Quality Upgrading and the Stages of Diversication

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Abstract

This paper explores the contribution of product quality upgrading in the process of export diversification. To do this, the paper builds a multisector model following Eaton and Kortum (2002) in which product quality is incorporated as a key feature. The model is then calibrated to generate predictions about the degree of export diversification in a number of East Asian countries. It is shown that quality upgrading is a key factor to understand the changes in the degree of export diversification in the majority of countries in our sample.

1 Introduction

Broad patterns in the relationship between export diversification and the level of per capita income have been recently uncovered. In particular, Imbs and Wacziarg (2003) document that higher incomes per capita are associated first with diversification, and then with re-concentration, in production and employment, following a U-shaped pattern across a wide variety of data sources. Klinger and Lederman (2004) and Cadot et al. (2011) find similar results for exports. In addition, as recently shown by an emerging literature, economic development crucially involves changes not only in the type, but also in the quality of goods produced (IMF 2014; Henn, Papageorgiou and Spatafora (2015)). Higher quality varieties of existing products can constitute a way of building on existing comparative advantage. As Henn et al. (2015) show, there is a strong positive correlation between the quality of exported goods, measured by their unit value, and the level of economic development. East Asia constitutes, for example, a clear case of economies that have benefited significantly from quality upgrading over that last two decades.

Motivated by these facts, this paper aims at assessing the contribution of product quality upgrading in export diversification. Even though the main focus is on sectoral quality, the effects of worldwide demand trends and country's labor costs are also analyzed. To achieve this objective, we first build a framework of Ricardian trade that allows assessing the contribution of different determinants of firms' activity to the evolution of export concentration. The proposed framework extends the model developed by Eaton and Kortum (2002, EK henceforth) to incorporate sectors and permit for product quality. Subsequently, a key implication on relative exports obtained by the model is estimated, and employed to form predictions about export diversification as measured by the Theil index.

We focus the analysis on 2-digit SITC (review 1) data for the period 1970 to 2010 and use quality upgrading estimates from Henn et al. (2015).[1] Specifically, the paper aims at understanding the export diversification experience of a set of East Asian nations that rely heavily on exports especially over the last few decades.[2] As predicted by the patterns established in the existing literature, developing economies in our sample, like Philippines, Vietnam and Cambodia, show either increasing or a U-shape diversification path over the sample period; whereas more develop nations, like Japan and Singapore, depict rising concentration.

On average, the predictions obtained from the model using quality, wages and German exports (the latter included to control for worldwide trends) tend to overestimate the level of export concentration. This points out that a combination of efficiency, trade costs, and other input-cost differences (variables that we do not take into account to form predictions) are also important drivers of the diversification process. Importantly, we show that relative sectoral quality and global trends have a sizable power to explain the changes experienced by the Theil index, and that the strength of this power depends on the country and the time interval.

Quality is identified as a key factor to understand the changes in the export diversification level in China, Japan and South Korea, where it can explain more than 50%, 17% and 25% of the total variation, respectively. Cambodia is also a prominent example; relative quality accounts there for about 50% of the changes shown by export diversification from 1970 to 1999. Other countries in which quality has helped shape the Theil index includes Indonesia, Malaysia, Singapore, Thailand and Vietnam. We find no sizable effect of quality upgrading on Hong Kong, India and Philippines.

Papers that try to explain countries' stages of diversification are scarce. Imbs et al. (2014) argue that increasing diversification can obey to a rising integration of markets within countries, and that the posterior product concentration can be a consequence

[1] There exist alternative sources of quality indices such as Hallak (2006), Hallak and Schott (2011), and Freenstra and Romalis (2014). However, these papers do not provide estimates for the entire set of countries contained in our sample. Results using alternative measures do not change qualitatively.

[2] Countries in our sample are: China, Hong Kong, Indonesia, India, Japan, Cambodia, South Korea, Malaysia, Philippines, Singapore, Thailand and Vietnam.

of an increasing integration of markets across countries. Samaniego and Sun (2016), in turn, present a close economy model of economic growth and structural change. They explain the stages of diversification as a result of transitions among industries that experience different productivity growth rates.

Our work is also related to the literature that uses multisector variants of the EK model. These papers include, among many others: Uy et al. (2013) that incorporate the three main sectoral aggregates (agriculture, manufacturing and services); Eaton et al. (2011), Costinot et al. (2012), and Levchenko and Zhang (2016) that impose common trade elasticities across an array of manufacturing sectors; and Caliente and Parro (2014) and Bolatto (2016) that allow for differences in those elasticities. Like some of these papers, we allow for different trade elasticities across sectors. However, unlike all of them, we include product quality into the analysis, and focus on explaining the stages of export diversification.

The rest of the paper is organized as follow. Section 2 introduces the theoretical framework of international trade, while Section 3 discusses the implications of the model for the diversification measure adopted. The empirical methodology and data used as well as the results obtained are discussed in Section 4. Section 5 concludes.

2 The Model

We present a static framework that considers three main dimensions of product exports and imports: the intensive, the extensive, and the quality margins. The intensive margin refers to more units produced of a good. The second dimension, the extensive margin, is related to the number of product lines. The quality margin affects changes in the unit value of a given product. Trade is formalized in a Ricardian framework following EK, but extended to include different activity sectors and product quality. The model allows decomposing the diversification process into different components. As driven mechanism behind this process of diversification and posterior concentration, the model proposes the existence of heterogeneity in quality-upgrading and efficiency-growth potential 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

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

subject to the budget constraint

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

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} depends on h_k, an increasing sector-specific function of the consumed-product's quality $q_{nk}(j)$. Notice that quality-adjusted consumption levels are aggregated according to constant 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:

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

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

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

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, $h_k\left[q_{nk}(j)\right] c_{nk}(j)$. As a consequence, the relevant variable in the consumption decision is the price per unit of effective quality, $p_{nk}(j)/h_k\left[q_{nk}(j)\right]$; 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.

2.2 Producers

In our economy, all markets are perfectly competitive, and the only input of production is labor.[3] 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:

$$Y_{nk}(j) = z_{nk}(j) \frac{L_{nk}(j)}{a_k\left[q_{nk}(j)\right]}; \tag{8}$$

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 an increasing sector-specific function of the quality embodied in the product.

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

[3] We could also introduce intermediate inputs in the production function, as in EK. The only difference in our analysis would be given by the unit cost of the input bundle. However, because we only consider wages to measure input prices, this alternative formulation would deliver the same results.

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:

$$p_{nik}(j) = a_k \left[q_{nik}(j)\right] \frac{w_i}{z_{ik}(j)}; \tag{9}$$

where $q_{nik}(j)$ is the quality level of that good.

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 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 $d_{nik}p_{nik}(j)/h_k\left[q_{nik}(j)\right]$. From (9), we can deduce that the producer price per unit of effective quality equals:

$$\frac{p_{nik}(j)}{h_k\left[q_{nik}(j)\right]} = \frac{w_i}{z_{ik}(j)}\frac{a_k\left[q_{nik}(j)\right]}{h_k\left[q_{nik}(j)\right]}. \tag{11}$$

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. In order to guaranty that more costly, higher quality versions of the goods are preferred, we need that equality (11) falls with quality, or in other words, that the utility effect dominates.

For ease of notation, from now on, we capture the net effect of quality as:

$$\tilde{h}_k\left(\cdot\right) = \frac{a_k\left(\cdot\right)}{h_k\left(\cdot\right)}. \tag{12}$$

Furthermore, to simplify the analysis, we assume that all products within the same sector and country posses the same level of quality, that is, $q_{nik}(j) = q_{nik}$ for all j. Hence, from expression (11), we can write the link between consumer and producer prices is given by

$$\frac{p_{nk}(j)}{h_k\left[q_{nk}(j)\right]} = \min\left\{\frac{d_{nik}w_i}{z_{ik}(j)\tilde{h}_k(q_{nik})},\ i = 1, ..., N\right\}. \tag{13}$$

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 (13), 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:

$$G_{nik}(\rho) = \Pr\left[\frac{d_{nik}p_{nik}(j)}{h_k(q_{nik})} \leq \rho\right] = 1 - F_{ik}\left[\frac{d_{nik}w_i}{\rho\tilde{h}_k(q_{nik})}\right]. \tag{14}$$

In addition, from (13) and (14), the distribution of the price-to-quality ratio for what country n actually buys sector-k commodities (unconditional on their source) is given by

$$G_{nk}(\rho) = \Pr\left\{\frac{p_{nk}(j)}{h_k\left[q_{nk}(j)\right]} \leq \rho\right\} = 1 - \exp(-\Phi_{nk}\rho^{\theta_k}), \tag{15}$$

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

An implication of (15) is that the sector price index, defined in expression (6), can be rewritten as

$$P_{nk} = \gamma_k \Phi_{nk}^{-1/\theta_k}, \quad \text{with } \gamma_k = \Gamma\left[\left(\frac{\theta_k + 1 - \eta}{\theta_k}\right)^{\frac{1}{1-\eta}}\right]; \tag{16}$$

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

$$\pi_{nik} = \frac{\Upsilon_{ik}\left[\frac{d_{nik} w_i}{\tilde{h}_k(q_{nik})}\right]^{-\theta_k}}{\Phi_{nk}}. \tag{17}$$

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 (17) 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,

$$\frac{X_{nik}}{P_{nk} c_{nk} L_n} = \pi_{nik}; \tag{18}$$

where X_{nik} represents the value of sector-k exports from source i to n at destination prices.[4] Notice that the denominator in the LHS equals country n's total spending in industry k's commodities.

3 Measuring Export Diversification

To assess the level of export concentration, we choose the Theil index (T). This is a common measure that have been employed by, among others, Cadot *et al.* (2001) and

[4] 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.

Papageorgiou and Spatafora (2012). Compared to other indices, its advantage is that it can be split into within- and between-group components (TW and TB, respectively), which allows having separate measures of the importance of the intensive and extensive margins in the diversification process.

The Theil index is constructed considering all items that can be potentially traded. Our framework, however, does not provide a value of exports for each single good; it gives the value of exports per sector. Consequently, in order to study how the elements of the model affect this concentration index, we assume that the value of a product-line exports is the same for all products that are exported within a sector. Given that goods in each production activity is a mass of size *one*, we can write the Theil index that provides country i's level of export concentration as follows:

$$T_i = \frac{1}{K} \sum_{k=1}^{K} \frac{X_{nik}}{\mu_i} \ln \left(\frac{X_{nik}/\pi_{nik}}{\mu_i} \right); \tag{19}$$

where

$$\mu_i = \frac{1}{K} \sum_{k=1}^{K} X_{nik}. \tag{20}$$

Following Cadot *et al.* (2011), we know that $T_i = TB_i + TW_i$, and that TB_i and TW_i can serve to capture the evolution of the extensive and intensive margins, respectively. This occurs when we split the set of total product lines, for example, in the following two groups: one subset formed by active lines, which show strictly positive exports in country i; and the other one composed of inactive lines, that is, with zero exports.

In particular, we can write:

$$TB_i = \ln \left(\frac{K}{\sum_{k=1}^{K} \pi_{nik}} \right); \tag{21}$$

$$TW_i = \frac{1}{\sum_{k=1}^{K} \pi_{nik}} \sum_{k=1}^{K} \frac{X_{nik}}{\mu_i^W} \ln \left(\frac{X_{nik}/\pi_{nik}}{\mu_i^W} \right); \tag{22}$$

where μ_i^W is the export mean among active lines,

$$\mu_i^W = \frac{1}{\sum_{k=1}^{K} \pi_{nik}} \sum_{k=1}^{K} X_{nik}. \tag{23}$$

We can easily see that the evolution of TB_i captures variations in the fraction of product lines exported; whereas the one of TW_i is affected by changes in the export value of exported lines.

Next, we describe the main determinants of TB_i and TW_i. Let us start with the extensive margin. As we see in expression (21), TB_i is influenced by the fraction of goods in each sector π_{nik} that a country exports to other nations. Expression (17) then suggests that achieving larger levels of diversification along the extensive margin (i.e., raising π_{nik}) requires increasing quality and input-saving efficiency, and diminishing shipping costs and input prices. Interestingly, improvements in the values of these determinants must be relative to other nations.

The intensive margin, captured by TW_i, is on the other hand mainly affected by changes in the export share of the different sectors in total exports. This can be easily seen combining expressions (22) and (23) to obtain:

$$TW_i = \sum_{k=1}^{K} \left(X_{nik} / \sum_{v=1}^{K} X_{niv} \right) \ln \left[\left(X_{nik} / \sum_{v=1}^{K} X_{niv} \right) \left(\pi_{nik} / \sum_{v=1}^{K} \pi_{niv} \right)^{-1} \right].$$

Let us focus on two of these sectors: v and s. From expressions (5) and (16) to (18), we can write:

$$\frac{X_{niv}}{X_{nis}} = \frac{\pi_{niv}}{\pi_{nis}} \frac{\omega_v}{\omega_s} \frac{\left\{ \gamma_v \sum_{i=1}^{N} \Upsilon_{iv} \left[\frac{d_{niv} w_i}{\tilde{h}_v(q_{niv})} \right]^{-\theta_v} \right\}^{-(1-\varepsilon)/\theta_v}}{\left\{ \gamma_s \sum_{i=1}^{N} \Upsilon_{is} \left[\frac{d_{nis} w_i}{\tilde{h}_s(q_{nis})} \right]^{-\theta_s} \right\}^{-(1-\varepsilon)/\theta_s}}. \tag{24}$$

Therefore, relative sectoral exports depend on the relative values across sectors of the variables that determine the extensive margin (discussed above).

Thinking about the consequences of expression (24) for the path of export diversification, if we suppose that n represents a set of developed nations, it is sensible to believe that as economy i converges towards the advanced world, Υ_{iv} and q_{niv} will convergence to Υ_{nv} and q_{nnv}, respectively, for all i. Assuming also for simplicity that $d_{niv} = d_{nis}$, we end up with the following expression:

$$\frac{X_{niv}}{X_{nis}} = \frac{\pi_{niv}}{\pi_{nis}} \frac{\omega_v}{\omega_s} \frac{\gamma_v}{\gamma_s} \left[\frac{\Upsilon_{ns}^{1/\theta_s} \tilde{h}_s(q_{nns})}{\Upsilon_{nv}^{1/\theta_v} \tilde{h}_v(q_{nnv})} \right]^{1-\varepsilon}. \tag{25}$$

Because the ratio π_{niv}/π_{nis} in expression (25) will play a progressively smaller role, the main determinants at later stages of development of the evolution of the sectoral export shares will be changes across sectors in the relative quality and efficiency levels at the technology frontier. This is what we call worldwide demand trends in our analysis.

Furthermore, the effect of these two variables will depend on the cross-sector elasticity of substitution, ε. More specifically, focusing on the terms inside squared brackets in (25), if sectors are complements (substitutes) – i.e., $\varepsilon \in (0,1)$ ($\varepsilon > 1$) – exports will become more concentrated on products that experience relatively lower (higher) quality and production-efficiency growth in the rest of the world; quality and efficiency differences across sectors abroad will play no role if $\varepsilon = 1$.[5] The capacity of efficiency growth heterogeneity to explain the evolution of product diversification in a closed economy has been already pointed out by Samaniego and Sun (2016). We add to this, the open-economy analysis, and the possible importance of heterogeneity in quality-upgrading potential across product lines.

4 Export Diversification Across Asian Nations

In this section, we assess the contribution of product quality and other factors to the evolution of export diversification. In order to do that, we generate predictions for exports in several East Asian nations under different counterfactuals, compute the implied Theil index, and compare it to the one obtained from the data. Our chosen countries are the following: China, Hong Kong, Indonesia, India, Japan, Cambodia, South Korea, Malaysia, Philippines, Singapore, Thailand and Vietnam. The reason for this choice is that they represent a relatively homogeneous set of emerging and developed economies that relay heavily on exports. Our main measure of analysis will be the within-groups index; this is a consequence of the lack of available quality index values when countries show zero exports.

The Theil index in our experiments will be computed from mirror data, that is, cost-insurance-and-freight (CIF) exports reported by the destination country or importer. These numbers are seen in the literature (e.g., see Cadot *et al.* 2011) as more

[5] Across big activity sectors, estimates point out complementary. For example, Herrendorf, Rogerson and Valentinyi (2013) estimate a value of ε close to zero across agriculture, manufacturing and services. Within big sectors, however, products seem to be relative substitutes. Ilyina and Samaniego (2012) estimate a value for ε of 3.75 employing manufacturing data. This estimate is consistent with alternative numbers offered in the international trade literature surveyed, among others, by Anderson and Van Wincoop (2004).

accurate than direct free-on-board (FOB) exports reported by the origin nation, especially for developing countries. In addition, because the EK model is mainly designed to determine the shares of export values, rather than the fraction of goods exported, we will compute indices (19) and (22) assuming that π_{nik} equals *one* if sector k shows an strictly positive export value, and *zero* otherwise.

4.1 Methodology and data

Before generating predictions, we need to give a specific form to function $\tilde{h}$ and assign values to the parameters in expression (17). 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 Caliente 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 (18) 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 as far as we know 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 adopting some of the estimated coefficients for different sectors from Henn *et al.* (2015), given that they estimate a regression following SITC that contains some of the features of expressions (17) and (18). 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, the approach that we follow is working with a version of the above equations that does not require information on domestic production and demand. In particular, from (17) and (18), we can write relative sector-k exports from countries i and e to nation n as:

$$\frac{X_{nik}}{X_{nek}} = \frac{\Upsilon_{ik}}{\Upsilon_{ek}} \left[\frac{d_{nik}}{d_{nek}} \frac{w_i}{w_e} \frac{\tilde{h}_k\left(q_{nek}\right)}{\tilde{h}_k\left(q_{nik}\right)} \right]^{-\theta_k} . \tag{26}$$

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

The choice of the *reference* country (nation e above) is based on our model. According to expression (25), we want an economy that can reflect global trends in quality and efficiency levels in the rest of the world. This needs to be an advanced economy like Germany or the US. Given that the world economy will be our proxy for economy n, and Germany receives a much lower fraction of exports from Asian nations than the US, we prefer Germany to play the role of e.[6]

Our data comprises exports and quality numbers from SITC, revision 1, at the two digit level, from 1962 to 2010. However, because quality is available for Germany only from 1970 onwards, the main analysis focuses on the 1970-2010 time interval, except for Vietnam that starts in 1976. FOB and CIF exports come from the *Comtrade* database. The quality index constructed by Henn et al. (2015) 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*. Finally, ad-valorem tariff information are obtained from the *WITS* dataset; although in this case, the numbers available are more scarce, starting in 1989 for Indonesia, Japan, South Korea, Philippines, Singapore and Thailand, 1991 for India and Malaysia, 1992 China, 1994 for Vietnam, 1996 for Hong Kong, and 2001 for Cambodia.

In order to obtain the parameter values needed to apply expression (26), we estimate the following regression for each 1-digit set of 2-digit-SITC sectors:[7]

$$\ln \frac{X_{nik,t}}{X_{nek,t}} = \beta_0 + \beta_{1i} E_i + \beta_{2k} E_k + \beta_{3i}\, t + \beta_4 \ln R_{ikt} + \beta_5 \ln W_{ikt} + \beta_6 Q_{ikt} + \varepsilon_{ikt}. \tag{27}$$

Notice that we have added a time subscript t to exports. In (27), country and sector fixed effects dummies – E_i and E_k, respectively – along with the country-specific time

[6] By (17), expression (26) requires that economy n contains neither i nor e so that Φ_{nk} is the same for both nations. Therefore, because n is the world economy, we need to choose for our sample countries that show relatively small bilateral trade flows with the reference nation.

[7] For example, one of the regressions corresponds to *0:Beverages and tobacco*, implying that k goes from 2-digit-SITC sectors 00 to 09.

trends control for differences in efficiency levels $\Upsilon_{ik}/\Upsilon_{ek}$ and other omitted variables.

Variable R_{ikt} in regression (27) represents tariffs in country i, sector k, and time t. This is our proxy for relative iceberg costs d_{nik}/d_{nek}.[8] Consequently, coefficient β_4 will deliver an estimate for $-\theta_k$; we expect β_4 to be negative. The regressor Q_{ikt} stands for relative product quality q_{nik}/q_{nek}, and then $\beta_6 * q_{nik}/q_{nek}$ will capture the effect of $\tilde{h}_k(q_{nik})/\tilde{h}_k(q_{nek})$ on relative exports.[9] In principle, we expect β_6 to be positive.

Finally, the input-cost proxy W_{ikt} is country's i marginal product of labor per unit of product-line quality relative to its German counterpart. We divide the wage by quality because the value of labor productivity increases with product quality when higher quality requires more skilled labor. In addition, notice that the wage can also reflect cross-time variation in the economy's efficiency level. Its coefficient β_5 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, β_5 can be positive or negative.

We use the tariff data to estimate with more precision the model parameters. However, because of the relatively short time series that tariffs provide, we will not employed them to generate predictions. More specifically, model predictions for exports ($\hat{X}_{nik,t}$) will be generated for each sector according to:

$$\hat{X}_{nik,t} = \exp\left[\hat{\beta}_5 \ln W_{ikt} + \hat{\beta}_6 Q_{ikt}\right] * X_{nek,t}; \tag{28}$$

where a hat ($\hat{}$) above a coefficient denotes its estimated value.

Regression 27 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. (2015) in its estimation. Note that this fact implies that our approach is more appropriate to predict the within-groups Theil index.

Given the limitations imposed by tariffs, the number of observations available to estimate expression 27 goes down from 25,917 to 12,298, split among the different sector groups. Tables 1 and 2 show the correlations among regressors and the estimation results, respectively.[10] In Table 2, Regression (1) gives estimates when all 2-digit sectors

[8] Tariffs are not relative to the German ones because of the lack of tariff data for Germany.

[9] The ratio q_{ik}/q_{vk} is the specification that provided a better fit in our sample.

[10] Tables and Figures are located at the end of the paper.

are included. Regressions (2) to (11), in turn, correspond to the different sector-groups, and provide the coefficients that will be employed to build the predictions. The fit is good with an R^2 that goes from 0.474 to 0.912, and the coefficients show most of the time the expected signs.

4.2 Results

This subsection first looks at the evolution of the main variables (the Theil index, quality, wages, and tariffs) observed in the data for the economies that compose our sample: Cambodia (KHM), China (CHN), Hong Kong (HKG), India (IND), Indonesia (IDN), Japan (JPN), Malaysia (MYS), Philippines (PHL), Singapore (SGP), South Korea (KOR), Thailand (THA), and Vietnam (VNM). 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 the explanatory variables proposed by the model to reproduce the path of export diversification, paying special attention to the role of quality upgrading.

Figure 1 shows the time series of the Theil index of export concentration across the twelve Asian countries plus Germany and the US. We include the US (USA) in this occasion for comparison. The LHS and RHS charts provide the seven countries with the lowest and highest per capita income, respectively.

In the first row, the Theil index is computed from CIF exports reported by the destination country. We see a wide range of experiences. Countries like Cambodia, Germany, Philippines, China, Malaysia and South Korea show the typical inverted hump-shape found in the cross-section of countries by papers like Imbs and Wacziarg (2003) and Cadot *et al.* (2011). More specifically, these countries decrease the level of concentration at the beginning of the sample period, and later on increase it. Other nations like Indonesia, Thailand, Vietnam, and India have seen the level of diversification (a lower Theil) rise as time goes by. Rich economies like Japan, Singapore and the US has experienced increasing concentration, whereas Hong Kong shows no significant variation.

The paths of Germany and the US in Figure 1 are the ones with the lowest variance. Their evolution have been very similar, showing both after 1975 increasing concentration until year 2000. As we mentioned previously, the patterns shown by these two large economies, Germany and US, can be interpreted as a proxy for the trends in worldwide demand pointed out by expression (25). Interestingly, after year 2000 a few economies (KHM, PHL, SGP, MYS, HKG, DEU and USA) that have advanced during many years along the path of increasing concentration have reversed this tendency.

For comparison purposes, the second and third rows give the evolution of the Theil constructed from FOB exports and 5-digit SITC (rev 3) sectors, respectively; albeit in the last case only for Malaysia, South Korea and Vietnam. We can see that these charts offer very similar patterns to the ones depicted in the first row. This supports that our focus on mirror exports and 2-digit sectors is not critical for the results.

Moving now to the variables from which the regressors in expression (27) are constructed, Figure 2 gives an idea of their evolution. The first row shows the time series of the average quality level weighted by exports across sectors. In general, the index rises over time in all economies. In some countries – namely, Philippines, Indonesia, Vietnam and Malaysia – we observe a U-shape. Perhaps more important, even though poorer nations show lower product quality, quality is converging towards its frontier in all countries, with the exception of Malaysia. Interestingly, Germany is at all times very close to that frontier, which reinforces its choice as reference nation.

The second row gives labor productivity, showing that it has been rising rapidly in Asia. As in the case of quality, the most remarkable ascension among less developed economies corresponds to China, and the worse performers are Vietnam, Indonesia and Cambodia. Finally, the third row shows tariffs, where we can see the fast decrease in developing Asian nations, and the constancy at low rates in the developed economies.

Our next task is to decompose the Theil index in its between-groups and within-groups components. Figures 3 and 4 show the total Theil (dashed lines) and the within-groups component (solid lines) from 1970 to 2010. Each chart depicts four lines: *T Data* and *TW Data* correspond to the Theils constructed using export data (thick lines); and *T Pred* and *TW Pred* give the Theils predicted by the model (thin lines) applying expression (28) that uses relative quality, relative wage per unit of sector quality, and German exports.

We can see that predictions tend to overvalue the level of concentration. The exceptions occur in the less developed economies: Indonesia and Philippines show both over- and under-valued concentration; whereas Cambodia and Vietnam provide predictions with too much diversification in the within-groups index. Clearly, these results point out that a combination of efficiency, trade costs, and cross-product input-cost differences are also important drivers of the diversification process. Nevertheless, at first sight, quality, aggregate labor productivity and global trends do a good job at reproducing variations in the export diversification index during certain time intervals in at least eight countries; namely, China, Hong Kong, Japan, and Cambodia (TW series) in Figure 3, and South Korea, Malaysia, Singapore, and Thailand in Figure 4.

Comparing now the T and TW paths, we see that except for Cambodia and Vietnam, these paths are fairly parallel. An important reason for their symmetry is the degree of disaggregation – a 2-digit approach is, for example, far from the 6-digit data employed in Cadot et al. (2011) – which limits the amount of zero-export observations that can be found. This feature and the parameter estimation method used above make us focus on the within-groups for our next exercise.

An interesting experiment is looking at the direction towards which the different components of the model push export diversification. In order to analyze it, we generate predictions for the diversification measure adding each variable sequentially. This allows decomposing the within-groups Theil index into the parts explained by relative quality, relative labor costs per unit of quality, and the general forces captured by the reference nation. In addition, because we are now more interested in studying how the different forces shape the changes in the index, predictions are rescaled so that initial values correspond to the ones observed in the data. Figures 5 and 6 present the results.

In those Figures, the Q path corresponds to TW obtained from export predictions when relative quality values vary, but W_{ikt} and $X_{nvk,t}$ are kept constant in expression (28) at their average level in each sector and country. The path QW, in turn, is the result of allowing Q_{ikt} and W_{ikt} change over time, but $X_{nvk,t}$ remains fixed at its mean value. Finally, QWD represents predictions when the three variables – quality, wages and German exports – are permitted to vary over time.

In general, the evolution of relative sectoral quality pushes the diversification index towards increasing concentration. This is why quality does a better job at depicting the trend of the Theil index in economies that show increasing concentration. The exceptions (all of them in Figure 5) are Cambodia, where quality initially helps diversification, and India and Indonesia, where the predicted Q line is fairly flat. The rest of determinants for which we control promote diversification in about half of the cases, and concentration in the other half.

In order to dig deeper on the capacity of the model to explain changes in the data, Table 3 reports the pseudo-R^2 obtained using deviations of the Theil index series with respect to their initial value in the corresponding time interval. Let us focus first on the 1970-2010 period (columns 1 to 3), that is, on the whole time interval of the sample. The best fit of the predictions is for China, followed by Japan, Singapore, South Korea and Philippines, with R^2 for the QWD predictions equal to 0.558, 0.409, 0.358 and 0.110, respectively. In those nations, with the exception of PHL, quality upgrade accounts for a significant fraction of the deviation with respect to the initial value – in CHN the R^2 for the Q series is 0.522, 0.173 for Japan, and 0.220 for Singapore.

Table 3 also provides a more detailed view in columns 4 to 15, giving numbers for each decade. China and Japan, again, show up as the best performing cases. In China, the lack of success to explain the variations of the Theil index during the 1970s changes dramatically in the subsequent decades. Chinese quality upgrading can explain 59% of the deviation in the 1980s, and 38% in the 2000s. In turn, the global trends behind German exports can explain about 43% during the 1990s and 52% in the 2000s, making the R^2 reach 0.904 in the latter case. Moving next to Japan, the Q series account for a sizable fraction of the Theil index deviation during three decades, from 1970 to 1999 (R^2 of 0.115, 0.319 and 0.109). Global trends explain now about 8%, 65% and 93% during the 1970s, 1980s and 2000s, respectively. The wage index does not show any power.

Quality upgrading is also a main factor in the evolution of export diversification in Cambodia. Its importance falls over time, but the R^2 related to the Q series achieves sizable values in the three decades from 1970 to 1999; in particular, it equals 0.779 (1970s), 0.584 (1980s) and 0.140 (1990s). Quality is as well important in the following countries and periods: during the 1970s in Vietnam and Singapore (R^2 for Q series of 0.213 and 0.135, respectively); Malaysia from 1980 to 1999 (R^2 equals 0.113 and 0.132); South Korea in the 1980s and 2000s (R^2 of 0.339 during the former and 0.203 during the latter); and in Indonesia and Thailand in the 1990s (R^2 for Q series of 0.219 and 0.401, respectively).

Aggregate labor productivity is the variable that shows less power to shape the variations shown by the index of export diversification. Only India and Singapore present some instances in which it has a contribution above 10%. In particular, during the 1980s, it accounts for about 21% of the Theil index deviation in India, and about 5% during the 1970s in Singapore.

Besides China and Japan, worldwide demand trends help a few other nations in our sample to fit the evolution of the Theil index. Out of the three variables that we consider to build the predictions, German exports are the only important one for Hong Kong and the Philippines, during the last two decades in the former, and in the first 10 years in the latter; more specifically, the R^2 shows values (QWD series) of 0.569 for 1990-1999 and 0.703 for 2000-2010 in HKG, and 0.370 for 1970-1979 in PHL. In India and Indonesia, in the 1970s, global trends also show power to explain about 20% and 10%, respectively. Finally, in other countries German exports help increase the R^2 above the highest value given by the other series: 5% in the 1970s and 61% in the 2000s for Singapore; around 9% in the 1970s, and 13% in the 1990s in Cambodia; 8% in the 1980s for South Korea; and during the 1990s, 52% for Malaysia and 27% for Thailand.

Interestingly, notice that in the developed countries that composed out sample, with the exception of South Korea, worldwide trends are responsible for the increasing degree of diversification after 2000. More specifically, Hong Kong, Japan and Singapore show R^2 for the QWD series equal to 0.703, 0.928 and 0.609 in the 2000s, whereas their other series during the same period show negative numbers.

5 Conclusion

This paper has made a first attempt to estimate the contribution of product quality upgrading to export diversification. For this purpose, we have extended the Eaton and Kortum's (2002) framework to incorporate many sectors and product quality. Later, a regression derived from the model has been estimated, and employed to form predictions about the degree of export diversification in a number of East Asian nations. These predictions have been compared to the data employing 2-digit SITC (review 1) numbers for the time interval 1970 to 2010.

We have shown that quality upgrading is a key factor to understand the changes in the degree of export diversification in the majority of countries in our sample, but specially in China, Japan, South Korea and Cambodia. It is interesting to observed that this group of countries is associated with periods of sustained growth accelerations, therefore in future work we will be exploring more carefully whether quality upgrading is not only a key to export diversification but also growth accelerations.

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[12] Related files: technical appendix and data and programs used to generate the results.

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Table 1: Correlations between explanatory variables

	Q	R	W
Q	1.000		
R	-0.255	1.000	
W	0.353	-0.579	1.000

Table 2: regression estimates

Dependent variable: country exports relative to Germany

	2-digit SITC codes included in each 1-digit SITC group regression										
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Regressors	01-96	00-09	11-12	21-29	32-35	41-43	50-59	61-69	71-73	81-89	91-96
Q	1.442 ***	1.046 ***	0.369	2.498 ***	0.665	2.833 ***	1.951 ***	-1.312 ***	-0.174	-0.154	1.409 **
	(0.193)	(0.386)	(0.729)	(439)	(1.109)	(0.561)	(0.546)	(0.457)	(1.334)	(0.807)	(0.579)
ln *W*	0.522 ***	0.468 **	0.358	0.347	0.485	0.106	-0.034	0.274 *	0.141	-0.186	0.751 **
	(0.092)	(0.184)	(0.295)	(0.233)	(0.597)	(0.305)	(0.179)	(0.160)	(0.225)	(0.227)	(0.321)
ln *R*	-0.055 ***	-0.166 ***	-0.007	0.086 ***	0.168 ***	-0.805 ***	-0.010	-0.201 ***	-0.246 ***	-0.290 ***	-0.074 ***
	(0.008)	(0.024)	(0.027)	(0.017)	(0.052)	(0.096)	(0.016)	(0.038)	(0.036)	(0.033)	(0.027)
Observations	12,298	1,898	436	1,958	623	620	1,897	1,951	657	1,524	521
R-squared	0.558	0.748	0.740	0.474	0.464	0.754	0.750	0.779	0.912	0.704	0.606

Q represents relative product quality. *W* is the country's marginal product of labor per unit of product-line quality. R corresponds to tariffs. Country and sector fixed effects as well as coutry-specific time trends included in all regressions. *** significant at the 1% level, ** significant at the 5% level, * significant at the 10% level.

Table 3: Pseudo R-squared for different within-groups Theil-index prediction series and time-intervals

	1970-2010			1970-1979			1980-1989			1990-1999			2000-2010		
ISO	Q	QW	QWD	Q	QW	QWD	Q	QW	QWD	Q	QW	QWD	Q	QW	QWD
CHN	**0.522**	**0.610**	**0.558**	**-0.623**	**-3.306**	**-0.702**	**0.589**	**0.417**	**0.448**	**-0.076**	**-0.472**	**0.425**	**0.380**	**-0.231**	**0.904**
HKG	**-0.678**	**0.167**	**-2.764**	**-0.201**	**-0.363**	**-0.174**	**-0.144**	**-0.173**	**-1.688**	**-0.400**	**-2.129**	**0.569**	**-0.563**	**-1.321**	**0.703**
IDN	**-0.050**	**-0.082**	**0.045**	**0.019**	**-0.028**	**0.105**	**-0.149**	**-0.226**	**-0.018**	**0.219**	**0.195**	**0.061**	**-1.572**	**-0.872**	**-3.195**
IND	**-0.564**	**-1.592**	**0.074**	**-0.699**	**-1.229**	**0.197**	**-0.042**	**0.210**	**0.254**	**-0.119**	**-0.587**	**-0.208**	**-0.504**	**-0.516**	**-0.531**
JPN	**0.173**	**-0.072**	**0.409**	**0.115**	**-0.027**	**0.191**	**0.319**	**-0.512**	**0.968**	**0.109**	**-0.553**	**-1.603**	**-0.243**	**-1.319**	**0.928**
KHM	**-0.907**	**-0.523**	**-1.123**	**0.779**	**0.714**	**0.862**	**0.584**	**0.448**	**-0.639**	**0.140**	**-0.016**	**0.274**	**-0.425**	**-0.389**	**-0.905**
KOR	**0.256**	**0.007**	**0.200**	**-1.237**	**-1.558**	**-1.039**	**0.339**	**-0.545**	**0.421**	**-0.086**	**-0.329**	**-0.114**	**0.203**	**0.221**	**-0.690**
MYS	**-0.703**	**-0.848**	**-0.488**	**-0.364**	**-0.407**	**-0.108**	**0.113**	**-0.075**	**-0.379**	**0.132**	**0.018**	**0.658**	**-0.280**	**-0.100**	**-0.064**
PHL	**-0.146**	**-0.253**	**0.110**	**-0.325**	**-0.489**	**0.370**	**-0.517**	**-1.625**	**-5.218**	**0.023**	**0.015**	**0.057**	**-0.528**	**-0.499**	**-0.487**
SGP	**0.220**	**0.116**	**0.358**	**0.135**	**0.184**	**0.080**	**-0.036**	**-0.279**	**-0.304**	**-0.325**	**-0.615**	**0.138**	**-0.168**	**-0.434**	**0.609**
THA	**-0.601**	**-0.697**	**-0.377**	**-0.632**	**-0.736**	**0.048**	**-0.291**	**-0.282**	**-0.916**	**0.401**	**0.193**	**0.674**	**-1.876**	**-2.176**	**-2.183**
VNM	**-2.883**	**-2.001**	**-2.131**	**0.213**	**0.006**	**-0.583**	**-2.012**	**-2.372**	**-2.363**	**-0.140**	**-0.008**	**-0.758**	**-0.517**	**-0.375**	**-1.427**

The R-squared is computed using differences of the Theil index with respect to the initial value in each time interval. Predictions correspond to the following cases. Q: when only relative quality varies. QW: when relative quality and relative wages per unit of quality change. QWD: when relative quality, relative wages per unit of quality, and German exports vary.

Figure 1: Theil indices for different export measures

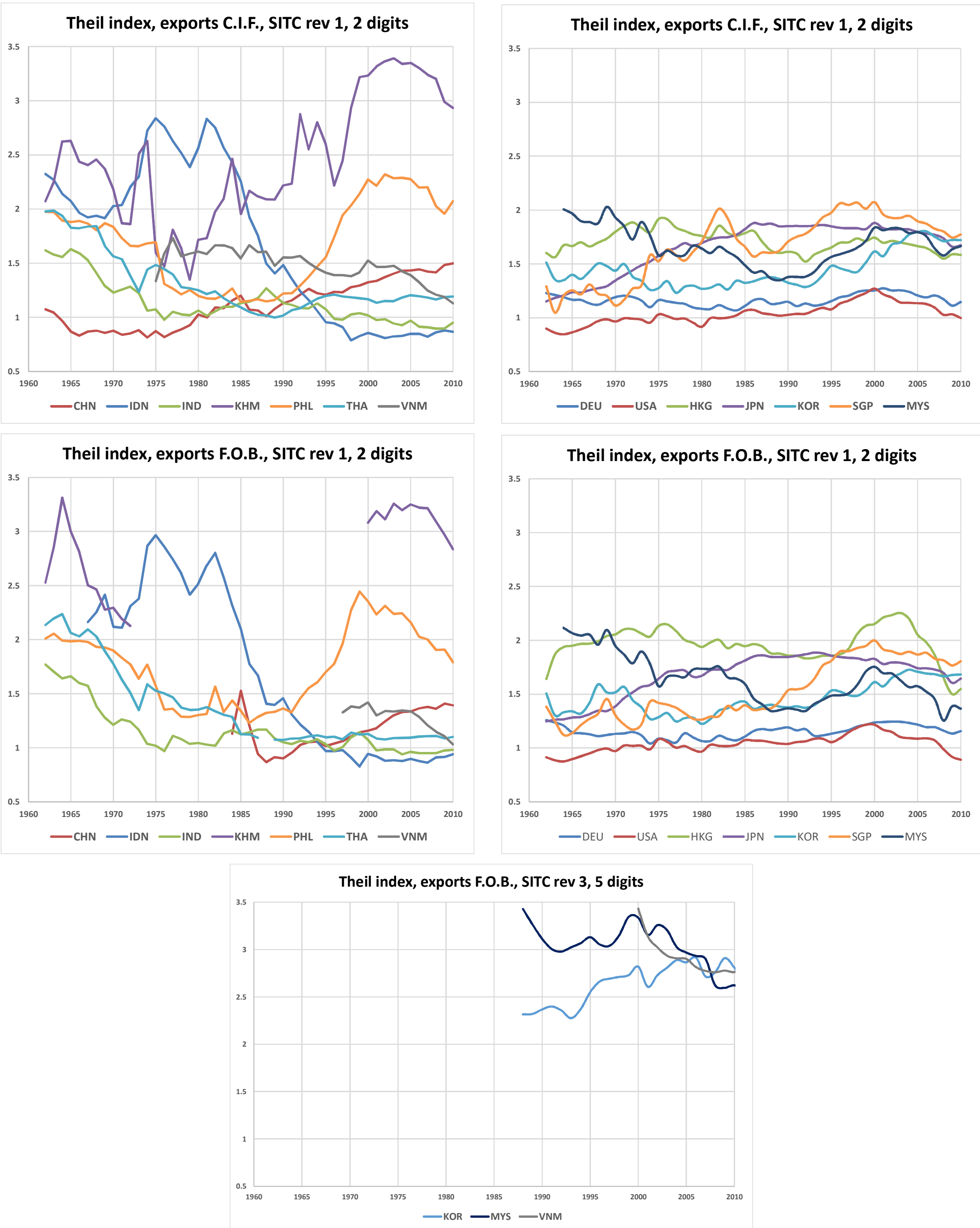
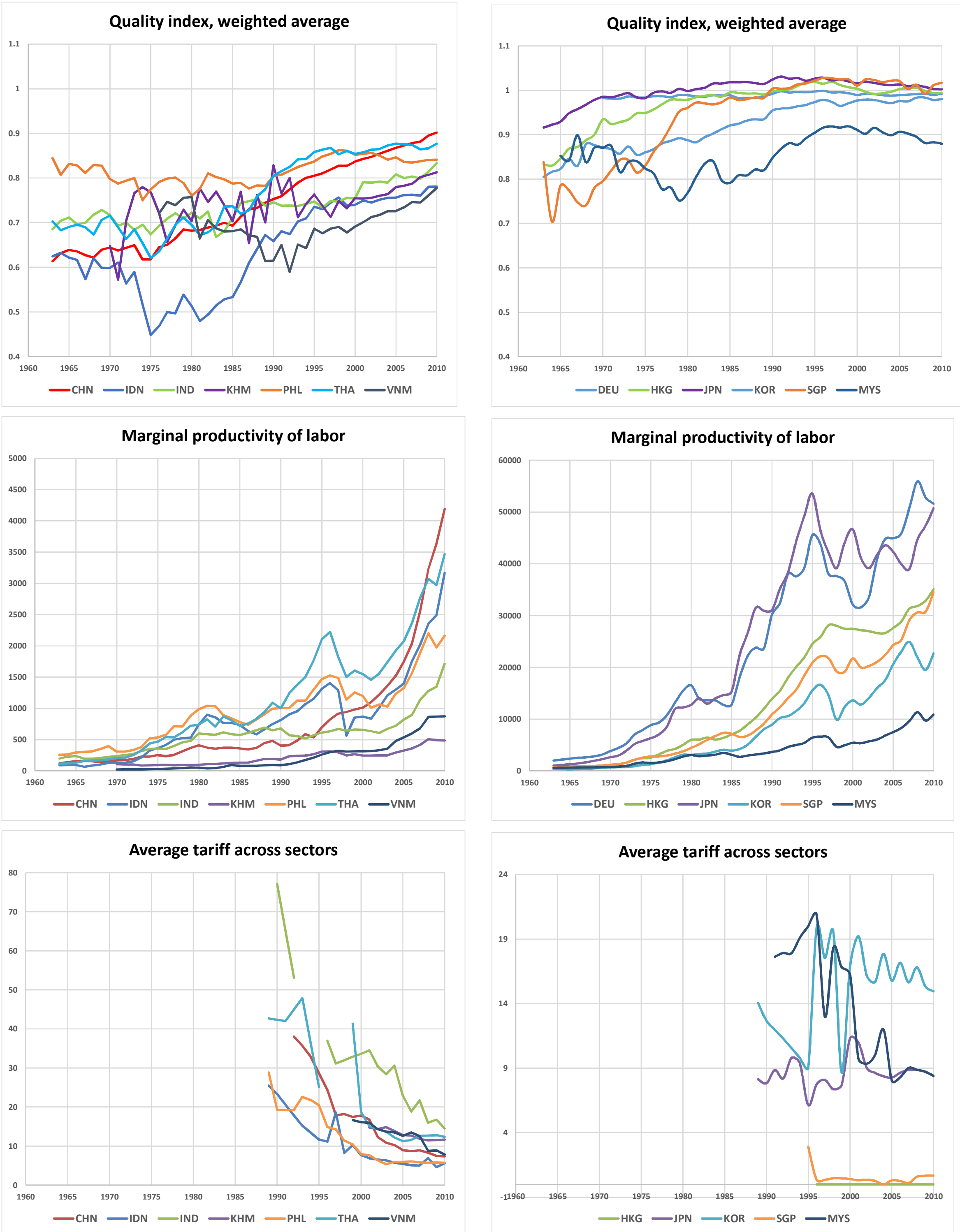
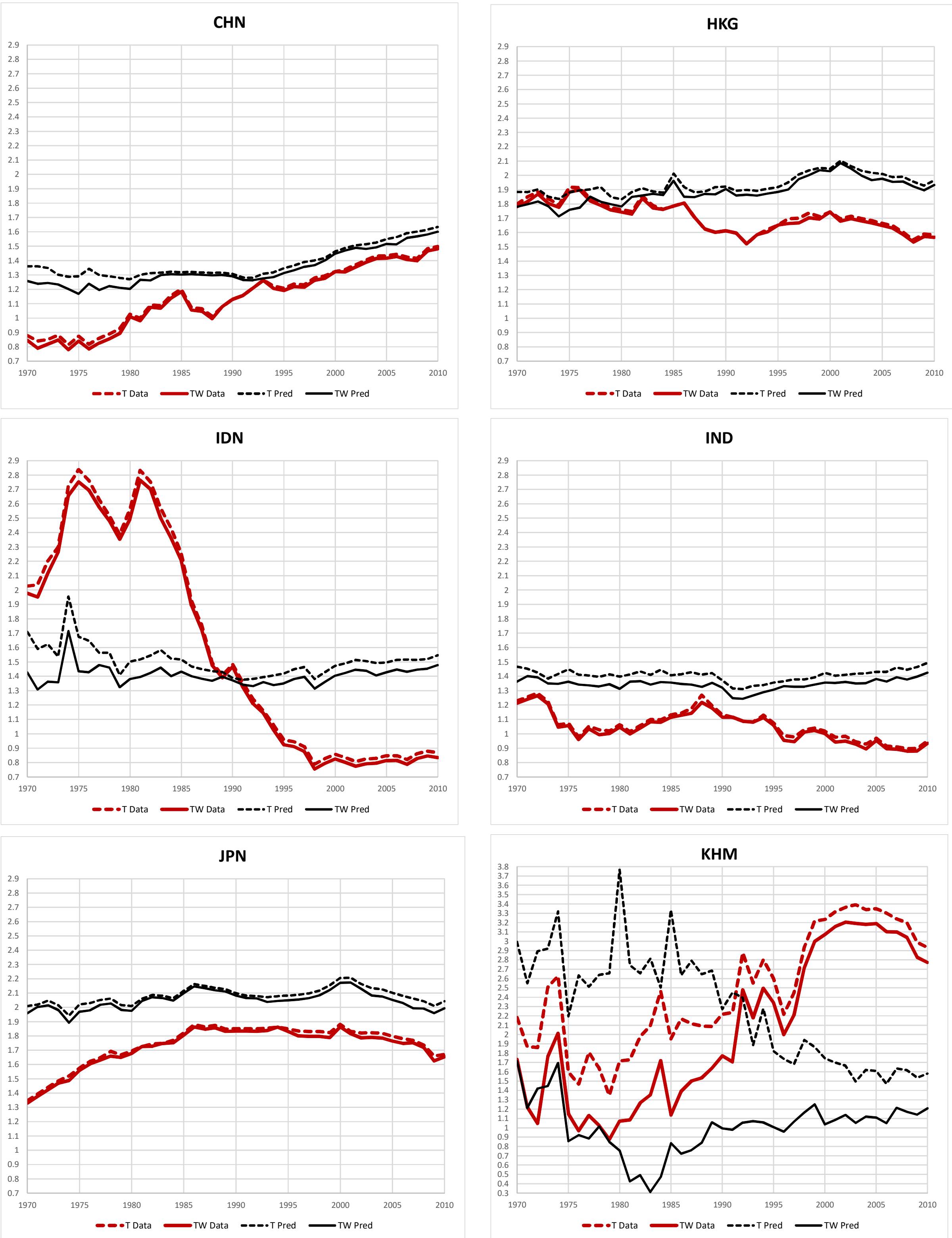


Figure 2: Different variables for selected countries



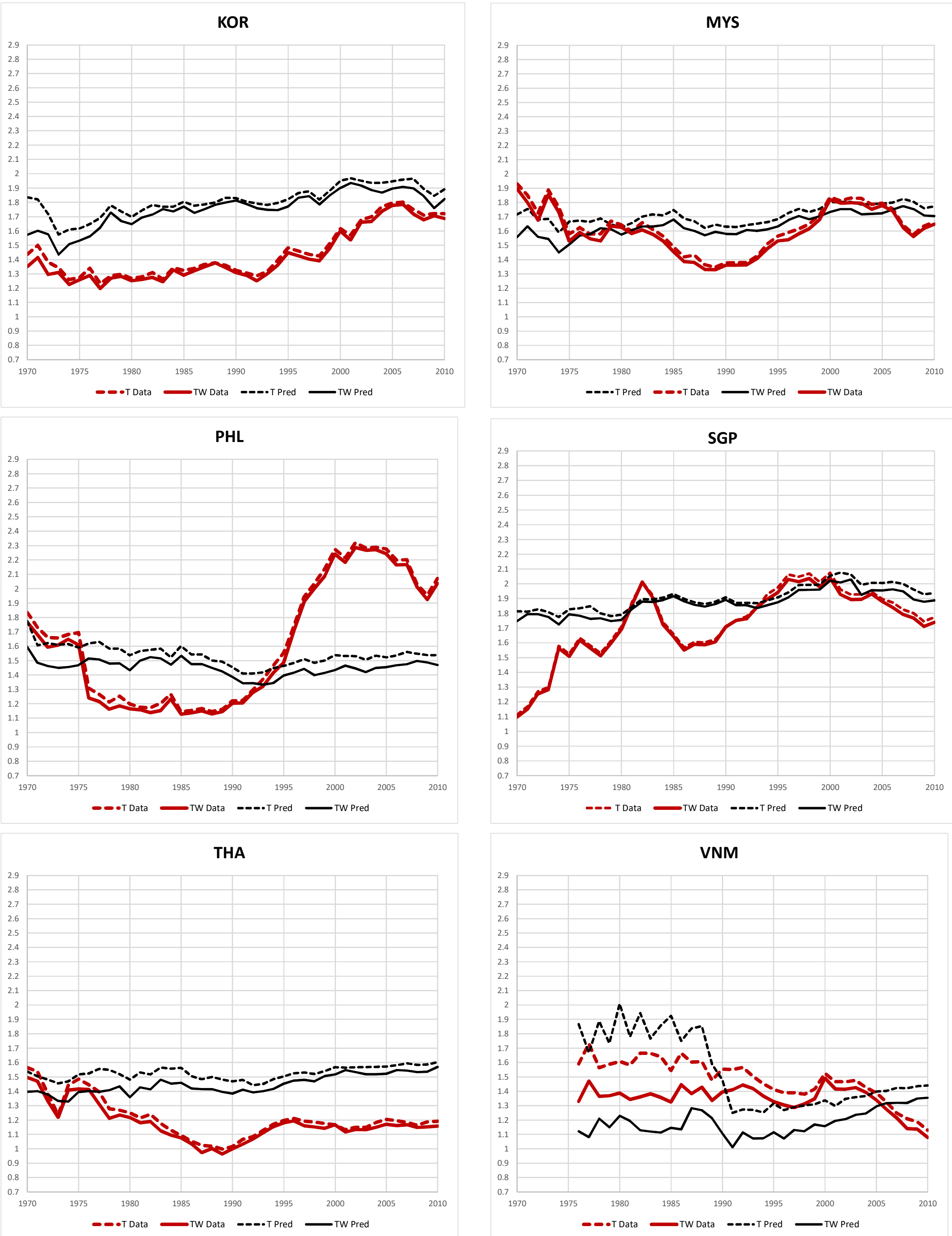
Note: quality is the average, weighted by exports per sector; in order to calculate the marginal product of labor, nominal income, employment and labor shares come from PWT; tariffs are given by the simple average across sectors.

Figure 3: Total and within-groups Theil indices for selected Asian countries



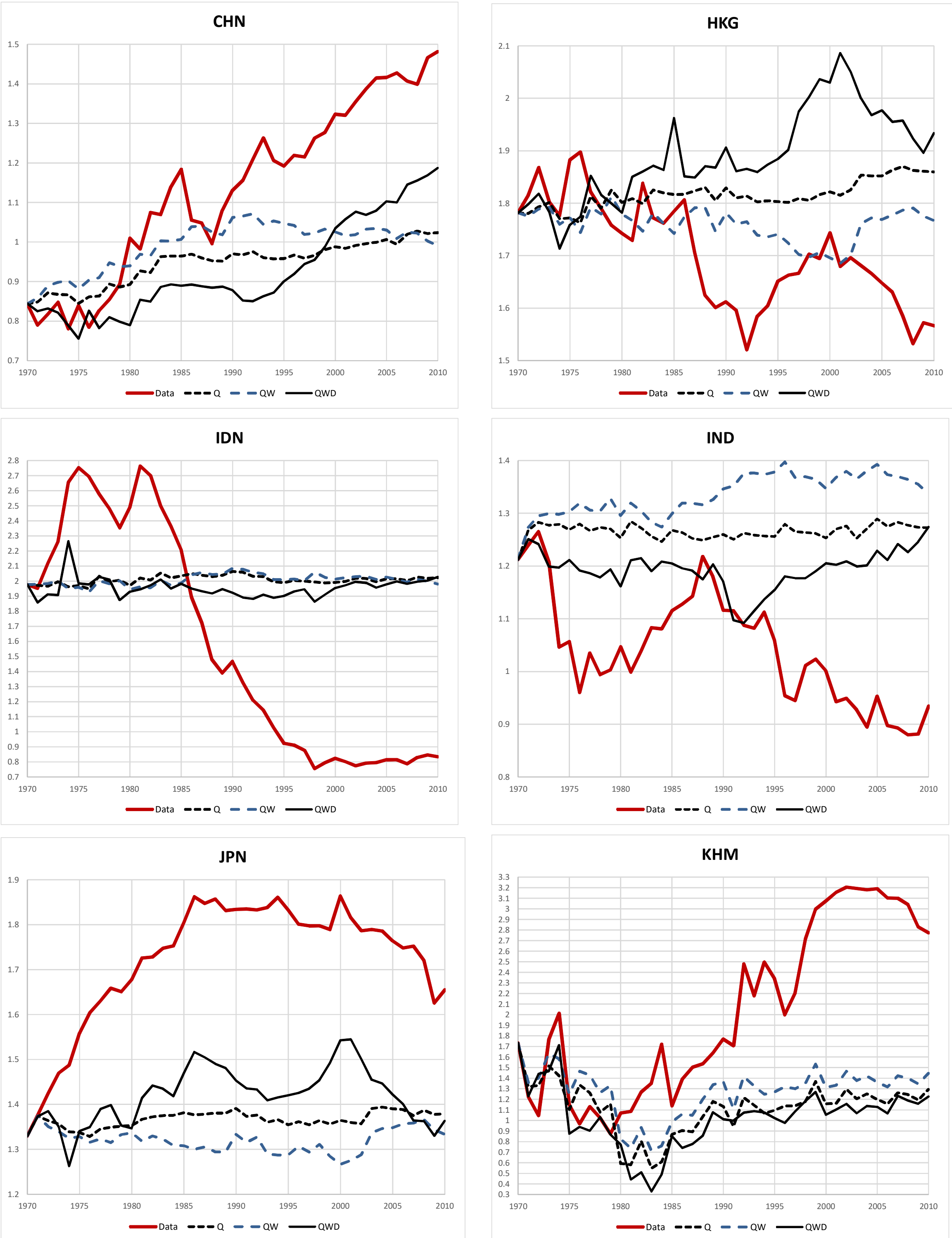
Note: T, TW and Pred stand for total-Theil, within-groups-Theil and predictions, respectively.

Figure 4: Total and within-groups Theil indices for selected Asian countries, cont'd



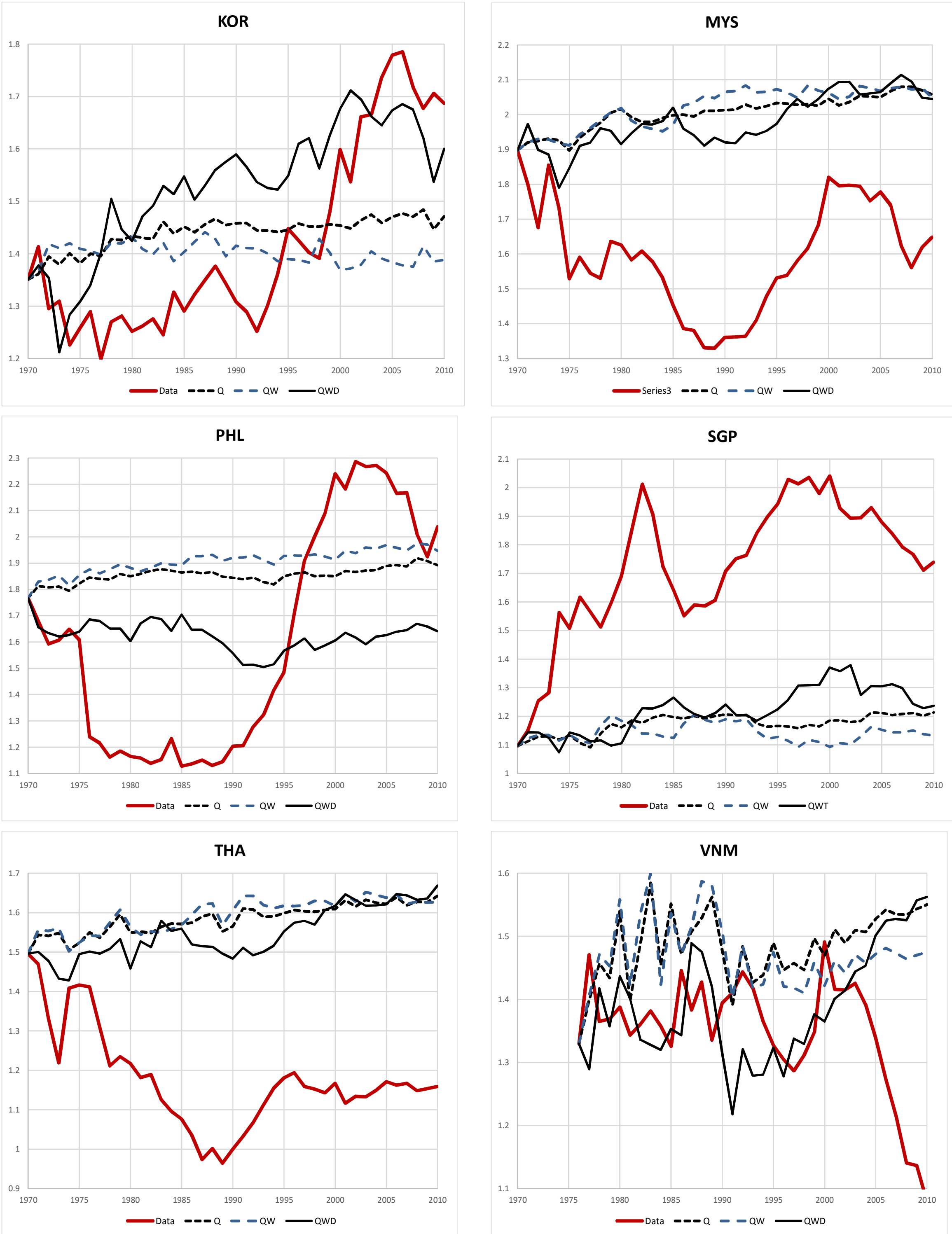
Note: T, TW and Pred stand for total-Theil, within-groups-Theil and predictions, respectively.

Figure 5: Components of within-groups Theil index for selected Asian countries



Notes: data and predicted within-groups Theil index values. Predictions correspond to the following cases. Q: when only relative quality varies. QW: when relative quality and relative wages per unit of quality change. QWD: when relative quality, relative wages per unit of quality, and German exports vary.

Figure 6: Components of within-groups Theil index for selected Asian countries, cont'd



Notes: data and predicted within-groups Theil index values. Predictions correspond to the following cases. Q: when only relative quality varies. QW: when relative quality and relative wages per unit of quality change. QWD: when relative quality, relative wages per unit of quality, and German exports vary.