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Quality Upgrading and Export Performance in the Asian Growth Miracle

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Abstract

We explore the contribution of product-quality upgrading to the export performance of six fast-growing Asian economies: China, India, Indonesia, Malaysia, South Korea, and Thailand. We focus on measuring the impact of quality upgrading on the changes in these countries' sectoral export shares during 1970–2010. We build a multisector Ricardian trade model which allows for changes in product quality, and calibrate it to generate predictions about export volumes. Unlike previous literature, our approach allows estimation without employing domestic production data. Our results point to quality upgrading being a key driver of export shares.

1   Introduction

This paper assesses the contribution of product-quality upgrading to the export performance of a set of fast-growing Asian economies—China, India, Indonesia, Malaysia, South Korea, and Thailand—during the period 1970–2010. It is motivated by the recognition that a fundamental factor behind the East Asian "growth miracle" was the rapid rise in the region's exports (see for instance Rodrik 1999, Stiglitz and Yusuf 2001, and for recent evidence Jongwanich 2010). Rapid export growth provided, among other benefits, a strong demand stimulus, incentives for technology improvements, and access to imports (Weiss 2005). Further, an emerging literature has recently shown that economic development crucially involves changes not only in the type, but also in the quality of goods produced (Hallak and Schott 2011, IMF 2014). Producing higher-quality varieties of existing products can constitute a way of building on existing comparative advantage to accelerate income convergence. For instance, Henn at al. (2019) demonstrates a strong positive correlation between the quality of exports and the level of economic development.

We first build a Ricardian trade model that allows for an assessment of the contribution of different determinants of firms' activities to the evolution of exports. The proposed framework extends the Eaton and Kortum (2002) model (EK henceforth) to incorporate different sectors and to allow for changes in product quality. We then use the model to derive and estimate a key relationship between different countries' sector-level exports, and use the estimated parameters to calculate what share of the variation over time in a country's sectoral export shares stems from changes in product quality. Under this approach estimation does not require the use of domestic production data, a significant advantage over the previous literature (e.g., Caliendo and Parro 2014). We focus on sectoral export shares rather than aggregate export volumes to minimize the effect of country-specific unobservables. We analyze the importance of quality over time horizons that stretch from a decade to the entire sample period.

The results identify quality as a key factor in understanding the export performance of China, Malaysia, South Korea and Thailand: in the baseline scenario, quality upgrading can explain, respectively, at least 32, 20, 32, and 28 percent of the total variation of these economies' sectoral export shares. In India and Indonesia, economies

characterized by generally slower growth in product quality and in exports, quality upgrading shows up as important during some decades but not over the whole period of analysis. For the nations where quality is key, the capacity of the model to explain changes in sectoral export shares increases as the time horizon becomes longer. This suggests that strategies to facilitate quality upgrading should adopt the long view.

Our work is related to several different strands of the literature. The first studies the composition of exports as a function of countries' and sectors' characteristics. Schott (2004), for example, employing cross-sectional data across nations and industries finds that richer and more human- and physical-capital abundant economies export higher quality varieties, proxied by higher unit prices. Hummels and Klenow (2005), in turn, find that richer countries export more units with higher quality, and that quality differences could be a cause of income per capita differences across countries. Gervais (2015) focuses on the set of U.S. manufacturing plants and quantifies the contribution of product quality and production efficiency in explaining exports. He finds that product quality has a stronger effect on selection into exporting than does productivity. Eckel et al. (2015) also find similar evidence using Mexican data for differentiated products. Finally, papers such as Amiti and Khanderwal (2013) and Medina (2018) document that trade openness leads to quality upgrading.[1] Unlike these papers, we quantitatively assess the contribution of quality upgrading to export performance, and do so over a longer time period, taking advantage of a new panel dataset on product quality (Henn et al. 2017).[2]

Our paper is also related to the literature that uses multisector variants of the EK model. These papers include, among many others: Uy, Yi and Zhang (2013), which incorporates the three main sectoral aggregates (agriculture, manufacturing, and services); Costinot, Donaldson and Komunjer (2012), Eaton, Kortum, Neiman and Romalis (2016), and Levchenko and Zhang (2016), which impose common trade elasticities across an array of manufacturing sectors; and Caliendo and Parro (2014) and Bolatto (2016) which allow for differences in those elasticities. We also allow for different trade elasticities across sectors. Unlike these other papers, we focus on

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[1] Other related papers include Khandelwal (2010), Baldwin and Harrigan (2011), and Alcala (2016).

[2] Alternative datasets on product quality include Hallak (2006), Hallak and Schott (2011), and Freenstra and Romalis (2014). However, these other datasets provide smaller coverage across countries and over time.

product quality as a key driver of exports.

The rest of the paper is organized as follow. Section 2 introduces the theoretical model of international trade. The empirical methodology and data used as well as the results obtained are discussed in section 3. Section 4 presents a robustness exercise. Section 5 concludes.

2   The Model

We present a static framework that considers three main dimensions of product exports and imports: the intensive, extensive, and quality margins. The intensive margin refers to the number of units produced of a good. The extensive margin is related to the number of product lines. The quality margin affects the price that a given product will fetch in the market. Trade is formalized in a Ricardian framework following EK, extended to incorporate different sectors and to allow for changes in product quality. As the driving mechanism behind changes in exports levels, the model proposes the existence of heterogeneity in quality and efficiency across export lines and countries.

2.1   Consumers

Consider a nation n populated by L_n individuals. Each agent is endowed with *one* unit of time that is inelastically allocated to labor. Households have preferences defined over products supplied by K different sectors that offer, each of them, a continuum of mass *one* of product lines. The flow of utility depends on the amount of the different goods consumed weighed by their quality.

More specifically, at each point of time, a representative agent in nation n that has a taste for variety solves the following problem:

$$\max_{\{c_{nk}(j)\}} c_n = \left(\sum_{k=1}^{K} \omega_k^{1/\varepsilon} c_{nk}^{1-1/\varepsilon} \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{1}$$

with

$$c_{nk} = \left\{ \int_0^1 \left[e^{\beta_k q_{nk}} c_{nk}(j) \right]^{1-\frac{1}{\eta}} dj \right\}^{\frac{\eta_k}{\eta_k-1}}, \tag{2}$$

subject to the budget constraint

$$w_n = \sum_{k=1}^{K} \left[\int_0^1 p_{nk}(j) c_{nk}(j) \; dj \right]. \tag{3}$$

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Above, $c_{nk}(j)$ is the amount of good j from sector-k consumed by the representative individual in country n. According to budget constraint (3), the sum of the demanded quantities times their corresponding consumer prices $p_{nk}(j)$ must be equal to the agent's income, which is given by the wage rate w_n.

Equality (2) shows a key feature of the problem: the weight of each product in the sector-k consumption bundle c_{nk} is an exponential function of the sector-specific quality q_{nk} multiplied by a sector-specific parameter β_k.[3] Notice that quality-adjusted consumption levels are aggregated according to CES functions; where the parameters $\varepsilon, \eta_k > 0$ represent the elasticity of substitution between sectors and among goods within a given sector, respectively; and $\omega_k > 0$ weighs the contribution of sector-k consumption in the individual's utility.

The solution to this problem obtains the following optimality conditions for consumption:

$$\frac{e^{\beta_k q_{nk}} c_{nk}(j)}{c_{nk}} = \left[\frac{p_{nk}(j)/e^{\beta_k q_{nk}}}{P_{nk}} \right]^{-\eta_k}, \tag{4}$$

and

$$\frac{c_{nk}}{c_n} = \omega_k \left(\frac{P_{nk}}{P_n} \right)^{-\varepsilon}; \tag{5}$$

where the CES exact price indices equal

$$P_{nk} = \left\{ \int_0^1 \left[\frac{p_{nk}(j)}{e^{\beta_k q_{nk}}} \right]^{1-\eta_k} dj \right\}^{\frac{1}{1-\eta_k}}, \tag{6}$$

and

$$P_n = \left(\sum_{k=1}^{K} \omega_k P_{nk}^{1-\varepsilon} \right)^{\frac{1}{1-\varepsilon}}. \tag{7}$$

Intra-sector condition (4) points out very clearly the importance of the quality dimension. It says that individuals care about the effective units of quality provided by the purchased goods, that is, $e^{\beta_k q_{nk}} c_{nk}(j)$. As a consequence, the relevant variable in the consumption decision is the price per unit of effective quality, $p_{nk}(j)/e^{\beta_k q_{nk}}$; goods that offer a lower price-to-quality ratio are more demanded. Inter-sector condition (5) obeys the same logic, albeit this time the relevant demand elasticity is $-\varepsilon$ (instead of $-\eta_k$). Similarly, the intra- and inter-sector price aggregates shown in expressions (6) and (7), respectively, are both defined in terms of prices adjusted for quality.

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[3] The choice of the exponential specification is made because it provides a better fit to the data in section 3.

2.2 Producers

In our economy, all markets are perfectly competitive, and the only input of production is labor.[4] Focusing first on the quantity of good j produced in sector k by country n – which we denote by $Y_{nk}(j)$ – this amount is generated according to the following function:

$$Y_{nk}(j) = z_{nk}(j) \frac{L_{nk}(j)}{e^{\alpha_k q_{nk}}};$$

(8)

where $L_{nk}(j)$ represents the amount of labor; $z_{nk}(j)$ is the efficiency level in producing good j in sector k and country n; and a_k is a sector-specific parameter that weighs the exponential impact of quality on costs. Expression (8) follows Melitz (2003) assuming that product quality requires input quality as in Kugler and Verhoogen (2012) and Baldwin and Harrigan (2011). More specifically, it supposes that an additional number of workers is required to produce higher quality goods.

An implication of that assumption is that, under perfect competition, the free-on-board price of a good j manufactured in country i and sold in nation n, which we denote by $p_{nik}(j)$, is given by:

$$p_{nik}(j) = e^{\alpha_k q_{nik}} \frac{w_i}{z_{ik}(j)}.$$

(9)

Notice that the free-on-board price $p_{nik}(j)$ – that is, the producer price – can be different than the price $p_{nk}(j)$ paid by consumers; for example, because of trade costs. In the same way, the quality associated with a product of sector k manufactured in country i and sent to nation n, denoted by q_{nik}, can be different from the quality brought by the good finally consumed in country n, q_{nk}, which might not be the one offered by i. Put differently, while $p_{nik}(j)$ and q_{nik} represent potential prices and quality levels depending on origin, the pair $p_{nk}(j)$ and q_{nk} are the actual values associated with the product consumed in the destination nation n.

2.3 Trade

Our next task is embedding the above structure into the EK model. Compared to the EK setup, the main difference is that we consider several sectors and product

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[4]We could also introduce human capital or, as in EK, intermediate inputs in the production function. The only difference in our analysis would be given by the unit cost of the input bundle. Because in the quantitative part we consider wages to measure input prices, human capital is also controlled for. We do not though control for intermediate-input prices.

quality. In order to generate trade flows, we consider that the world is composed of N nations, and that the efficiency parameter $z_{nk}(j)$ is a draw from a random variable Z_{nk} independently distributed across sectors and countries as a Fréchet with cumulative distribution function:

$$F_{nk}(z) = \Pr[z_{nk}(j) \leq z] = \exp(-\Upsilon_{nk} \ z^{-\theta_k}). \tag{10}$$

The scale parameter $\Upsilon_{nk} > 0$ serves as a proxy for the technology level, and therefore, controls for the absolute advantage of nation n in sector k. A higher Υ_{nk} implies that a higher draw of $z_{nk}(j)$ is more likely for any j. The shape parameter $\theta_k > 1$, on the other hand, controls the degree of efficiency heterogeneity within sector k. A lower value of θ_k implies a larger heterogeneity, and therefore, a stronger pressure of comparative advantage in favor of international trade.

Products cross borders, whereas labor is only supplied domestically. There are geographical barriers captured by an iceberg cost involved in shipping goods from the origin country to the destination nation. In particular, for each unit of sector-k products that country i ships to nation n, only $1/d_{nik}$ units arrive; we suppose that $d_{nnk} = 1$. In practice, these barriers include transportation, insurance, and tariffs, among others.

Under perfect competition, each individual market is only served by the cheapest supplier. More specifically, consumers' demand function (4) says that country i will be able to sell product j in country n if it can offer a better consumer price per unit of effective quality in the destination market, that is, a lower $d_{nik}p_{nik}(j)/e^{\beta_k q_{nik}}$. From (9), we can deduce that the producer price per unit of effective quality equals:

$$\frac{p_{nik}(j)}{e^{\beta_k q_{nik}}} = \frac{w_i}{z_{ik}(j)} e^{(\alpha_k - \beta_k)q_{nik}}. \tag{11}$$

In expression (11), the effect of quality on the consumer's decision is then a consequence of the opposing impacts on the utility and production sides. On the one hand, there is a taste for quality. On the other, higher quality is more costly. To guaranty that more costly, higher quality versions of the goods are preferred, equality (11) needs to fall with quality, which requires that $\beta_k > \alpha_k$, that is, that the utility effect dominates; otherwise, if $\beta_k < \alpha_k$, higher quality will hurt exports. From expression (11),

we can write the link between consumer and producer prices as

$$\frac{p_{nk}(j)}{e^{\beta_k q_{nk}}} = \min\left\{\frac{d_{nik}w_i}{z_{ik}(j)e^{(\beta_k - \alpha_k)q_{nik}}} \ , \ i = 1, ..., N\right\}. \tag{12}$$

We do not know the exact price for each good in each country. However, as EK show, we can obtain their distribution. In particular, from expression (12), the probability that the price-to-quality ratio in destination country n for product j originated in country i is less than or equal to an arbitrary number ρ equals:

$$G_{nik}(\rho) = \Pr\left[\frac{d_{nik}p_{nik}(j)}{e^{\beta_k q_{nik}}} \leq \rho\right] = 1 - F_{ik}\left[\frac{d_{nik} \ w_i}{\rho e^{(\beta_k - \alpha_k)q_{nik}}}\right]. \tag{13}$$

Also, from (12) and (13), the distribution of the price-to-quality ratio for what country n actually buys sector-k commodities (unconditional on their source) is given by

$$G_{nk}(\rho) = \Pr\left\{\frac{p_{nk}(j)}{e^{\beta_k q_{nk}}} \leq \rho\right\} = 1 - \exp(-\Phi_{nk}\rho^{\theta_k}), \tag{14}$$

$$\text{where } \Phi_{nk} = \sum_{i=1}^{N} \Upsilon_{ik}\left[\frac{d_{nik}w_i}{e^{(\beta_k - \alpha_k)q_{nik}}}\right]^{-\theta_k}.$$

An implication of (14) is that the sector price index, defined in expression (6), can be rewritten as

$$P_{nk} = \gamma_k \Phi_{nk}^{-1/\theta_k}, \quad \text{with } \gamma_k = \Gamma\left[\left(\frac{\theta_k + 1 - \eta}{\theta_k}\right)^{\frac{1}{1-\eta}}\right]; \tag{15}$$

where Γ stands for the gamma function, and $\eta < 1 + \theta_k$.

EK proves that this distribution implies that the probability that country i provides to nation n the best price adjusted for quality in any good that belongs to sector k is

$$\pi_{nik} = \frac{\Upsilon_{ik}\left[\frac{d_{nik}w_i}{e^{(\beta_k - \alpha_k)q_{nik}}}\right]^{-\theta_k}}{\Phi_{nk}}. \tag{16}$$

This probability then depends on geographical barriers, input prices, and technological aspects associated with product quality and input efficiency (the latter proxied by Υ_{ik}).

Importantly, an equation for bilateral trade can be obtained from expression (16) employing a key property of the model. As EK shows, source country i exploits its comparative advantage in n by selling a wider range of product lines until the price distribution of goods exported to market n exactly matches country n's overall price distribution. An implication of this finding is that average spending per commodity

does not change by source. Consequently, in each industry k, the fraction of goods purchased by country n from i is as well the share of country n's spending on goods imported from i. And by the law of large numbers, we can conclude that this spending share is given by probability π_{nik}, that is,

$$\frac{X_{nik}}{P_{nk}c_{nk}L_n} = \pi_{nik}; \tag{17}$$

where X_{nik} represents the value of sector-k exports from source i to n at destination prices.[5] Notice that the denominator in the left-hand side (LHS) equals country n's total spending in industry k's commodities.

3 Exports and Quality Across Asian Nations

In this section, we assess the contribution of changes in product quality to the evolution of exports. To do that, we generate predictions across 2-digit sectors for six Asian nations and compare them to the data. For each country, we assess the capacity of quality to predict export changes averaged out over different time intervals. By looking at averages we try to reduce the bias that mismeasurement problems and business cycle effects can generate. We consider time intervals ranging from a decade to the entire sample period. In addition, the rich sectoral structure of our dataset allows us to focus on export shares rather than aggregate exports to assess the impact of quality; this minimizes the effect of country-specific unobservables. The changes in the shares through time also provide clear information about the sectors that gain and the ones that lose importance in total exports.

We focus on the following countries: China, India, Indonesia, Malaysia, South Korea, and Thailand. These are fast-growing economies (with average annual growth rates for the period 1970–2010 equal to 9.4, 5.6, 5.4, 7.7, 6.5 and 6.1 percent, respectively), which in most cases rely heavily on exports, and it is important to understand the sources of their success.[6]

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[5]In our version of the EK model, this is as well true because demand depends on the price-to-quality ratio, and quality is the same for all goods that belong to the same sector in a given economy.

[6]Numbers constructed from World Bank data, accessible online at https://data.worldbank.org /indicator/NY.GDP.MKTP.KD.ZG. Other Asian miracles that show similar growth rates between 1970 and 2010 are Singapore (7.6%), Hong Kong (6.1%), Vietnam (6.5%) and Cambodia (5.5%). We exclude the first two because their average quality levels are already too close to the frontier in 1985

3.1 Methodology and data

Before generating predictions, we need to assign values to the parameters in expression (16). Estimates obtained by the previous literature are not useful for this purpose. The reason is that we focus on a different product classification. In particular, our exports data come from SITC, revision 1, at the two digit level. Previous literature that develops sectoral versions of the Eaton and Kortum model, on the other hand, like Caliendo and Parro (2014) and Bolatto (2016), concentrates on classifications such as ISIC for which domestic production numbers are available.

To understand these two different choices, notice that equation (17) is the main expression extracted from the model that allows generating predictions for exports. Note as well that its use requires knowledge of sectoral production and domestic consumption across countries. However, the quality index that we adopt has been constructed for SITC sectors, and domestic production is not available for this last classification.

To circumvent this problem, we could convert ISIC data into SITC. Nevertheless, we choose not to do so in order to enjoy a longer time series. An alternative is to adopt some of the estimated coefficients for different sectors from Henn *et al.* (2017), given that they estimate a regression following SITC that contains some of the features of expressions (16) and (17). However, to obtain the estimates, this last paper follows a preferences approach as in Hallak (2006) that does not offer a good match with our model. Because of this, we propose a novel approach that employs a version of the above equations that does not require information on domestic production and demand. In particular, from (16) and (17), we can write relative sector-k exports from countries i and o to nation n as:

$$\frac{X_{nik}}{X_{nok}} = \frac{\Upsilon_{ik}}{\Upsilon_{ok}} \left[\frac{d_{nik}}{d_{nok}} \frac{w_i}{w_o} \, e^{(\alpha_k - \beta_k)(q_{nik} - q_{nok})} \right]^{-\theta_k}. \tag{18}$$

From the last equality, we can generate predictions for country i using the relative values of the variables and country o's export numbers.

As *reference* country (nation o above), we want an economy that can serve as a

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and therefore do no offer enough variability for identification. Vietnam is, in turn, excluded because data are not available for the whole period. Finally, Cambodia is not included in our sample because of the large fraction of zeros in export numbers; these zeros represented 35% of total observations, reaching 55% for some years.

reflection of the evolution of the quality frontier. This country also needs to show relatively low bilateral trade flows with our six Asian nations, otherwise equation (18) is not appropriate.[7] We therefore choose Germany, a nation relatively close to the quality frontier that receives a relatively low fraction of exports from the countries that compose our sample, certainly much lower than the fractions that arrive to other nations such as Japan and the United States that also produce, on average, high quality products.[8] As destination economy (n) we choose the rest of he world to simplify the analysis.

Our data comprises exports and quality numbers from SITC, revision 1, at the two digit level, for a total of 60 product lines from 1962 to 2010.[9] However, because quality is available for Germany only from 1970 onwards, the main analysis focuses on the 1970–2010 time interval. Export volumes come from the *Comtrade* database. They represent mirror data, that is, cost-insurance-and-freight (CIF) exports reported by the destination country or importer. These numbers are generally viewed (see for instance Cadot *et al.* 2011) as more accurate than direct free-on-board (FOB) exports reported by the origin nation.

The quality index constructed by Henn et al. (2017) is downloaded from the *Export Diversification and Quality Databases* at the IMF. Wages are proxied using the economy-wide marginal product of labor calculated from employment, labor shares and nominal GDP values from *PWT 8.0.* Trade costs to the rest of the world are assumed to be the same across nations, that is, $d_{nik}/d_{nok} = 1$.[10]

In order to obtain the parameter values needed to apply expression (18), we use the panel composed of our six Asian countries to estimate the following regression for each 2-digit sector k:

$$\ln \frac{X_{nik,t}}{X_{nok,t}} = \gamma_{k0} + \gamma_{k1i} \, E_i + \gamma_{k3i} \, t + \gamma_{k4} \ln \frac{w_{it}}{w_{ot}} + \gamma_{k5} \, (q_{nik,t} - q_{nok,t}) + \varepsilon_{ikt}. \qquad (19)$$

[7]By (16), expression (18) requires that economy n contains neither i nor o so that Φ_{nk} is the same for both nations.

[8]Data from *Comtrade* implies that in 2014, for example, exports to Germany from China, Indonesia, India, South Korea, Malaysia and Thailand accounted for 3.17, 1.66, 2.48, 1.36, 2.41 and 2.03 percent of those Asian nations' total exports, respectively.

[9]See the appendix for a list of the sectors included. One product line was discarded: product 35, which covers electric energy and has a negligible weight in total exports. It was eliminated because we had only 18 observations available to estimate the quality parameter in that sector.

[10]Because we do not employ bilateral trade data in the estimation, we cannot use the distant variables typically employed in gravity equations.

Expression (19) is the result of taking logs in equation (18); notice that we have added a time subscript t to the different variables that in our sample represents a year between 1970 and 2010. In (19), country fixed effects dummies (E_i) along with the country-specific time trends proxy the log of the relative efficiency level $\Upsilon_{ik}/\Upsilon_{ok}$ and other possible omitted variables.

In turn, the term $q_{nik,t} - q_{nok,t}$ stands for the difference in relative product quality between country i and Germany in sector k at date t.[11] As a result, the coefficient γ_{k5} will capture its effect on sector-k relative exports. The value and sign of γ_{k5} is sector specific, and can be positive or negative depending on whether β_k is larger or smaller than α_k.

The input-cost variable w_{it} is measured as the country i's marginal product of labor divided by the average quality across product-lines. Even though in our model quality requires more units of labor, we divide the salary by quality because in the real world the value of labor productivity increases with product quality due to the use of more skilled labor. Ceteris paribus, higher labor costs will contribute to make products more expensive, and therefore, reduce exports. However, notice that a larger wage can also reflect a more efficient economy. Its sector-specific coefficient γ_{k4} will then deliver a compound estimate of the effect of labor costs, economy-wide domestic efficiency, and the shape parameter θ_k on relative exports. Consequently, γ_{k4} can be positive or negative.

Regression 19 is estimated by OLS using only non-zero export data. The reason for the elimination of the zero-export observations is that the quality index is not available for those cases, due to the method employed by Henn et al. (2017) in its estimation.[12] Table 1 shows the estimation results.[13] In particular, it provides, in consecutive columns, the sector, the estimated coefficient for quality ($\hat{\gamma}_5$) and its stan-

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[11]Later, in the Robustness section, we employ $q_{nik,t-1} - q_{nok,t-1}$ to estimate γ_{k5}. That is, we introduce in regression (19) relative quality with a lag to try to reduce potential endogeneity problems.

[12]This also implies that it is not possible to differentiate between the contribution of quality upgrading to export-line deepening and its contribution to the increase in export lines. Nevertheless, this is not a problem for our purposes, because the impact of the increase in export lines to the rise in exports is negligible—in our sample, 100.0% of the total annual increment in the export volume in each of the six Asian nations is the result of export-line deepening.

[13]For product line 84, observations for the years 1970 to 1972 were treated as outliers and eliminated from the estimation exercise. The reason is that their inclusion caused the estimated coefficient go up from 4.15 to 8.00, generating a very strong overprediction of export numbers.

dard deviation (Stand. Dev.), the number of observations (Obs.), and the coefficient of determination (R^2). We can see that the number of observations available varies from 104 to 246 depending on the sector. The fit is good, with an R^2 that goes from 0.61 to 0.97. Estimated coefficients are significant at standard levels for 60.0% of the products, and the sign is positive in 77.8% of the significant cases. This means that there is evidence supporting that quality upgrading and exports move together in 46.7% of the products.

Once the estimated coefficients $\hat{\gamma}_{k5}$ have been obtained, we generate, for each product and year, a prediction of the increase in its export share assuming that the only variable that changes is the level of quality relative to the reference country. Specifically, from equation (18), given that $\hat{\gamma}_{k5}$ is an estimate of $\theta_k(\beta_k - \alpha_k)$, the predicted share of exports to the rest of the world (n) of product k in economy i at date t – denoted by $\hat{S}_{nik,t}$ – is calculated as

$$\hat{S}_{nik,t+1} = \frac{\hat{X}_{nik,t+1}}{\sum_{v \in K} \hat{X}_{niv,t+1}} = \frac{e^{\hat{\gamma}_{k5}\left[(q_{nik,t+1}-q_{nik,t})-(q_{nok,t+1}-q_{nok,t})\right]}X_{nik,t}}{\sum_{v \in K} e^{\hat{\gamma}_{v5}\left[(q_{niv,t+1}-q_{niv,t})-(q_{nov,t+1}-q_{nov,t})\right]}X_{niv,t}}; \quad (20)$$

where $\hat{X}_{nik,t}$ and $X_{nik,t}$ represent predicted and actual volumes of exports, respectively; and $K = \{00, ..., 96\}$ is the set of 2-digit-SITC-revision-1 industries. Because the reference country is close to the quality frontier in most instances, this prediction should give a relatively accurate measure of the effect of quality upgrading. Then, the predicted and actual increases in the export shares of sector k in country i from year t to $t + 1$ – denoted by $\hat{I}_{nik,t+1}$ and $I_{nik,t+1}$ – are computed as $\hat{I}_{nik,t+1} = \hat{S}_{nik,t+1} - S_{nik,t}$ and $I_{nik,t+1} = S_{nik,t+1} - S_{nik,t}$, respectively; where $S_{nik,t}$ represents the actual export share.

Finally, the fit to the data is assessed through the use of a *pseudo-R^2* that calculates the fraction of the observed deviation from zero of the average increments in the sectoral shares explained by the predictions. That is,

$$pseudo\text{-}R^2 = 1 - \frac{\sum_{k \in K} \sum_{\tau \in \Psi} \left[I^*_{nik}(\tau) - \hat{I}^*_{nik}(\tau)\right]^2}{\sum_{k \in K} \sum_{\tau \in \Psi} \left[I^*_{nik}(\tau)\right]^2}; \quad (21)$$

where Ψ is the set of periods; and $I^*_{nik}(\tau)$ and $\hat{I}^*_{nik}(\tau)$ represent the average for $I_{nik,t}$ and $\hat{I}_{nik,t}$ in period τ, respectively.

We measure the fit for seven subsamples, each of them corresponding to a different set Ψ. Five are cross sections formed by only one observation for each sector, and the other two are data panels. This implies that in five of the subsamples the set Ψ is composed of only one element. The first cross section considers the period 1970–2010. The other four correspond to each of the decades that composed the sample: 1970–1979, 1980–1989, 1990–1999, and 2000–2010. In turn, one of the panels corresponds to the two twenty-year periods split around 1990; correspondingly, $\Psi = \{1970\text{–}1989, 1990\text{–}2010\}$. Finally, the second panel is formed by the four decades, that is, $\Psi = \{1970\text{–}1979, 1980\text{–}1989, 1990\text{–}1999, 2000\text{–}2010\}$. By looking at different time horizons over which we compute the average increases, we can see whether a longer commitment to quality upgrading is important to generate significant improvements in export volumes.

Focusing on the changes in export shares rather than on the export volume, in addition to the advantages already pointed out, also helps to better assess the fit. This is because the sum, and therefore the mean, of these changes is relatively close to zero; in fact, in the absence of missing values, their sum must exactly equal zero. This should improve the reliability of the *pseudo-R^2* as a measure of the capacity of the predictions to explain the observed variance.[14]

Some sectors have a much larger weight in total exports than other sectors. The ability of the predictions to match the evolution of these relatively large sectors might be perceived as particularly important. Consequently, we also show results using a *weighted-R^2*. This alternative measure of fit is calculated following also expression (21) but multiplying each of the sectoral squared-errors located in the numerator and denominator of the right-hand side (RHS) of expression (21) by its average sectoral export-share within the time interval considered, denoted by $S_{nik}^*(\tau)$. In mathematical terms,

$$weighted\text{-}R^2 = 1 - \frac{\sum_{k \in K} \sum_{\tau \in \Psi} S_{nik}^*(\tau) \left[I_{nik}^*(\tau) - \hat{I}_{nik}^*(\tau) \right]^2}{\sum_{k \in K} \sum_{\tau \in \Psi} S_{nik}^*(\tau) \left[I_{nik}^*(\tau) \right]^2}. \tag{22}$$

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[14]In principle, the *pseudo-R^2* is bounded above by one, but is not bounded below. The choice of a variable—the increase in the export share in our case—whose mean is close to zero, for both predictions and data, helps to make the possibility of obtaining negative values less likely. In fact, we also computed this statistic using in the denominator differences of the observed values from their mean (instead of from zero). This exercise gave negligible differences in the results.
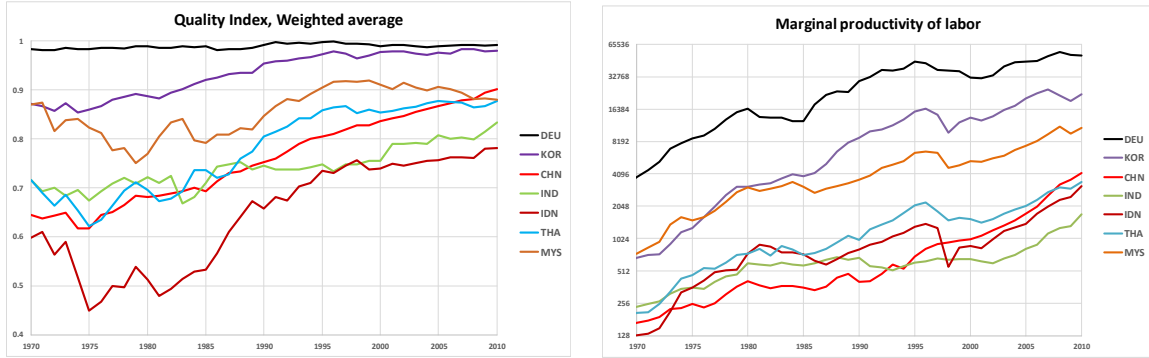
Table 1: Regression estimates for the quality coefficient in each sector

Dependent variable: country exports relative to Germany				
2-Digit SITC Sector	Estimated Coefficient	Stand. Dev.	Obs.	R-squared
00: Live animals	-0.278	0.782	239	0.72
01: Meat and meat preparations	1.649 **	0.724	246	0.84
02: Dairy products and eggs	-0.555	0.916	234	0.72
03: Fish and fish preparations	2.176 ***	0.707	246	0.82
04: Cereals and cereal preparations	0.713	0.561	246	0.91
05: Fruit and vegetables	-0.053	0.384	246	0.94
06: Sugar, sugar preparations and honey	0.072	0.671	246	0.64
07: Coffee, tea, cocoa, spices & manufacs. Thereof	2.256 ***	0.049	246	0.95
08: Feed. Stuff for animals excl. Unmilled cereals	-1.286 ***	0.283	246	0.91
09: Miscellaneous food preparations	4.695 **	1.984	246	0.86
11: Beverages	0.225	0.642	243	0.89
12: Tobacco and tobacco manufactures	0.935	0.926	246	0.68
21: Hides, skins and fur skins, undressed	-0.273	0.480	245	0.74
22: Oil seeds, oil nuts and oil kernels	1.791 ***	0.347	245	0.88
23: Crude rubber including synthetic and reclaimed	3.185 ***	0.773	242	0.95
24: Wood, lumber and cork	0.973 ***	0.246	246	0.94
25: Pulp and paper	2.007 ***	0.534	201	0.81
26: Textile fibres, not manufactured, and waste	-1.568 ***	0.590	246	0.87
27: Crude fertilizers and crude minerals, nes	4.177 ***	0.910	246	0.95
28: Metalliferous ores and metal scrap	1.285 ***	0.434	246	0.85
29: Crude animal and vegetable materials, nes	1.338 ***	0.500	246	0.94
32: Coal, coke and briquettes	-0.051	1.398	218	0.90
33: Petroleum and petroleum products	-0.346	0.531	246	0.76
34: Gas, natural and manufactured	3.030 *	1.579	187	0.71
41: Animal oils and fats	-4.344 *	-4.344	214	0.66
42: Fixed vegetable oils and fats	0.212	0.390	242	0.94
43: Animal and vegetable oils and fats, processed	-4.636 ***	1.064	242	0.87
51: Chemical elements and compounds	1.126	1.701	246	0.97
52: Crude chemicals from coal, petroleum and gas	-0.438	2.158	176	0.61
53: Dyeing, tanning and colouring materials	9.516 ***	1.266	246	0.96
54: Medicinal and pharmaceutical products	4.703 ***	1.137	246	0.93
55: Perfume materials, toilet & cleansing preptions	-1.917 *	1.092	246	0.93
56: Fertilizers, manufactured	-2.566 **	1.192	224	0.83
57: Explosives and pyrotechnic products	0.682	0.980	203	0.92
58: Plastic materials, etc.	15.866 ***	3.502	240	0.93
59: Chemical materials and products, nes	5.144 ***	1.224	246	0.92
61: Leather, lthr. Manufs., nes & dressed fur skins	0.189	0.363	246	0.93
62: Rubber manufactures, nes	9.514 ***	1.797	243	0.93
63: Wood and cork manufactures excluding furniture	-0.338	0.694	246	0.81
64: Paper, paperboard and manufactures thereof	-2.665	2.018	238	0.85
65: Textile yarn, fabrics, made up articles, etc.	-1.973 *	1.039	246	0.94
66: Non metallic mineral manufactures, nes	0.013	0.866	246	0.92
67: Iron and steel	7.554 ***	1.755	240	0.92
68: Non ferrous metals	0.820 *	0.495	246	0.76
69: Manufactures of metal, nes	-4.866 ***	1.041	244	0.94
71: Machinery, other than electric	9.332 ***	1.524	246	0.95
72: Electrical machinery, apparatus and appliances	14.016 ***	1.902	246	0.94
73: Transport equipment	1.884 **	0.778	246	0.92
81: Sanitary, plumbing, heating and lighting fixt.	0.503	0.985	239	0.92
82: Furniture	5.827 ***	2.184	244	0.9
83: Travel goods, handbags and similar articles	0.443	1.431	242	0.90
84: Clothing	4.152 **	1.596	228	0.93
85: Footwear	-2.063	1.489	246	0.86
86: Scientif & control instrum, photogr gds, clocks	5.359 ***	1.256	246	0.94
89: Miscellaneous manufactured articles, nes	5.279 ***	0.814	246	0.95
91: Postal packages not class. According to kind	0.968 ***	0.166	108	0.92
93: Special transact. Not class. According to kind	0.060	1.174	195	0.69
94: Animals, nes, incl. Zoo animals, dogs and cats	1.096 ***	0.289	238	0.73
95: Firearms of war and ammunition therefor	-0.524	1.019	177	0.81
96: Coin, other than gold coin, not legal tender	0.137	0.571	104	0.81

Wages, country fixed effects and coutry-specific time trends included in all regressions along with quality.

*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Figure 1: Different variables for selected countries

4   Results

This subsection first looks at the evolution observed in the data of the main two explanatory variables employed to generate predictions – the quality index and the marginal productivity of labor – for the economies that compose our sample: China (CHN), India (IND), Indonesia (IDN), Malaysia (MYS), South Korea (KOR), and Thailand (THA). We also include Germany (DEU) since it serves as reference country. After that, we present the findings. In particular, we look at the capacity of quality upgrading to reproduce the observed variation in the sectoral export shares.

Figure 1 shows the time series of the average quality level weighted by exports across sectors (left panel) and the marginal productivity of labor (right panel). In general, the quality index (left panel) rises over time in all economies. In Indonesia and Malaysia we observe a U-shape. Perhaps more important, even though poorer nations show lower product quality, quality is converging towards its frontier (which equals 1 by construction) in all countries, with the exception of Malaysia during the last decade. Interestingly, Germany is at all times very close to that frontier, which reinforces its choice as reference nation. The right panel displays labor productivity, showing that it has been rising rapidly in Asia. China saw particularly rapid productivity growth, while India was a relatively weak performer. Germany, South Korea and Malaysia, in that order, enjoy higher productivity levels than the other countries. Similar patterns hold for product quality.

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Figure 2: Results for China
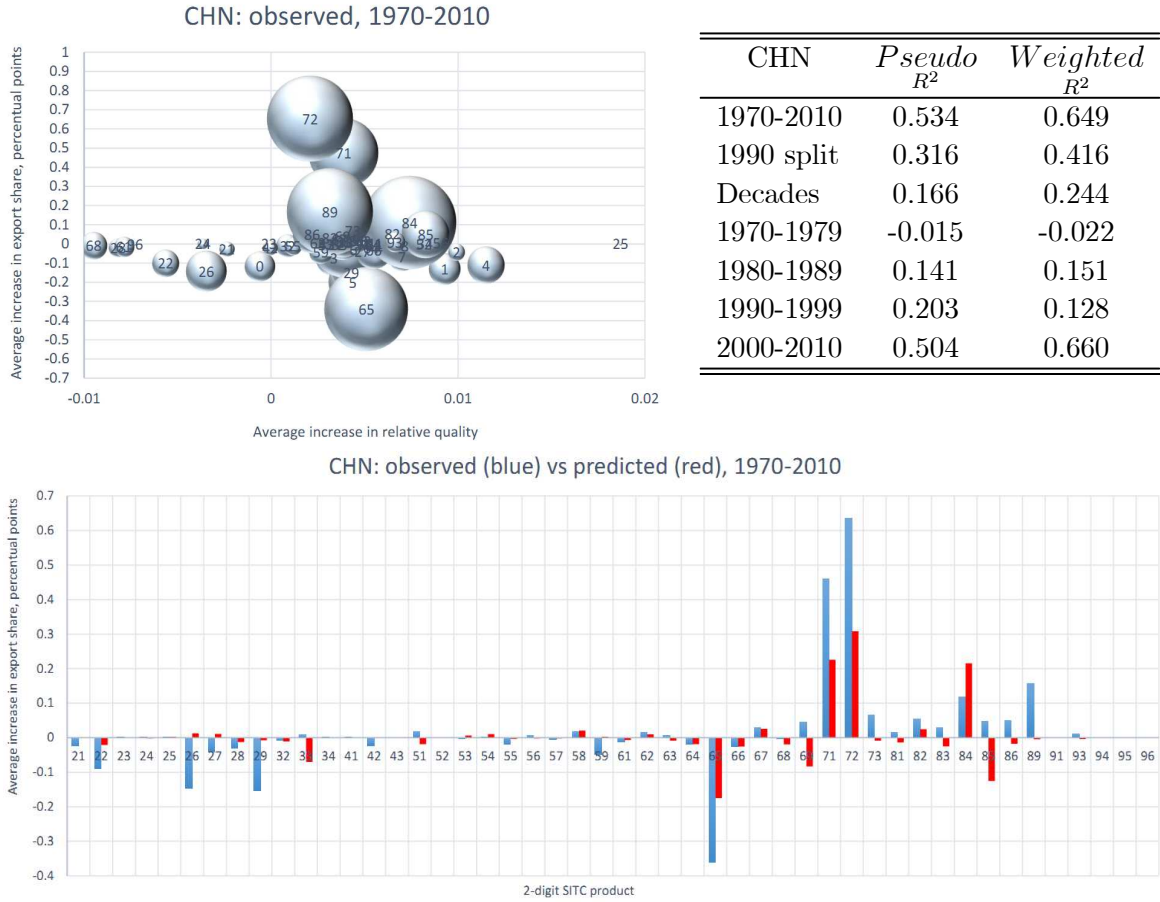
Figures 2 to 7 present the results for each country that composes our sample. Each Figure provides three panels. The first row shows one chart (top left) and a table (top right). The chart plots the average increase in relative quality (x axis) against the average increase in the export shares (y axis) for the period 1970–2010, that is, for the whole sample coverage. The table, in turn, gives the pseudo-R^2 and the weighted-R^2 for the different subsamples considered. The bottom panel compares the average increase in the observed export shares against the predicted values for each 2-digit industry for the period 1970–2010.

Figure 2 focuses on China. During the period 1970–2010 (top left chart) the larger exporters were, in this order, sectors 84 (clothing), 89 (miscellaneous manufacturing articles), 72 (electrical machinery, apparatus and appliances), 65 (textile yarn, fabrics,
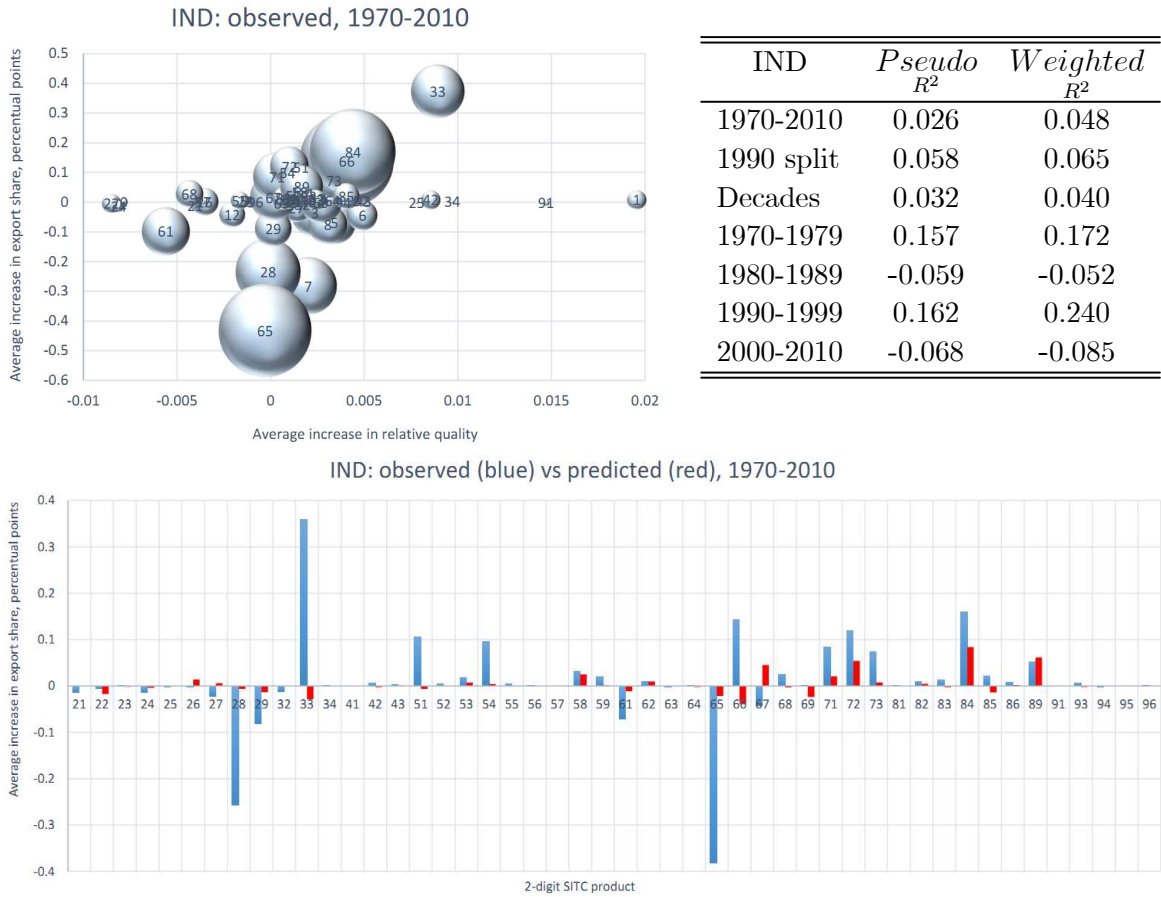
made-up articles), 33 (petroleum and petroleum products) and 71 (machinery, other than electric), all of them showing shares above 6 percent. Twenty four industries (i.e., 40 percent) showed positive increases in their export share, and 49 (i.e., 82 percent) in their relative quality. The fact that less than half raised their export share suggests increasing concentration. We can see in the top left panel that no industry that saw the relative quality fall experienced an increase in the export share. In addition, with the exception of product lines 23 (crude rubber) and 24 (wood, lumber and cork), all industries that increased their shares also raised their relative quality. It is also worth mentioning that most industries in which the quality index substantially increased but did not enjoy larger shares are commodity related, like 1 (meat and meat preparations), 2 (dairy products and eggs) and 4 (cereals and cereal preparations).

In order to provide a graphical image of the goodness of fit, the bottom chart in Figure 2 compares the observed average changes (in blue) to the predicted values (in red) for the period 1970–2010. We can see that the predictions do relatively well. For example, the largest variations correspond to sectors 65, 71 and 72, and the model is able to predict about half of the observed change. Obviously, there are also sectors that experience sizable changes in the shares for which the model does not do a good job, like 26 (textile fibres, ...) and 85 (footwear). Nevertheless, as we report next, our R-squareds turn out to be relatively high.

More specifically, the table in the top left panel of Figure 2 shows that when we look at average changes within the 40-year horizon, 1970–2010 (first row in the table), the pseudo-R^2 and weighted-R^2 are large. In particular, the fraction of the variation in the export-share increments across sectors that can be explain by quality upgrading is 53.4 percent; this number rises to 64.8 percent if we look at the weighted-R^2. Notice that the latter number is larger because, with the exception of product line 65, the sectors that show shares above 6 percent, which were mentioned previously, also enjoyed an increase in both quality and the export share.

When we concentrate on shorter periods, these measures of fit fall. They become 0.316 and 0.416, respectively, when we focus on 20-year periods (denoted by "1990 split" in the table), and 0.166 and 0.244 when we assess the fit using decades (denoted by "Decades"). Still, the variation explained by changes in quality is substantial. This decrease in fit means that the impact of quality upgrading on China's exports is more

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Figure 3: Results for India

IND	Pseudo R^2	Weighted R^2
1970-2010	0.026	0.048
1990 split	0.058	0.065
Decades	0.032	0.040
1970-1979	0.157	0.172
1980-1989	-0.059	-0.052
1990-1999	0.162	0.240
2000-2010	-0.068	-0.085

evident over longer time horizons. This suggests that strategies to facilitate quality upgrading should adopt the long view.

Looking in more detail at the cross sections formed by each of the decades in isolation (last 4 rows in the top-right table), it is clear that the positive effect of quality has: (i) increased over time; (ii) become already sizable in the 1980s; and (iii) achieved the highest fit in the 2000s, after China joint the World Trade Organization—for the period 2000–2010, the pseudo-R^2 and weighted-R^2 equal 0.504 and 0.660, respectively.

Figure 3 gives the results for India. In the Indian case, export shares above 6 percent in the period 1970–2010 are provided by industries 66 (non-metallic mineral manufactures), 65, 84 and 28 (metalliferous ores and metal scrap). Now a greater number of products (36 in particular, that is, 60 percent) enjoy positive increases in
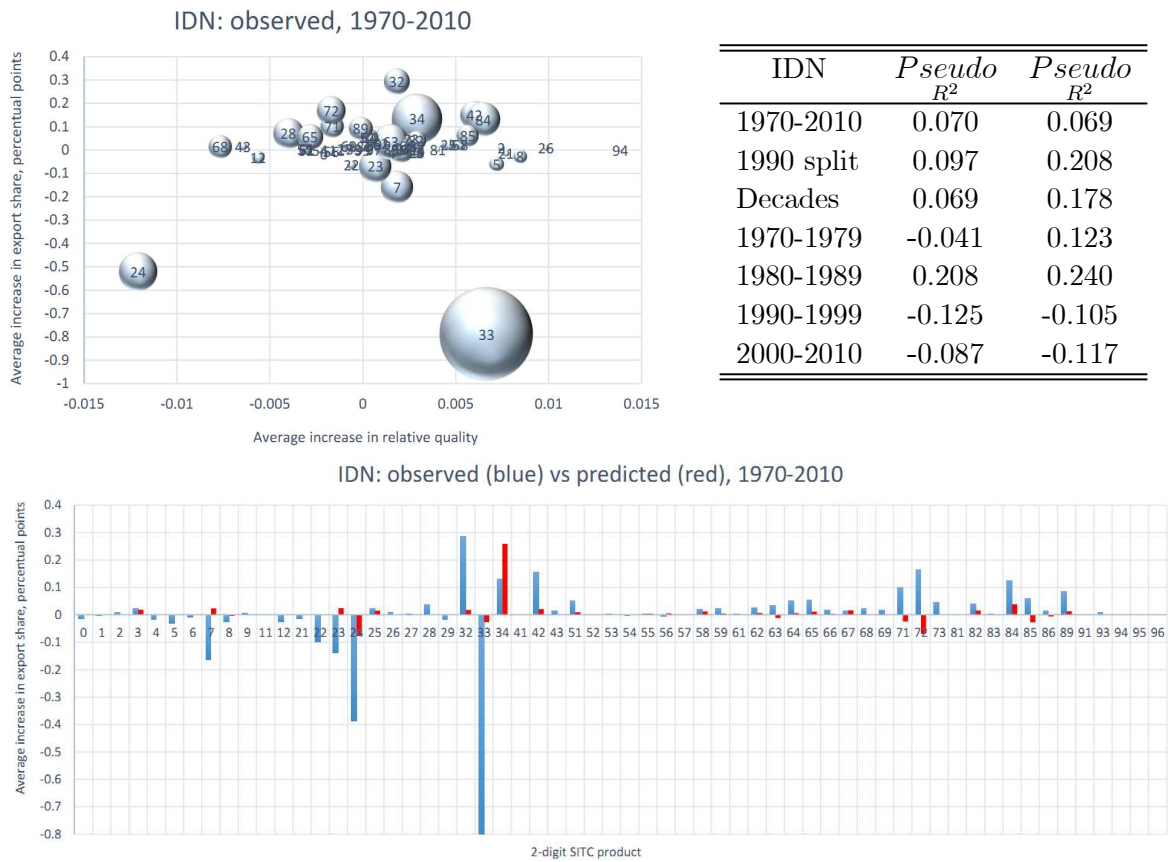
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their export share, which points towards a more diversified export-product portfolio in 2010 than in 1970, and 45 (75 percent) experienced increases in the average relative quality. In the top left panel, we see that several large sectors display movements in quality and the export share that go in the same direction. Specifically, industries 33, 66 and 84 offer positive average increments in both variables from 1970 to 2010, whereas sector 61 (leather, leather manufactures, ...) shows the opposite. However, at the same time, many industries lie very close to the axis, meaning that either quality upgrading or the variation in the export share was negligible. Again, many of the industries that show relatively large increases in quality without a sizable rise in the export share, like 1 and 34, are commodity related.

Concurrently, the bottom chart reveals that the predictions do worse at reproducing the observed export share changes in the Indian case than in the Chinese one. Notable exceptions are sectors 58 (plastic materials), 71, 72, 84 and 89, where the prediction can reproduce a large fraction of the observation.

This is confirmed by the measures of fit shown in the top-right panel. In the first row of the table, we see that for the full-period cross section the pseudo-R^2 and weighted-R^2 equal 0.026 and 0.048, respectively. As in the Chinese scenario, the weighted-R^2 is bigger than the pseudo-R^2 because changes in quality and export shares go in the same direction for large export-volume products. Although still lower than for China, the panel subsamples provide slightly better fits: 0.058 and 0.032 in the case of the pseudo-R^2 for the 1990 split and for the decades, respectively. Looking now at the decade cross sections (last four rows in table), the 1970s and the 1990s do show significant power of quality upgrading to predict the export share increases with a pseudo-R^2 of 0.157 and 0.162, respectively, and a weighted-R^2 of 0.172 and 0.240. We conclude that in India quality upgrading is positively correlated with the changes in export shares during some of the decades, but this correlation goes down as we increase the time horizon, becoming negligible when we look at the 40 year averages.

Indonesia is an economy that relies heavily on commodities. The products that generated the largest volumes of exports, on average, during the 1970–2010 period was petroleum, industry 33, and gas, sector 34. These two industries accounted for 41.5 percent of total exports. Looking at the top left chart in Figure 4, which reports the results for this country, we observe important exporting sectors in all quadrants.

Figure 4: Results for Indonesia

IDN: observed, 1970-2010

IDN	$Pseudo$ R^2	$Pseudo$ R^2
1970-2010	0.070	0.069
1990 split	0.097	0.208
Decades	0.069	0.178
1970-1979	-0.041	0.123
1980-1989	0.208	0.240
1990-1999	-0.125	-0.105
2000-2010	-0.087	-0.117

IDN: observed (blue) vs predicted (red), 1970-2010

Nevertheless, the chart also suggests that the main accumulation of data points takes place in the top right and bottom left quadrants, where relative quality and the export shares evolve in the same direction. During the 1970–2010 period, twenty five industries (42 percent), which included big exporting sector like 32 (coal, coke and briquettes), 34 (gas, natural and manufactured), 42 (fixed vegetable oils and fats), 84 and 85, experienced an average positive increase in relative quality and the export share. In the opposite quadrant, with both variables taking on negative values, there are 11 products (18 percent of the total). We also find important sectors showing opposite changes in the quality and export measures. For example, products 28, 65, 71 and 72 have a positive increase in the share but a negative one in quality, and sectors 7 (coffee, tea, cocoa, ...), 23 and 33 show exactly the opposite, a negative rise in the share and a positive one in relative quality.
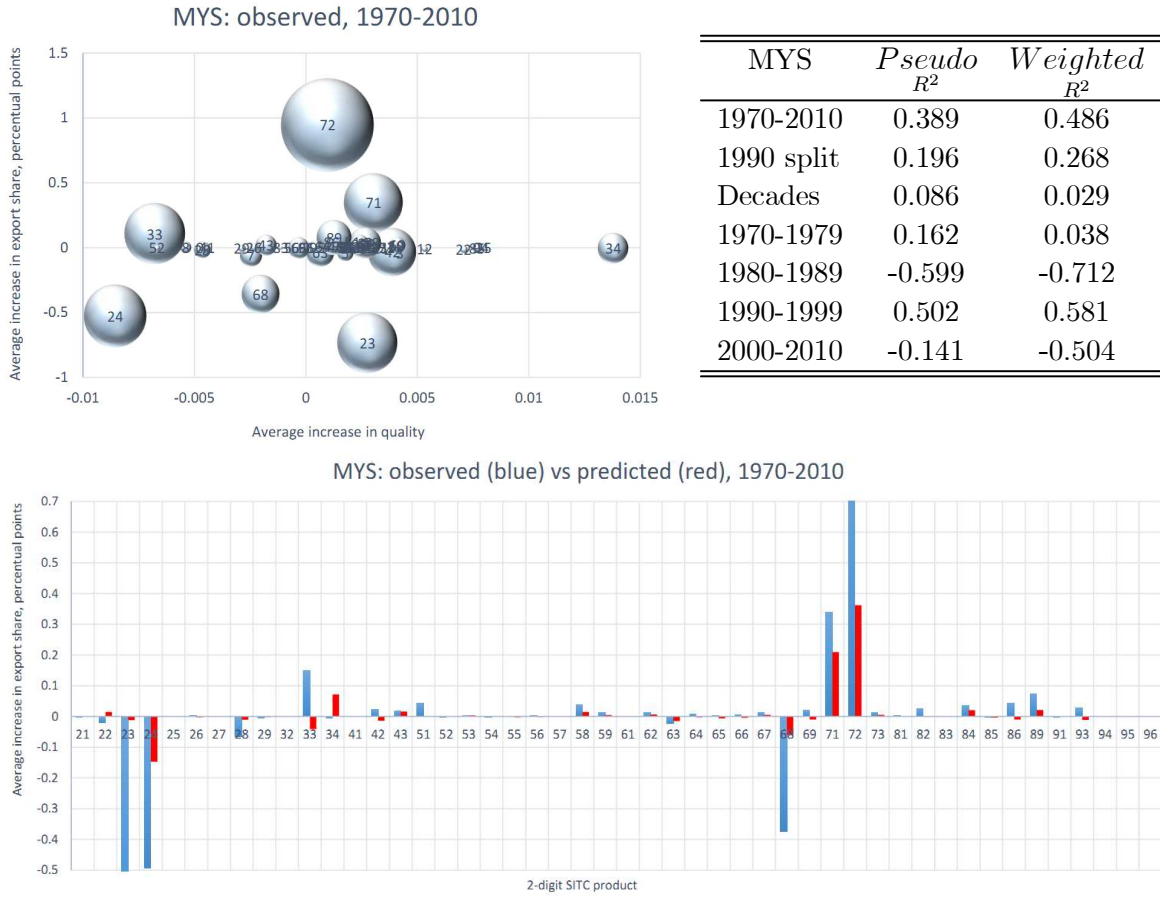
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The predictions chart (bottom panel in Figure 4) illustrates that the predictions go most of the time in the right direction and tend to underestimate the changes. An exception is industry 34 where there is an overprediction. There are also sectors for which the predictions go in the wrong direction; notable examples are industries 71 and 72, where the fall in relative quality leads to predict a decrease in the export share, which goes against the data.

This translates in the top-right panel in a pseudo-R^2 of 0.070 for the period 1970–2010, of 0.097 for the 1990-split panel, and of 0.069 for the decades panel. The weighted-R^2 suggest a better fit, with values of 0.069, 0.208 and 0.178, respectively. These numbers denote some power of quality upgrading to explain export shares, especially over shorter periods of time. This unstable effect is corroborated by the decade cross-sections. The weighted-R^2 says that the power of quality to explain the export share is strong during the 1970s and 1980s, but disappears in the 1990s and 2000s.

In Malaysia, a handful of sectors show average export shares above 6 percent. Electrical machinery (sector 72) provides the largest share, 24 percent, more than double the one of any other sector. The other industries above 6 percent are, in decreasing order of importance, 24, 33, 23, 71 and 42. Positive average annual increases in relative quality and the export share was achieved by 73 and 53 percent of the sectors in 1970–2010, respectively. In the top-left chart of Figure 5, 65 percent of the observations are located in the top-right and bottom-left quadrants, where the two variables move in the same direction. In these two quadrants we can see product lines 71, 72 and 89 in the positive range, and 24 and 68 (non ferrous metals) in the negative one, which together account for more than 50 percent of total exports. This is already signaling a likely positive correlation between quality and the export share.

The bottom panel confirms that the model predictions regarding those last five industries do particularly well. More generally, the predictions explain large fractions of the observed changes in many sectors. For this reason, when we move to the goodness-of-fit table, in the top-right panel of Figure 5, the pseudo-R^2 for the period 1970–2010 is as high as 0.389, and the weighted-R^2 is even higher, 0.486. When we look at the panels, the measures of fit fall by half. More specifically, focusing on the the pseudo-R^2, the predictions can explain 19.6 and 8.6 percent of the observed export-share variation in the 1990-split and Decades subsamples, respectively. As in the case of China, these

Figure 5: Results for Malaysia

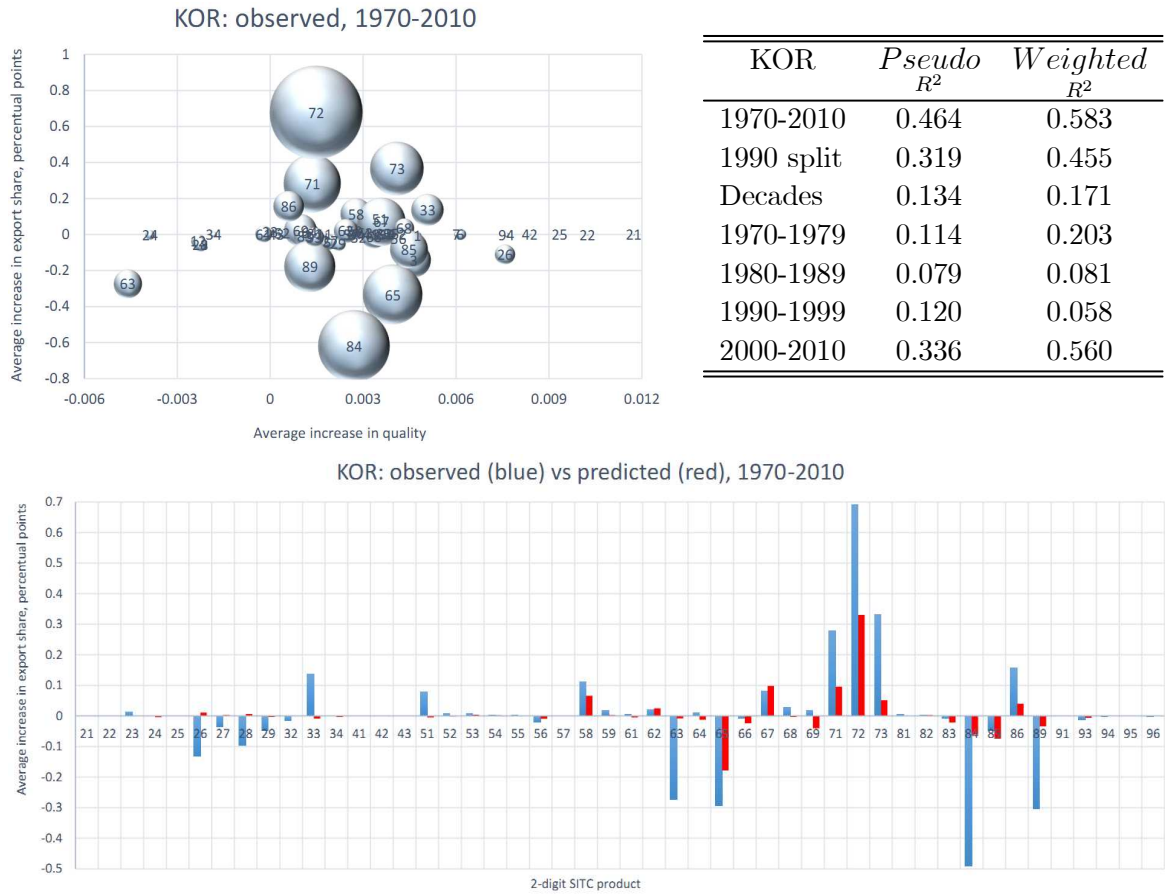| MYS	Pseudo R^2	Weighted R^2
1970-2010	0.389	0.486
1990 split	0.196	0.268
Decades	0.086	0.029
1970-1979	0.162	0.038
1980-1989	-0.599	-0.712
1990-1999	0.502	0.581
2000-2010	-0.141	-0.504

results suggest that a long commitment to quality upgrading is necessary to enjoy strong benefits in terms of export volumes.

At the decades level, the 1970s and 1990s cross sections are the ones that show strong explanatory power of relative quality. In the 1970s, the fraction of the export-share variance explained by changes in relative quality is 16.2 percent when we look a the pseudo-R^2 and 3.8 percent according to the weighted-R^2. These fractions greatly increase in the 1990s, reaching values of 50.2 and 58.1 percent, respectively.

Results for South Korea are depicted in Figure 6. Half of the sectors show an increase in their average export share for the whole sample coverage; and 51 sectors (85 percent) benefit from a rise in relative quality, more than in any of the other countries that compose our sample. The largest share in exports is for sector 72 as in
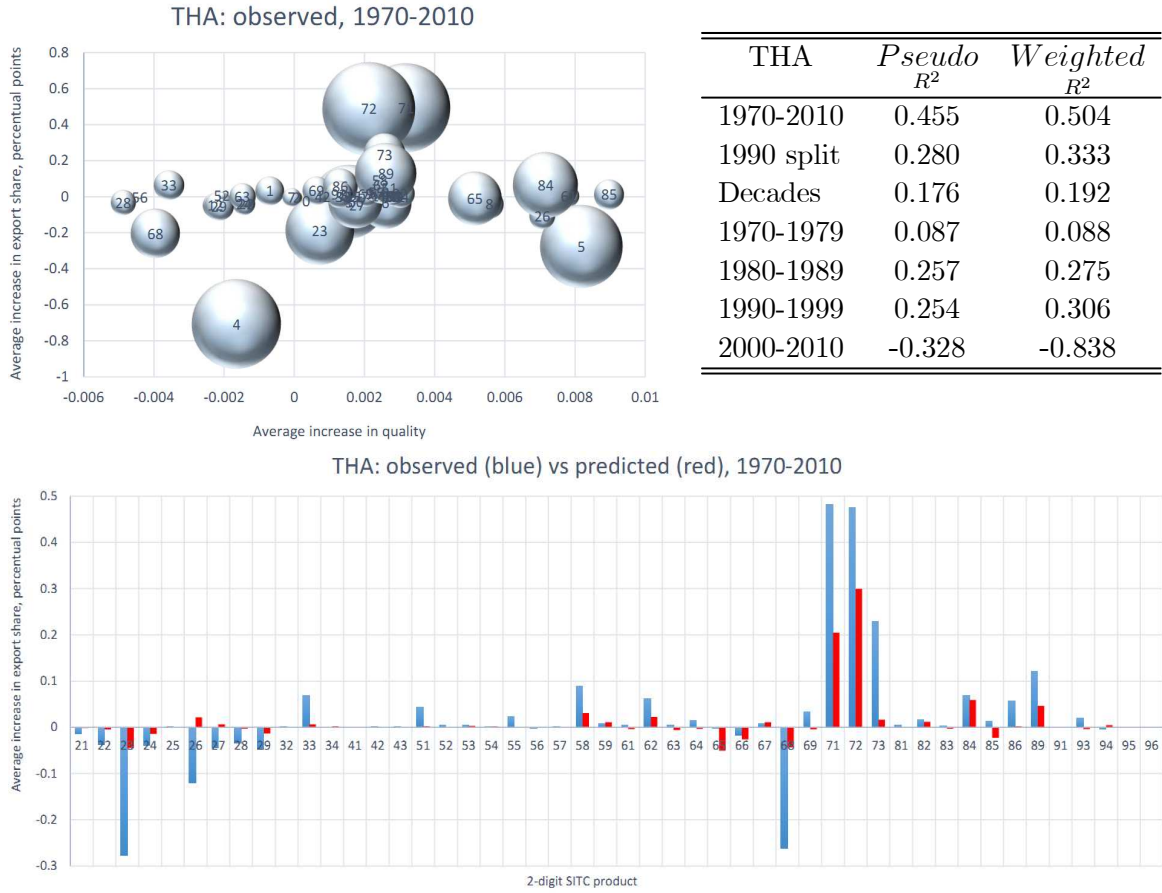
Figure 6: Results for South Korea

KOR: observed, 1970-2010

KOR	*Pseudo* R^2	*Weighted* R^2
1970-2010	0.464	0.583
1990 split	0.319	0.455
Decades	0.134	0.171
1970-1979	0.114	0.203
1980-1989	0.079	0.081
1990-1999	0.120	0.058
2000-2010	0.336	0.560

KOR: observed (blue) vs predicted (red), 1970-2010

the Malaysian case, with an average for the period 1970–2010 of 20.6 percent. As shown in the top-left chart of Figure 6, large industries related to machinery and transport equipment, sectors 71, 72 and 73, which account for about 35 percent of total exports, show positive changes in both relative quality and the export share. There are also sectors with shares above 6 percent in which quality has increased but their export share has gone down, namely products line 65, 84 and 89, which are related to the textile sector.

Moving to the bottom chart, the predictions do a good job, and reproduce in many instances a relatively large fraction of the export share variation. This is particularly so in industries classified under codes 51 to 96 that are not directly related to the extraction of raw materials. As a consequence, the measures of fit take on high

Figure 7: Results for Thailand

THA: observed, 1970-2010

THA	Pseudo R^2	Weighted R^2
1970-2010	0.455	0.504
1990 split	0.280	0.333
Decades	0.176	0.192
1970-1979	0.087	0.088
1980-1989	0.257	0.275
1990-1999	0.254	0.306
2000-2010	-0.328	-0.838

THA: observed (blue) vs predicted (red), 1970-2010

values. In particular, for the period 1970–2010, the pseudo-R^2 equals 0.455 and the weighted-R^2 is 0.504. Like for China and Malaysia, the R-squareds decrease when the averages are taken over shorter time horizons, but by less than in those other two countries. The pseudo-R^2 and weighted-R^2 fall to 0.319 and 0.455 in the 1990-split subsample, respectively, and to 0.134 and 0.171 in the Decades subsample. The four cross sections related to each of the decades reveals that the good fit comes from all of them. Nonetheless, the last decade, 2000-2010, shows up as the one in which quality upgrading has been more decisive, with a pseudo-R^2 and a weighted-R^2 equal to 0.360 and 0.560, respectively. Again, sticking to quality upgrading seems to have paid off in the case of South Korea.

Finally, we look a Thailand. The results are collected in Figure 7. It depicts a

scenario very similar to the one of South Korea. Machinery products—that is, sectors 71 and 72—show together an export share of 20.8 percent, being the largest exporters, on average, during 1970–2010. However, unlike previous economies, three agriculture and fishing products had export shares above 6 percent; these are sectors 3 (fish and fish preparations), 4 (cereals and cereal preparations) and 5 (fruit and vegetables). More than 50 percent of industries increased their export share between year 1970 and 2010, and 77 percent saw strictly positive quality upgrading. In the top-left chart, twenty eight industries show positive increases in relative quality and the export share, and 10 show exactly the opposite. Thus implying that 63 percent of the sectors suggest a positive relationship between the two variables.

As we see on the bottom panel, the model predictions do well. Industries in which the predictions can reproduce a relatively large fraction of the observed change include, for example, the machinery sectors (71 and 72) and clothing (84). Consequently, the R-squared in the top-right panel take on relatively large numbers. In particular, the pseudo-R^2 and weighted-R^2 in the 1970–2010 cross section equal 0.455 and 0.504, respectively, falling to 0.176 and 0.192 in the 1990-split panel, and to 0.087 and 0.088 in the Decades panel. In terms of the cross sections related to each decade, the 1970s and specially the 1980s and 1990s have contributed to the high correlation of quality upgrading and the export shares in Thailand. In these last two decades, for example, the fraction of the within-decade average variation of the export share explained by the changes in relative quality is above 25 percent.

5   Robustness

It might be argued that the previous section informs about the correlation between quality and exports but not about causality due to potential endogeneity problems. A reason is that we have employed the contemporaneous sectoral change in relative quality to estimate its effect on the sectoral export shares. This section addresses this concern by estimating regression (19) introducing the quality variable with a lag; that is, we employ $q_{nik,t-1} - q_{nok,t-1}$ to estimate the coefficient γ_{k5}. This is equivalent to assuming that the level of last year's product quality is the determinant of this year's product exports.

Table 2: Pseudo and weighted R-squared when the first lag of relative quality is employed

	China's R^2		India's R^2		Indonesia's R^2		Malaysia's R^2		S. Korea's R^2		Thailand's R^2	
	Pseudo	Weig'd	Pseudo	Weig'd	Pseudo	Weig'd	Pseudo	Weig'd	Pseudo	Weig'd	Pseudo	Weig'd
1971-2010	0.476	0.584	-0.007	0.002	-0.232	-0.149	0.268	0.315	0.339	0.517	0.377	0.403
1990 split	0.317	0.399	0.054	0.055	-0.450	-0.699	0.121	0.175	0.264	0.473	0.288	0.319
Decades	0.135	0.193	0.034	0.017	-0.355	-0.294	0.051	0.024	0.087	0.069	0.172	0.158
1971-1979	-0.036	-0.053	0.070	-0.019	0.175	0.045	0.027	-0.072	0.050	0.006	0.014	0.044
1980-1989	0.230	0.234	-0.054	-0.049	-0.262	-0.360	-0.351	-0.456	0.324	0.543	0.283	0.266
1990-1999	-0.051	-0.250	0.188	0.289	-1.316	-1.246	0.389	0.487	0.036	-0.095	0.337	0.369
2000-2010	0.529	0.645	0.016	0.020	-0.145	-0.192	-0.315	-0.485	-0.004	0.109	-0.455	-1.523

The methodology that we follow is equivalent to the one employed in the previous section. Regression (19) is estimated by OLS using $q_{nik,t-1} - q_{nok,t-1}$ instead of $q_{nik,t} - q_{nok,t}$, and only non-zero export data. Once the estimated coefficients $\hat{\gamma}_{k5}$ have been obtained, we generate, for each product and year, a prediction of the increase in its export share assuming that the only variable that changes is the level of quality relative to the reference country in the previous year. After that, we compute the pseudo-R^2 and the weighted-R^2 according to expressions (21) and (22).

Table A, included in the appendix, shows the estimation results.[15] In particular, it provides, in consecutive columns, the sector, the estimated coefficient for quality ($\hat{\gamma}_5$) and its standard deviation (Stand. Dev.), the number of observations (Obs.) and the coefficient of determination (R^2). We can see that the number of observations available varies from 99 to 240 depending on the sector. The fit is good, with an R^2 that goes from 0.65 to 0.97. Estimated coefficients are significant at standard levels for 58.3% of the products, and the sign is positive in 74.3% of the significant cases. This means that, this time, we find again evidence supporting that quality upgrading and exports move together in 43.3% of the products.

We can see also in Table A that the importance of quality upgrading is more evident in industries that rely less on commodities. For example, if we compare industries 00–43 to sectors 51–96, significance of estimated coefficients occurs for 48.1% of the products and 66.7%, respectively, and quality upgrading and exports rise together in 37.0% of the industries in the former subgroup and 48.5% in the latter.

Table 2 shows the measures of fit between the model predictions and the data. They reveal that, in general, compared to the tables presented in Figures 2 to 7, the pseudo-R^2 and the weighted-R^2 fall slightly. The only country for which the results clearly deteriorate is Indonesia, leaving quality upgrading in this economy almost no role to explain the export shares, with the exception is the 1970s cross section. Nevertheless, our main findings for the rest of countries look robust.

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[15] As before, for product line 84, observations for the years 1970 to 1972 were treated as outliers and eliminated from the estimation exercise.

6   Conclusion

This paper formally analyzes product-quality upgrading in a model of Ricardian trade, extending Eaton and Kortum (2002) to incorporate different sectors and to allow for changes in product quality. The model is then estimated using disaggregated sectoral data (2-digit SITC level) to calculate the impact of changes in product quality on the export performance of six fast-growing Asian economies—China, India, Indonesia, Malaysia, South Korea and Thailand—during 1970–2010. Our estimation approach, in contrast with previous literature, does not require domestic production data.

Previous papers has found that quality matters for firms that want to target export markets. We reinforce these results using aggregate sectoral data. We show that quality upgrading is a key factor in understanding changes in sectoral export shares in China, Malaysia, South Korea, and Thailand. In India and Indonesia, not surprisingly, the role of quality upgrading has been less critical. Indonesia relies heavily on commodities such as hydrocarbons and palm oil, making it harder to invest in raising product quality. In India, services have been a key driver of growth, but our dataset on product quality only considers goods. Measuring the quality of services remains an important avenue for future research.

Our results offer three main policy implications. First, efforts directed to improve product quality can potentially offer a high return to expand exports. Second, because, nevertheless, there are other factors that can impact export performance, like input costs and productivity, and the contribution of each of these aspects to the experience of different nations can greatly vary (as our results also suggest), quality upgrading should be preferably pursued when the quality ladder if sufficiently long. Third, and perhaps more important, a long-term commitment to quality upgrading lasting several years seems to be necessary to achieve a significant impact on export volumes.

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Table A: Regression estimates for the lagged-quality coefficients in each sector

Dependent variable: country exports relative to Germany				
2-Digit SITC Sector	$\hat{\gamma}_5$	Stand. Dev.	Obs.	R^2
00: Live animals	1.272	0.805	233	0.72
01: Meat and meat preparations	1.961**	0.760	240	0.84
02: Dairy products and eggs	-0.443	0.859	228	0.74
03: Fish and fish preparations	1.357**	0.650	240	0.84
04: Cereals and cereal preparations	1.649***	0.536	240	0.92
05: Fruit and vegetables	0.175	0.377	240	0.94
06: Sugar, sugar preparations and honey	0.153	0.660	240	0.65
07: Coffee, tea, cocoa, spices & manufacs. Thereof	2.778***	0.425	240	0.96
08: Feed. Stuff for animals excl. Unmilled cereals	-0.858***	0.290	240	0.91
09: Miscellaneous food preparations	1.943	1.907	240	0.87
11: Beverages	0.691	0.633	237	0.90
12: Tobacco and tobacco manufactures	-1.125	0.897	240	0.71
21: Hides, skins and fur skins, undressed	0.079	0.475	239	0.74
22: Oil seeds, oil nuts and oil kernels	1.871***	0.332	239	0.89
23: Crude rubber including synthetic and reclaimed	-0.785	0.870	236	0.94
24: Wood, lumber and cork	1.003***	0.225	240	0.95
25: Pulp and paper	0.879	0.628	194	0.77
26: Textile fibres, not manufactured, and waste	-0.477	0.578	240	0.88
27: Crude fertilizers and crude minerals, nes	4.062***	0.935	240	0.95
28: Metalliferous ores and metal scrap	1.374***	0.434	240	0.86
29: Crude animal and vegetable materials, nes	1.150**	0.499	240	0.94
32: Coal, coke and briquettes	-1.006	1.342	209	0.91
33: Petroleum and petroleum products	0.552	0.521	240	0.77
34: Gas, natural and manufactured	6.804***	1.528	178	0.74
41: Animal oils and fats	-8.123***	2.494	207	0.68
42: Fixed vegetable oils and fats	0.568	0.394	236	0.94
43: Animal and vegetable oils and fats, processed	-2.527**	1.068	236	0.87
51: Chemical elements and compounds	1.111	1.644	240	0.97
52: Crude chemicals from coal, petroleum and gas	-3.207	2.117	167	0.66
53: Dyeing, tanning and colouring materials	6.531***	1.269	240	0.96
54: Medicinal and pharmaceutical products	3.664***	1.061	240	0.94
55: Perfume materials, toilet & cleansing preptions	-3.473***	0.980	240	0.94
56: Fertilizers, manufactured	-4.304***	1.094	217	0.86
57: Explosives and pyrotechnic products	1.048	0.940	193	0.92
58: Plastic materials, etc.	12.021***	3.398	234	0.94
59: Chemical materials and products, nes	4.803***	1.223	240	0.92
61: Leather, lthr. Manufs., nes & dressed fur skins	0.257	0.345	240	0.93
62: Rubber manufactures, nes	7.450***	1.803	237	0.93
63: Wood and cork manufactures excluding furniture	0.005	0.687	240	0.81
64: Paper, paperboard and manufactures thereof	-1.260	2.086	232	0.85
65: Textile yarn, fabrics, made up articles, etc.	-2.227**	0.999	240	0.94
66: Non metallic mineral manufactures, nes	-0.067	0.763	240	0.93
67: Iron and steel	7.755***	1.518	234	0.94
68: Non ferrous metals	1.247**	0.510	240	0.75
69: Manufactures of metal, nes	-4.352***	1.036	238	0.94
71: Machinery, other than electric	7.995***	1.549	240	0.95
72: Electrical machinery, apparatus and appliances	11.348***	1.852	240	0.94
73: Transport equipment	-1.301*	0.783	240	0.92
81: Sanitary, plumbing, heating and lighting fixt.	-0.364	0.966	233	0.92
82: Furniture	6.044***	2.079	238	0.90
83: Travel goods, handbags and similar articles	-1.058	1.358	236	0.91
84: clothing	3.739***	1.138	228	0.93
85: Footwear	-3.076**	1.459	240	0.86
86: Scientif & control instrum, photogr gds, clocks	4.203***	1.212	240	0.95
89: Miscellaneous manufactured articles, nes	4.872***	0.813	240	0.95
91: Postal packages not class. According to kind	1.543***	0.226	108	0.85
93: Special transact. Not class. According to kind	2.014*	1.150	195	0.71
94: Animals, nes, incl. Zoo animals, dogs and cats	1.053***	0.306	233	0.74
95: Firearms of war and ammunition therefor	0.175	1.030	172	0.82
96: Coin, other than gold coin, not legal tender	-0.102	0.611	99	0.82

Wages, country fixed effects and coutry-specific time trends included in all regressions along with quality.
*** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.