

Export Quality and Patent Protection: Stage-Dependent Effects in Development

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Abstract

This paper provides empirical evidence on the effects of patent protection on the vertical innovation of developing country exporters. We find that the relationship between export quality upgrading and patent protection is dependent on the technological stage of an economy. Specifically, patent protection promotes quality growth if an economy's product quality is sufficiently close to the world frontier level. We characterize the density of the distribution of country products, determining which share of country-product combinations fall under or pass a threshold, & draw some implications for patent policy design. While a majority of combinations exceeds the critical threshold, the results nevertheless call for differentiation in the strength of patent protection by income group and product class. To establish these findings, we employ a very extensive index of export product quality at the 4-digit SITC level and utilize a country-level measure of effective patent protection for the period 1990 - 2010, including an analysis of the different components of patent rights.

Keywords: Patent Rights, Export Quality, Technological Stage Dependence, Developing Economies

JEL classification: O30, O34, F10, F14

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1 Introduction

This paper investigates whether stronger patent protection induces exporters in developing countries to upgrade the quality of their products. Since the mid-1990s, the developing world has had to adopt stronger intellectual property (IP) provisions in order to meet the minimum standards set globally and to partake in the expanded global trade regime.¹ The strengthening of IP systems occurred despite the fact that developing economies were net importers of technologies, possessed relatively few and less valuable intellectual assets, & produced goods of comparatively lower product quality.

What motivates our investigation is two-fold. First, as discussed in Khandelwal (2010), upgrading export quality improves the chances of export success for developing countries competing in the new trading environment. Second, the premise is that stronger patent rights should spur innovation and lead eventually to an improvement in the product quality of developing country exports. Yet currently, evidence linking export quality to patent protection is absent. Recent work has shown that patent reforms can affect export capacity, but has not yet considered the effects on export quality (Ivus, 2010, Maskus and Yang, 2018, & Ivus and Park, 2019). Studies exist on the relationship between innovative activity and export product quality (Akcigit et al., 2018 and Sampson, 2016), but this indicates only indirectly that patent rights can affect export quality via innovation. However, innovation responds to patent protection in diverse, complex ways – sometimes positively, other times adversely – that it would be useful to examine directly the relationship between export quality and patent rights.²

Our investigation shows why uniform (high) standards across countries is not suitable. The effects of patent protection on export quality vary by country and products. In particular, we estimate a threshold level of quality that is country and product-specific such that below this threshold, patent rights hinder vertical innovation; above it, they help promote quality upgrading. The threshold is based on a scale, which we construct from 0 to 100, of how close a country's product

¹Via agreements such as the *Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement* among member-states of the World Trade Organization (WTO).

²See Saggi (2016) for a survey of the international IP literature.

quality is to the world frontier quality. In this regard, we find the effects of patent protection on export quality to be *stage-dependent*; that is, dependent on a country-product combination achieving a critical level of product quality. The intuition is that a sufficient level of technological capacity is required for bearing the increased costs of R&D development due to stricter patent protection and for generating sufficient market returns. Because of the stage-dependent effects, we argue that patent standards should ideally be differentiated by product and country.

In this paper, we use a quality ladders theoretical framework to guide our empirical analysis and discuss the Chinese ball-point pen industry as an example of how product quality and the IP regime varied by technological stage. For our empirical analysis, we exploit a rich dataset on detailed SITC 4-digit level export product qualities across eighty-two developing countries over the period 1990 - 2010. Our empirical approach focuses on finding the critical threshold implied by the data. We then study how the threshold varies by income group. We find that the threshold is higher for upper middle income countries than it is for lower middle income countries because the products of upper middle income economies likely compete more intensely with the high quality products of advanced economies. For low income countries, we find no significant effects of patent protection on export quality upgrading. A disproportionately large share of their exports is at the low end of the product quality spectrum. We also study how the threshold varies by product group. We find the threshold to be higher for high IP and high patent intensity products since they require greater quality differentiation against existing IP-protected goods.

We then characterize the distribution of country-product qualities in the sample, comparing the density of country-product combinations above the threshold and below. Because the majority of combinations in a pooled sample are *above* the threshold, we deduce that on balance, stronger patent protection worldwide will increase export upgrading more than it will stifle it. However, we find an important share (namely 31.5%) of products in the developing world for which quality upgrading could be hindered by stronger patent rights. The lesson again is that international IP policies should be attuned to gaps in technological development rather than be applied uniformly.

Our paper adds to existing work on export quality, which to our knowledge has not yet studied patent rights as a determinant.³ Recent work has focused on the effects of FDI⁴ and of trade liberalization.⁵ In this strand of the literature, Amiti and Khandelwal (2013) is the closest to our study in that they also analyze whether the effects of tariffs on export quality vary by closeness to the world frontier. A key difference is that we use a more recent measure of export quality derived from *world* exports data, whereas Amiti and Khandelwal (2013) use an index of quality based on exports to the U.S. only. Therefore, our paper develops a more generalized measure of the closeness to technological frontier, as we elaborate later.

Our paper also contributes to the recent literature emphasizing the stage-dependent effects of IPRs on innovation, economic growth, & development. Kim et al. (2012) find that countries at different stages of economic development utilize different types of IPRs, such as patents and utility models. Utility models are pervasive in the developing world since they are conducive to the kinds of incremental innovation that occur there. Chen and Puttitanun (2005) find that the optimal degree of IPR protection depends on the level of economic development. In less developed countries where indigenous innovative capacity is low, less stringent protection allows for useful catch-up imitation, while in countries where that capacity is sufficiently high, more stringent protection can stimulate innovative R&D. Hwang et al. (2016) provide a theoretical model to explain the U-shaped relationship between IPRs and economic development. For low-income countries the strength of IPRs falls with income since a low-income economy has not yet reached its critical market size for spurring innovation. Chu et al. (2014) find a stage-dependent effect of IPRs on innovation and economic growth using a Schumpeterian growth model of distance to frontier. The model shows that the growth-maximizing and welfare-maximizing levels of patent strength increase as a country evolves towards the world technology frontier.

The paper proceeds as follows: Section 2 provides a case study to motivate our analysis. Section

³See Schott (2004), Hallak (2006), Baldwin and Harrigan (2011), & Feenstra and Romalis (2014).

⁴See Harding and Javorcik (2012) and Anwar and Sun (2018).

⁵See Amiti and Khandelwal (2013) and Fan et al. (2015).

3 discusses our conceptual framework and section 4 the main data sources. Section 5 discusses our empirical framework and section 6 our results. Section 7 provides concluding thoughts.

2 Case study: the Ball-Point Pen Industry

The following industry case study helps illustrate a possible stage-dependent relationship between IPR protection and export quality.⁶ China is the largest exporter of ball-point pens in the world. In 2017, China exported 8.38 billion units to the rest of the world, accounting for 28.5% of world exports of such products, with Japan ranking second with a 14.3% share.⁷

The town of Fen Shui, nestled in Hang Zhou, Zhejiang province, is the manufacturing center of ball-point pens in China, accounting for around 40% of total national production. In 2009, the town was dubbed as the export hub of ball-point pens by the Ministry of Commerce of China. By 2017, 613 ball pen manufacturing companies and 379 supporting companies were in operation, making the town world renown for pen-making.

The pen business in Fen Shui started in the 1970s when China was largely an impoverished country. In the early stages, with limited resources and limited R&D capacity, the industry developed through imitation. Businesses expanded and competition was fierce and price-based. Firms that accumulated some technological capacity through decades of imitation attempted to beat the competition by undertaking some limited R&D. The aim was to climb the quality ladder by incorporating some minor attributes into the homogeneous ball-point pen. The minor quality differentiated ball-point pens provided a good return for the innovating company. However, in the absence of effective IPR protection, imitators inundated the industry and quickly turned the quality

⁶For this case study, we drew upon several materials. First, an interview with a sales manager of *Cixi Dengfeng Pen Manufacturing Co. Ltd.*, a leading company in the industry. Second, through company and association literature; in particular, by *Tonglu Guanghua Pen-making Co. Ltd.*, ranked first in sales in the Fen Shui region during 2014-2017 (<http://www.guanghuapen.com/>); *China Writing Instrument Association* (http://www.china-writing.com.cn/E_Show.aspx?type=82), & *China Light Industry Internet* (http://www.clii.com.cn/zhuantixinwen/jq/201707/t20170717_3910110.html).

⁷Export data can be found on www.Trademapp.org using the class HS960810 for ball-point pens.

differentiated products back to homogeneous products. Minor product improvements developed by an innovator would diffuse throughout the whole industry at low cost. Thus, although intense imitative competition pushed prices down to the break-even point, the average quality for the industry tended to grow slightly over time as new attributes were built into the pens.

Disputes between innovators and imitators persisted as the size of the market and technological capacity of firms in the industry grew. As a solution to these disputes, a local administrative rule was enacted in the 1990s to maintain fair competition amid a weak national patent law system. Subsequently, to conform with the TRIPS agreement, China undertook a major reform of its patent system in 2000. The reforms continued, with China further amending its patent law by late 2009. As IPR protection had strengthened in China, innovators in Fen Shui pursued a strategy of quality differentiation and sought design patents. Independently, the quality of education in China improved and the knowledge base expanded from knowledge imported through foreign trade and inward FDI. These were fortuitous developments for innovators in Fen Shui as they were able to forge partnerships and cooperative ties with universities and industrial design centers. These ties were central to capacity-building and enabled firms to generate more design patents and upgrade their product qualities further, & with stronger IPRs, capture higher returns. In 2001, when China joined the WTO, few patent applications were filed by ball-point pen producers, but in 2002 the number of patent applications in Fen Shui surged to 110, & by 2006, it reached 541 applications. In 2017, over 4,100 patents were owned by ball-point pen producers in Fen Shui, accounting for 35% of national pen patents.

In brief, this case study provides contrasting experiences at different stages of technological development. In the early stages when the innovative capacity of pen producers was low, product quality growth occurred as the less stringent IPR regime enabled firms to focus on making small quality “jumps” and incorporating minor attributes into their product offerings. In the later stages, producers had acquired greater technological competencies through the support of complementary institutions and resources. Stronger IPRs – through either local administrative power or national

patent law enforcement – led pen producers to intensify their applications for patent rights. More rapid product quality growth followed. Reduced imitation risks raised producers’ expected profit margins and led them to focus on making larger quality “jumps. The ball-point industry is but one example in which the impact of IPR protection on product quality depended on some threshold level of innovation potential. In the remainder of the paper, we present more formal evidence of stage dependence using a broad set of country-product data.

3 Conceptual Framework

We build on the themes in Chen and Puttitanun (2005), Chu et al. (2014), & Hwang et al. (2016) regarding the stage-dependent outcomes of IP protection. As a conceptual framework for guiding our empirical research, the quality ladders model of Grossman and Helpman (1991) augmented with an IPR factor is used.⁸ This model suits our purposes because it helps identify the channels by which patent protection affects the size and frequency of quality improvements, & the means by which technological development can condition the impact of patents. In what follows, we first derive a steady-state relationship between product quality and patent protection. We then show how the impact of patents on product quality is stage-dependent.

On the demand side, consumers face the following intertemporal utility functional:

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

where ρ is the time preference rate and $\ln u(t)$ the instantaneous utility function:

$$\ln u(t) = \int_0^1 \ln \sum_m q_{mj} x_{mj}(t) dj \quad (2)$$

where $x_{mj}(t)$ denotes the quantity of product j of quality m consumed at time t , & q_{mj} the corre-

⁸See Glass and Saggi (2002) for a more detailed quality ladders model incorporating IPRs.

sponding quality level. Through innovations, product quality evolves as follows: $q_{mj} = \lambda(\kappa)q_{m-1j} = \lambda(\kappa)^m$, where $\lambda(\kappa)$ is the size of the quality jump and m the number of times the product climbed up the quality ladder. The initial quality level is normalized to one (i.e., $q_{0j} = 1$). The size of the quality jump $\lambda(\kappa)$ is a function of the level of patent protection, given by κ . To the extent that stronger patent protection creates incentives for more radical innovations, $\lambda'(\kappa) > 0$. As will be shown below, a larger quality jump size enables firms to charge a higher markup (over a given amount of marginal cost) and earn a greater flow of instantaneous profits; this provides the incentive for investing in large step innovations rather than incremental ones.

Total expenditure at time t , $E(t)$, over a fixed measure of products is given by:

$$E(t) = \int_0^1 \ln p_{mj}(t) x_{mj}(t) dj \quad (3)$$

Static maximization of (2) subject to (3) yields the demand for product j of quality \tilde{m} at time t : $x_{\tilde{m}j}(t) = \frac{E(t)}{p_{\tilde{m}j}(t)}$, where consumers purchase the quality level associated with the lowest quality-adjusted price, $\frac{p_{mj}(t)}{\lambda(\kappa)^m}$. Dynamic maximization of (1) subject to an intertemporal flow budget constraint $\dot{A}_t = rA_t + W_t - E_t$ (where A denotes assets, W income, & r the interest rate) and a transversality condition, yields the Euler equation $\frac{\dot{E}_t}{E_t} = r - \rho$. Assuming no international lending or borrowing, we get $r = \rho$ and constant expenditures, $E(t) = E$.

On the supply side, firms face the following value functional:

$$V = \int_0^\infty e^{-(\rho+\iota)t} \pi(t) dt \quad (4)$$

where ι (in the discount factor) captures the risk of losing this stream of profits due to an innovation of a new quality product that displaces the existing quality product.⁹ Thus, ι denotes innovation intensity. At this intensity, a firm that invests ιdt units of labor, over a time interval dt , has a probability of ιdt of successfully increasing product quality by one step, namely $\lambda(\kappa)$, & displacing

⁹In (4), there is symmetry among products such that $\pi_j(t) = \pi(t)$ because each leading brand is priced $\lambda(\kappa)$ times the marginal cost (namely the wage, w) in order to displace the previous leading brand.

a current incumbent and securing a new discounted stream of profits, V .

We say a few more words about the parameter a . This parameter acts as a measure of the inverse productivity of R&D: the lower it is, the more efficient research is, as fewer resources (labor) are required to conduct a task. It is an integral part of the fixed cost of research and development. But we also assume that ‘ a ’ is a function of the level of patent protection, namely $a(\kappa)$, such that $a'(\kappa) > 0$. That is, stronger patent rights work to raise the developmental cost of conducting R&D. There are numerous reasons why. First, they increase the cost of innovation inputs. Under stronger patent protection, input sellers are able to charge higher prices or licensing fees for their technologies. Second, there are upfront transactions costs associated with negotiating rights and cross-licensing agreements, about which stronger patent rights raise the bargaining power of the licensor. Third, the *doctrine of equivalents* puts the onus on the next innovator to clearly differentiate its technology or product quality from the previous generation; the doctrine governs the scope of patent protection. The stronger the patent system, the more widely the doctrine is interpreted such that new quality variations may still fall under the scope of an existing protected innovation. The cost of R&D increases, therefore, as product developers incur more resources and effort to ensure that a new product quality does not infringe upon existing versions. All of these costs are measured in terms of the labor required to conduct the upfront work.¹⁰

To derive an equation for vertical innovation, we require two more pieces, both of which are needed to obtain an equilibrium solution: (i) a free entry/exit condition for market entry and (ii) a resource (labor market) constraint. First, the free entry/exit condition. The cost of innovation equals $wa(\kappa)\iota dt$, where w denotes the wage. The expected gain is $V\iota dt$. A finite amount of R&D, ι , occurs if $V = wa(\kappa)$ (or else, ι is either zero or unbounded). In (4), instantaneous profits are given by $\pi = (p - w)x$ (omitting subscripts). The firm charges a markup over marginal cost, $p = \lambda(\kappa)w$,

¹⁰See Merges and Nelson (1990) and Merges and Duffy (2017) for a discussion of the doctrine of equivalents. See Glass and Saggi (2002) for a treatment of how IPRs can affect the parameter ‘ a ’ by raising the costs of inventing or imitating around existing quality products. Yang and Maskus (2001) analyze the effects of patent rights on the bargaining position (or rent share) of the licensor. Chu et al. (2012) model an entrant paying a license fee to the incumbent that covers for the degree of infringement.

& *limit-prices* the previous innovator out of the market. Hence, we can rewrite instantaneous profits as $\pi = E(1 - \frac{1}{\lambda(\kappa)})$. Using (4), we can write the free entry/exit condition as:

$$\frac{E(1 - \frac{1}{\lambda(\kappa)})}{\rho + \iota} = wa(\kappa) \quad (5)$$

Next, the resource constraint is:

$$\bar{L} = a(\kappa)\iota + \frac{E}{\lambda(\kappa)w} \quad (6)$$

where \bar{L} is the total supply of labor. The first term on the RHS is the amount of labor used in R&D and the second term the amount used in production. For the latter, it is assumed that one unit of output requires one unit of labor. The quantity of each product quality is given by $\frac{E}{p}$ and we saw that price is a markup over marginal cost, $\lambda(\kappa)w$, & the total measure of products is 1.

Solving for equations (5) and (6) -- specifically, eliminating wages -- gives us the equation for vertical innovation in steady-state:

$$\iota^* = \frac{\bar{L}}{a(\kappa)}(1 - \frac{1}{\lambda(\kappa)}) - \frac{\rho}{\lambda(\kappa)} \quad (7)$$

We can use equation (7) to determine the impact of patent rights κ on product quality upgrading. First, the quality level of an exportable product is given by $q = \lambda(\kappa)^m$, where $\lambda(\kappa)$ is the size of the jump and m the number of jumps over some time interval $(0, t)$. Second, assume that the jumps followed a *Poisson process* with arrival rate ιt . The mean number of jumps is then $E(m) = \iota t$ over that interval. Thus the quality level of a product is $q = \lambda(\kappa)^{\iota t}$, or:

$$\ln q = \iota^* \ln \lambda(\kappa) \quad (8)$$

where we normalize to the unit time interval. The impact of patent protection on product quality

upgrading can then be derived as follows:

$$\frac{\partial \ln q}{\partial \kappa} = \Omega_\lambda \frac{\lambda'(\kappa)}{\lambda(\kappa)} - \Omega_a \frac{a'(\kappa)}{a(\kappa)} \geq 0 \quad (9)$$

The impact is positive if stronger patent protection increases the growth of product quality ($\frac{\lambda'(\kappa)}{\lambda(\kappa)}$) more than it increases the growth of R&D development costs ($\frac{a'(\kappa)}{a(\kappa)}$), & negative otherwise.¹¹ Thus, if rising R&D development costs are onerous and the potential for product quality growth low, then $\frac{\partial \ln q}{\partial \kappa} < 0$. In this case, lowering the level of patent protection, κ , would spur vertical innovation and raise product quality. A less stringent patent system makes it easier for firms to invent around existing product qualities (i.e., the doctrine of equivalents would be interpreted narrowly). The size of the quality jumps would be relatively small and the instantaneous profit flow modest. But coupled with a lower fixed cost of innovation (due to a lowering of $a(\kappa)$), the modest stream of expected profits can support a steady rate of quality upgrading, the kind of incremental improvements that the case of the Chinese ball-pen industry illustrated. A very strong patent system would otherwise raise the entry cost and impede innovation.

In contrast, if the potential for product quality growth is high, a strengthening of patent protection would spur vertical innovation and product quality upgrading, $\frac{\partial \ln q}{\partial \kappa} > 0$. Stronger patent protection would provide incentives for firms to invest in larger product upgrades, & the firms would be willing to incur the higher R&D development costs, given the larger expected firm value upon successful innovation. A weak patent system would otherwise lower the returns to making significant quality improvements.

While the net impact of patent protection on product quality upgrading, $\frac{\partial \ln q}{\partial \kappa}$, is therefore ambiguous, we can show that the impact depends on the level of technological development. In our model, we focus on the fixed cost of R&D, $a(\kappa)$. In order to upgrade a given product line, an economy high in technological capacity should incur a lower development cost, $a(\kappa)$, than one with

¹¹The weights are $\Omega_\lambda = \frac{\bar{L}(\ln \lambda(\kappa) + \lambda(\kappa) - 1)}{\lambda(\kappa)a(\kappa)} + \frac{\rho(\ln \lambda(\kappa) - 1)}{\lambda(\kappa)} > 0$ and $\Omega_a = \frac{\bar{L} \ln \lambda}{a(\kappa)}(1 - \frac{1}{\lambda(\kappa)}) > 0$ for $\lambda(\kappa) > 1$.

a low technological capacity, given the same level of patent protection, κ . We have explicitly made the R&D development cost, $a(\kappa)$, a function of κ , but implicitly there are other determinants. Let us denote $\overline{a(\kappa)}$ as the exogenous component of the cost of development. We assume that an economy with a higher level of technological capacity enjoys a lower level of $\overline{a(\kappa)}$.

Note that in (9), both weights Ω_λ and Ω_a are decreasing functions of $\overline{a(\kappa)}$; that is, $\frac{\partial \Omega_\lambda}{\partial \overline{a(\kappa)}} < 0$ and $\frac{\partial \Omega_a}{\partial \overline{a(\kappa)}} < 0$.¹² The first partial derivative captures the fact that a lower $\overline{a(\kappa)}$ (or a higher level of technological capacity) magnifies the impact of patent protection (κ) on quality jump sizes and frequency by increasing innovation productivity (via reducing the resources required to innovate). The second partial derivative captures the fact that a lower $\overline{a(\kappa)}$ mitigates the expansion in R&D development costs resulting from stronger patent rights on transactions costs (by reducing the base level of development costs). Combined, these imply that an increase in technological capacity (i.e., a *decline* in $\overline{a(\kappa)}$) facilitates the impact of patent protection on product quality upgrading:

$$\frac{\partial^2 \ln q}{\partial \kappa \partial \overline{a(\kappa)}} < 0 \quad (10)$$

This result suggests at high levels of $\overline{a(\kappa)}$, the net effect of patent rights on product quality is likely to be negative and at low levels it is likely to be positive. We posit some interior, or critical, value of $\overline{a(\kappa)}^*$ such that for $\overline{a(\kappa)} > \overline{a(\kappa)}^*$, $\frac{\partial \ln q}{\partial \kappa} < 0$, & for $\overline{a(\kappa)} < \overline{a(\kappa)}^*$, $\frac{\partial \ln q}{\partial \kappa} > 0$.

These considerations allow us to derive our hypotheses:

H1: Below a threshold level of technological capacity, the relationship between patent protection and product quality upgrading is negative.

H2: Above a threshold level of technological capacity, the relationship between patent protection and product quality upgrading is positive.

In the empirical analysis, we proxy this level of technological capacity by how close a country's product quality level is to the world frontier.

¹²Specifically, $\partial \Omega_\lambda / \partial \overline{a(\kappa)} = \frac{-\bar{L}(\ln \lambda(\kappa) + \lambda(\kappa) - 1)}{\lambda(\kappa) \overline{a(\kappa)}^2}$ and $\partial \Omega_a / \partial \overline{a(\kappa)} = \frac{-\bar{L}(\lambda(\kappa) - 1) \ln \lambda(\kappa)}{\lambda(\kappa) \overline{a(\kappa)}^2}$.

4 Data

We have a sample of 82 developing economies for the period 1990 - 2010. The classification of developing countries is the World Bank's classification of non high-income economies. During the sample period, several countries have transitioned between different income groups (upper middle-income, lower middle-income, & low income). Appendix I provides a list of the countries in the sample and their associated income group. Our sample also consists of 235 *Standard International Trade Classification* (SITC) 4-digit quality differentiated products. Appendix II provides a list of industries covered in our study. Although we utilize data at the detailed four-digit SITC level, Appendix II clusters them into 23 two-digit SITC sectors so as to conserve space.

4.1 Export Quality

Our measure of export product quality comes from Henn et al. (2017), which builds on Hallak (2006).¹³ We briefly explain the intuition behind how the export quality of a product is obtained. It is, of course, an unobservable characteristic that needs to be determined from observable factors. Price indices are typically constructed from export unit values – namely, the ratio of the value of exports to the quantity of exports – and interpreted as quality measures, subject to adjustments made to reduce the ‘noise’ associated with unit values, such as the possibility that they partly reflect production costs and pricing strategies. The unit value of an exportable product traded between exporter x and importer m at time t is assumed to be a function of unobserved quality (q), the exporter's per capita income (y), & the distance (D) between the exporter and importer:

$$\ln P_{mxt} = \psi_0 + \psi_1 \ln q_{mxt} + \psi_2 \ln y_{xt} + \psi_3 D_{mx} + \xi_{mxt} \quad (11)$$

For instance, distance captures shipping costs and per capita income production costs, where y has a downward effect on export price for capital-intensive industries and an upward effect for

¹³From <https://data.imf.org/?sk=3567E911-4282-4427-98F9-2B8A6F83C3B6>.

labor-intensive ones. The goal here is to obtain estimates of ψ_0 , ψ_1 , ψ_2 , & ψ_3 , so that we can use (11) to infer quality (q_{mxt}) from the observables (P_{mxt} , y_{xt} , & D_{mx}).

To derive estimates of the ψ 's, Henn et al. (2017) specify a quality-augmented gravity equation for imports, such as:

$$\ln IMPORTS_{mxt} = \dots + \delta(\ln q_{mxt} \times \ln y_{mt}) + \dots + \varepsilon_{mxt} \quad (12)$$

where imports are a function of, among other things, the interaction between quality (q_{mxt}) and the importer's income per capita (y_{mt}) on the grounds that this interaction can capture the importer's *demand for the quality* of the exporter's good (if $\delta > 0$). Thus, rearranging (11) with $\ln q_{mxt}$ as the LHS variable and substituting the expression into (12) yields a regression model with which to estimate the $\hat{\psi}$'s for each type of exportable product; that is, by running separate regressions for each product category.¹⁴ This provides us with a set of *bilateral* quality estimates (i.e., between exporter x and importer m) for each product (say j) at time t:

$$\text{quality}_{mxt}^j \approx \frac{\delta}{\psi_1} \ln P_{mxt}^j + \frac{-\delta\psi_2}{\psi_1} \ln y_{xt} + \frac{-\delta\psi_3}{\psi_1} D_{mx} \quad (13)$$

In effect, (13) computes quality as the unit value adjusted for differences in production costs and for the selection bias due to relative distance. It is by aggregating (13) across importers that we obtain our desired measure of export quality of the jth product for the ith exporter at time t, $QLTY_{ijt}$ (which denotes our dependent variable). The product quality data are based on revision 1 of the SITC and are available down to the 4-digit product level, which we use. Moreover, we focus on manufacturing products consisting of SITC product groups 5 to 8.

Manufacturing products are either quality heterogeneous or quality homogeneous. Given our interest in vertical innovation, we focus on quality heterogeneous products and exclude quality homogeneous products. The trim is based on Rauch (1999), which classifies products as quality

¹⁴Note that quality q_{mxt} and δ are not separately identified. See Henn et al. (2017) for details.

differentiated or non-differentiated.¹⁵ The Rauch (1999) classification of quality differentiated products follows SITC revision 2.¹⁶ We therefore concorded the IMF product quality index, as reported in SITC revision 1, to the SITC revision 2 classification, & then kept those quality differentiated manufacturing products as classified by Rauch (1999) in the dataset.¹⁷

4.2 Patent Protection

Our key explanatory factor is the strength of patent protection.¹⁸ We use an index of strength that is based on the legal provision of rights and exceptions to patent holders. It is important to note that the patent rights index (denoted by *PRI*) does not capture the quality or efficiency of patent protection. From a social welfare point of view, patent reforms create both costs and benefits, so that the optimal level of patent protection need not be the one associated with maximal strength. Thus the index is composed of features measuring the strength of patent rights rather than factors that contribute to the quality or efficiency of patent systems.

The index consists of five components: first, the duration of patent protection (*DUR*). Longer patents are generally stronger for they exclude rivalry and imitation for a longer period. The second component is coverage (*COV*) or subject matter that is patentable. Patent systems are stronger if they provide protection for a wider range of subject matter, such as biological innovations or computer software programs. The third is a country's membership (*MEM*) in international agreements on intellectual property. This component signals greater institutional participation in setting global standards for IP rights. The fourth is enforcement mechanisms (*ENF*) that better enable rights-holders to assert their rights and seek injunctions or damages against infringement.

¹⁵Specifically, Rauch (1999) classifies products into homogeneous, reference priced, & differentiated categories. Bastos and Silva (2010) show that Rauch's differentiated products are well suited for capturing quality differentiation. Bas and Strauss-Kahn (2015) also utilize a similar procedure.

¹⁶See http://econweb.ucsd.edu/~jrauch/rauch_classification.html.

¹⁷The concordance table is from the UN Statistics Division. See <https://unstats.un.org/unsd/trade/classifications/correspondence-tables.asp>

¹⁸The data source is Park (2008), retrievable from <http://fs2.american.edu/wgp/www/>. We annualized the data by interpolating between periods.

The fifth component pertains to limitations and exceptions in patent rights (*LOSS*). Patent statutes specify not only rights but also obligations and restrictions in exchange for protection; for example, a requirement that the patent holder commercialize (or *work*) the invention or else forfeit the right. This component scores how less restrictive the limitations and exceptions are. Each of these components is scored out of one. *DUR* is a fraction representing the duration of patent protection relative to the international standard (20 years from the date of filing). The score for *COV*, *ENF*, & *MEM* is the fraction of the legal provisions in each component that the country makes available. The score for *LOSS* is the fraction of limitations and exceptions in the component that the country does *not* impose. The overall index of patent protection is the sum of the components ($PRI = DUR + COV + MEM + ENF + LOSS$), & thus varies from zero to five, with higher numbers reflecting stronger levels of patent rights.

However, in measuring the level of patent protection, it is important to account for the enforcement of legal provisions in practice. We therefore follow Hu and Png (2012) (and subsequently by Maskus and Yang, 2018) and utilize an index of legal enforcement effectiveness developed by the *Fraser Institute* to adjust the index of patent protection. Specifically, effective patent rights, *PRI*, in country *i* at time *t* is given by:

$$PRI_{it} = \theta_{it} \times \text{Patent Rights Index}_{it} \quad (14)$$

where $0 \leq \theta_{it} \leq 1$ is the Fraser index of legal enforcement effectiveness. θ downward adjusts the measured index of patent protection for imperfect enforcement. The Fraser index of legal enforcement effectiveness ranges from zero to ten. We scaled it so that it varies from zero to one; i.e., deflated the Fraser index by 10. If enforcement effectiveness is at a maximum, then $\theta = 1$ and $PRI = \text{Patent Rights Index}$. If enforcement is non-existent, then $\theta = 0$ and $PRI = 0$. The Fraser index is based on three aspects of legal enforcement: legal security from confiscation of property rights, viability of contracts, & the rule of law.¹⁹ The Fraser index is a subjective assessment, as it

¹⁹Available at http://www.freetheworld.com/datasets_efw.html.

is compiled from surveys of international business executives. Thus *PRI* should capture the scope of effective IPR protection (Maskus and Yang, 2018).

4.3 Closeness-to-Frontier

Another key variable of interest is a measure of the *stage* of technological development. The stage will vary by product, country, & year; that is, a country may be relatively higher up the technology ladder in certain goods than in other products at a particular time. We thus measure the closeness to the world frontier, *CTF*, for each country and product combination, as follows:

$$CTF_{ijt} = \left(\frac{QLTY_{ijt-1} - QLTY_{lowest,jt-1}}{QLTY_{highest,jt-1} - QLTY_{lowest,jt-1}} \right) \times 100 \quad (15)$$

where $QLTY_{ijt-1}$ and so forth are lagged by a year (to precede patent reforms). Note that when calculating the world's highest quality ($QLTY_{highest,jt}$) and world's lowest ($QLTY_{lowest,jt}$) quality for product j we examined all countries in the database, including advanced countries. The formula (15) borrows from the 'Distance to Frontier' methodology underlying the World Bank *Doing Business* dataset, except that we take the inverse so that higher values of *CTF* reflect higher positions in the technology ladder.²⁰ The index of CTF_{ijt} ranges from zero to 100, where 'hundred' signifies that a country's product is the world's premier quality for that product category.

In the absence of data on product-level labor productivity, previous studies have employed total factor productivity (TFP) as a proxy for the level of technology (e.g., Acemoglu et al., 2006). Here we believe that product quality itself is a natural proxy for product-level technology. In previous research, the measure of distance to frontier has been constructed in multiple ways. Chu et al. (2014) employ country-level data from the *Penn World Tables* on labor productivity relative to the U.S. as an inverse measure of the distance to frontier; however, this does not allow for differences across products. Acemoglu et al. (2006) defines industry-level "proximity to technology frontier"

²⁰Details of the methodology can be found at <https://www.doingbusiness.org/content/dam/doingBusiness/media/Annual-Reports/English/DB18-Chapters/DB18-DTF-and-DBRankings.pdf>.

as the level of TFP per industry, country, & time, divided by the highest TFP per industry and time in the sample. Our approach allows for more disaggregation at the product level. Amiti and Khandelwal (2013) constructs a detailed product-level measure of proximity to the technology frontier by using their self-developed product-level quality index divided by the highest quality level within each HS ten-digit product. Rather than take the ratio of a product's quality to the world maximum, we use a instead different formula for distance to frontier, as shown in (15). This approach creates more spread in the values of CTF .

Furthermore, an advantage of the formula in (15) is that it can quantitatively depict the positions that countries occupy in the technology ladder for each product; for example, a value of $CTF_{ijt} = 50$ indicates that the quality of product j of country i , at time t , is halfway between the world's leading quality and the world's lagging. Another difference with most previous work is that we base our quality index on world exports rather than on exports to the U.S. only. This allows us to include more products of developing countries than if we had just concentrated on a market like the U.S.²¹

4.4 Control Variables

We include the exporter's gross domestic product per capita (GDP_PC) in constant 2005 U.S. dollars. Generally, this variable could pick up national productivity or the level of economic development, which should be positively associated with an economy's export quality. We also include the stock of inward foreign direct investment (FDI), which for developing economies could be an important conduit for inward knowledge transfers. The acquisition of knowledge should contribute to local innovation and the capacity to improve product quality. But of course, not all FDI necessarily involves substantive technology transfers. Some may be primarily for expanding sales and distribution channels. Access to knowledge could also be acquired through joining regional

²¹For example, China has been the world's largest automobile market since 2011 in terms of both supply and demand (see <https://www.cnbc.com/2011/09/12/Worlds-10-Largest-Auto-Markets.html>). But until recently, China did not export passenger cars to the U.S., only auto parts. Hallak (2006) and Feenstra and Romalis (2014) also use exports to the world rather than exports to the U.S. only.

free trade agreements that facilitate trade in knowledge. Moreover, these agreements may include other institutional reforms such as pro-competitive reforms, service liberalization, & measures to liberalize trade, investment and public procurement, that could affect export quality. And the greater the ‘depth’ of an agreement, the more profoundly export quality should be affected. For that reason, we also control for the cumulative number of preferential trade agreements (*PTA*) that an exporter participates in, as adjusted for depth. In other words, the variable we use is the cumulative depth of PTA’s.²² Yet, those kinds of agreements could also impact quality upgrading negatively if they contain TRIPS-plus provisions that render the patent systems of certain countries too strong for their stage of technological development.²³

We also control for an index of human capital (*HC*) that takes into account the average years of schooling in the population and an assumed rate of return to education. Human capital is an important input into R&D activities and should positively influence export quality; however, innovation may be more dependent on specialized education rather than levels of education in general. Lastly, we control for the most favored nation applied tariffs rate (*TARIFF*). In general, we expect a negative influence on export quality given that tariffs may impede trade in knowledge as well as access to resources and markets. But prior research has identified some ambiguous effects associated with tariffs. For instance, firm level evidence in Bas and Strauss-Kahn (2015), Fan et al. (2015), & Liu et al. (2019) show that tariff reductions can promote export quality upgrading by allowing higher quality inputs to be imported or by increasing competition. On the other hand, Amiti and Khandelwal (2013) show that if product quality is far from the frontier, tariff reductions could discourage lagging firms from undertaking product innovation, given their inability to cope with increased competition. Appendix III summarizes our data sources and Table 1 provides some descriptive statistics.

²²The source is Dür et al. (2014). Depth is measured with an additive index that ascertains whether an agreement foresees tariffs being reduced to zero and whether its provisions go beyond tariff reductions.

²³Maskus and Ridley (2016) analyze how exports (but not the quality thereof) are affected by PTAs with IP chapters. Campi and Dueñas (2019) caution that trade agreements without IP chapters can stimulate more trade than those with IP chapters, & that the latter may require more implementation time.

5 Empirical Methodology

Based on the conceptual framework, we estimate the following model:

$$QLTY_{ijt} = \alpha_i + \alpha_{jt} + \beta_1 PRI_{it} + \beta_2 (PRI_{it} \times CTF_{ijt}) + \beta_3 CTF_{ijt} + \beta \mathbf{X}_{ijt} + \epsilon_{ijt} \quad (16)$$

where the subscripts i , j , & t index country, product, & year respectively. $QLTY$ denotes export product quality, PRI the measure of effective patent rights, & CTF the index of the closeness-to-the-world technological frontier. The variables $QLTY$ and PRI are in natural logarithms. \mathbf{X} represents a vector of control variables that includes GDP per capita (in logs), import tariff rate, participation in preferential trade agreements, the rate of human capital, & FDI inflows. The α_i and α_{jt} represent country and product-year fixed effects respectively. The country fixed effects control for unobserved factors that drive country differences in product quality. The product-year fixed effects ensure that qualities are comparable within a product category, as per the construction of the CTF indexes in (15).

In (16), we follow Maskus and Yang (2018) and lag the effective patent protection variable, PRI , by one period (which in our case is a year) to take into account that patent policies take some time to influence investments in product quality. For consistency we lag other control variables in the same way. Such a strategy combined with the inclusion of fixed effects in the regression, as Maskus and Yang (2018) argue, can help mitigate potential endogeneity concerns.²⁴ In section 6, we confirm with a test of reverse causality that our results do not suffer from a simultaneity bias.

$PRI \times CTF$ is the interaction between effective patent protection and the closeness-to-the-world technological frontier. It is the key term for measuring the stage-dependent effect of patent rights on export quality. Differentiating the vertical innovation measure with respect to effective patent

²⁴Delgado et al. (2013) argue that the TRIPS agreement constituted a sort of ‘natural experiment’ in that most countries (especially developing) were reluctant to join it. Their membership in the agreement was not likely an endogenous response to shifts in policy or innovative capacity. Delgado et al. (2013) find no pre-TRIPS patterns that suggest a major endogeneity issue. The authors argue that their “differences-in-differences approach allows [them] to address unobserved country-level changes that might also drive the adoption of IPRs.

protection in equation (16) gives us:

$$\frac{\partial QLTY_{ijt}}{\partial PRI_{it}} = \beta_1 + \beta_2 CTF_{ij} \quad (17)$$

From our conceptual framework, our hypotheses H1 and H2 require that $\beta_1 < 0$ and $\beta_2 > 0$. If these hold true in the data, they would confirm the sign of our second partial derivative (10). Consequently, if the quality level of a country-product combination is far away from the world technology frontier (i.e., a small CTF_{ij}), the effect of PRI on export quality would be negative. If the quality level of a country-product combination is close to the world technology frontier (i.e., a large CTF_{ij}), the effect of PRI on export quality would be positive. From (17) we can derive the critical value of the closeness-to-the-world technological frontier as:

$$CTF_{ij}^{\text{threshold}} = -\frac{\beta_1}{\beta_2} \quad (18)$$

which is a mean across countries and products. Note that if the coefficient signs are *opposite* (and significant) – i.e., $\beta_1 > 0$ and $\beta_2 < 0$ – they would imply that patent protection is positively associated with quality upgrading for $CTF_{ij} < CTF_{ij}^{\text{threshold}}$ and negatively for $CTF_{ij} > CTF_{ij}^{\text{threshold}}$.

6 Results

6.1 Preliminary Analyses

From the raw data, we can observe some signs of a stage-dependent effect. Consider Table 2 where we computed the average annual change in export product quality for different slices of the data. First, we formed quartiles of the percentage change in the patent rights index; the changes in the index represent reforms in patent rights. Second, we formed quartiles of CTF , the closeness-to-frontier index, which serves as our measure of the stage of technological development. The table

shows that increases in export product quality, or quality upgrading, appear to depend jointly on the distance to frontier and the degree of patent reforms in the manner we had hypothesized. When countries are far from the frontier (say, in the bottom quartile of CTF), we observe a negative association between quality upgrading and patent reforms. For the third quartile of CTF , where products and economies are still far from the world frontier, modest patent reforms are associated with small percentage increases in export quality; however, under major patent reforms (i.e., at the top quartile of patent reforms), we observe decreases in quality levels. In contrast, at the top quartile of CTF , where the technological stage of development is highest, patent reforms are associated with relatively larger growths in export quality; and the average growth rate is higher as we go from the bottom to the third quartile of patent reforms. While the shifts in quality growth do not all fit the patterns we expect exactly, the overall picture is supportive of our hypotheses.

6.2 Regression Results

We next examine our hypotheses in a more controlled setting. Table 3 contains our main results. Consider first the pooled sample (see column (1)). The coefficient of the interaction term ($PRI \times CTF$) is positive and significant at the 1% level, & the coefficient of effective patent protection PRI is negative and also significant at the 1% level, meaning that unless technological potential, as captured by CTF , is sufficiently high, stronger patent rights are not conducive to upgrading export product quality.

Based on the two estimated coefficients in column (1) ($\hat{\beta}_1 = -1.101$, $\hat{\beta}_2 = 0.025$), the threshold value for the stage-dependent effect is 44.0 ($= 1.101/0.025$) from the formula derived in (18). This suggests that if the technological level of a country's product is below 44% of the world frontier, effective patent protection is negatively associated with export product quality. But if it is more than 44% close to the world level, effective patent protection would be positively associated with export product quality. Thus, the lower the threshold value or cutoff is, the greater the range of product qualities (from the top of the quality ladder down to the threshold) that could improve

from stronger patent protection.

Next, we split the sample into different groups and find some heterogeneity in results. In column (2) of Table 3, we show the estimates of the model for the low income countries. This group tends to produce goods that are at the lowest end of the quality ladder. As shown in column (2), neither the estimated coefficient of effective patent protection nor the estimated coefficient of the interaction term is statistically significant. In effect, patent protection in low-income countries has an insignificant effect on export quality. Quality upgrading is, however, positively associated with GDP per capita and human capital. Being closer to the world frontier also helps with quality growth. Nonetheless, the stage-dependency hypothesis does not apply to this group.

The lower middle and upper middle income countries do specialize in goods that are at a higher end of the quality ladder than what the low income economies produce. Thus, in columns (3) and (4) where we examine these groups respectively, we do find the estimated coefficient of the interaction term to be both positive and significant at the 1% level. Using (18), we find the estimated threshold cutoffs to be 47.2 for the lower middle income group and 55.7 for the upper middle income group. Above these thresholds, a strengthening of effective patent protection would spur export quality upgrading. But note that the range of product qualities that could be spurred by stronger patents is narrower for the upper middle income countries than for the lower middle income countries. Among the upper middle income group, those country-product qualities within 44.3% of the world's apex quality would profit from stronger effective patents, whereas among the lower middle income group, those within 52.8% can. One possible reason has been explored in Shin et al. (2016), which argued that if upper middle income countries produce goods that are at the relatively higher end of the world's quality ladder, producers there encounter vigorous competition with exporters from advanced economies. Consequently, in order to benefit from stronger effective patent rights, the required technological potential of exporters in upper middle income countries should be greater than that of exporters in lower middle income countries.

Next we split the sample by product groups. In columns (5) and (6), we estimate the model on

a sample of high intellectual property (IP) products and non-high IP products respectively. The classification of products into high IP versus the rest is based on Delgado et al. (2013).²⁵ In both the high IP group and non-high IP group, we detect a stage-dependent effect: the estimated coefficient of *PRI*, the effective patent protection variable, is significantly negative, while the estimated coefficient of the interaction between *PRI* and *CTF*, the closeness-to-frontier, is significantly positive. The estimated threshold level is 46.3 for high IP products and 42.3 for the rest. The reason the threshold value is higher for high IP products is that the quality differentiation needs are greater so as to avoid stepping upon (or infringing upon) existing product qualities. Thus stronger effective patent protection would spur the upgrading of high IP exports if the technological potential is sufficiently high or the distance-to-the-world frontier is sufficiently close.

We repeat the above exercise using another way to measure the IP contents of products. Following Hu and Png (2012), we classify products according to whether they are highly patent intensive. Patent intensity is measured as the number of U.S. patents granted to an industry relative to total industry sales in the U.S. We matched the industries to our product classes. Patent intensity is coded as low if it is below the median value and as high if it is above the median. The results appear in the last two columns of Table 3 and are consistent with the findings in columns (5) and (6). In each sub-sample of products, we find a stage-dependent effect and find that the threshold value is higher for high patent intensity products (as reported in the last row of Table 3).

As for the control variables, GDP per capita has a positive association with the upgrading of export product quality, which is consistent with the findings in the previous literature.²⁶ Membership in preferential trading agreements and inward foreign direct investment contribute positively to export quality as well, except in low income countries. The *PTA*'s may serve more to expand the market for imports in low income countries rather than be a platform for their exports. Moreover, the *FDI* received by low income countries may not be knowledge-intensive but labor-intensive,

²⁵We follow Table 3A of their online appendix. High IP products include office machines, chemicals, power generating machinery, professional apparatus, telecommunications, & so forth. Their definitions are based on SITC rev. 3, which we concurred to our version.

²⁶For example, Schott (2004), Khandelwal (2010), & Henn et al. (2017).

for low-wage manufacturing activities. As we saw, human capital has a statistically significant association with export product quality only in the low-income group. This underscores the importance of overcoming educational barriers in regions lacking technological capacities (Chen and Puttinanum, 2005, Chu et al., 2014, & De Fuentes et al., 2020); however, for the middle income groups, a measure of more advanced human capital accumulation, such as R&D training, might serve as a better control variable. Tariffs mostly have a negative association with export quality, but interestingly the relationship is strongly significant only in the pooled sample, low income group, & in the high IP or highly patent intensive sample of products. Tariffs therefore seem to hinder either the low quality exporter or the high quality innovator; tariffs may be shielding competition for the former and possibly raising the cost of knowledge inputs for the latter.

6.3 Robustness Check: Sample Sensitivities

One potential concern is that the highest or lowest quality products may influence the result. Therefore, we exclude product qualities below the 5th percentile and above the 95th percentile of the quality index. We re-run the regression for the pooled sample. The results are reported in Column 1, Table 4. The threshold value for the pooled sample is 46.3, which is close to the finding in Table 3, column 1. The threshold values for the upper and middle income groups are virtually unchanged. Hence, the top and bottom five percents do not constitute severe outliers.

Another concern is the bias that may arise from the inclusion of the export quality index for China. Schott (2008) analyzes the dramatic growth of Chinese goods in world product markets, but finds big discounts in Chinese export prices, suggesting that China exports relatively less sophisticated varieties. In a similar vein, Amiti and Khandelwal (2013) argue that China's export quality may be overstated because the U.S. imports data report gross values rather than value added. This concern may also apply to the methodology adopted in Henn et al. (2017). In our dataset, China ranks eighth in terms of the number of observations, accounting for about 4.33% of the sample, & has traversed across income groups during the sample period (see Appendix

I). Column 2, Table 4 shows the result of excluding China from the sample. Again our stage-dependence hypothesis still holds and the calculated threshold values remain the same or similar.

The motivation for the next robustness test is that the location of innovation may differ from the location of the production of the exportable good, as in the case where a multinational firm conducts R&D in the headquarter country but offshores or outsources the manufacturing of a good embodying the technology elsewhere. Do the patent rights of the country of offshoring or outsourcing still matter? Are our results biased because the innovative component of the exportable good was developed elsewhere? Even in this instance, patent rights should matter to the foreign companies that transfer their technology to the local producer in the offshoring/outsourcing country, as the foreign technology owner could have concerns about misappropriation or piracy (see Glass and Saggi, 2002; Saggi, 2016). Under weak protection, the foreign company may not transfer the necessary knowledge or know-how to enable the local producer to manufacture a higher quality good. Moreover, offshoring can involve significant shifts of in-house R&D to the foreign location (see Nordås, 2020), in which case the local patent environment should be important.

To test whether patent rights are less important in situations involving offshoring and outsourcing, it would be ideal to have a sample of country and product combinations involved in these activities. Unfortunately, our database does not explicitly identify these activities. Therefore, as a rough exercise, we selected countries known to be major destinations of offshoring and outsourcing, such as India, China, Mexico, Malaysia, & so forth.²⁷ We also selected product classes (SITC codes 72, 73) commonly known to be associated with offshoring/outsourcing, such as electrical components and transportation parts. The objective here is two-fold: to re-estimate the model on a sample that is purged of countries and products suspected of being significantly involved in offshoring and outsourcing; and to estimate the model where offshoring and outsourcing might be quite prevalent. The results are shown in Table 4, columns 3 - 4 respectively.²⁸ The results show

²⁷We obtained a list of nine leading countries from <https://www.statista.com/statistics/329766/leading-countries-in-offshore-business-services-worldwide/>

²⁸In column 3, observations are dropped if both the country *and* the product are suspected of being involved in offshoring/outsourcing. In column 4, observations are included if either the country *or* the product is suspect.

that patent rights matter to both sub-samples, & that stage dependency applies to them both.

6.4 Timing of Patent Reforms

This section addresses the potential endogeneity between export product quality and patent protection. The decision to strengthen patent rights could have been driven by the growth in export capacity and quality, as this may have raised the demand for intellectual property protection by innovating industries. The techniques employed in the paper thus far – lagging the index of PRI and including country and product fixed effects – help mitigate these concerns but do not fully correct for endogeneity. In this sub-section, we check for reverse causality – the possibility that patent reforms are the result of the growth in innovative capacity and export quality. We follow the approach of Branstetter et al. (2006), Duggan et al. (2016), & Ivus and Park (2019).

We modify our model (16), as follows:

$$\begin{aligned}
 QLTY_{ijt} = & \alpha_i + \alpha_{jt} + \sum_{k=0}^N [\beta_1^{t+k} REFORM_{it+k} + \beta_2^{t+k} REFORM_{it+k} \times CTF_{ijt+k} + \beta_3^{t+k} CTF_{ijt+k}] \\
 & + \sum_{k=2}^N [\beta_1^{t-k} REFORM_{it-k} + \beta_2^{t-k} REFORM_{it-k} \times CTF_{ijt-k} + \beta_3^{t-k} CTF_{ijt-k}] + \beta \mathbf{X}_{ijt} + \epsilon_{ijt}
 \end{aligned} \tag{19}$$

where *REFORM* denotes patent reform. To implement this test, we first determine the year of a major patent reform in each country based on the shifts in the index of patent rights. Data on this are from Ivus and Park (2019), which analyze the period of greatest substantive revisions in a national patent system, which includes TRIPS-related obligations and other national measures. In (19), $REFORM_{it-N} = 1$ for N or more years *before* a patent reform and zero otherwise, while $REFORM_{it+N} = 1$ for N or more years *after* a patent reform and zero otherwise. All other reform dummies equal one in the year specified and zero in all other years.

If export quality does lead to patent reforms, the timing should be such that quality upgrading

should precede the reforms. Thus, if the estimated coefficients β_1^{t-k} and β_2^{t-k} are significantly different from zero, this would suggest that quality upgrading influenced later patent reforms, which goes against our hypotheses. In contrast, estimated coefficients β_1^{t+k} and β_2^{t+k} that are significantly different from zero represent lagged effects on quality upgrading, whereby quality responds in periods after a patent reform, which would support the direction of causality from patent rights to export quality.

Table 5 shows the results of our test of reverse causality. In our estimation equations, we allowed up to six forward lags and up to six backward lags of patent reform. Year t represents the current period so that, for example, the four years ahead (forward operator) variable is actually the variable $\text{Reform}(t-4)$; it captures the anticipated reforms. $\text{Reform}(t-4) = 1$ indicates that reform has not happened yet but will happen in four years. A positively significant coefficient on this variable would indicate that current export product quality is positively associated with future reform, an outcome that would support reverse causality – that export quality determines reforms. The four years behind (backward operator) variable is represented, for example, by the variable $\text{Reform}(t+4)$; it captures the four year lagged effect of the reform, whereby quality upgrading is not observed until four years later. $\text{Reform}(t+4) = 1$ indicates that the reform has happened and its coefficient estimate measures the upgrading response four years after the fact. We drop the $\text{Reform}(t-1)$ variable since this will be the reference year against which the reform coefficient estimates will be measured.

The results of Table 5 indicate no significant pre-reform trend. The anticipated reform variables $\text{Reform}(t-3)$, $\text{Reform}(t-4)$, $\text{Reform}(t-5)$, & $\text{Reform}(t-6)$ – and their joint interactions with the distance-to-frontier measure (CTF) – are all insignificant determinants of the quality of export products, rendering no support for the view that export quality developments influenced local patent reform. Instead patent reforms have both contemporaneous as well as delayed impacts on export quality. This lack of reverse causation is consistent with the findings in Branstetter et al. (2006), Delgado et al. (2013), & Ivus and Park (2019). The patent reforms and subsequent

increases in patent rights were largely the outcome of new international norms and obligations.

6.5 Discussion: Policy Implications

Thus far, we have been showing estimates of the closeness-to-frontier threshold CTF , above which overall patent protection is positively associated with export quality grading and below which it is negatively associated. But what is the density of the distribution of CTF below and above that threshold? This is important for knowing whether on balance stronger effective patent protection spurs or hinders export quality upgrading for most of the products and economies in the sample. For example, if most of the country-products are below the threshold, patent reforms would overall impede vertical innovation in the developing world.

Recall from (15) that CTF ranges from zero to 100. In Table 6, we distribute all the CTF values in our sample into ten ranges (or deciles); for example, 0 to 10, 10 to 20, ..., 90 to 100. We especially take note of our main threshold value of 44 which was derived from the pooled sample and is marked in bold in Table 6. For each range, we show the percentage share of country-product pairs or combinations that fall in that range during the whole sample period. We further break down the distribution by income group: low income, lower middle income, & upper middle income countries. Not surprisingly, products in the low income group are heavily concentrated in the lowest ranges of closeness-to-frontier (see the first four deciles in column 2). In contrast, most of the country-product combinations in the higher ranges of CTF – from 50 to 100 – belong to the upper middle income developing countries (see column 4).

For the pooled sample, the table shows that stronger effective patent protection would spur export upgrading for the majority of country-product combinations. According to column (1) of Table 6, about 70% of country-product combinations are above the critical value of the closeness-to-the-world frontier. This is the range of cases where stronger patent rights would facilitate vertical innovation. However, for more accuracy, we need to take into account each income group's

own specific thresholds (as shown in Table 3). When we split the sample by income group, we find that about 75% of country-product combinations in the upper-middle income group have a *CTF* index above the group-specific critical threshold value of 55.7, the threshold required for stronger patent rights to spur quality improvements. And in the lower middle income group, about 61% of combinations have *CTF* values which exceed the group-specific threshold of 47.2. Thus, among middle income economies, patent reforms would help enhance export quality for most products, namely two-thirds of the country-product combinations, & inhibit quality growth for a third of them.²⁹

What makes patent policy recommendations complex is that we cannot simply make a blanket recommendation that patent rights and enforcement be strengthened in wealthier countries and relaxed in lower income nations. The reason is that the unit of analysis is the country-product pair. Within a country, different products can be above or below a critical threshold. Or a given product can be on different sides of a threshold in different countries. To hark back to our case study, when China undertook its major patent reform in 2000 as a lower middle income economy, the *CTF* index for Chinese ball-point pens was above the threshold for its type of product, making it ripe for quality upgrading under patent reforms.³⁰ On the other hand, the *CTF* index for Chinese pharmaceutical goods, a high IP product, was below the threshold. Interestingly, in India in 2005, when product patents for pharmaceuticals were introduced, the closeness-to-frontier index for pharmaceutical goods was also below the threshold for lower middle income economies, while the level of development of India's telecommunications industry met the critical threshold. It was not until 2010 that India's pharmaceutical goods achieved a *CTF* value that exceeded the threshold.

Similar experiences exist in two upper-middle income economies, Brazil and Chile. When Chile

²⁹From Table 6, columns 3 and 4, the total count of country-products above the threshold is 89,256 (=42,026+47,230), which is 67.6% of the total counts between the LM and UM groups.

³⁰Separate regressions of (16) were run for each middle income group (upper or lower) and IP intensity group (high or non-high, as identified in Appendix II). The results are not reported to conserve space, & are available from the authors upon request. The threshold estimate of *CTF* for lower middle income countries exporting high IP intensity products is 48.2. Ball-point pens (SITC 8952) fall in the high IP group.

reformed its patent law in 1991 and Brazil in 1997, only Brazil's pharmaceutical products had technological levels above the threshold. Other high IP products like telecommunication goods in Brazil were still below the threshold at the time of reform, while non-high IP products like articles of paper and pulp in Brazil were above their threshold.³¹ These select experiences raise the question of whether there should be product or industrial differentiation in the design of patent policy. Currently across the world, patent laws are national; that is, with few exceptions, they apply uniformly to different industries or products. More serious thought should now be given to IP regimes that differentiate the strengths of protection by industry, product, or technology.³²

7 Conclusion

This paper bridges two areas of the literature on trade and IPR. First, it contributes new insights into the export quality literature. While there has been vibrant research on the determinants of product quality upgrading, no study has yet explicitly examined the impact of IPR policy on quality upgrading, as far as we are aware. As Delgado et al (2013) argue, many developing economies were obligated to undertake patent reforms. Empirical research has actively sought evidence on the impacts of these reforms, be they on innovation, economic growth and development, or participation in international trade. Our study shows that the effects of effective patent protection on export quality are not unambiguous but conditional on the stage of the technological development of countries and products. As we had hypothesized, a strong effective patent system rewards innovators capable of producing sufficiently large quality jumps and hinders innovation targeted at incremental jumps.

Second, the paper contributes to the literature on the stage-dependent effects of IPR by focusing on export quality. Research by Chen and Puttitanun (2005), Chu et al. (2014), among others, has

³¹In upper middle income countries, the threshold CTF equals 60.2 for high IP products and 46.4 for non-high IP products.

³²Cho et al. (2015) discuss the possibility of differentiating IP standards by industry and Acemoglu and Akcigit (2012) argue for different protection levels for industry leaders and followers.

analyzed a stage-dependent effect of IPRs on economic development and growth, but to date no formal evidence has been produced to show that the effects of IPR protection on export product quality vary by stage, particularly for the developing countries that have had to undertake sweeping IPR reforms. By employing the most extensive IMF product quality index thus far and data on effective patent protection during two decades, this paper fills a gap in the literature and produces direct product-level evidence of a technological stage-dependent effect.

Our results have relevance for policy. First, for developing countries, enforcing identical standards of patent protection across countries and/or industries is not desirable for promoting the growth of export product quality. Under uniform standards, patent rights might be too strong for some products – that is, create excess rents and deadweight losses – while insufficiently provided for other products. Under the current international system under TRIPS, uniform minimum standards apply across member states. There have been some accommodations for stage of economic development in terms of allowing for transition periods for least developed countries. However, differentiated protection by industry or product is not *explicitly* recognized. Article 27 of the TRIPS Agreement merely stipulates that “... patents shall be available for any inventions ... in all fields of technology, provided that they are new, involve an inventive step and are capable of industrial application.”³³ Our research proposes that patent protection levels implemented by policymakers should be differentiated across products by their closeness to the world’s technological frontier; for example, different patentable subject matter should be treated differently, such as software, pharmaceuticals, & machinery, where their levels of product sophistication can vary considerably across regions. Furthermore, countries that are farther from the world frontier could adopt more flexible limitations and exceptions to patent rights, such as requiring firms to practice (or work) their patented inventions rather than hold them merely to exclude rivals from entering their markets. Indeed our analysis of the different components of patent rights shows that more flexible patent systems with adequate enforcement mechanisms help improve export quality when technological levels are below the threshold, as when economies are at the learning and adaptation

³³https://www.wto.org/english/docs_e/legal_e/31bis_trips_04c_e.htm.

stages.³⁴ In contrast, broader coverage, the backing of global IP agreements, & longer duration are more suitable for elevating product quality when technological levels are above the threshold and innovation occurs at the more frontier stage.

We suggest the following extensions for future research. First, trademark rights should be considered as another source of incentives for investing in quality improvements. Second, our paper abstracted from issues of optimal quality upgrading. Clearly, higher (quality) need not always imply better, particularly if the quality improvement has marginal social value relative to the cost of development. In the case of pharmaceuticals, new and improved drugs might be minor compared to available medicines. Lastly, it would be useful to explore richer, nonlinear effects of patent protection and closeness-to-frontier on export quality. Thresholds would become endogenous to patent rights, & more heterogeneity across countries and products could be discerned.

³⁴The analysis by a breakdown of the different components of patent rights – coverage, enforcement, loss of rights, membership in international agreements, & duration – are available from the authors upon request. The results mimic that of the overall index, except for the loss of rights component which shows that restrictions on patent strength, such as compulsory licensing, can be conducive to the export upgrading of economies with limited technological capacities.

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Table 1: **Descriptive Statistics**

Variable	Mean	Std.Dev.	Min	Max
Export Quality Index (<i>QLTY</i>)	0.85	0.076	0.64	1.11
Effective Patent Protection (<i>PRI</i>)	1.40	0.59	0.01	3.18
Closeness to Frontier (<i>CTF</i>)	51.6	17.5	0.01	100
GDP per capita (<i>GDP_PC</i>)	3,750	3,122	124	16,147
Human Capital (<i>HC</i>)	2.28	0.50	1.03	3.49
Foreign Direct Invest. Stock (<i>FDI</i>)	33.8	59.3	0.08	461.4
Tariff (<i>TARIFF</i>)	6.98	11.0	0	421.5
Preferential Trade Agreement (<i>PTA</i>)	6.9	6.85	0	60

Number of Observations = 160,700
FDI is in billions of real U.S. 2005 dollars

Table 2: **Export Quality Upgrading and Patent Reforms, by *CTF***

		<i>Closeness to Frontier, CTF</i>			
		(1)	(2)	(3)	(4)
		Lowest Quartile	3 rd Quartile	2 nd Quartile	Top Quartile
%	Lowest Quartile	-0.600	0.025	0.275	0.667
<i>Change in</i>	3 rd Quartile	-0.586	0.033	0.275	0.695
<i>Patent Index</i>	2 nd Quartile	-0.423	0.023	0.319	0.806
<i>PRI</i>	Top Quartile	-0.390	-0.007	0.245	0.726

Each entry is the average annual percentage change in export quality, 1990-2010

Table 3: Baseline Results: Patent Protection on Export Quality

Dependent Var.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Pooled <i>QLTY</i>	Low Income Countries <i>QLTY</i>	Lower Middle Income Countries <i>QLTY</i>	Upper Middle Income Countries <i>QLTY</i>	Non-High IP Products <i>QLTY</i>	High IP Products <i>QLTY</i>	Low Patent Intensity Products <i>QLTY</i>	High Patent Intensity Products <i>QLTY</i>
<i>PRI</i>	-1.101*** (0.133)	0.110 (0.154)	-1.368*** (0.241)	-2.227*** (0.524)	-1.016*** (0.197)	-1.064*** (0.173)	-1.182*** (0.168)	-0.674*** (0.205)
$PRI \times CTF$	0.025*** (0.003)	-0.002 (0.004)	0.029*** (0.005)	0.040*** (0.008)	0.024*** (0.004)	0.023*** (0.004)	0.027*** (0.004)	0.014*** (0.005)
<i>CTF</i>	0.367*** (0.003)	0.313*** (0.007)	0.358*** (0.004)	0.346*** (0.007)	0.394*** (0.004)	0.327*** (0.004)	0.378*** (0.004)	0.314*** (0.006)
<i>GDP_PC</i>	0.799*** (0.125)	2.189*** (0.307)	1.105*** (0.192)	0.877*** (0.242)	0.400** (0.194)	1.499*** (0.152)	0.686*** (0.156)	1.590*** (0.221)
<i>HC</i>	0.302 (0.409)	6.558*** (1.207)	-0.492 (0.689)	-0.919 (0.748)	-0.261 (0.658)	0.440 (0.485)	0.438 (0.519)	-0.088 (0.658)
<i>FDI</i>	0.226*** (0.021)	0.062 (0.059)	0.265*** (0.029)	0.110** (0.047)	0.294*** (0.033)	0.135*** (0.025)	0.242*** (0.026)	0.136*** (0.032)
<i>TARIFF</i>	-0.036*** (0.010)	-0.040** (0.019)	0.012 (0.014)	-0.018 (0.020)	-0.022 (0.015)	-0.050*** (0.012)	-0.019 (0.012)	-0.066*** (0.017)
<i>PTA</i>	0.095*** (0.025)	0.067 (0.078)	0.066* (0.040)	0.040 (0.037)	0.121*** (0.038)	0.074** (0.032)	0.100*** (0.032)	0.083** (0.040)
<i>CONSTANT</i>	-0.442*** (0.010)	-0.535*** (0.016)	-0.458*** (0.015)	-0.411*** (0.023)	-0.437*** (0.015)	-0.459*** (0.011)	-0.446*** (0.012)	-0.450*** (0.016)
Observations (N)	160,662	28,231	69,057	62,655	82,158	78,504	113,402	35,578
No. singletons	38	568	125	64	24	14	35	2
Original N	160,700	28,799	69,182	62,719	82,182	78,518	113,437	35,580
Adj. R-squared	0.844	0.896	0.821	0.763	0.833	0.863	0.840	0.869
Implied Threshold	44.0	--	47.2	55.7	42.3	46.3	43.8	48.1

Robust standard errors, clustered at the country level, are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Country, product, and year fixed effects are included. The classification of high IP products is based on Delgado et al. (2013). The classification of patent intensity is based on Hu and Png (2012). The implied threshold is calculated using equation (18). Singletons (one observation per group) are dropped.

Table 4: **Robustness Check: Sample Sensitivities**

Dependent Var.	(1) Excluding Lowest 5% and Top 5% quality <i>QLTY</i>	(2) Excluding China <i>QLTY</i>	(3) Non-Offshore Country and product <i>QLTY</i>	(4) Offshore country or product <i>QLTY</i>
<i>PRI</i>	-1.482*** (0.117)	-1.055*** (0.134)	-1.070*** (0.160)	-0.858*** (0.236)
<i>PRI</i> × <i>CTF</i>	0.032*** (0.002)	0.024*** (0.003)	0.025*** (0.003)	0.016*** (0.006)
<i>CTF</i>	0.327*** (0.003)	0.366*** (0.003)	0.363*** (0.004)	0.335*** (0.007)
<i>GDP_PC</i>	1.049*** (0.110)	0.761*** (0.142)	1.000*** (0.157)	1.449*** (0.230)
<i>HC</i>	-0.158 (0.354)	0.273 (0.412)	0.197 (0.462)	1.374 (0.992)
<i>FDI</i>	0.166*** (0.018)	0.234*** (0.021)	0.183*** (0.023)	0.319*** (0.061)
<i>TARIFF</i>	-0.032*** (0.008)	-0.034*** (0.010)	-0.041*** (0.011)	-0.063*** (0.020)
<i>PTA</i>	0.095*** (0.022)	0.094*** (0.026)	0.105*** (0.031)	0.147*** (0.048)
<i>CONSTANT</i>	-0.428*** (0.009)	-0.440*** (0.011)	-0.451*** (0.013)	-0.495*** (0.017)
Observations (N)	144,565	156,325	115,179	45,323
Adj. R-squared	0.883	0.844	0.850	0.859
Implied Threshold	46.3	44.0	42.8	53.6

Robust standard errors, clustered at the country level,
are in parentheses. *** p<0.01, ** p<0.05, * p<0.1.
Country, product, and year fixed effects are included.
See (18) for the threshold formula.

Table 5: **Timing of Patent Reforms and Export Quality, Pooled Sample**

Dependent Var.	(1) <i>QLTY</i>	(2) <i>QLTY</i>	(3) <i>QLTY</i>	(4) <i>QLTY</i>
<i>CTF(t-6)</i>				-0.022***
<i>CTF(t-5)</i>			-0.031***	-0.024***
<i>CTF(t-4)</i>		-0.033***	-0.024***	-0.022***
<i>CTF(t-3)</i>	-0.041***	-0.034***	-0.029***	-0.030***
<i>CTF(t-2)</i>	-0.036***	-0.028***	-0.020***	-0.026***
<i>CTF(t)</i>	0.822***	0.844***	0.843***	0.839***
<i>CTF(t + 1)</i>	-0.057***	-0.053***	-0.045***	-0.040***
<i>CTF(t + 2)</i>	-0.035***	-0.029***	-0.023***	-0.016**
<i>CTF(t + 3)</i>	-0.022***	-0.012	-0.015**	-0.003
<i>CTF(t + 4)</i>		-0.026***	-0.027***	-0.025***
<i>CTF(t + 5)</i>			-0.005***	-0.004
<i>CTF(t + 6)</i>				-0.015**
<i>REFORM(t - 6)</i>				0.012
<i>REFORM(t - 5)</i>			0.008	-0.003
<i>REFORM(t - 4)</i>		0.002	0.002	0.003
<i>REFORM(t - 3)</i>	0.003	0.003	0.005	0.004
<i>REFORM(t - 2)</i>	0.009	0.011	0.006	0.011
<i>REFORM(t)</i>	0.027***	0.034***	0.028***	0.022*
<i>REFORM(t + 1)</i>	-0.015***	-0.015***	-0.011***	-0.012***
<i>REFORM(t + 2)</i>	-0.006	-0.004	-0.003	-0.002
<i>REFORM(t + 3)</i>	0.001	0.003	0.000	0.005
<i>REFORM(t + 4)</i>		-0.005*	-0.007***	-0.008**
<i>REFORM(t + 5)</i>			0.005**	0.003
<i>REFORM(t + 6)</i>				0.002
<i>REFORM(t - 6) × CTF(t - 6)</i>				-0.017
<i>REFORM(t - 5) × CTF(t - 5)</i>			-0.012	0.005
<i>REFORM(t - 4) × CTF(t - 4)</i>		-0.005	-0.006	-0.015
<i>REFORM(t - 3) × CTF(t - 3)</i>	-0.006	-0.004	-0.008	-0.008
<i>REFORM(t - 2) × CTF(t - 2)</i>	-0.013	-0.018	-0.008	-0.017
<i>REFORM(t) × CTF(t)</i>	-0.045***	-0.055***	-0.046***	-0.035
<i>REFORM(t + 1) × CTF(t + 1)</i>	0.025***	0.024***	0.020**	0.021***
<i>REFORM(t + 2) × CTF(t + 2)</i>	0.012*	0.010	0.007	0.005
<i>REFORM(t + 3) × CTF(t + 3)</i>	-0.003	-0.006	-0.001	-0.009
<i>REFORM(t + 4) × CTF(t + 4)</i>		0.010**	0.015***	0.016***
<i>REFORM(t + 5) × CTF(t + 5)</i>			-0.009**	-0.006
<i>REFORM(t + 6) × CTF(t + 6)</i>				-0.001
Control Variables	Included	Included	Included	Included
Observations	125,608	113,696	105,425	81,713
Adj. R-squared	0.812	0.812	0.815	0.817

Standard errors in parentheses, clustered by country. Not reported to conserve space.

*** p<0.01, ** p<0.05, * p<0.1. Year, Country, and Product fixed effects included.

Controls include as before: *GDP_PC*, *HC*, *FDI*, *PTA*, and *TARIFF*.

Table 6: **Distribution of *CTF* by Income Group**

Range of <i>CTF</i>	(1) Pooled Countries	(2) Low Income (L)	(3) Lower Middle Income (LM)	(4) Upper Middle Income (UM)
<i>Percentages of Country-Product Combinations:</i>				
0-10	1.2	4.9	0.7	0.2
10-20	3.7	14.7	2.0	0.5
20-30	7.4	25.9	5.2	1.2
30-44	17.8	31.5	22.5	6.2
44-50	11.6	9.4	17.1	6.4
50-60	22.8	7.8	29.8	21.9
60-70	22.1	3.3	17.1	36.2
70-80	10.2	1.3	4.2	20.7
80-90	2.8	0.8	1.0	5.8
90-100	0.6	0.4	0.3	0.9
# below threshold	48,304	n/a	27,156	15,489
# above threshold	112,396	n/a	42,026	47,230
% below threshold	30.1%	n/a	39.2%	24.7%
% above threshold	69.9%	n/a	60.8%	75.3%
Total Counts	160,700	28,799	69,182	62,719

The threshold value **44.0** is for the pooled sample. The threshold for LM is **47.2** and for UM is **55.7**. See Table 3, columns 1, 3, 4 respectively. Threshold for L is not available (n/a) due to the statistical insignificance of patent rights. All countries are non-high income. See Appendix I.

Appendix

I. Countries in the Sample

Upper Middle Income Group – Share of Sample 64%				
Algeria **	Argentina **	Botswana	Brazil ††,**	Bulgaria **
Chile **	China †,*,**	Colombia **	Costa Rica **	Ecuador **
Fiji **,††	Gabon	Greece ***	Hungary ***	Iran **
Jamaica **	Jordan **	Korea ***	Lithuania **	Malaysia **
Malta ***	Mauritius **	Mexico	Panama **	Peru **
Poland **,***	Portugal ***	Russian Fed. **	Saudi Arabia ***	Slovak Rep. **,***
South Africa ††,**,††,**	Thailand **	Trinidad & Tobago	Tunisia **	Turkey **,††,**,††,**
Uruguay	Venezuela ††,**			
Lower Middle Income Group – Share of Sample 30%				
Angola †,*	Bolivia	Cameroon †,*	Congo, Rep. †,*	Egypt *
El Salvador	Ghana *	Guatemala	Honduras *	India *
Indonesia *,†,*	Iraq **	Mauritania *	Morocco	Nicaragua *
Nigeria *	Pakistan *	Paraguay	Philippines	Senegal †,*
Sri Lanka *	Syrian Arab Rep.	Ukraine †,*	Vietnam *	Zambia *
Zimbabwe				
Low Income Group – Share of Sample 6%				
Bangladesh	Benin	Burkina Faso	Burundi	Central Afr. Rep.
Ethiopia	Haiti	Kenya	Liberia	Madagascar
Malawi	Mali	Mozambique	Nepal	Niger
Rwanda	Tanzania	Togo	Uganda	

Number of Observations = 160,700. Country transitions between groups are shown in chronological order:

**** indicates transition from upper middle income to high income country during the sample period,*

*** from lower middle income to upper middle income, and * from low income to lower middle income.*

†† indicates transition from upper middle income to lower middle income country,

† indicates transition from lower middle income to low income.

II. Industries, 2-Digit SITC Revision 1

Industry Name	Industry Code	% Share of Sample	IP Intensity
Chemical elements and compounds	51	0.08	High
Chemical materials and products, n.e.s	59	1.66	High
Clothing	84	3.97	Non-high
Dyeing, tanning and coloring materials	53	0.99	High
Electrical machinery, apparatus, & appliances	72	8.86	High
Explosives and pyrotechnic products	57	0.57	Non-high
Footwear	85	0.70	High
Furniture	82	0.70	High
Iron and steel	67	3.80	Non-high
Leather manufactures n.e.s., & dressed fur skins	61	2.30	Non-high
Machinery, other than electrical	71	15.2	High
Manufactures of metals, n.e.s.	69	9.57	Non-high
Medicinal and pharmaceutical products	54	2.31	High
Miscellaneous manufactured articles	89	11.2	High
Non-metallic mineral manufactures, n.e.s.	66	9.20	Non-high
Paper, paperboard and manufactures thereof	64	0.63	High
Perfume materials; toilet and cleansing preparations	55	3.31	High
Plastic materials, etc.	58	0.36	High
Rubber manufactures, n.e.s.	62	2.16	High
Sanitary, plumbing, heating, & lightning fixtures	81	1.48	Non-high
Scientific and control instruments, etc.	86	4.56	High
Textile yarn, fabrics, made-up articles, etc.	65	8.10	Non-high
Transport equipment	73	5.87	High
Travel goods, handbags, and similar articles	83	0.65	Non-high
Wood and furniture (excl. manufactures of cork wood)	63	1.79	Non-high

Total Observations = 160,700. IP Intensity is based on Delgado et al. (2013).

III. Data Sources and Explanatory Notes

Variable	Description	Source
Index of Patent Protection	Based on elements of patent rights	Park (2008)
Export Quality	Based on unit values adjusted for differences in production cost, pricing and distance bias	IMF, Henn et al. (2017)
Legal Enforcement Effectiveness	Legal security, contract, enforcement, rule of law	Fraser Institute https://www.fraserinstitute.org/
Distance to Frontier	Closeness to World Frontier	Computed from Export Quality (see text)
GDP per capita	Gross Domestic Product per capita, constant 2005 USD	World Bank <i>World Development Indicators</i>
Human Capital	Index of human capital, per person based on years of schooling and return in total popn.	Penn World Tables 9.0 www.ggdcc.net/pwt
FDI	FDI stock in constant 2005 USD (millions)	UNCTAD Statistics
Import Tariff %	Most Favored Nation applied tariff (weighted by corresponding trade values)	World Bank <i>World Integrated Trade Solution</i>
PTA	Cumulative Depth of Preferential Trade Agreements	Dür et al. (2014) https://www.designoftradeagreements.org/