Competition and Quality Upgrading*

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Abstract

We analyze the effect of competition on quality upgrading, using highly disaggregated data for a large set of countries. Our analysis is based on recent theoretical frameworks that predict that the effect of competition on innovative activity depends on firms' distance to the world technological frontier. For firms far from the frontier, an increase in competition reduces incentives to innovate since the ex-post rents from innovation are eroded by new entrants. However, as firms approach the world technology frontier, competition can increase incentives to innovate because it reduces firms' pre-innovation rents by more than it reduces its post-innovation rents. We find strong support for these theories. Using import tariffs as a proxy for competition, we find that lower tariffs spur quality upgrading for products close to the technology frontier, but limit quality upgrading for products distant from the frontier.

Keywords: Quality Upgrading, Competition, Distance to Frontier, Growth

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1. Introduction

A fundamental question facing governments is how policy can promote growth. Theories from industrial organization suggest that policies promoting competition could discourage innovation. Pro-competitive policies may result in under-investment if firms only capture a fraction of the benefits of innovation while incurring the full investment costs. This appropriation argument dates back to a negative relationship between competition and innovation suggested by Schumpeter (1943). Policies that protect innovation rents could therefore encourage incumbent firms to increase investment. More recent theories suggest that the relationship between competition and growth need not be monotonic. Hausmann and Rodrik (2003), Aghion and Howitt (2005), and Acemoglu, Aghion and Zilibotti (2006) show that policies that initially facilitate growth could end up inhibiting growth at later stages of economic development. Aghion, Blundell, Griffith, Howitt and Prantil (henceforth, ABGHP, 2009) develop an industry model where the response of innovation to competition policy or increased entry threat depends on how far away the industry is from the world technology frontier.

Empirically investigating these theories at the country level is difficult because competition policy can take many forms and is likely to be correlated with other country characteristics, such as relative factor endowments. While industry-level studies within countries circumvent problems associated with cross-country analysis, they are difficult to generalize across countries that span a wide income distribution. The lack of internationally comparable measures of growth at a micro level has prevented previous studies from adopting a hybrid approach.

In this paper, we analyze the non-monotonic relationship between competition policy and innovation formalized in these theories by using a novel approach to measure product quality, as a proxy for innovation, which is internationally comparable across countries and over time. This quality measure, based on Khandelwal (2008), is inferred from highly disaggregate data that spans U.S. imports from 58 countries across 16,000 products. In our framework, quality is estimated from both price and quantity information in the trade data, where, conditional on price, higher quality is assigned to products with higher market shares. To measure competition policy, we use detailed industry-level import tariff data, which are comparable across industries and countries. The high level of disaggregation of both the tariff and quality measures are crucial for isolating the effects of competition on innovation that are distinct from other channels, such as changes in a countries' relative endowments, product-specific productivity shocks, changes in consumer demands, or changes in countries' institutional structures. Thus, our approach enables us to analyze the non-monotonic relationship between competition policy and innovation using cross-country data, but allows us to deal with many of the issues that plague such studies.

To allow for the possibility of a non-monotonic relationship between competition and

quality upgrading, we draw on models by Aghion and Howitt (2005), Aghion, Bloom, Blundell, Griffith and Howitt (henceforth, ABBGH 2005) and ABGHP (2009) to guide our empirical analysis. The key idea behind these models is that the effect of competition on innovation activity depends on firms' distance to the world technology frontier. These models highlight two forces. First, for firms far from the technology frontier, an increase in competition reduces incentives to innovate since the ex-post rents from innovation are eroded by new entrants; this idea is similar to the Schumpeterian appropriability effect of competition. Following ABGHP (2009), we refer to this effect as the discouragement effect. However, as firms approach the world technology frontier, competition can increase incentives to innovate because it reduces firms' pre-innovation rents by more than it reduces its post-innovation rents. We refer to this force as the escape competition effect.[1]

We examine predictions of these models by allowing the effect of competition on quality upgrading to depend on a product's distance to the world frontier, defined as the highest quality product exported to the U.S. in a given year. Our empirical results are consistent with the non-monotonic relationship between competition and quality upgrading predicted by the models. Products that face a relatively low degree of competition in their home market (i.e., high import tariffs) exhibit relatively faster quality upgrading when they are distant to the world frontier. In contrast, for products close to the world frontier, a competitive home market (i.e., low import tariffs) spurs quality upgrading. Our empirical results are strongest for countries characterized by strong business climates.[2] This is reasonable given that in countries with multi-dimensional sources of market frictions, changes in import tariffs are likely to have limited consequences on the competitive pressures faced by domestic firms. Interestingly, our results hold for both high and low income per capita countries, provided that they have a favorable business climate, suggesting that a minimum institutional "quality" may be needed for the mechanisms to operate.

A number of empirical studies in the industrial organization literature have considered a non-monotonic relationship between competition and innovation or growth, using competition measures such as firm concentration ratios. ABBGH (2005) use a panel of UK firms to examine the relationship between competition, measured by a Lerner index, and innovation using patent data; ABGHP (2009) consider the effects of entry threat on innovation. Both studies find support for the non-monotonic relationship between innovation and competition. Vandenbussche, Aghion and Meghir (2004) shows that a country's per capita GDP growth rate depends on the interaction between the country's aggregate TFP distance to the world frontier and its share of skilled labor force. Aghion, Boustan, Hoxby

[1] ABGHP (2009) refer to this as the "escape-entry" effect which dominates when incumbent firms are in a neck-and-neck industry. In Acemgolu, Aghion and Zilibotti (2006), it is referred to as a "selection effect"; in their model, pro-competitive policies stimulate innovation when firms are close to the technology frontier due to a selection effect of more talented entrepreneurs.

[2] As discussed in more detailed below, we rely on the World Bank's Doing Business Report to infer a country's business climate.

and Vandenbussche (2005) find that graduate education occurring in research universities is most growth enhancing in U.S. states that are close to the technological frontier. Aghion, Burgess, Redding and Zilibotti (2008) show that the impact of India's delicensing episode (a measure of increased competition) on state-level output growth depends on labor market regulations. While all these studies find support for the non-monotonic relationship between innovation and competition, they are either confined to a single country analysis or aggregate cross-country level. In contrast, our study analyses disaggregated products across a wide income distribution.

The remainder of the paper is as follows. In Section 2, we provide a sketch of the model in ABGHP (2009) which serves as the basis for our empirical specification. In Section 3, we outline our empirical strategy and the methodology used to extract product quality. In Section 4, we present the results, and in Section 5, we conclude.

2. Model

We draw on the model in ABGHP(2009) to guide our empirical specification. It is a multi-sector Shumpeterian growth model where entry threat affects innovation by incumbents. A final good, y_t, is produced under perfect competition with a continuum of intermediate inputs, $x_t(i)$:

$$y_t = \int_0^1 A_t(i)^{1-\alpha} x_t(i)^\alpha \, di, \qquad \alpha \in (0,1). \tag{1}$$

where $A_t(i)$ is the productivity associated with input i. The final good is used as capital in producing intermediates. Only two firms are capable of producing an innovation for each intermediate input. The model assumes Bertrand competition, so if two firms have equal technology then profits are zero, and if the two technologies differ then the leader has positive profits. It is assumed that the world technology frontier grows at an exogenous rate, $\gamma > 1$.

There are three different types of firms: type 1 firms are those with $A_{t-1}(i) = \overline{A}_{t-1}$; type 2 firms are one step behind the frontier, with $A_{t-1}(i) = \overline{A}_{t-2}$; and type 3 firms are two steps behind the frontier with $A_{t-1}(i) = \overline{A}_{t-3}$. This last firm type is automatically upgraded by γ. Innovation allows the incumbent to increase productivity by γ and keep up with the the growth of frontier, but technology progress is step-by-step.[3]

When entry occurs, it takes place at the frontier. An entrant captures the entire market and becomes the new leading firm unless the incumbent leader is also at the frontier after innovation, in which case the new entrant chooses not to enter. An incumbent laggard never invests in innovation because at best it would catch up to rival and earn zero profits. Thus

[3] Note that if the type 2 firm could jump two steps and catch up to the frontier then the escape entry effect would always dominate.

in steady state, there are never two firms that are both of type 1 or type 2. Therefore, in equilibrium there are only three possible states: (1) state 1 sectors - type 1 leader; (ii) state 2 sectors - type 2 leader; state 3 sectors - two type 2 incumbents.

To solve for equilibrium, ABGHP(2009) show that firms choose investment z to maximize the expected net profit gain from innovation less the cost of research and development. Noting that it is never profitable for a laggard to innovate, they solve the first order conditions for a state 1 and a state 2 leader. Denote p_j as the probability that the potential entrant pays the cost of entry in sector j, which depends negatively on a common cost parameter, Λ, so $p_j^{'}(\Lambda) < 0$. This cost parameter can be interpreted as a measure of competition, with higher Λ implying less competition. Then in state 2 sectors, they show that the probability of increasing productivity, $\partial z_2 / \partial \Lambda$, is positive due to the "discouragement effect." Firms behind the frontier know they cannot survive entry even if they successfully innovate, thus any policies that reduce the cost of entry discourage innovation for firms behind the frontier. In contrast, in state 1 sectors where the leader is at the frontier, a reduction in Λ that increases the entry threat increases innovation: $\partial z_2 / \partial \Lambda < 0$. An increase in entry threat increases the incumbent leader's losses from entry if it does not innovate thus increasing the incentive to escape entry by innovating. Expected productivity growth, g_i, in each sector is proportional to innovative investment, thus:

$$\frac{dg_1}{d\Lambda} = \frac{\partial z_1}{\partial \Lambda} (\gamma - 1) < 0; \qquad \frac{dg_2}{d\Lambda} = \frac{\partial z_2}{\partial \Lambda} (\gamma - 1) > 0.$$

This implies that for firms at the frontier (sector 1 firms), a reduction in the entry cost (tougher competition) increases innovation and growth. Conversely, for firms behind the frontier (sector 2 firms), a reduction in the entry cost decreases innovation and growth.

3. Empirical Specification

To examine the effect of competition on innovation, first we construct measures of quality and distance to the world frontier, and then link these to competition measures.

3.1. Quality and Distance to Frontier Measures

We estimate the quality of imports using U.S. import data. Given that exporting firms are more productive, larger, and produce higher quality products than non-exporters, measuring the quality of a country's exports, rather than production, focuses our analysis on the most productive firms in a country (Melitz, 2003). The International Trade literature typically use prices or unit values, defined at the ratio of import values to quantity (e.g., Schott (2004)), to proxy for quality. The obvious advantage of this approach, of course, is that unit values are easily calculated in the trade data. However, if products possess both vertical (e.g., comfort) and horizontal (e.g., style) attributes, unit values may be inappropriate proxies for quality. For example, consider varieties of women's trousers, defined at the

HS 10-digit level (HS 6204624020), exported to the U.S. in 2005 by India and Venezuela.[4] The c.i.f. unit values (inclusive of transportation and tariff costs) associated with these imports were \$140 and \$163, respectively. Under the "price equals quality" assumption, Venezuela trousers would be assigned higher quality. However, the income per capita of Venezuela exceeds India's by a ten-fold factor and so it is possible that the differences in unit values also reflect, in part, the wage differentials. Our measure of quality also takes into account differences in market shares; thus for two varieties with identical unit values, the variety with a higher market share is assigned higher quality (how much higher quality depends, as is seen below, on the slope of the demand schedule). Indeed, India exported over one million units more than Venezuela; and after accounting for these differences in market shares, the methodology described below assigns a higher quality to Indian trousers, despite lower prices.

We use the procedure in Khandelwal (2008) to obtain the measurement of variety quality used in the analysis, which estimates demand curves using the U.S import data based on a discrete choice utility framework (e.g., Berry (1994)). We derive the structural equation for a single SITC industry, comprised of many HS 10-digit products, and then estimate this equation separately for each industry. Consumer n's preferences for country c's export of HS product h (e.g., a variety ch) at time t is given by (note that we suppress the industry subscript).

$$V_{ncht} = \lambda_{1ch} + \lambda_{2t} + \lambda_{3cht} - \alpha p_{cht} + \sum_{h=1}^{H} \mu_{nht} d_{ch} + (1-\sigma)\epsilon_{ncht}. \tag{2}$$

The λ terms represent the variety's valuation that is common across consumers (notice that these terms are not subscripted by n). The first term, λ_{1ch}, is the time-invariant valuation that the consumer attaches to variety ch. The second term, λ_{2t}, controls for secular time trends common across all varieties. The λ_{3cht} term is a variety-time deviation from the fixed effect that consumers observe but we do not as the econometricians. Consequently, this last component of quality is potentially correlated with the variety's c.i.f. unit value, p_{cht}.

The "logit" error term ϵ_{ncht} and $\sum_{h=1}^{H} \mu_{nht} d_{ch}$ capture consumer n's horizontal tastes for the variety. The latter term interacts the valuation that consumer n places on product h, μ_{nht}, with a dummy variable d_{ch} that takes a value of 1 if country c's export is classified in product h. This term allows for correlations among consumer n's preferences for all varieties within product h and generates nesting structures that imply more plausible substitution patterns (e.g., see Goldberg (1995)). Following the literature, we assume that the ε shocks are Type-I extreme value which enables a closed form aggregation of individual purchasing

[4] The HS 10-digit level is the most disaggregated trade data available.

decisions to the aggregate market shares.[5]

An outside option completes the demand system. The consumer chooses this outside option if it exceeds his or her utility obtained from purchasing any of the inside options. Following Berry (1994), the utility of the outside option is given by

$$u_{n0t} = \lambda_{10} + \lambda_{2t} + \lambda_{30t} - \alpha p_{0t} + \mu_{n0t} + (1 - \sigma)\epsilon_{n0t}, \tag{3}$$

and is normalized to zero. The outside variety market share is unobserved, and we therefore approximate this share by one minus the average import penetration in the U.S.[6] The consumer chooses variety j if $V_{ncht} > V_{nc'h't}$, $\forall\, c' \neq c, \forall h$. Under the distributional assumptions for the random component of consumer utility, Berry (1994) has shown that the demand curve from the preferences in (2) is

$$\ln(s_{cht}) - \ln(s_{0t}) = \lambda_{1ch} + \lambda_{2t} - \alpha p_{cht} + \sigma \ln(gs_{cht}) + \lambda_{3cht}, \tag{4}$$

where gs_{cht} is variety ch's share within product h at time t (the "group share").[7] The term s_{0t} is the outside good market share.[8] The expression in (4) states that a variety's (relative) market share is equal to its quality plus its significance within the nest it occupies, less its price. Because trade data do not record characteristics of varieties, we exploit the panel dimension and estimate λ_{1ch} and λ_{2t} with variety and year fixed effects, respectively.

The third component of quality, λ_{3cht}, is not observed and plays the role of the estimation error. Both this term and the nest share are potentially correlated with the variety's price, so instrumental variables are required to identify the parameters. We instrument the c.i.f price with the variety's transportation costs and distance to the U.S. interacted with oil prices. Transport costs are obviously correlated with c.i.f. prices, but may also be correlated with prices if firms ship higher quality goods in order to lower per unit transport costs. This potentially raises concerns that trade costs may be correlated with variety quality (Hummels and Skiba, 2004). However, the exclusion restriction remains valid as long as transport costs do not affect deviations from average quality, λ_{3cht}. In other words, if an Australian firm

[5] Cardell (1997) has shown that the distribution of $\sum_{h=1}^{H} \mu_{nht} d_{ch}$ is the unique distribution such that if ϵ is distributed extreme value, then the sum is also distributed type-I extreme value. The degree of within nest correlation is controlled by $\sigma \in (0, 1]$ and is assumed to be identical across all products. As σ approaches one, the correlation in consumer tastes for varieties within a nest approaches one; as σ tends to zero, the nested logit converges to the standard logit model.

[6] This assumption on the outside good market share is innocuous for our results for two reasons. First, since the outside good market share is common for all imports within an SITC, altering the outside good market share will be captured by the year fixed effects in the estimation. Second, in our analysis, we use a full set of country-year and product-year fixed effects to control for the absolute changes in quality. While the outside good market share therefore affects the absolute growth rate of quality, the relative quality growth rate is unaffected by this measure.

[7] This term is a consequence of the nested logit structure. If one adopts a standard logit utility function, this term disappears from equation (4).

[8] The total market size for the SITC industry is $MKT_t = \sum_{j \in \mathcal{J}_{kt}, j \neq 0} q_{ckt}/(1 - s_{0t})$, where q_{ckt} denotes the import quantity of variety ck. The imported variety market shares are computed as $s_{ckt} = q_{ckt}/MKT_t$.

chooses to export higher quality varieties to the U.S. because of distance, the instruments remain valid as long as shocks to transportation costs do not affect deviations from the firm's average quality choice. Indeed, the Washington Apples discussed in Hummels and Skiba (2004) identify the impact of distance on prices using cross-country variation in distance rather than shocks to transport costs over time. Finally, gs_{cht} is also endogenous and so we instrument this term with the number of varieties within product h and the number of varieties exported by country c.[9]

A second issue that arises in estimating (4), first noted by Feenstra (1994) and also by Hallak and Schott (2008), is the unobserved or hidden problem. To understand how hidden varieties could confound the measurement of quality, suppose that the reason India exported far more women's trousers than Venezuela was simply because India exported more unobserved twelve-digit HS varieties (for instance, more colors). If the Venezuelan and Indian varieties were identically priced with equal market share, then when aggregating to the observed ten-digit HS level, we would assign a larger market share to the Indian varieties. From equation (4), India's estimated quality would be biased upward simply due to the hidden varieties. We follow standard models (e.g., Krugman 1980) that predict that a country's population will proxy for the number of hidden varieties. Allowing the (log of) population to shift the logit error mean implies that it becomes an additional covariate in (4).

The demand curve that corrects for the hidden varieties problem is given by

$$\ln(s_{cht}) - \ln(s_{0t}) = \lambda_{1ch} + \lambda_{2t} - \alpha p_{cht} + \sigma \ln(gs_{cht}) + \gamma \ln pop_{ct} + \lambda_{3cht}, \tag{5}$$

where pop_{ct} is the population in country c. Using the estimated parameters, we define the quality of variety ch at time t as[10]

$$\lambda_{cht} \equiv e^{\lambda_{1ch}+\lambda_{2t}+\lambda_{3cht}} \tag{6}$$

We estimate equation (5) separately for each of the SITC industries. While separate estimations allow for heterogeneity in the α parameter across industries, it implies that the qualities cannot be compared across estimations (that is, while we can compare the quality of imported machine engines from Taiwan and Korea, we cannot compare the quality

[9] The validity of these instruments to identify σ rely on weaker assumptions than made in the discrete choice literature. The discrete choice literature typically instruments $gs_{cht}$with the average characteristics of varieties within product h. The validity of this assumption rests on assuming that the firms' quality choices are fixed. Here, we use a less restrictive assumption by instrumenting gs_{cht} by a count of varieties. This assumes that the number of varieties is uncorrelated with the deviation from average quality, λ_{3cht}. This will be the case in any model where entry and exit occur prior to the firms' quality choice. For example, this occurs in models where firms choose quality in the final stage of a multi-stage game of location, price, and quality decisions (e.g., Vogel (2008)).

[10] We apply this monotonic transformation to the quality measures to ensure that all qualities are non-negative. This is required in this paper because we need to obtain a measure of the distance to frontier (see equation (7)).

of a Taiwanese machine engine to a Taiwanese cotton shirt). In the analysis below, we describe how we avoid comparing quality across industries by specifying appropriate fixed effects that ensure that our analysis focuses on differential quality responses across countries within products.

Once the quality estimates are obtained, we define a variety's proximity to the world frontier as

$$P2F_{cht} = \frac{\lambda_{cht}}{\max_{c \in ht}(\lambda_{cht})} \tag{7}$$

where the max operator chooses the maximum λ_{cht} within a product-year and $P2F_{cht} \in (0, 1]$. For varieties close to the frontier, this measure is close to one. For varieties far from the frontier, this measure is close to zero.

3.2. Data Description

We combine several databases for our analysis. We obtain six-digit HS import tariffs for 58 countries for 1990, 1995, and 2000. The sample of countries was limited by the availability of tariff data for those years.[11] Our quality measures are obtained from estimating the demand systems in equation (5) on ten-digit U.S. import data from 1990-2005. Since unit values are notoriously noisy (GAO 1995), prior to estimating the demand systems in equation (5), we trim the data along three dimensions: we drop variety-year observations above or below the 1st and 99th percentile of unit values, exclude varieties with annual price increases of more than 200 percent or a price declines of more than 66 percent, and drop varieties with export quantities of less than ten. Using this data, we estimate qualities from the estimated parameters in equation (5). This procedure yields quality numbers that are highly skewed and so we drop any observations with five-year quality growth outside the 1st and 99th percentiles (we trim along five year growth since our ultimate analysis relies on 5-year intervals).

Table (1) reports summary statistics of the proximity to frontier measure and tariffs for each country and year. As shown in Khandelwal (2008), the quality estimates indicate that richer countries export higher quality varieties within products, consistent with findings in the previous literature.[12] Thus, on average, more advanced countries sit atop a product's quality ladder while developing countries are further from the frontier. The relationship between income and the quality leaders is seen in Figure (1). The left panel of Figure (1) plots the fraction of varieties for which a country is a leader ($P2F_{cht} = 1$) as a share of total varieties exported to the U.S. against its income per capita in 2005.[13] As expected, there

[11] If tariff data were unavailable for a particular year, we included the data for the year before. Note that tariffs are common for all countries within the European Union.

[12] The income per capita and population variables are obtained from the the World Development Indicators database.

[13] This distance to frontier is defined relative to the highest quality product exported by any country in our sample.

is a positive and statistically significant relationship between a country's income level and the fraction of its exported products for which it has the highest quality. Similarly, there is a positive relationship between income and the fraction of highest priced varieties within an HS 10-digit product in the right panel of the figure, as also shown in earlier work (e.g., Schott 2004). However, the slope between the price-based leader measure and income is steeper than the quality-based leader measure. For example, although China exports the highest-priced variety in 4 percent of products in 2005, the quality-based measure indicates that China is the leader in 30 percent of products. There are several reasons for this discrepancy. First, although China exports low-priced varieties, it has exceptionally high market shares, particularly for labor-intensive products. That is, the regressions yield high quality estimates for China because its market shares are larger than the predicted market shares given its price and the estimated elasticity of demand. Thus, the methodology will record higher quality for China in these product groups. Second, trade statistics are recorded on a value, and not value-added basis. Given the importance of processing trade for Chinese exports, its value added will vary across sectors. For example, in computers its domestic value added has been estimated to be as low as 5 percent (see Koopman, Wang and Wei (2008)). If the U.S. Census collected value-added trade data, China's inferred quality would presumably be lower. Note that as additional robustness checks, we will also analyze our results using the more conventional unit values to proxy for quality.

3.3. Estimation Strategy

With the import tariffs and quality measures in hand, we can turn to analyzing how competition affects quality upgrading while allowing for the discouragement and escape competition forces discussed above. The following baseline regression relates quality growth with the prior period's import tariffs, the distance to the frontier, and the interaction of the two.[14]

$$\Delta \ln \lambda_{cht} = \alpha_{ht} + \alpha_{ct} + \beta_1 P2F_{cht-5} + \beta_2 tariff_{cht-5} + \beta_3 (P2F_{cht-5} * tariff_{cht-5}) + \varepsilon_{cht} \quad (8)$$

The dependent variable, $\Delta \ln \lambda_{cht}$, is the change in a variety's quality between period t and $t-5$. All the explanatory variables are in levels for the period $t-5$. The product-year fixed effects (α_{ht}) deal with two issues. First, because the qualities are estimated separately across industries, the quality estimates are only comparable within the industry or product. Second, product-year fixed effects control for shocks that are common to all varieties within a product, including demand shocks or world-wide technology shocks that would also influence quality upgrading. The country-year fixed effects (α_{ct}) control for country-level shocks such as technological shocks and changes in relative endowments. Thus, this specification flexibly controls for different shocks that may be correlated with tariff changes and affect quality

[14] ABGHP (2009) specify a similar estimating equation in their context.

growth. It is important to note that the inclusion of these fixed effects implies that we identify the impact of tariffs off a quality upgrading trend, rather than the absolute effect.

The theoretical predictions from the models discussed above suggest that $\beta_2 > 0$ and $\beta_3 < 0$. Thus, a marginal drop in the country's tariff rate would spur a variety's quality growth in subsequent periods only if the product variety is close to the world quality frontier ($P2F_{cht-5}$ close to 1). This is the escape competition effect discussed above. In contrast, if a product variety is a long way from the frontier, a fall in tariffs could reduce quality upgrading due to the discouragement effect. That is, products a long way from the frontier need high tariffs to protect rents in order to promote quality upgrading. Note that a $\beta_1 < 0$ implies that varieties that are far from the frontier ($P2F_{cht-5}$ close to 0) experience faster quality upgrading, implying convergence in quality. In the next section, we present the empirical findings.

4. Empirical Results

Before estimating equation (8), we first look for a monotonic relationship between competition and quality growth by regressing changes in a variety's quality growth on product-year fixed effects and the home market's tariffs. The first column of Table 2 shows that a fall in tariffs is associated with slower quality upgrading, consistent with the "discouragement effect." In column 2, we separate the effect for OECD countries from non-OECD countries to see if this relationship holds for both groups, and we find that both coefficients are positive and significant, with the magnitude for non-OECD countries more than twice that for OECD countries. The results in column 1 and 2 do not, however, control for factors such as changes in a country's relative endowments or technology shocks. In column 3, we include country-year fixed effects which control for possible supply-side shocks, and find that the monotonic relationship is not robust. The coefficient on tariffs for OECD countries switches signs, now indicating that a fall in tariffs increases quality upgrading; the coefficient on the tariff variable for non-OECD countries remains positive but is not statistically significant. Column 3 therefore highlights the importance of flexibly controlling for country-year shocks which may be correlated with industry level competition measures such as tariffs. In all subsequent regressions, we therefore include both country-year and product-year fixed effects.

Next, we examine if the relationship between quality upgrading and tariffs depends on a variety's distance to the frontier in column 4. The negative coefficient on the lag distance to the frontier implies a faster catch-up for varieties far from the frontier. The coefficient on the interaction of tariffs with the distance to frontier is negative and significant, highlighting the "escape competition" effect, where the varieties closest to the world frontier are more likely to upgrade quality in response to tougher competition in the domestic market. Note that the coefficient on the linear tariff variable is now insignificant. This may be due to

restricting the coefficient to be the same on both OECD and non-OECD countries in this estimation, which may be at odds with the potential heterogeneity in the impact of tariffs on competition across these two groups of countries.

In column 5, we allow for separate effects for OECD and non-OECD countries. The results are consistent with model predictions in ABGHP (2009). First, consider OECD countries. For OECD varieties that are farther away from the frontier ($P2F_{cht-5}$ close to 0), there is a positive relationship between tariffs and quality growth: a 10 percentage point fall in tariffs is associated with a 3.4 percent fall in quality upgrading for products a long way from the frontier. However, for OECD varieties close to the frontier, a fall in tariffs has the opposite effect: a 10 percentage point fall in tariffs is associated with a 4.3 percent increase in quality for varieties very close to the frontier. For non-OECD countries the coefficient on the linear tariff variable continues to be insignificant, but the interactive term between tariffs and distance to the frontier is significant with the expected negative sign, showing that the escape competition effect is present, but the magnitude is less than half that for the OECD countries. A 10 percentage point fall in tariffs is associated with a 2.6 percent growth in quality.

4.1. Institutions and Quality Upgrading

The results in column 5 raise the question as to why there are larger quality responses in OECD countries than in non-OECD countries as tariffs change. For the effects in the theory to be present, market forces need to be able to operate. In particular, entry and exit of firms is crucial for tariffs to invoke more competition in the home market. However, non-tariff barriers, bureaucratic red tape, and other entry regulations are likely to imply heterogeneity in the impact of tariffs on the competitive environment across countries. In countries with more regulation, additional domestic reforms may be needed so that lower tariffs induce further competition in the market. We therefore consider a specification that tests for heterogenous effects in the tariff-frontier interaction coefficient according to institutional quality.

Our measure of institutional quality is a measure of the regulatory environment from the World Bank's Doing Business Survey.[15] The index ranges from 0 to 1 with a higher value indicating a better business environment. In the first column of Table 3, we allow for separate coefficients for countries with a doing business indicator greater than the median, HDB, from those with a doing business indicator lower than the median, LDB.[16] We see

[15] We construct an aggregate Doing Business Index by following the procedure outlined in World Bank (2005). The Doing Business database tracks constraints along several dimensions, including the ease of starting a business, enforcing contracts, obtaining credit, hiring and firing, etc. We compute each country's percentile ranking for each outcome. The aggregate Doing Business measure takes the (simple) average of a country's percentile rankings across the outcomes. A higher value indicates an environment more conducive to conducting business.

[16] See Table 1 for the list of countries classified as above and below the median Doing Business index.

that for countries with strong business environments, all coefficients have the hypothesized signs and are statistically significant. In contrast, the countries with relatively weak business environments do not show support for the theory. In fact, the signs on the tariff variables flip over.

Interestingly, the business environment indicator is picking up an effect beyond differences in income per capita. To see this, we allow for additional flexibility in the coefficients for strong and weak business environments further broken down by OECD and non-OECD countries in the middle panel of Table 3 (columns 2a and 2b). The results indicate that even non-OECD countries characterized by strong business environments display both the discouragement and escape competition forces. Moreover, for OECD countries characterized by weaker business environments, both tariff terms are insignificant. This result is suggestive that a minimum institutional "quality", and not simply differences in income per capita, is required for the two forces to operate. In particular, the lack of support for the models among weaker business climate countries appears consistent with a variant on the Acemoglu, Aghion and Zilibotti (2006) model that discusses how political economy factors can inhibit the escape competition effect from operating (see section 5.2 of Acemoglu et al (2006)).

In column 3, we therefore reestimate equation 8 with only the sample of countries with business environments above the median. The results indicate that for varieties far from the frontier, a 10 percentage point fall in tariffs is associated with a 2.5 percent decline in quality growth, while an equivalent tariff decline for varieties close to the frontier is associated with a 3.7 percent increase in quality growth. However, for the mean proximity to the frontier variety ($P2F = 0.28$), a 10 percentage point fall in tariffs is only associated with a 0.4 percent increase in quality growth . The subsequent analysis will be restricted to the set of countries characterized by a relatively stronger business environment since countries with poorer business climates are unlikely to fit the theory.

The baseline results in column 5 support the non-monotonic relationship between competition and quality upgrading predicted by ABGHP (2009). Figure 6. provides a graphical illustration of the discouragement and escape effects in column 3 of Table 3. The figure plots the predicted quality growth, $\Delta \ln \hat{\lambda}_{cht} = \hat{\beta}_1 P2F_{cht-5} + \hat{\beta}_2 tariff_{cht-5} + \hat{\beta}_3 (P2F_{cht-5} * tariff_{cht-5})$, against the $P2F_{cht-5}$, evaluated at the 10th (dashed line) and 90th tariff percentile. The downward sloping lines are indicative of convergence in the data; varieties far from the frontier experience faster quality upgrading than those that are proximate to the frontier. The predicted quality growth line evaluated at the 90th percentile tariff (a 20 percent tariff) is a clock-wise rotation of the 10th percentile tariff (a 0 percent tariff), and this reflects the two forces. For varieties far from the frontier, moving from a low tariff to a high tariff is associated with an increase in the rate of quality upgrading, which is the Schumpeterian discouragement effect. However, for varieties close to the frontier, moving from a

low to high tariff is associated with a slower rate of quality upgrading, which illustrates the escape competition effect.

Khandelwal (2008) notes that markets differ in their scope for quality differentiation, where some markets are characterized by a large dispersion of qualities, or "long" quality ladders, while other markets are characterized by a smaller dispersion of quality, or "short" quality ladders.[17] The reason for these differences may be due to either technological differences and/or consumer preferences, but these differences imply that markets will differ in their scope for quality upgrading according to their quality ladder lengths. In Table 4, we interact the baseline specification with an HS10 product's initial period quality "ladder" measure, which captures a product's scope for quality differentiation (see Khandelwal (2008)). The quality ladder is measured as the (log) difference between the best and worst quality within a product in the baseline year, 1990. This regression indicates that the response of quality upgrading to changes in tariffs are larger in magnitude in markets that possess a higher scope for quality differentiation. This is intuitive as we should expect limited quality upgrading in markets in which significant quality upgrading is not feasible either due to technological constraints or consumer preferences.

4.2. Robustness

In the remaining tables, we check the robustness of the results. One potential concern is that the interaction effect is simply picking up inherent non-linearities in the relationship between quality growth and tariffs. In column 1 of Table 5, we include proximity to frontier squared and tariffs squared to check for non-linear effects in these terms. The squared tariff term is not statistically significant, and we still find that the interaction between tariffs and proximity to frontier remains negative and statistically significant. This implies that our results are not simply picking up an arbitrary non-linear effect. In column 2, we check the sensitivity of the results by excluding varieties at the frontier (so exclude observations for which $P2F_{cht-5} = 1$). Likewise, the results are not sensitive to excluding these observations; the interaction term remains negative and statistically significant. In column 3 of Table 5, we check the sensitivity of the results by re-defining the frontier in equation (7) using the average of the top three qualities, rather than the maximum.[18] As seen in the column, the results are also not sensitive to this alternative definition of the distance to the frontier.

Another important concern is that countries may be selectively liberalizing their industries based on forces that we are unable to observe. For instance, if countries receive productivity shocks that enable them to improve the quality of their products, pressures against

[17] A market's intrinisic scope for quality differentiation is closely related to an escalation principle developed in Sutton (1998). Other papers that rely on hetergeneity in the scope for quality differences include Kugler and Verhoogen (2008) and Johnson (2008).

[18] We set the $P2F$ of the top 3 varieties equal to one, but the results also hold if we allow these varieties to have a $P2F$ that exceeds one.

liberalizing those markets may subside. To the extent that these shocks are country-specific, the country-year fixed effects will control for productivity shocks. Likewise, productivity (or demand) shocks that are common across all varieties within a product will be captured by the product-year fixed effects. However, productivity shocks could be market specific. To address this concern, we include the change in a country's total exports to the world for each HS 6-digit industry by year, based on the idea that higher productivity is expected to be reflected in larger exports.[19] In Column 4 of Table 5, we see that the while the change in exports is positively correlated with quality upgrading, its inclusion leaves the key results unchanged. Moreover, the magnitudes are extremely close to the baseline results reported in column 3 of Table 3.

In column 5, we re-estimate equation (8) using unit values, the more common proxy for quality in international trade (e.g., see Schott 2004). Specifically, we define the distance to the frontier based on how far a variety's price is from the maximum price, and the dependent variable is change in log prices.[20] The table shows that we find similar effects; for varieties close to the unit value frontier, there is a positive relationship between tariffs and subsequent price growth, and for varieties far from the frontier, there is a negative association. This result shows that the discouragement and escape competition effects appear when using prices, instead of the alternative measure of quality proposed by Khandelwal (2008).

Finally, an additional concern with the baseline specification is that the coefficients on $P2F_{ch,t-5}$ and $(P2F_{cht-5} * tariff_{cht-5})$ might be downward biased because, all else equal, a high $\lambda_{ch,t-5}$ implies a high $P2F_{ch,t-5}$ but a low $\Delta \ln \lambda_{cht}$. Following Acemoglu et al (2006), we therefore instrument $P2F_{ch,t-5}$ (and the interactions) with its 5-year lag value. The results for this regression are reported in column 6 of Table 5. Not surprisingly, the coefficients on the distance to frontier and the interaction become smaller in magnitude (column 3 of Table 3). The linear tariff term is still positive but not statistically significant, perhaps because standard errors are generally amplified in instrumental variable regressions. However, the interaction term remains negative and statistically significant.

5. Conclusion

This paper analyzes the relationship between competition and quality upgrading using a novel approach to measuring quality with detailed data on countries' competition policy. Consistent with recent theoretical models, we find support for two opposing forces of the effect of lower tariffs on a variety's quality depending on its distance to the world technology frontier. Varieties that face a relatively low degree of competition in their home market (i.e., high import tariffs) exhibit relatively faster quality upgrading when they are distant from the world frontier. In contrast, for products close to the world frontier, a competitive

[19] We obtain a country's total exports to the world, by HS6, from the UN Comtrade database.

[20] We exclude observations that report unit value changes above or below the 99th and 1st percentiles.

home market (i.e., low import tariffs) spurs quality upgrading. Our findings are robust to performing a number of sensitivity checks, including instrumenting tariffs and the distance to frontier, and using prices as the alternative measure of quality.

Our empirical results are strongest for countries characterized by strong business climates, which is perhaps not surprising given that lower tariffs are unlikely to significantly alter competitive environments in countries with strong government regulations. This result is suggestive that a minimum institutional "quality", and not simply higher income per capita, is required for the two forces to operate. In particular, the lack of support for the models among weaker business climate countries appears consistent with a variant on the Acemoglu, Aghion and Zilibotti (2006) model which explains that political economy factors can inhibit the escape competition effect from operating (see section 5.2 of Acemoglu et al (2006)). Our paper therefore provides evidence consistent with earlier work that suggests that the quality of a country's institutions are important for economic performance (Acemoglu, Johnson, and Robinson, 2004).

Our results also suggest that initial heterogeneity in industry characteristics is important for understanding subsequent industry performance following trade liberalizations. In particular, aggregate implications of industry-level trade models, such as Melitz (2003), may differ according to the industry's initial distance to the world frontier. Further theoretical research on this source of heterogeneity may therefore be important.

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6. Tables and Figures

OECD			Non-OECD		
Country	Proximity to Frontier (Quality)	Tariff	Country	Proximity to Frontier (Quality)	Tariff
Australia+	0.208	0.110	Argentina	0.240	0.162
Austria+	0.336	0.119	Bangladesh+	0.340	1.240
Bel/Lux+	0.334	0.073	Brazil	0.219	0.234
Canada+	0.303	0.100	Chile+	0.273	0.100
Denmark+	0.358	0.068	China	0.445	0.347
Finland+	0.377	0.119	Colombia	0.246	0.175
France+	0.214	0.080	Costa Rica+	0.480	0.143
German+	0.215	0.072	Ecuador	0.320	0.187
Greece	0.316	0.096	Egypt	0.279	0.467
Ireland+	0.460	0.080	El Salvador	0.517	0.212
Italy+	0.252	0.087	Guatemala	0.376	0.207
Japan+	0.251	0.037	Hondura	0.448	0.196
Mexico	0.249	0.184	Hong Kong+	0.496	0.000
Netherlands+	0.217	0.069	India	0.313	0.646
New Zealand+	0.403	0.096	Indonesia	0.262	0.251
Norway+	0.400	0.051	Kenya	0.265	0.345
Poland	0.231	0.099	Malaysia+	0.318	0.212
Portugal	0.368	0.106	Morocco	0.301	0.685
South Korea+	0.226	0.101	Nepal	0.324	0.267
Spain+	0.198	0.078	Nicaraga	0.522	0.156
Sweden+	0.338	0.059	Pakistan	0.272	0.634
Turkey	0.205	0.118	Paraguay	0.260	0.156
UK+	0.200	0.075	Peru	0.246	0.185
			Philippines	0.268	0.233
			Saudi Arabia+	0.334	0.119
			Singapore+	0.493	0.008
			South Africa+	0.232	0.156
			Sri Lanka	0.380	0.381
			Taiwan+	0.300	0.097
			Thailand+	0.260	0.428
			Tunisia+	0.387	0.407
			Uruguay	0.458	0.179
			Venezuela	0.200	0.146
			Vietnam	0.321	0.408

Notes: Table reports (simple) average of proximity to frontier (see equation 9) for each country for 1990, 1995, 2000 and 2005. The tariffs are simple averages from 1990, 1995 and 2000. + denotes countries above the median World Bank's Doing Business business climate variable. Source: Authors' calculations from the data; tariff data obtained from World Integrated Trade Solution (WITS).

Table 1: Summary Statics

Regressors	(1)	(2)	(3)	(4)	(5)
$P2F_{cht-5}$				-0.446 ***	
				0.016	
$Tariff_{c,h6,t-5}$	0.267 ***			-0.063	
	0.019			0.050	
$P2F_{cht-5}$ X $Tariff_{c,h6,t-5}$				-0.124 **	
				0.049	
OECD Indicator interacted with					
$P2F_{cht-5}$					-0.426 ***
					0.023
$Tariff_{c,h6,t-5}$		0.110 **	0.119		0.340 ***
		0.053	0.092		0.121
$P2F_{cht-5}$ X $Tariff_{c,h6,t-5}$					-0.766 ***
					0.204
Non-OECD Indicator interacted with					
$P2F_{cht-5}$					-0.398 ***
					0.023
$Tariff_{c,h6,t-5}$		0.256 ***	-0.137 ***		-0.087
		0.019	0.045		0.054
$P2F_{cht-5}$ X $Tariff_{c,h6,t-5}$					-0.173 ***
					0.056
Product-Year FEs	yes	yes	yes	yes	yes
Country-Year FEs	no	no	yes	yes	yes
R-squared	0.44	0.44	0.45	0.46	0.46
Observations	149,358	149,358	149,358	149,356	149,356

Notes: Table reports regression results of change in (log) quality of a variety on the lag HS6 level tariff faced in the origin country, the varieties lag proximity to frontier and the interaction. Columns 1 reports quality growth on tariffs. Column 2 interacts tariffs with a dummy if the country belongs to the OECD or rest of the world (ROW) and column 3 introduces country-year fixed effects. Column 4 reports the baseline specification with the interaction between proximity to frontier and tariffs. Columns 5 estimates separate coefficients for the OECD and ROW countries. All regressions include product-year fixed effects. Standard errors clustered by exporting country (with EU countries treated as one country because of its common trade policy). Significance * .10 **.05 *** .01.

Table 2: Quality Upgrading, Competition, and Distance to Frontier

Regressors	All Countries (1)		OECD Indicator interactions (2a)		Non-OECD Indicator interactions (2b)		HDB Countries Only (3)	
Countries Above Median DB								
$P2F_{cht-5}$	-0.431	***	-0.397	***	-0.373	***	-0.518	***
	0.017		0.025		0.030		0.019	
$Tariff_{c,h6,t-5}$	0.217	***	0.593	***	0.154	**	0.253	***
	0.066		0.144		0.072		0.074	
$P2F_{cht-5}$ X $Tariff_{c,h6,t-5}$	-0.464	***	-1.199	***	-0.448	***	-0.618	***
	0.082		0.256		0.088		0.093	
Countries Below Median DB								
$P2F_{cht-5}$	-0.498	***	-0.592	***	-0.466	***		
	0.030		0.072		0.035			
$Tariff_{c,h6,t-5}$	-0.277	***	-0.179		-0.258	***		
	0.068		0.195		0.073			
$P2F_{cht-5}$ X $Tariff_{c,h6,t-5}$	0.114		0.327		0.054			
	0.070		0.397		0.076			
Product-Year FEs	yes		yes				yes	
Country-Year FEs	yes		yes				yes	
R-squared	0.46		0.46				0.46	
Observations	149,356		149,356				105,572	

Notes: Column 1 reports regression results of change in (log) quality of a variety on the lag HS6 level tariff faced in the origin country, the varieties lag proximity to frontier and the interaction, with each coefficient interacted with a dummy variable if the country is above (HDB) or below (LDB) the median Doing Business value. Panel two introduces an additional interaction if the country is an OECD country. Column 2a reports the OECD interactions and column 2b reports the non-OECD interactions; note that these coefficients are estimated in a single regression. Column 3 reports the baseline specification for just countries above the median Doing Business values. All regressions include product-year and country-year fixed effects. Standard errors clustered by exporting country (with EU countries treated as one country because of the common trade policy). Significance * .10 **.05 *** .01.

Table 3: Quality Upgrading, Competition, and Institutions

Regressors	(1)	
$P2F_{ch\,t\text{-}5}$	-0.572	***
	0.028	
$P2F_{ch\,t\text{-}5}$ X $Ladder_h$	0.016	***
	0.005	
$Tariff_{c,h6,t\text{-}5}$	-0.008	
	0.099	
$Tariff_{c,h6,t\text{-}5}$ X $Ladder_h$	0.052	***
	0.013	
$P2F_{ch\,t\text{-}5}$ X $Tariff_{c,h6,t\text{-}5}$	-0.084	
	0.126	
$P2F_{ch\,t\text{-}5}$ X $Tariff_{c,h6,t\text{-}5}$ X $Ladder_h$	-0.143	***
	0.042	
Product-Year FEs	yes	
Country-Year FEs	yes	
R-squared	0.46	
Observations	84,348	

Notes: Table reports the results where baseline coefficients are interacted with a product's quality ladder (LADDER), defined as the difference between the best and worst quality within a product in the baseline year, 1990. The regression includes product-year and country-year fixed effects and is run on the set of HDB countries only. Standard errors clustered by exporting country (with EU countries treated as one country because of the common trade policy). Significance * .10 **.05 *** .01.

Table 4: Quality Upgrading, Competition, and Quality Ladders

Regressors	Squared Tariffs and D2F (1)	Exclude P2F = 1 (2)	Frontier defined as Avg of Top 3 Qualities (3)	World Export Growth (4)	Unit Values (5)	IV Regression (6)
$P2F_{ch\,t\text{-}5}$	-1.720 ***	-0.650 ***	-0.534 ***	-0.539 ***	-1.108 ***	-0.329 ***
	0.067	0.027	0.017	0.020	0.016	0.041
$Tariff_{c,h6,t\text{-}5}$	0.259 ***	0.223 ***	0.354 ***	0.229 ***	0.193 ***	0.146
	0.086	0.075	0.087	0.076	0.045	0.113
$P2F_{ch\,t\text{-}5}$ X $Tariff_{c,h6,t\text{-}5}$	-0.539 ***	-0.548 ***	-0.410 ***	-0.605 ***	-0.458 ***	-0.328 **
	0.091	0.094	0.074	0.095	0.085	0.139
$P2F_{ch\,t\text{-}5}$ Squared	1.184 ***					
	0.060					
$Tariff_{c,h6,t\text{-}5}$ Squared	-0.012					
	0.035					
Log World Export $Growth_{c,h6,t}$				0.088 ***		
				0.009		
Product-Year FEs	yes	yes	yes	yes	yes	yes
Country-Year FEs	yes	yes	yes	yes	yes	yes
R-squared	0.46	0.46	0.47	0.47	0.21	3,916
Observations	105,572	96,430	105,572	101,602	102,731	40,615

Notes: Table reports regression results of change in (log) quality of a variety on the lag HS6 level tariff faced in the origin country, the varieties lag proximity to frontier and the interaction along with additional controls. Column 1 includes controls for squared lag D2F and square lag tariffs. Column 2 excludes observations with proximitys to frontier equal to one. Column 3 re-defines the proximity to frontier measure using the average of the top three qualities within a product. Column 4 includes a measure of growth in total exports, by country-HS6-year. Column 5 uses unit values as the proxy for quality, and so it regresses the change in unit values on tariffs, a unit value proximity to frontier measure, and the interaction. Column 6 instruments the lag proximity to frontier with the previous period D2F measure (i.e., the lag lag proximity to frontier). All regressions include product-year fixed effects and are run on the set of high DB countries. Standard errors clustered by exporting country (with EU countries treated as one country because of the common tariff). Significance * .10 **.05 *** .01.

Table 5: Robustness Checks

Figure 1: Graph reports the fraction of products for which each country has the highest quality or unit value in 2005.