is derived by solving out the equation $g(z) = \lambda(z)^2 = \omega$ if the R&D intensity is treated as endogenous. In fact, my function for the second cutoff is the same as Lu (2007), though the proof is a little different.

(1) For any low-technology industry $z_L \in [0, \underline{z}]$, $\lambda(z_L)^2 < \omega$. The increment to quality is very low.

- If a non-producing Northern firm succeeds in R&D and creates a new version of product, it will earn instantaneous profits equal to $\pi_N^{NP}(z_L) = (1 - \omega/\lambda(z_L)^2) E^W < 0$. Hence, it is unprofitable to conduct innovation, neither based on multinationals or imitators. These Northern non-producing firms will exit the market.

$$r_N^{NP}(z_L) = \frac{\pi_N^{NP}(z_L)}{v_N^{NP}} - \phi(z_L) < 0$$

- As proved in Proposition 1, moving-out strategy is preferred to moving-up strategy in all non-high-technology industries. Specifically, in low-technology industries, by charging a price of $\pi_F^{P^*} = \omega/\lambda(z_L)$, the producing MNE leader makes a flow of profits as $\pi_F(z_L) = (1 - \lambda(z)/\omega)E^W$, with the free-entry requirement $v_F^{P^*} - a_F = 0$.

Now I consider whether there is any motivation for these multinational leaders to undertake innovation and return production to the North. The instantaneous profits are $\pi_N^{P^*}(z_L) = (1 - \omega/\lambda(z_L))E^W$, if it leapfrogs the current leading-edge technology. In steady state, the market value equals to $v_N^{P^*}(z_L) = [\pi_N^{P^*}(z_L) - \pi_F^{P^*}(z_L)]dt - (1 - r_N^{P^*}(z_L)dt)\{[1 - \phi^{P^*}(z_L)dt]v_N^{P^*}(z_L) + \phi^{P^*}(z_L)dt \cdot 0\}$, with the probability that the ex-leader shifts production to the South and makes it valueless. Solving out this equation, the instantaneous rate of return is

$$r_N^{P^*}(z_L) = \frac{\pi_N^{P^*}(z_L) - \pi_F^{P^*}(z_L)}{v_N^{P^*}(z_L)} - \phi(z_L) < 0$$

It is because that the incremental profits to innovate for the MNE leader $\pi_N^{P^*}(z_L) - \pi_F^{P^*}(z_L) = (1 - \omega(z_L)/\lambda(z_L))E^W - (1 - \lambda(z_L)/\omega)E^W = [\frac{\lambda(z_L)}{\omega} - \frac{\omega}{\lambda(z_L)}]E^W < 0$ is negative. Hence, it makes $r_N^{P^*}(z_L) < 0$, since $\phi(z_L) \geq 0$ by definition.

(2) For any medium-technology industry $z_M \in (\underline{z}, \bar{z}')$, $\lambda(z_M)^2 \geq \omega$. The increment to quality is moderate.

- The Northern non-production firms are still discussed first. When the Northern leader improves upon the existing leading-edge blueprint, its instantaneous profits $\pi_N^{NP}(z_M) = (1 - \omega/\lambda(z_M)^2)E^W > 0$, with the free-entry condition $v_N^{NP}(z_M) - \omega a_N = 0$. In steady state, $v_N^{NP}(z_M) = \pi_N^{NP}(z_M)dt + (1 - r_N^{NP}(z_M)dt)\{(1 - \phi(z_M)dt)v_N^{NP}(z_M)dt + \phi(z_M)dt \cdot 0\}$. The instantaneous rate of return is figured out as

$$r_N^{NP}(z_M) = \frac{\pi_N^{NP}(z_M)}{v_N^{NP}(z_M)} - \phi(z_M) = \frac{(1 - \omega/\lambda(z_M)^2)E^W}{\omega a_N} - \frac{(1 - \omega/\lambda(z_M)^2)E^W}{\omega a_N} + \rho = \rho > 0$$

where the function of $\phi(z_M)$ comes from equation (16). These Northern firms will undertake R&D in order to recapture the leadership.

- For the multinational leader in medium-technology industries, there is no incentive for this firm to innovate, neither. Similar to the low-technology industries, the instantaneous profits for it is $\pi_F^{P^*}(z_M) = (1 - \frac{\omega(z_M)}{\lambda(z_M)})E^W$. After successful R&D, the profits become $\pi_N^{P^*} = (1 - \omega/\lambda(z_M))E^W$.

Combined with free entry condition $v_N(z_M) - \omega a_N = 0$, the potential incremental rate of return equals to

$$r_N^{P^*}(z_M) = \frac{\pi_N^{P^*}(z_M) - \pi_F^{P^*}(z_M)}{v_N^{P^*}(z_M)} - \phi(z_M) = \frac{(1-\frac{\omega(z_M)}{\lambda(z_M)})E^W - (1-\frac{\lambda(z_M)}{\omega})E^W}{\omega a_N} - \phi(z_M) < 0$$

4.2 Industry characteristics

Recall that the first cutoff is the solution $\bar{z}'$ to a complicated function (12), and the second cutoff is the solution $\underline{z}'$ to $G(\underline{z}) = \lambda(\underline{z})^2 = \omega$. The product cycle composition is presented in Figure 3.

4.2.1 High-technology industries

High-technology industries z_H are all located in the North, where $z_H \in Z_H = [\bar{z}', 1]$. The measure of these industries are denoted as n_H. Obviously, $n_H = 1 - \bar{z}'$.

When a new generation comes out in the North, the innovator becomes the leader $J(z_H) = J^*(z_H) + 1$. Without competition from the South, the price charged is a slightly lower than $p_N(z_H) = \lambda(z_H)\omega$, in order to debar all potential rivals. The total sales are $X_N(z_H) = \frac{E^W}{\lambda(z_H)\omega}$ world-widely, making its instantaneous profits $\pi_N(z_H) = (1 - \frac{1}{\lambda(z_H)})E^W$. The leader's expected value is $v_N(z_H)$. No arbitrage condition is $v_N(z_H) = \frac{\pi_N(z_H)}{\rho+\iota(z_H)}$, with the probability that a higher version of quality comes into being. In equilibrium, free-entry into R&D venture requires that the expected benefits equal costs, that is, $v_N(z_H) - \omega a_N = 0$.

Non-producing followers in the North engage in innovation, and $\iota(z_H) > 0$. A successful R&D investment brings the next quality version to light, and makes the current leader lose its dominant position. When a follower turns to be an industry leader, its price strategy is the same as its predecessor. The optimal research intensity is calculated out from the non-arbitrage condition:

$$\iota(z_H) = \frac{\pi_N(z_H)}{v_N(z_H)} - \rho = \frac{(1 - 1/\lambda(z_H))E^W}{\omega a_N} - \rho \tag{14}$$

It is $\partial\iota(z_H)/\partial\lambda(z_H) > 0$, $\partial\iota(z_H)/\partial L > 0$[4], $\partial\iota(z_H)/\partial L^* > 0$, $\partial\iota(z_H)/\partial\omega < 0$, $\partial\iota(z_H)/\partial a_N < 0$, $\partial\iota(z_H)/\partial\rho < 0$[5]. Higher R&D productivity and larger population in both countries promote the

[4] It is because $E^W = \omega L + L^*$

[5] The analytical functions for the derivatives are shown in Appendix 1.

Northern firms' interest to innovate, while a higher Northern wage, innovation cost or consumer discount rate reduces it.

In a nutshell, the high-technology industries stay in the North and the quality of products is upgraded continuously. None of the production line shifts to the South.

4.2.2 Low-technology industries

Because of imitation, the low-technology industries present different characteristics from Lu (2007). In fact, they are separated into two parts: the group of Firm F (denoted by z_{L1}) and the group of Firm S (denoted by z_{L2}). It is easy to think that $z_{L1} + z_{L2} = z_L$, where $z_L \in Z_L = [0, \underline{z}]$.

At the beginning, for a low-technology product, the second-to-top follower successfully invests in the South and begins to take advantage of the cheaper manufacturing cost. Hence, the technology leader in the South $J^*(z_{L1}) = J(z_{L1}) - 1$ is one step behind the North on the quality ladder. Its price is set at $p_F(z_{L1}) = \frac{\omega}{\lambda(z_L)}$, discounted by the lower-quality level to appeal to the consumers. With a flow of sales $X_L(z_{L1}) = \frac{\lambda(z_L)E^W}{\omega}$, its instantaneous profits are $\pi_N(z_{L1}) = (1 - \frac{\lambda(z_L)}{\omega})E^W$. The Northern firms will not engage in innovation, since the potential benefits are negative[6]; therefore, there is further innovation and $\iota(z_L) = 0$. However, there is incentive for Southern indigenous firms to imitate, with $M > 0$. As a result, no arbitrage condition makes the market value of $J^*(z_{L1})$ to be $v_F(z_{L1}) = \frac{\pi_F(z_L)}{\rho + M}$. In equilibrium, the free entry condition requires $v_F(z_{L1}) - a_F = 0$.

When imitation is successful, Firm S occupies the dominant position in the market. I call this kind of industries as z_{L2}. The technology level is $J^*(z_{L2}) = J(z_{L2}) - 1$. With a price of $p_S(z_{L2}) = 1$, the firm makes a flow of sales $X_S(z_{L2}) = E^W$, and instantaneous profits $\pi_S(z_{L2}) = 0$. Free-entry condition requires that $v_S(z_{L2}) = 0$. When technology is seized by Firm S, Northern innovators still have no incentive to conduct R&D. In addition, Firm F is unable to regain their market, since they charge a higher price. That is to say, $\phi(z_L) = 0$, and $\iota(z_L) = 0$.

Hence, in low-technology industries, the second-to-top technology is migrated to the multinationals first, then copied by the Southern imitators, and finally stagnate in these firms. The measure of multinationals declines over time, and correspondingly that of Southern imitators increases. Eventually, the indigenous firms will dominate all low-technology industries since they can

[6]If they win R&D, the price charged is $p_N(z_{L1}) = \lambda(z_L)^2$. The profits are $\pi_N = [p_N(z_L) - \omega]d_N^W < 0$.

hire labor at a lower cost.

4.2.3 Medium-technology (product-cycle) industries

For any medium-technology product $z_M \in Z_M = [\underline{z}, \bar{z}']$. There are three repeatable stages, which makes production to cycle between the North and South. In Stage 1, the multinational leader wins the Bertrand game and its quality is one step behind the industry leader. These industries are denoted as z_{M1}. In Stage 2, the Southern imitators might learn from the multinationals and have possibility to copy the patent. Once they succeed, they capture the entire market. There industries are denoted as z_{M2}. In Stage 3, the Northern leader wins the Bertrand game again and its quality is two steps above the multinational leader. These industries are denoted as z_{M3}. In total, it is $z_{M1} + z_{M2} + z_{M3} = z_M$. A product cycle might complete from Stage 1 to 2 to 3, or jump from Stage 1 to 3 directly.

At first, the nearest follower succeeds in FDI and shifts manufacturing to the South. The quality of this multinational leader's product is $J^*(z_{M1}) = J(z_{M1}) - 1$. Hence, it charges a price at $p_F(z_{M1}) = \frac{\omega}{\lambda(z_M)}$, with quantity sold $X_F(z_{M1}) = \frac{\lambda(z_M)E^W}{\omega}$, and positive profits $\pi_F(z_{M1}) = (1 - \frac{\lambda(z_M)}{\omega})E^W$. No arbitrage condition is $v_F(z_{M1}) = \frac{\pi_F(z_M)}{\rho + \iota(z_M) + M}$, with the displacement probability that the Northern leader recapture the market with an even higher quality level or the Southern imitators steal the technology. Combined with free-entry condition $v_F(z_{M1}) = a_F$, I obtain the research intensity of the Northern innovators:

$$\iota(z_M) = \frac{(1 - \lambda(z_M)/\omega)E^W}{a_F} - \rho - M \tag{15}$$

with $\partial\iota(z_M)/\partial\lambda(z_M) < 0$, $\partial\iota(z_M)/\partial\omega > 0$, $\partial\iota(z_M)/\partial L > 0$, $\partial\iota(z_M)/\partial L^* > 0$, $\partial\iota(z_M)/\partial a_F < 0$, $\partial\iota(z_M)/\partial\rho < 0$, and $\partial\iota(z_M)/\partial M < 0$. A higher R&D productivity, adaptation cost, consumers' discount rate, or the extent of imitation decreases the Northern firms' willingness to innovate. However, a higher relative wage and expanded labor endowment in both countries increase it.

It is also possible for Southern firms to acquire the whole market share after successful imitative R&D, with the same quality level of the previous multinational leader, or $J^*(z_{M2}) = J(z_{M2}) - 1$. Products are sold at a price of $p_S(z_{M2}) = 1$ with a quantity of $X_S(z_{M2}) = E^W$. Their instantaneous profits are $\pi_S(z_{M2}) = 0$. Free entry condition makes $v_S(z_{M2}) = 0$. No arbitrage condition requires $v_S(z_{M2}) = \frac{\pi_S(z_M)}{\rho+\iota(z_M)}$, with the probability that the Northern leader wins the pricing game and controls the market again.

Finally, production will return to the North if the innovators achieve success, and then the product cycle completes. There are two sources for the Northern firms to seize market: from a multinational leader or a Southern firm. The quality is now two generations ahead of the South, i.e. $J(z_{M3}) = J^*(z_{M3}) + 2$. Price is set at $p_N(z_{M3}) = \lambda(z_M)^2$, and quantity is $X_N(z_{M3}) = \frac{E^W}{\lambda(z_M)^2}$. The instantaneous profit is $\pi_N(z_{M3}) = (1 - \frac{\omega}{\lambda(z_M)^2})E^W$. No further innovation will take place since it is unprofitable. But the followers try to engage in FDI, and $\phi(z_M) > 0$. Free entry condition is $v_N(z_{M3}) - \omega a_N = 0$. No arbitrage condition is $v_N(z_{M3}) = \frac{\pi_N(z_M)}{\rho+\phi(z_M)}$. The intensity of the Northern followers is

$$\phi(z_M) = \frac{(1 - \frac{\omega}{\lambda(z_M)^2})E^W}{\omega a_N} - \rho \tag{16}$$

with $\partial\phi(z_M)/\partial\lambda(z_M) > 0$, $\partial\phi(z_M)/\partial\omega < 0$, $\partial\phi(z_M)/\partial L > 0$, $\partial\phi(z_M)/\partial L^* > 0$, $\partial\phi(z_M)/\partial a_N < 0$, and $\partial\phi(z_M)/\partial\rho < 0$. The extent of adaptation in z_{M3} industries rises with an increase in quality jump or expanded labor endowment in either country, and a decline in relative wage, innovation cost or consumers' discount rate.

Medium-technology industries reveal a product cycle pattern. Technology is transferred to the South through FDI first. Later, it may be imitated by indigenous firms over there. Northern firms make endeavor to improve the quality based on multinationals and imitators. Once they succeed, manufacturing shifts back to the North, and a new product cycle starts.

4.3 Market clearing conditions

Let n_H, n_{M1}, n_{M2}, n_{M3}, n_{L1} and n_{L2} be the measures of industries z_H, z_{M1}, z_{M2}, z_{M3}, z_{L1} and z_{L2} respectively. $n_{L1} + n_{L2} + n_{M1} + n_{M2} + n_{M3} + n_H = 1$. Specifically, the measure of high-technology industries is

$$n_H = 1 - \bar{z}' \tag{17}$$

All medium-technology industries aggregate to be

$$n_M = n_{M1} + n_{M2} + n_{M3} = \bar{z}' - \underline{z}' \tag{18}$$

The total measure of low-technology industries is

$$n_L = n_{L1} + n_{L2} = \underline{z}' \tag{19}$$

Product cycle only appears in medium-technology industries. The flows of goods adapted to the South via FDI and re-innovated in the North are constant in steady state, as shown in equation (20). Note that there are two sources of Northern innovation: multinationals and Southern local firms.

$$\phi(z_M) \cdot n_{M3} = \iota(z_M) \cdot (n_{M1} + n_{M2}) \tag{20}$$

From the equations (18) and (20), the measure of medium-technology industries dominated by Northern innovations is

$$n_{M3} = \frac{\iota(z_M)(\bar{z}' - \underline{z})}{\phi(z_M) + \iota(z_M)} \tag{21}$$

The labor market in the North is

$$L = \frac{E^W}{\lambda(z_M)^2} \cdot n_{M3} + \frac{E^W}{\lambda(z_H)\omega} \cdot n_H + \iota(z_M)a_N n_{M1} + \iota(z_M)a_N n_{M2} + \iota(z_H)a_N n_H \tag{22}$$

The first two terms on the right hand are the workforce engaged in manufacturing, and the last three terms are the workforce engaged in innovative R&D.

The labor market in the South is

$$L^* = \frac{\lambda(z_L)E^W}{\omega} n_{L1} + \frac{\lambda(z_M)E^W}{\omega} n_{M1} + E^W n_{L2} + E^W n_{M2} + \phi(z_M) n_{M3} a_F \tag{23}$$

On the right hand, the first two terms are the workers engaged in multinational manufacturing in low-technology and medium-technology industries respectively; the next two terms are the workers employed by Southern local firms in low-technology and medium-technology industries respectively;

and the last term is the workers engaged in adaptation; and the last two terms are the workers participated in adaption. There is no labor employed to engage in imitative R&D.

I define the aggregate rate of innovation $\iota(z) = \iota(z_M)n_{M1} + \iota(z_M)n_{M2} + \iota(z_H)n_H$. Taking this definition into equation (22) and also plugging in (17), (18) and (21), I solve out

$$\iota(z) = \frac{L - \frac{E^W}{\lambda(z_M)^2}\frac{\iota(z_M)(\bar{z}'-\underline{z})}{\phi(z_M)+\iota(z_M)} - \frac{E^W(1-\bar{z}')}{\lambda(z_H)\omega}}{a_N} \tag{24}$$

The aggregate rate of adaptation is defined as $\phi(z) = \phi(z_M)n_{M3}$. From equation (20), I can write ϕ in term of $\tilde{\iota}$ and other known functions.

$$\phi(z) = \iota(z) - \iota(z_H)(1 - \bar{z}') \tag{25}$$

where the function of $\iota(z)$ is shown in equation (24) and the function of $\iota(z_H)$ is shown in equation (14).

The average technology level in any country can be proxied by the aggregate industry measure. The proportion of industries located in the North in the steady-state is

$$n = n_H + n_{M3} = 1 - \bar{z}' + \frac{\iota(z_M)(\bar{z}' - \underline{z})}{\phi(z_M) + \iota(z_M)} \tag{26}$$

and the proportion of industries located in the South is

$$n^* = n_L + n_{M1} + n_{M2} = \bar{z}' - \frac{\iota(z_M)(\bar{z}' - \underline{z})}{\phi(z_M) + \iota(z_M)} \tag{27}$$

With the help of calibration, it seems possible to experiment the above concepts with an increased IPP in South. $\partial\tilde{\iota}/\partial a_S$, $\partial\tilde{\phi}/\partial a_S$, $\partial\tilde{\mu}/\partial a_S$, $\partial\tilde{n}/\partial a_S$ and $\partial\tilde{n}^*/\partial a_S$.

5 Comparative statics

Since the analytical model is sophisticated, I need the help of calibration to facilitate comparing different cutoff functions and their comparative statics graphically. I assign the quality increment $\lambda(z)$ to be a very simple function of z, i.e. $\lambda(z) = 1 + 0.1z + z^3$. It is obvious that $\lambda(z) \geq 1$,

$\lambda(z)' = 0.1 + 3z^2 > 0$, and in the extreme case $\lambda(0) = 1$. Hence, all previous assumptions of $\lambda(z)$ are satisfied. All parameter values are summarized in Table 2.

5.1 Shifts of the first cutoff $\bar{z}'$

First of all, I focus on the possible shift of cutoff points due to imitation. Obviously, the second cutoff point is the same as Lu's (2007) original point. I draw my cutoff functions and Lu's in the same Figure 4. The benchmark values in Table 2 are taken to sketch. The horizontal line represents the industry index from 0 to 1. $f(z)$ is the first cutoff function before imitation is added (Lu's (2007) result), and $F(z)$ is the corrected function with imitation. One of the solutions in equation (13) is dropped since it is negative with my parameter values[7]. It is very clear to see that the first cutoff point (where the $F(z)$ and $f(z)$ curves cross the horizontal line $\omega = 1.2$) has moved left from $\bar{z}$ to $\bar{z}'$. Meanwhile, the second cutoff point $\underline{z}$ (where the $G(z)$ curve cross $\omega = 1.2$) does not change. Part of previous medium-technology industries have switched to be high-technology ones, and hence the collection of product-cycle industries has been narrowed. It becomes safer to stay in the North when the multinationals face the risk of imitation, and then followers in more industries prefer moving-up strategy to moving-out strategy.

Proposition 3 *Adding imitation, fewer industries are transferred from the North to the South. The measure of product cycle industries gets narrowed.*

Next, I investigate the determinants to the cutoff points. Comparative statics are conducted with respect to various factors, such as the increment to quality, R&D costs, labor endowment and so on. Table 3 summarizes the simulated results. Further with the help of Figure 5 to 10, I show the movement of the cutoff functions as a result of the changes. Except Figure 10, all solid lines are plotted with the minimum values in Table 2, while all dashed lines are plotted with the maximum values. For simplicity, the $f(z)$ function is omitted from now on. I only experiment results with my own cutoff functions.

(1) Effect of relative wage ω

[7] The one dropped is $F(z) \equiv \frac{-B-\sqrt{B^2-4AC}}{2A}$, where $A = a_N L$, $B = a_N L^* - \lambda(z) a_N L - a_N a_F M - (1 - 1/\lambda(z)) a_F L$, and $C = -\lambda(z) a_N L^* - (1 - 1/\lambda(z)) a_F L^*$.

The relative wage is the value that the cutoff functions equal to, in order to find out the cutoff points. I suppose it to be exogenous in the theoretical model. As drawn in Figure 4, with an increase in ω (from 1.2 to 1.25), all cutoff points ($\underline{z}$, $\bar{z}$ and $\bar{z}'$) move to the right. The measure of low-technology industries expands, and that of high-technology industries shrinks. It is difficult to predict the change in medium-technology industry sizes. However, under reasonable parameterizations, it seems to be an expansion in medium-technology industries as well. Intuitively, when the relative wage rises, the manufacturing cost in the North increases, making less appealing to produce over there. The incentive for innovation also gets reduced. More firms will carry out FDI for cost saving. Hence, the measure of firms in the South enlarges.

(2) Effect of quality increment $\lambda(z)$

Hence, Figure 5 is sketched to test the influence of the increment to quality. From the left panel, the correlation between $\lambda(z)$ and $F(z)$ is discovered to be positive. It means that with an increase in the value of $\lambda(z)$ for each point z, the function should shift up. It is the same case for the $G(z)$ function.

This relationship is further illustrated in the right panel. The solid lines are the initial functions, drawn with $\lambda(z) = 1 + 0.1z + z^3$. And the dashed ones are new functions with an increase in $\lambda(z)$, calibrated with $\lambda(z) = 1+0.1z+2z^3$. For any $z \in [0, 1]$, the value of $\lambda(z) = 1+0.1z+2z^3$ is weakly greater than that of $\lambda(z) = 1 + 0.1z + z^3$ (if and only if $z = 0$, their values are equal). Except of the change in $\lambda(z)$ function, all other parameters remain their benchmark values. The simulation indicates that the dashed line generally locates above the solid one. As a result, the cutoff $\bar{z}'$ is moved to the left. It is because that when innovation productivity raises, it is more profitable to innovate in the North. The Northern firms' price is positively related to quality. Correspondingly, the share of industries preferring moving-up strategy is increased.

(3) Effect of the innovation cost a_N

As the unit innovation cost of the Northern firms a_N increases, the value of $F(z)$ decreases as a result, but the $G(z)$ function does not move. Thus, a right movement of $F(z)$ function makes $\bar{z}'$ to turn right as well. A few industries have switched from always staying in the North to experiencing a product cycle between the two regions. When the relative cost of further innovation rises, followers in more industries prefer to carry out FDI and transfer their production to the South. The range of product cycle industries is pushed toward the high-technology end of the industry spectrum.

(4) Effect of the adaptation cost a_F

Opposite to an increase of a_N, the adaptation cost a_F and $F(z)$ is positively correlated. Hence, the $F(z)$ function shifts up and then moves the cutoff point $\bar{z}'$ to the left, as displayed in Figure 9. The industries revealing product-cycle pattern turns to be a smaller group. More costly adaptation leads firms prefer to stay in the North.

(5) Effect of Northern labor endowment L

The left panel shows that the relationship between L and $F(z)$ is negative. As the labor resource in the North enlarges, the value of $F(z)$ goes up a little bit, which makes a right shift of the $F(z)$ curve. From Figure 6, the size of medium-technology industry expands slightly. On the other hand, the pressure in the Northern labor market has relieved, which is likely to pull down the relative wage. The collection of medium-technology industry gets fewer. In the right panel, it is shown that the latter influence overwhelms the former one. At last, the number of medium-technology industries goes down. It makes sense since it is easier and cheaper to hire labor in the North, thus leading to an expansion of high-technology industries.

(6) Effect of Southern labor endowment L^*

As display in Figure 7, at first, a larger Southern labor force shifts the $F(z)$ function to the right, resulting in a small expansion of medium-tech industry. Meanwhile, the competition in the Southern labor market is loosened, resulting in a lower Southern wage. While the Northern wage is unchanged, the relative wage ω goes up. It makes it relatively more expensive to produce in the North. The second effect dominates the first one. At last, the number of medium-technology industries grows even larger. More followers in the North prefer to carry out FDI in the South.

(7) Effect of imitation intensity M

Finally, I look at the potential impact from strengthened IPP in the South, with the help of Figure 10. Different from previous discussion, the solid line now is calibrated with the highest value of M in Table 2, and the dashed line is with the lowest value. The shifting from the solid line to the dashed line results from tighter IPP, which is reflected by a drop of M from 1.5 to 0.5.

The first cutoff $\bar{z}'$ moves to the right, indicating the measure of product-cycle industries turns larger, while the second cutoff $\underline{z}$ is fixed. The protection lets the multinationals feel safer, and makes them to earn a positive profit for a longer period. More Northern followers will join in the group to conduct FDI.

Proposition 4 *The strength in Southern IPP expands the number of product-cycle industries.*

6 Empirical tests

In the theoretical part, I set up a dynamic product cycle model with vertical differentiation. Heterogeneity in industrial R&D productivity drives non-producing firms to endogenously choose between push upward quality frontier or migrate manufacturing to the South. Particularly in industries of moderate technology levels, the production line moves back and forth between the North and South. These so-called product-cycle industries confront with a risk of Southern imitation, which can be relieved by tighter IPP. This section is to test empirically whether enhanced IPP in the South promotes the development of product-cycle industries.

6.1 Previous works

Compared to substantial theoretical works on product cycle, the investigation on related empirics is far lagging behind. The biggest empirical issue evolves identifying product cycle. Usually, trade economists believe that dynamics in production location results in a switch in trade balance. The Southerners initiate exporting to the North when the know-how leaks into their countries. On the basis of this change, the economists successfully capture the existence of product cycle by and large.

The most common technique is to look into the depth of U.S. trade balance. Firstly put forward by Gagnon and Rose (1995)[5], a product cycle good is defined as any Standard International Trade Classification (SITC) 5-digit code of whom a country trade balance changes from a net exporter to a net importer. Zhu (2005)[36] adjusts this definition to convert from a pure importer (positive imports and *zero* exports) to an exporter. Moreover, Xiang (2005[34], 2007[35]) compares the product listings of the 1987 Standard Industrial Classification (SIC) manual and the 1972 SIC manual, and claims that the new goods are those recently produced in the U.S. between 1972-1987. Then for each 4-digit industry, the South's new products exports (to the U.S.) relative to the North's, normalized by the South's old products exports relative to the North's, reveals a U-shape over time. On average, it takes the South fifteen years to catch up with the North. This discovery lends support to the product cycle theory.

All three papers mentioned above distinguish out product-cycle goods for each individual country. Feenstra and Rose (2000)[2] attempt to rank goods world-widely. They argue that commodities start exporting to the U.S. in an order of complexity. That is to say, the later a good appears in the global market, the less sophisticated it is. Since any product is exported by a partial list of countries, taking account of these "missing" observations make their work a very complicated process.

Based on more disaggregated Harmonized System (HS) ten-digit level data, Schott (2002)[28]'s method is totally different. The degree of intra-industry trade (IIT) is considered to be a striking signal of production shifting. The U.S. exports share a similar product mix with relatively high-wage countries. In a few industries, textile for example, they are substituted by low-wage countries, although the unit values of U.S. exports for overlapped products are still significantly higher. It indicates that the U.S. is moving up its production line while shifting out some dated ones to developing countries.

6.2 Basic specification

To track the changing pattern of product cycle trade across industries, I adopt Zhu's (2005)[36] concept. Recall that if a country turns from an importer (positive imports and zero exports) from the U.S. to an exporter to the U.S., this specific product is classified to be a product-cycle good. The shift in bilateral trade status accords with the essential feature of product cycle theory. As pointed out by Zhu (2005), it is difficult to observe the switch pattern at higher levels of aggregation, and the U.S. trade dataset from the NBER has changed the goods classification for a few times. So she picks up the longest 1978-88 period with products defined at SITC (Rev. 2) 5-digit level.

I take advantage of the most disaggregated data available to the public. A product is defined as any HS10 code shipping from a certain country. An industry is defined as any SIC 4-digit code. Since the HS codes came into use in 1989, I focus on trade data after that year. More aggregated definition of product and industry with longer sample period will be checked in the robustness part. Basically, there are two requirements for a product-cycle good: first, a country must export this good to the U.S. after 1989; second, before exporting, this country must have imported this good from the U.S.

Then for each industry, I calculate out the share of product cycle trade. Let X_{cjt}^{P} be the total export value of product-cycle goods and X_{cjt} is the export value of all goods, where j indexes for industry, c indexes for country and t indexes for year. The product-cycle intensity is defined as

$$PC_{cjt} = X_{cjt}^{P}/X_{cjt} \tag{28}$$

This intensity is a number between 0 and 1, making it comparable across countries.

There are two potential causes for any change in the product-cycle intensity: the number of product cycle goods within an industry (the extensive margin) and the volume of trade (the intensive margin). Due to Zhu (2005)'s definition, once a product cycle good is recognized, the extensive margin is consistent over time. From my theoretical model, the South starts exporting a good when the Northern followers migrate production to it, and later the know-how may be learnt by local firms. As assumed, the cost of imitation is negligible due to perfect competition in the South. The only thing to concern about is the investment from the U.S. On the other hand, for the intensive margin, the determinants of trade volume have been examined substantially. Trade costs, factor endowment, financial development, institution quality all might be influencing factors (Keller and Yeaple, 2013[20]; Manova, 2013[24]). I need to take these factors into account.

One big merit of measuring a trade share instead of trade volume is that some common impacts on bilateral trade have been ruled out. As long as they have symmetric effects on the product cycle goods and other products of the same industry, the product cycle intensity is not affected.

An observation is a 4-digit SIC industry j from country c in year t. The baseline specification looks as follows.

$$PC_{cjt} = \alpha_j + \alpha_t + \alpha_1 \cdot IPP_{ct} + \alpha_2 \cdot IPP_{ct} \cdot R\&D_{jt} + \alpha_3 \cdot IPP_{ct} \cdot R\&D_{jt}^2 + \sigma W_{ct} + \epsilon_{cjt} \tag{29}$$

where IPP_{ct} is the measure of IPP enforcement in country c at year t. $R\&D_{jt}$ is a measure of industry R&D intensity, which is the proxy for technology level. W_{ct} is a vector of time-variant controls, such as FDI, finance conditions, tariff and factor endowment. α_j are the industry fixed effects, and α_t are the year fixed effects. Adding these fixed effects is to account for unmeasured changes. Finally, since my regressor of interest is aggregated at the industry level, so the errors ϵ_{cjt} are also clustered by industry.

It is predicted that with stronger Southern IPP, the size of product-cycle trade gets enlarged, especially in industries with moderate technology level. A few high-technology industries which were restricted within the North are now transformed to shift between the two countries. It is difficult to figure out the exact cutoffs of of industries with real data. So basically, I am interested in whether IPP has a significantly positive impact on product-cycle intensity, that is, $\alpha_1 > 0$. Further more, I expect the coefficient on the linear interaction term is positive and the coefficient on the quadratic interaction term is negative, i.e. $\alpha_2 > 0$ and $\alpha_3 < 0$. The promoting effect of IPP is increasing with industrial R&D level. However, it stops growing in industries with relatively-high technology, since these industries never transfer to the South. Hence, the relationship between PC_{cjt} and IPP_{ct} displays an inverse-U shape.

The first econometric problem remaining is a selection bias. As justified by Xiang (2007), on average it takes the developing countries 15 years to catch up with the U.S. Though my dataset covers a period of 17 years, yet a large number of product-cycle intensities are valued at zero. It might be due to no product cycle good in industry i of country c at all, or the product cycle goods have not started exporting to the U.S. at year t. Hallak (2006)[13] points out that omitting these zero-valued observations may cause a bias in the coefficient magnitude, although it usually has no effect on the sign.

A common approach is to apply the Heckman 2-stage selection model (e.g. Helpman, Melitz, and Rubinstein, 2008; Johnson, 2008[18]; Keller and Yeaple, 2013). Following the previous work, I also estimate a binary outcome model at the first step and then use the predicted probability as an additional explanatory variable at the second step. The exclusion condition should be correlated with the probability of containing a product-cycle good within an industry, but unrelated to the size of the product-cycle intensity itself. In the light of my model, some fixed adaptation costs might be a good choice.

Another important concern is endogeneity. There might be a two-way effect between the dependent variable PC_{cjt} and the primary explanatory variable of interest IPP_{ct}. Countries of more product cycle trade may choose to adopt a tighter policy on intellectual property rights. To deal with this issue, I employ instrumental-variable approach. Any valid instruments should be correlated with a country's IPP enforcement, but uncorrelated with the standard errors.

In a few literature (Nunn, 2007[26]; Maskus and Yang, 2012[25]), the colonial or historical origin of a country's legal system is adopted as a natural candidate. It obviously relates to the degree of IPP, but seems no direct impact on trade. A country's legal system may emanate from any of these five origins: British common law, French civil law, Socialist law, German law and Scandinavian law. Among them, the Scandinavian law is taken out to be the reference group, in order to prevent collinearity. A group of dummy variables B_c, F_c, S_c and G_c is created to indicate whether a country c's legal system comes from British, French, Socialist or German respectively. Interactions will also be instrumented. Other instrumental variables may also be used.

6.3 Data source

The fundamental dataset I rely on is unbalanced U.S. trade panel in years 1989-2006 from the NBER[8]. It is the most disaggregated dataset publicly available, down to 10-digit Harmonized System level. I denote a HS10 code as a product and a SIC code as an industry. Then I make up the product-cycle intensity at the industry level.

Starting from Vernon (1966), the United State is considered to be the most advanced country in the world and is the birthplace of new technology. As a result, I suppose the U.S. as the North. The World Bank classifies countries into different income groups. Any country with a gross national income per capita below U.S. \$6,000 in 1988 (calculated using the Atlas method) is considered to be a South. The U.S. GNI is \$22, 740 that year. The list of Southern countries are shown in Table 4.

The R&D intensity data is calculated by Lei Yang in Hong Kong Polytechnic University. (should know how she calculates this) To make it concordant and trackable, I assume that the R&D intensity is the same for all sample countries.

There are two widely-used measures of IPP enforcement at the country level. The first one is the Ginarte and Park (1997[6]; GP for short) index, which covers five aspects of patent laws:

[8]Data is available on $http://faculty.som.yale.edu/peterschott/sub\_international.htm$.

coverage of fields of technology, membership in international patent agreements, provisions for loss of protection, legal enforcement, and patent duration. Each aspect takes a value between 0 and 1, and are summed up to get the GP index. This index is available every five year in a period of 1960 to 2005. However, a higher value of the GP index does not necessarily indicate an efficient administrative and judicial enforcement. Later, the Hu and Png (2013)[15] index (PR for short) comes out to correct for problems with GP. It is the product of two variables: $PR = GP \times Fraser$, where $Fraser$ is the Fraser Institute's index of legal systems and property rights[9]. This index ranges from 0 to 10 and exists at five-year intervals from 1970 to 2005. The PR index is my primary proxy for IPP enforcement. The GP index is also employed in the robustness part.

The Bureau of Economic Analysis provides open access to limited information about U.S. direct investment abroad, at a total of only 59 countries. So I choose the annual records of inward FDI stock from all countries instead, which is available on the UNCTAD website. Furthermore, the measure of financial development is the amount of credit by banks and other financial intermediaries to the private sector as a share of GDP (private credit), which I obtain from the World Bank's Financial Development and Structure Dataset.

GDP per capita is gross domestic product divided by midyear population in current U.S. dollars. Simple mean applied tariff is the unweighted average of effectively applied rates for all products subject to tariffs calculated for all traded goods, available from 1988. The adaptation cost is the business start-up procedures as a percentage of GNI per capita. It is calculated since 2003. All three controls come from the World Bank indicators.

Data on factor endowments are from Maskus and Yang (2012). The relative skilled-labor endowment is the ratio of the population over 25 that finished at least a secondary education to the population in this group that did not complete high school. The capital endowment is estimated by the perpetual inventory method using the investment data of each exporter.

Finally, population sizes are from the Penn World Table 7.0. Distance is the simple distance between most populated cities and is from the CEPii website. The rule of law and corruption indices are from the World Governance Indicators[10] by Kaufmann Kraay and Mastruzzi (2010)[19].

[9] Available at *http://www.freetheworld.com/release.html*.

[10] Available at *http://www.govindicators.org*.

6.4 Descriptive statistics

In all, the baseline panel data contains 348 four-digit SIC manufacturing industries from 37 countries every five year from 1990 to 2005. There is a total of 8,971 country-industry combinations, and 22,278 observations in total. Among these sample countries, ten countries' legal system originates from England; China, Hungary, Poland and Romania originates from the Socialism; South Korea originates from Germany, and the rest are all original from France.

Summary statistics are shown in Table 5. Specifically, PC is the product cycle intensity. The average value of my product-cycle intensity is a little lower than Zhu (2005), since my definition is more disaggregated. Figure 11 is a 50-bin histogram of product-cycle intensity. Not very surprising, 51.52% of observations have a zero value of PC and more than 75% observations has an intensity below 0.161. Moreover, Figure 12 describes the distribution of industrial R&D intensity. The 50-bin histogram skews to the left. With a tiny average of 0.022, it ranges from 0 to 0.337.

Table 6 and 7 test the correlation among regressors and IVs. The correlation between PC and PR is a small positive number of only 0.065. The correlations among the dependent variable and legal origin are all very small. If a country's law originates from the Socialism and Germany, it seems a negative correlation with the product cycle intensity. Also, it is negatively correlated between PC and geographic distance. The farther is this country away from the U.S., it is less likely for it to receive investment and learn the technology.

6.5 Empirical results

6.5.1 Basic results

I start from basic pooled OLS estimates. Table 8 presents a few attempts. Column (1) examines the simple relationship between the product cycle intensity and IPP enforcement without any controls. The coefficient on the IPP is below zero, although I expect it to be positive. However, the estimated coefficients of α_2 and α_3 accords with my prediction, and are also significant. The promotion effect of IPP on the product-cycle trade increases with industry R&D level, but it stops when the R&D intensity reaches a certain level. By adding the full set of controls in column (2), the sample size reduces to almost one-fifth. the signs on major regressors of interest do not change, while the magnitude becomes smaller. FDI, tariff and previous years' IPP are all discovered to be a negative effect, which contradicts the intuition. From column (3) to (8), year and industry fixed effects are taken into account. The R^2 improves a lot. However, the significance of interaction terms is lost. In column (8) with the full set of controls, the only significant positive impact results from the financial development measure, and this influence is small in size.

Since the dependent variable is a continuous number between 0 and 1, I conduct the logit estimation in Table 9, with the same set of regressions as OLS. The significance gets improved in almost all cases, and the magnitude gets enlarged.

Table 10 contains three groups of Heckman 2-stage estimates. For each group, the second column is the first stage results, the third column is the mills ratio and the first column shows the second stage results. The mills ratio λ is included in the second stage regressors. The sample size is even smaller, since I only look at the trade data in 2005. Since it usually takes a while to build up a factory, the cost of set up business in 2004 for sample countries is used as the exclusion restriction. The Wald χ^2 test shows that in all three groups the correlation is very significant. However, all IPP related terms is insignificant even at 10-percent level.

6.5.2 IV estimates

Table 11 is instrumented with legal origin. Since there are twelve instruments in total, only the second stage results are shown. Without any fixed effects, the estimates in the first two columns are closer to what I need, and not very different from pooled OLS estimates. The Durbin-Wu-Hausman (DWH) test rejects the hypothesis that the regressors are exogenous. However, when the year and industry fixed effects are added, I cannot reject the hypothesis of the exogeneity of regressors. Also, the coefficients on IPP terms are different from my expection.

Moreover, Table 12 is instrumented with geographic distance. I make an assumption that countries locating closer to the U.S. face more pressure from the U.S. to enforce better institution, especially patent protection. The results are no better than the previous trail.

6.5.3 Robustness checks

(will be added later. with different definition of PC, GP, with year dummy, annual trade data with lagged PR, different country income group, drop China, rule of law as IV)

7 Conclusion

limitation: exogenous wage rate

References

[1] David Dollar. Technological innovation, capital mobility, and the product cycle in north-south trade. The American Economic Review, 76(1):177–190, 1986.

[2] Robert C. Feenstra and Andrew K. Rose. Putting things in order: Trade dynamics and product cycles. The Review of Economics and Statistics, 82(3):pp. 369–382, 2000.

[3] H. Flam and E. Helpman. Vertical product differentiation and north-south trade. The American Economic Review, pages 810–822, 1987.

[4] J Jaskold Gabszewicz, Avner Shaked, John Sutton, and J-F Thisse. International trade in differentiated products. International Economic Review, pages 527–534, 1981.

[5] Joseph E. Gagnon and Andrew K. Rose. Dynamic persistence of industry trade balances: How pervasive is the product cycle? Oxford Economic Papers, 47(2):pp. 229–248, 1995.

[6] Juan C Ginarte and Walter G Park. Determinants of patent rights: A cross-national study. Research policy, 26(3):283–301, 1997.

[7] Amy Jocelyn Glass. Outsourcing under imperfect protection of intellectual property. Review of International Economics, 12(5):867–884, 2004.

[8] Amy Jocelyn Glass and Kamal Saggi. Intellectual property rights and foreign direct investment. Journal of International Economics, 56(2):387–410, 2002.

[9] Amy Jocelyn Glass and Xiaodong Wu. Intellectual property rights and quality improvement. Journal of Development Economics, 82(2):393–415, 2007.

[10] Gene Grossman and Elhanan Helpman. Endogenous product cycles. Economic Journal, 101(408):1214–29, 1991b.

[11] Gene M Grossman. Innovation and Growth in the Global Environment. MIT press, Cambridge, MA, 1991a.

[12] G.M. Grossman and E. Helpman. Quality ladders and product cycles. The Quarterly Journal of Economics, 106(2):557–586, 1991c.

[13] Juan Carlos Hallak. Product quality and the direction of trade. Journal of International Economics, 68(1):238 – 265, 2006.

[14] Elhanan Helpman. Innovation, imitation, and intellectual property rights. Econometrica, 61(6):1247–80, 1993.

[15] Albert GZ Hu and IPL Png. Patent rights and economic growth: Cross-country evidence. Oxford Economic Papers, 65(3):675–698, 2013.

[16] Richard Jensen and Marie Thursby. A strategic approach to the product life cycle. Journal of International Economics, 21(3):269–284, 1986.

[17] Richard Jensen and Marie Thursby. A decision theoretic model of innovation, technology transfer, and trade. The Review of Economic Studies, 54(4):631–647, 1987.

[18] Rober C. Johnson. Trade and prices with heterogeneous firms. Unpub. paper, UC Berkeley, 2008.

[19] Daniel Kaufmann, Aart Kraay, and Massimo Mastruzzi. The worldwide governance indicators: A summary of methodology, data and analytical issues. World Bank Policy Research Working Paper, 5430, 2010.

[20] Wolfgang Keller and Stephen R Yeaple. The gravity of knowledge. American Economic Review, 103(4), June 2013.

[21] Paul Krugman. A model of innovation, technology transfer, and the world distribution of income. the Journal of political economy, pages 253–266, 1979.

[22] Edwin L-C Lai. International intellectual property rights protection and the rate of product innovation. Journal of Development economics, 55(1):133–153, 1998.

[23] Chia-Hui Lu. Moving up or moving out? a unified theory of r&d, fdi, and trade. Journal of International Economics, 71(2):324–343, 2007.

[24] Kalina Manova. Credit constraints, heterogeneous firms, and international trade. The Review of Economic Studies, 80(2):711–744, 2013.

[25] Keith E Maskus and Lei Yang. The impacts of post-trips patent reforms on the structure of exports. Discussion Papers (by fiscal year), 2012:2011, 2013.

[26] Nathan Nunn. Relationship-specificity, incomplete contracts, and the pattern of trade. The Quarterly Journal of Economics, 122(2):569–600, 2007.

[27] Selin Sayek and Fuat Şener. Outsourcing and wage inequality in a dynamic product cycle model. Review of Development Economics, 10(1):1–19, 2006.

[28] P.K. Schott. Moving up and moving out: Us product-level exports and competition from low wage countries. Yale School of Management mimeo, 2002.

[29] Paul S Segerstrom, Thirumalai CA Anant, and Elias Dinopoulos. A schumpeterian model of the product life cycle. The American Economic Review, pages 1077–1091, 1990.

[30] Fuat Sener and Laixun Zhao. Globalization, r&d and the ipod cycle. Journal of International Economics, 77(1):101–108, 2009.

[31] Nancy L Stokey. Learning by doing and the introduction of new goods. The Journal of Political Economy, pages 701–717, 1988.

[32] M Scott Taylor. 'quality ladders' and ricardian trade. Journal of International Economics, 34(3):225–243, 1993.

[33] R. Vernon. International investment and international trade in the product cycle. The quarterly journal of economics, pages 190–207, 1966.

[34] Chong Xiang. New goods and the relative demand for skilled labor. The Review of Economics and Statistics, 87(2):pp. 285–298, 2005.

[35] Chong Xiang. Product cycles in us imports data. Purdue University working paper, 2007.

[36] S.C. Zhu. Can product cycles explain skill upgrading? Journal of International Economics, 66(1):131–155, 2005.

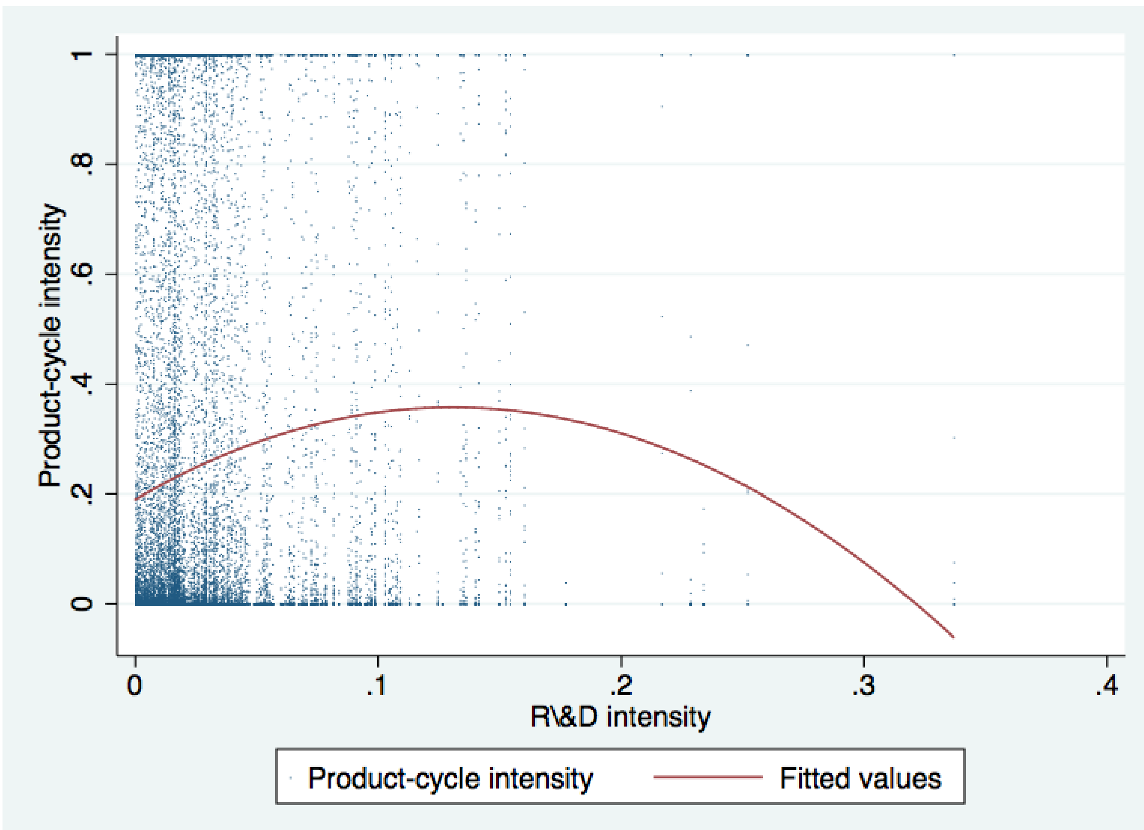

Figure 1: Quadratic fitted relationship between R&D intensity and product-cycle intensity

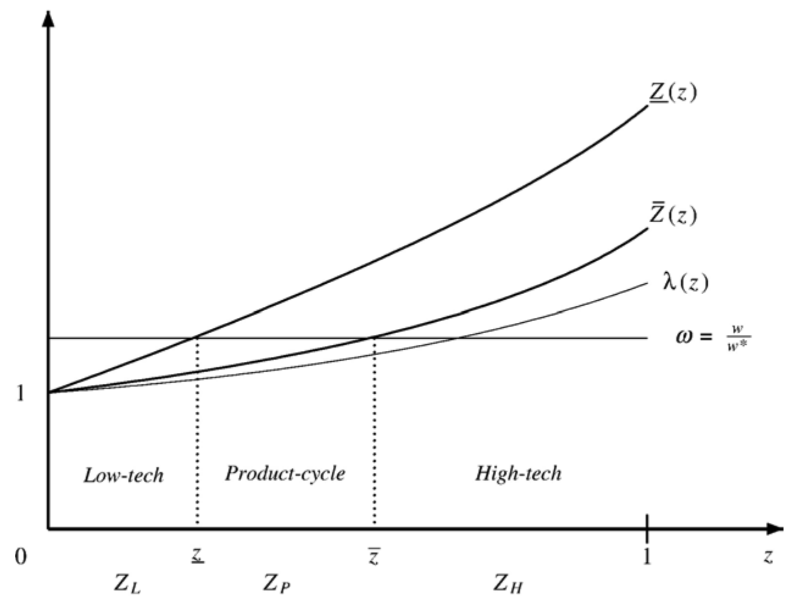

Figure 2: Industry spectrum is endogenously divided into three groups by z

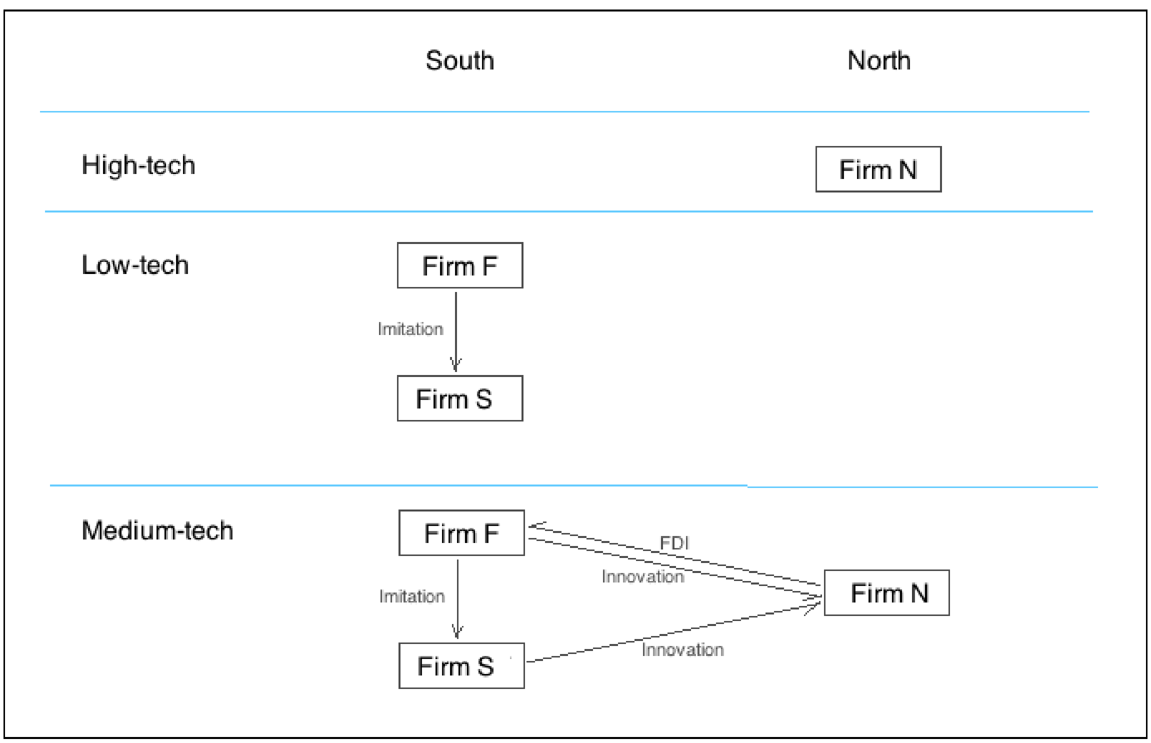

Figure 3: Product cycle composition

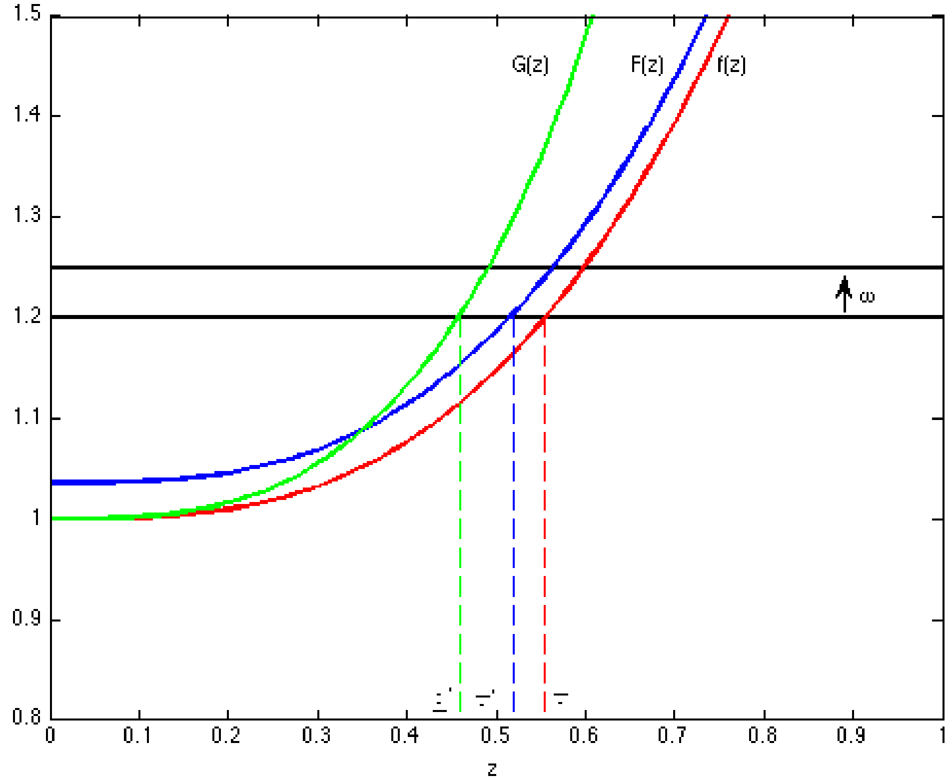

Figure 4: Cutoff shift with Southern imitation

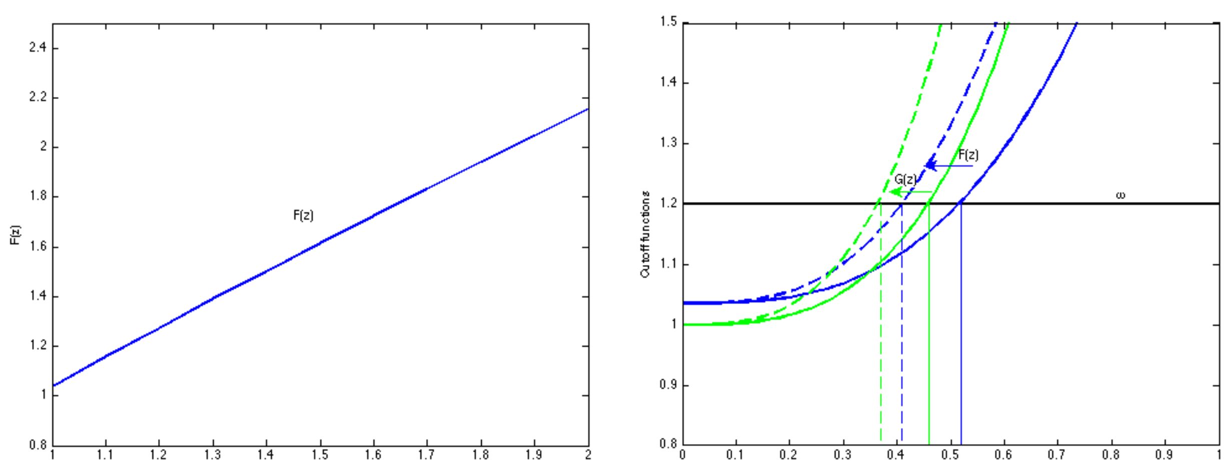

Figure 5: The effect of higher quality increment on cutoffs

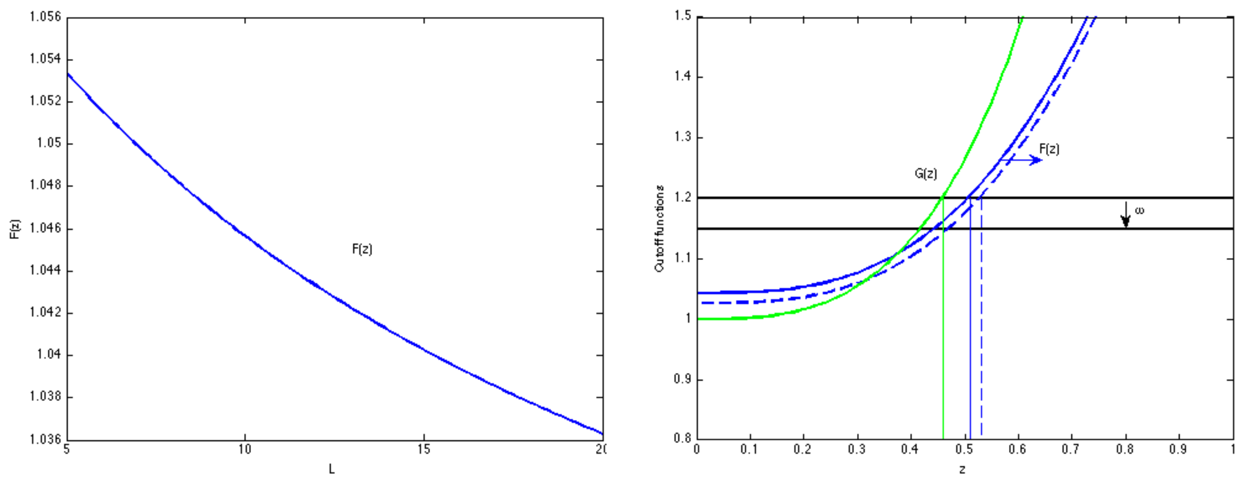

Figure 6: The effect of larger labor endowment in the North

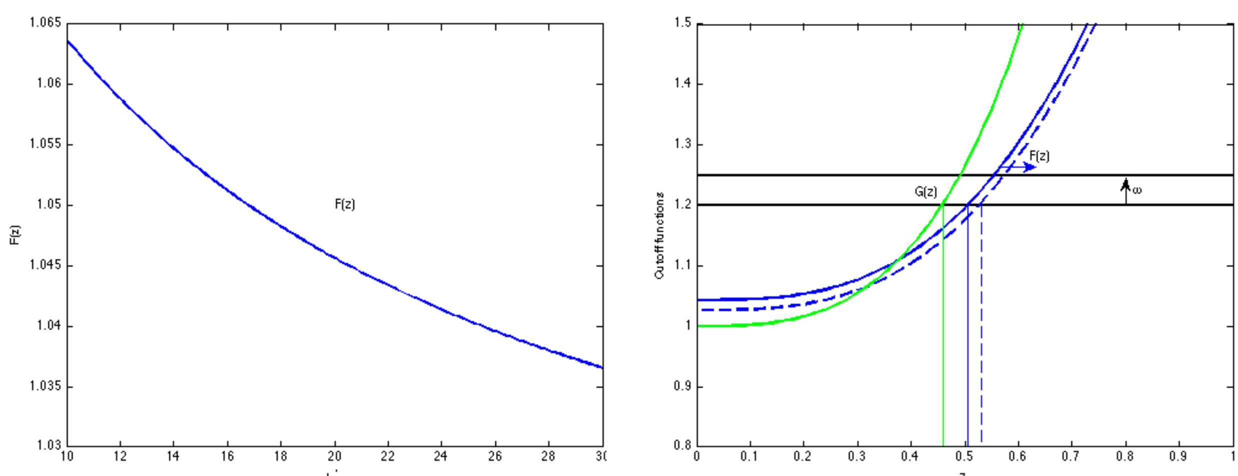

Figure 7: The effect of larger labor endowment in the South

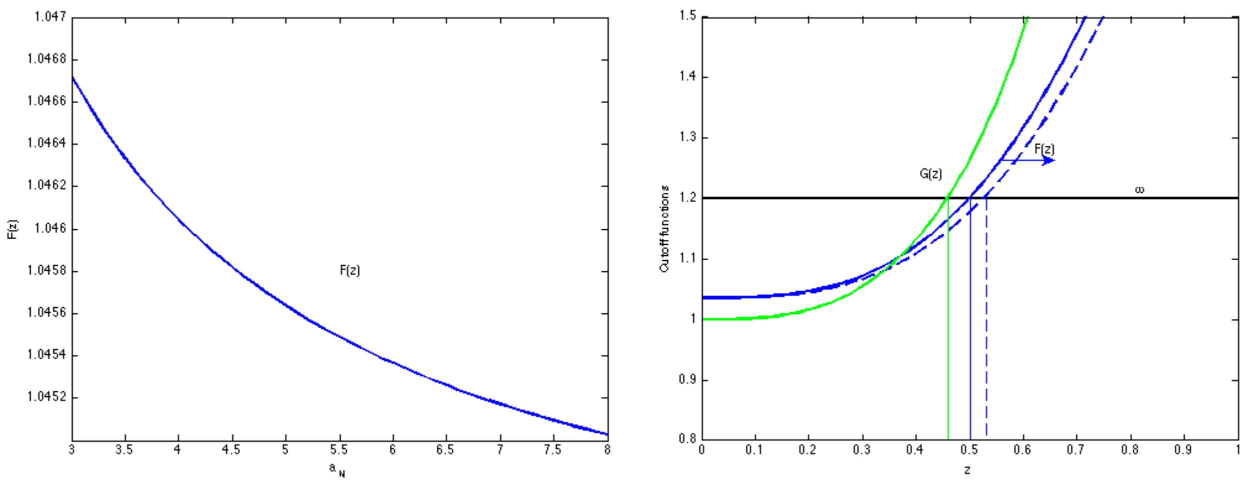

Figure 8: The effect of innovation cost on cutoffs

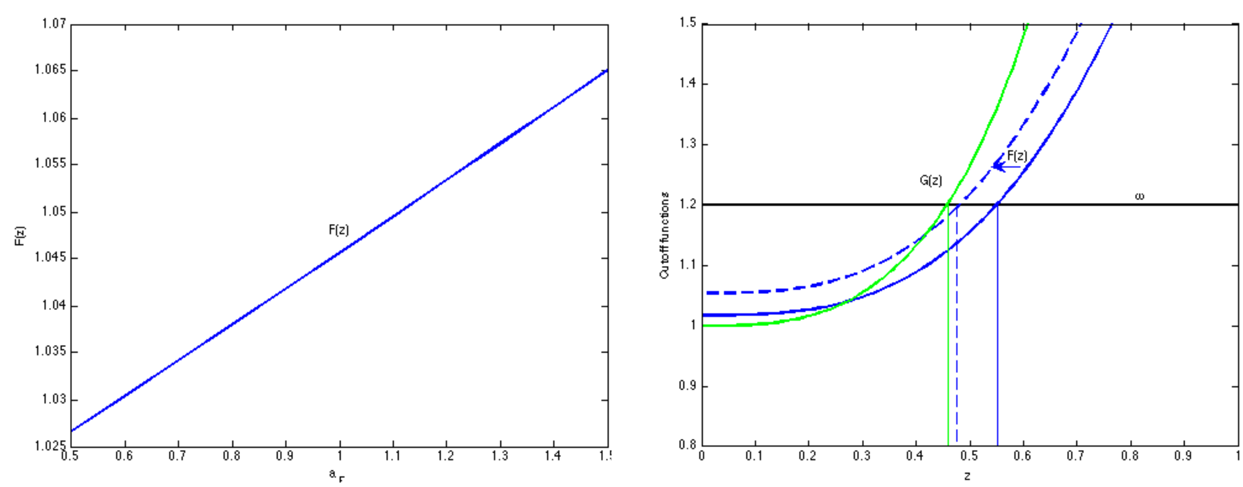

Figure 9: The effect of adaptation cost on cutoffs

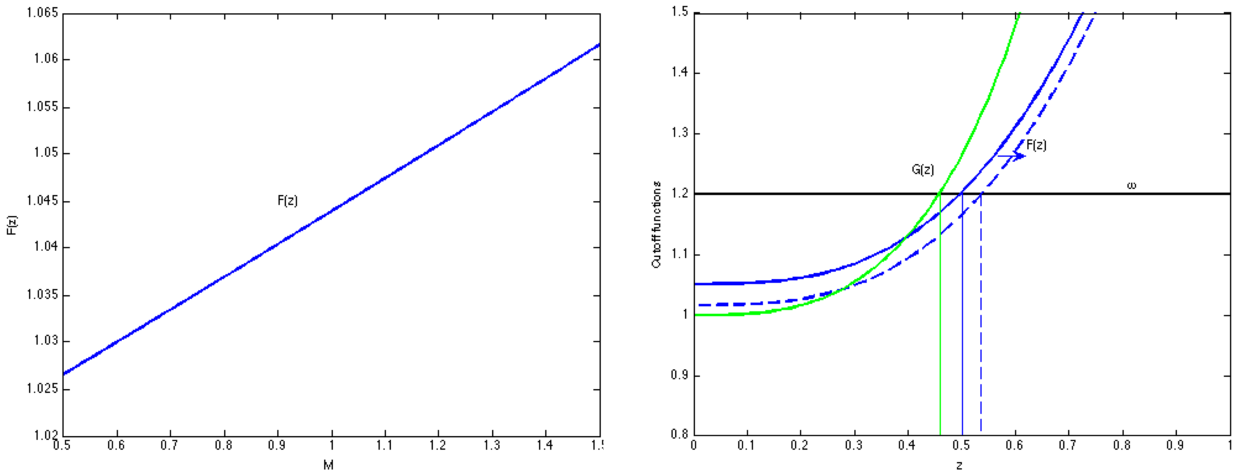

Figure 10: The effect of stronger Southern IPP on cutoffs

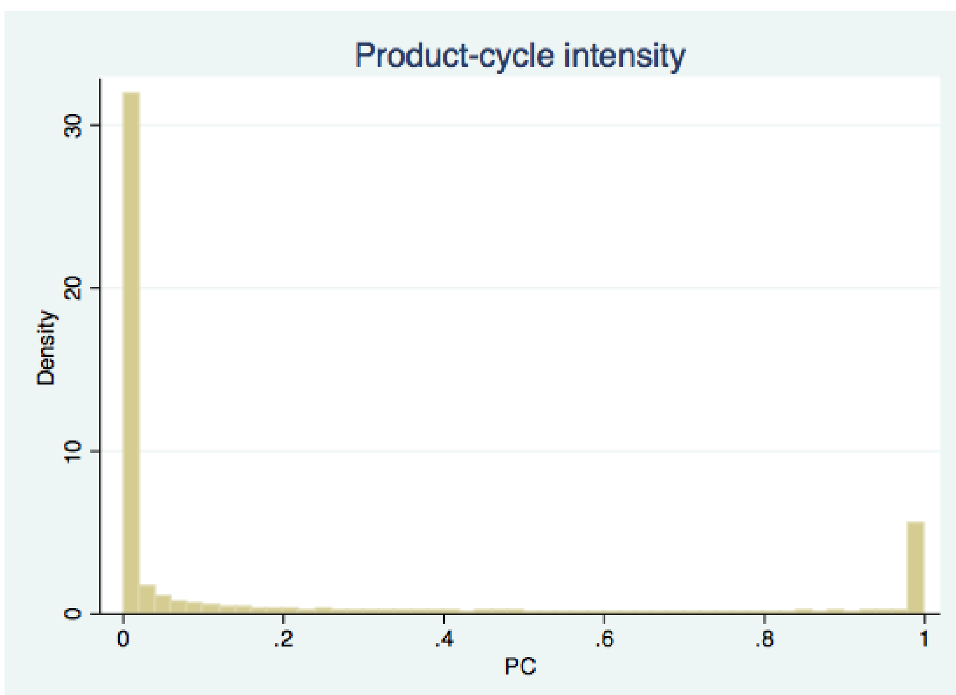

Figure 11: 50-bin histogram of product-cycle intensity

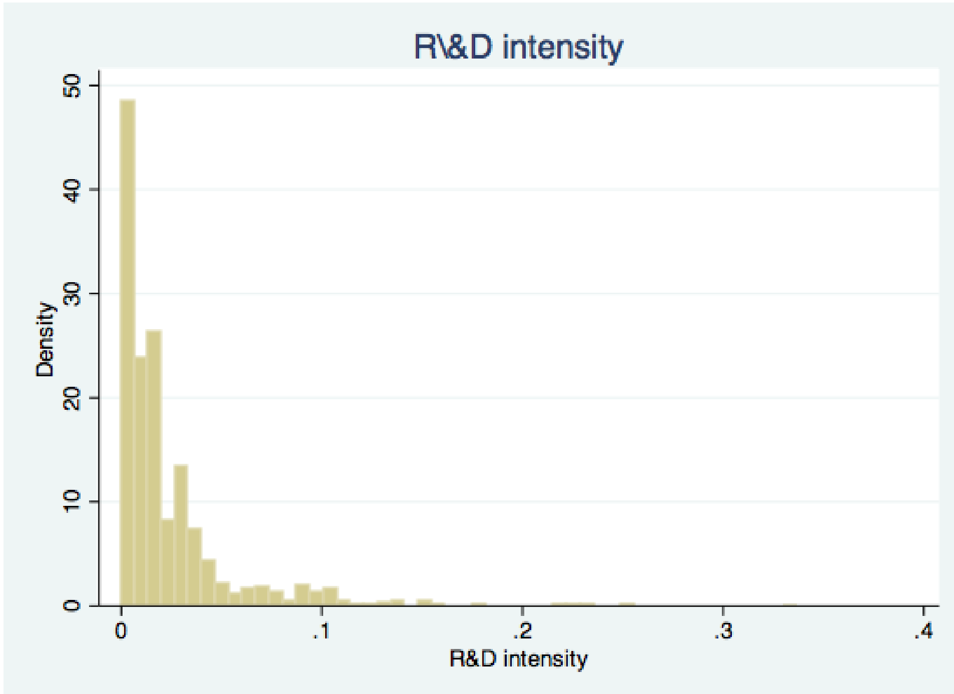

Figure 12: 50-bin histogram of R&D intensity

Table 1: Firm characteristics

Firm	Quality	Price[a]	Unit production cost	Unit R&D cost	R&D intensity	Stock value
N	J	$\lambda(z)^{J-J^*}\omega$ or $\lambda(z)^{J-J^*}$	$\omega > 1$	ωa_N	$\iota(z)$	v_N
F	J^*	$\frac{\omega}{\lambda(z)^{J-J^*}}$	1	a_F	$\phi(z)$	v_F
S	J^*	1	1	–	M	-

[a] Prices are calculated when profits are positive.

Table 2: Parameter values for simulation

Economic meaning	Notation	Benchmark	Low	High
Industry index	z	0.2	0	1
Relative wage	ω	1.2	-	1.3
Labor endowment in the North	L	10	5	20
Labor endowment in the South	L^*	20	10	30
Resource requirement in innovation	a_N	5	3	8
Resource requirement in imitation	a_S	3	1	5
Resource requirement in adaptation	a_F	1	0.5	1.5
Subjective discount rate	ρ	0.05	0.01	0.1
Quality increment[a]	λ	$\lambda(z) = 1 + 0.1z + z^3$	1	2
Imitation intensity	M	1.05	0.5	1.5

[a] The new $F(z)$ curve in Figure 5 is calibrated when $\lambda(z) = 1 + 0.1z + 2z^3$.

Table 3: Comparative statistics for cutoff functions[a]

	First cutoff function		Second cutoff function
Function	$\partial f(z)$	$\partial F(z)$	$\partial G(z)$
$\partial\lambda(z)$	+	+	+
∂L	unrelated	-	unrelated
∂L^*	unrelated	-	unrelated
∂a_N	-	-	unrelated
∂a_S	unrelated	unrelated	unrelated
∂a_F	+	+	unrelated
$\partial\rho$	unrelated	unrelated	unrelated
∂M	unrelated	+	unrelated

[a] The terms in the first row are the functions of interest, and parameters are in the first column. We are interested in how functions vary as the value of parameters increase. + indicates a positive correlation. - indicates a negative correlation.

Table 4: List of Southern countries

Argentina	Bangladesh	Bolivia	Brazil	Chile
China	Colombia	Costa Rica	Ecuador	Egypt
Greece	Guatemala	Honduras	Hungary	India
Indonesia	Iran	Jordan	Kenya	Malawi
Malaysia	Mexico	Pakistan	Panama	Peru
Philippines	Poland	Portugal	Romania	Sri Lanka
South Africa	South Korea	Thailand	Trinidad & Tobago	Turkey
Uruguay	Venezuela			

Table 5: Summary statistics

Variable	Mean	Std. Dev.	Min.	Max.	N
PC	0.191	0.348	0	1	22278
R&D	0.022	0.029	0	0.337	22278
GP	2.899	1.042	0.33	4.5	22278
PR	16.015	7.522	1.557	32.404	22278
FDI	0.517	0.863	0	3.958	12764
Tariff	12.658	10.994	2.25	81.56	15980
PCGDP	0.402	0.375	0.014	1.812	22278
Population	1.6	3.289	0.012	12.978	22278
Finance	44.952	33.262	4.89	135.77	20473
Corruption	-0.101	0.578	-1.41	1.54	12034
Capital	2.19	1.872	0.101	8.256	22278
Skilled	0.451	0.377	0.026	2.236	22278
Distance	8.790	3.791	3.234	16.18	22278
Cost	28.449	25.952	7.3	182.3	5766

Table 6: Cross-correlation: legal origin

Variables	PC	PR	Bc	Sc	Fc	Gc
PC	1.000					
PR	0.065	1.000				
Bc	0.011	-0.050	1.000			
Sc	-0.065	0.166	-0.220	1.000		
Fc	0.064	-0.190	-0.659	-0.444	1.000	
Gc	-0.064	0.264	-0.137	-0.092	-0.276	1.000

Table 7: Cross-correlation: geography

Variables	PC	PR	Distance
PC	1.000		
PR	0.065	1.000	
Distance	-0.071	-0.033	1.000

Table 8: Pooled OLS estimations

	Dependent variable: Product-cycle intensity							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPP	-0.000285	-0.000671	-0.00352***	-0.00282***	-0.00190**	0.00234	0.00213	0.00136
	(0.000579)	(0.00214)	(0.000485)	(0.000598)	(0.000946)	(0.00181)	(0.00223)	(0.00225)
IPP*R&D	0.178***	0.151***	0.0253	0.0224	0.0148	-0.0554	-0.0564	-0.0582
	(0.0318)	(0.0408)	(0.0188)	(0.0248)	(0.0316)	(0.0445)	(0.0445)	(0.0446)
IPP*R&D^2	-0.727***	-0.573**	-0.166**	-0.118	-0.0998	0.243	0.245	0.263
	(0.234)	(0.291)	(0.0786)	(0.104)	(0.159)	(0.164)	(0.164)	(0.166)
FDI		-0.0387***		-0.0557***	-0.0430***	-0.0414***	-0.0490***	-0.0390***
		(0.00949)		(0.00444)	(0.00493)	(0.00587)	(0.00920)	(0.00916)
Tariff		-0.00829***			-0.00529***	-0.00696***	-0.00567***	-0.00841***
		(0.00156)			(0.000670)	(0.00139)	(0.00146)	(0.00152)
PCGDP		-0.0636			-0.0908***	-0.105***	-0.0538	0.0300
		(0.0724)			(0.0134)	(0.0278)	(0.0654)	(0.0686)
Population		-0.00358			-0.00657***	-0.00922***	-0.00977***	-0.00625**
		(0.00269)			(0.00121)	(0.00163)	(0.00267)	(0.00270)
Finance		0.000232				0.000619***	0.000888***	0.000426*
		(0.000220)				(0.000151)	(0.000223)	(0.000225)
Corruption		0.0125				-0.0476*	-0.0133	0.00432
		(0.0335)				(0.0242)	(0.0331)	(0.0326)
Capital		0.00586					-0.0237	-0.00432
		(0.0206)					(0.0202)	(0.0200)
Skill		0.0277					0.0524	0.0499
		(0.0374)					(0.0358)	(0.0354)
Lagged IPP$_5$		-0.00848***						-0.0142***
		(0.00172)						(0.00201)
Constant	0.146***	0.431***	0.157***	0.0606***	0.244***	0.297***	0.285***	0.505***
	(0.00930)	(0.0575)	(0.0114)	(0.00752)	(0.0235)	(0.0476)	(0.0487)	(0.0629)
Observations	22,278	4,530	22,278	12,764	9,069	4,530	4,530	4,530
R-squared	0.026	0.061	0.237	0.256	0.292	0.380	0.381	0.390
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Errors are clustered by industry and shown in parentheses. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 9: Logit estimations

	Dependent variable: Product-cycle intensity							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
IPP	0.0119***	-0.0617***	0.00214	-0.00177	0.00551	-0.0257	-0.0793***	-0.0758***
	(0.00400)	(0.0135)	(0.00441)	(0.00596)	(0.00884)	(0.0187)	(0.0229)	(0.0230)
IPP*R&D	2.103***	2.611***	0.285*	0.309	0.428*	1.236***	1.328***	1.302***
	(0.298)	(0.382)	(0.149)	(0.201)	(0.253)	(0.436)	(0.424)	(0.421)
IPP*R&D^2	-8.746***	-10.23***	-1.178*	-1.013	-1.040	-4.137**	-4.590***	-4.497***
	(2.359)	(2.747)	(0.645)	(0.948)	(1.225)	(1.783)	(1.732)	(1.737)
FDI		0.0213		0.219***	0.163***	0.159***	0.0753	0.0301
		(0.0506)		(0.0405)	(0.0412)	(0.0557)	(0.0801)	(0.0792)
Tariff		-0.0128			0.0213***	0.00414	-0.0212	-0.00940
		(0.00891)			(0.00605)	(0.0129)	(0.0135)	(0.0144)
PCGDP		-2.028***			-0.185*	-0.346	-3.318***	-3.688***
		(0.407)			(0.108)	(0.256)	(0.601)	(0.628)
Population		0.0820***			0.0297**	0.0695***	0.162***	0.147***
		(0.0165)			(0.0117)	(0.0170)	(0.0265)	(0.0267)
Finance		-0.00804***				-0.00710***	-0.0164***	-0.0144***
		(0.00135)				(0.00143)	(0.00210)	(0.00212)
Corruption		0.206				0.688***	0.535*	0.453
		(0.192)				(0.243)	(0.303)	(0.302)
Capital		0.546***					1.101***	1.014***
		(0.119)					(0.184)	(0.184)
Skill		-0.131					0.0533	0.0571
		(0.184)					(0.300)	(0.298)
Lagged IPP_5		0.0371***						0.0634***
		(0.0107)						(0.0192)
Constant	-0.800***	0.582*	1.535***	1.749***	2.345***	3.406***	4.164***	3.248***
	(0.0658)	(0.346)	(0.0792)	(0.118)	(0.177)	(0.454)	(0.492)	(0.582)
Observations	22,278	4,530	21,520	12,277	8,551	3,834	3,834	3,834
Year FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes	Yes	Yes

Errors are clustered by industry and shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 10: Heckman selection estimations

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	PC	PC dummy	mills	PC	PC dummy	mills	PC	PC dummy	mills
IPP	-0.00763**	0.00735		0.00468	0.00961		0.0319***	-0.0754*	
	(0.00301)	(0.00504)		(0.00466)	(0.0130)		(0.00479)	(0.0390)	
IPP*R&D	0.0869	0.970***		-0.0227	1.099**		-0.0389	1.316***	
	(0.125)	(0.242)		(0.158)	(0.440)		(0.0973)	(0.507)	
IPP*R&D^2	-0.932	-4.841***		0.0414	-4.805*		-0.0323	-6.329**	
	(0.721)	(1.380)		(1.008)	(2.803)		(0.598)	(3.146)	
FDI				-0.0602***	-0.0172		-0.0854***	0.150**	
				(0.0128)	(0.0392)		(0.0112)	(0.0593)	
Tariff				-0.00420	-0.00561		-0.0121***	-0.0287**	
				(0.00331)	(0.00912)		(0.00261)	(0.0126)	
PCGDP				-0.199***	-0.627***		0.221***	-1.075**	
				(0.0500)	(0.140)		(0.0747)	(0.423)	
Population				-0.0177***	0.0173		-0.0388***	0.115***	
				(0.00392)	(0.0118)		(0.00483)	(0.0267)	
Finance							0.000422	-0.00797***	
							(0.000365)	(0.00217)	
Corruption							-0.276***	1.509***	
							(0.0705)	(0.533)	
Lagged IPP_5							-0.0443***	0.0181	
							(0.00420)	(0.0391)	
Cost		0.0188***			-0.0168			0.0382	
		(0.00545)			(0.0258)			(0.0917)	
Constant	0.170	0.787**		0.237	1.354**		0.347**	3.288***	
	(0.149)	(0.336)		(0.169)	(0.613)		(0.146)	(0.967)	
λ			0.638***			0.501***			-0.0423
			(0.166)			(0.120)			(0.0760)
Wald χ^2	631.30			695.54			2183.82		
p-value	0.000			0.000			0.000		
Observations	5,766	5,766	5,766	2,828	2,828	2,828	2,622	2,622	2,622
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note 1: $Cost_0 4$ is the cost of setting up a business in year 2004, which are used as exclusion restrictions in the first stage of Heckman selection.

Note 2: Standard errors are shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 11: IV estimations: Legal origin

	Dependent variable: PC					
	(1)	(2)	(3)	(4)	(5)	(6)
IPP	-0.0169***	0.00323	-0.0143***	-0.00455**	0.00539	0.00413
	(0.00146)	(0.00338)	(0.00132)	(0.00232)	(0.00339)	(0.00390)
IPP*R&D	0.227***	0.165***	-0.0577	-0.0430	-0.0446	-0.0426
	(0.0373)	(0.0425)	(0.0397)	(0.0512)	(0.0568)	(0.0558)
IPP*R&D^2	-0.865***	-0.640**	0.150	0.0782	-0.0556	-0.0476
	(0.271)	(0.296)	(0.202)	(0.269)	(0.301)	(0.288)
FDI		-0.0302***		-0.0421***	-0.0402***	-0.0347***
		(0.0110)		(0.00468)	(0.00578)	(0.0103)
Tariff		-0.00736***		-0.00607***	-0.00630***	-0.00798***
		(0.00155)		(0.000840)	(0.00137)	(0.00147)
PCGDP		-0.0181		-0.0551**	-0.117***	0.0546
		(0.0777)		(0.0239)	(0.0294)	(0.0703)
Population		-0.00721**		-0.00487***	-0.0107***	-0.00850**
		(0.00351)		(0.00160)	(0.00217)	(0.00372)
Finance		0.000350			0.000654***	0.000517**
		(0.000233)			(0.000152)	(0.000243)
Corruption		-0.0172			-0.0611**	-0.0123
		(0.0400)			(0.0278)	(0.0385)
Capital		-0.00951				-0.0149
		(0.0223)				(0.0226)
Skill		-0.000284				0.0325
		(0.0421)				(0.0408)
Lagged IPP_5		-0.00903***				-0.0140***
		(0.00178)				(0.00195)
Constant	0.398***	0.360***	0.457***	0.378***	0.184**	0.407***
	(0.0266)	(0.0702)	(0.0252)	(0.0429)	(0.0775)	(0.0852)
DWH test	63.2012	9.95702	52.8466	1.98688	1.07658	1.03348
p-value	0.0000	0.0000	0.0000	0.1157	0.3591	0.3779
Observations	22,278	4,530	22,278	9,069	4,530	4,530
R-squared		0.060	0.190	0.290	0.379	0.389
Year FE	No	No	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes
Country FE	No	No	No	No	No	No

Note 1: Two-stage estimation is conducted. Only second stage results are shown in this table. The first stage results are omitted. Durbin-Wu-Hausman (DWH) test is used for testing regressor endogeneity.

Note 2: Errors are clustered by industry and shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Table 12: IV estimations: Geography

	Dependent variable: PC					
	(1)	(2)	(3)	(4)	(5)	(6)
IPP	0.0967***	0.000207	1.166	0.00107	-0.000329	0.00967**
	(0.0154)	(0.00390)	(1.600)	(0.00306)	(0.00413)	(0.00475)
IPP*R&D	0.135***	0.157***	1.078	-0.111	-0.166	-0.149
	(0.0443)	(0.0437)	(1.853)	(0.0981)	(0.151)	(0.149)
IPP*R&D^2	-0.930***	-0.617**	-5.415	0.343	0.215	0.191
	(0.300)	(0.298)	(8.426)	(0.393)	(0.571)	(0.586)
FDI		-0.0367***		-0.0431***	-0.0435***	-0.0289***
		(0.0116)		(0.00470)	(0.00586)	(0.00997)
Tariff		-0.00807***		-0.00513***	-0.00816***	-0.00744***
		(0.00177)		(0.000882)	(0.00148)	(0.00156)
PCGDP		-0.0529		-0.0976***	-0.0800***	0.0886
		(0.0774)		(0.0301)	(0.0294)	(0.0699)
Population		-0.00441		-0.00695***	-0.00638***	-0.0114***
		(0.00400)		(0.00188)	(0.00217)	(0.00371)
Finance		0.000260			0.000555***	0.000637***
		(0.000233)			(0.000146)	(0.000235)
Corruption		0.00546			-0.0224	-0.0331
		(0.0424)			(0.0255)	(0.0370)
Capital		0.00233				-0.0292
		(0.0229)				(0.0223)
Skill		0.0212				0.0101
		(0.0428)				(0.0389)
Lagged IPP_5		-0.00861***				-0.0139***
		(0.00164)				(0.00196)
Constant	-1.386***	0.415***	-23.98	0.309***	0.375***	0.354***
	(0.240)	(0.0857)	(33.17)	(0.0509)	(0.0774)	(0.0864)
DWH test	30.3585	1.09137	23.5058	1.28361	2.24504	2.28973
p-value	0.0000	0.3529	0.0000	0.2798	0.0830	0.0783
Observations	22,278	4,530	22,278	9,069	4,530	4,530
R-squared		0.061		0.290	0.374	0.386
Year FE	No	No	Yes	Yes	Yes	Yes
Industry FE	No	No	Yes	Yes	Yes	Yes

Note 1: Two-stage estimation is conducted. Only second stage results are shown in this table. The first stage results are omitted. Durbin-Wu-Hausman (DWH) test is used for testing regressor endogeneity.

Note 2: Errors are clustered by industry and shown in parentheses. *** p<0.01, ** p<0.05, * p<0.1.