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FACTOR ACCUMULATION WITHOUT DIMINISHING RETURNS: THE CASE OF EAST ASIA

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Abstract: We investigate the similarity of the country endowments of the newly industrialized East Asian countries and their major developed trading partners since the 1960s. In particular, we analyze their factor endowments in years 1965, 1977 and 1990, using the lens condition of Deardorff (1994). Because of the similarity of endowments of the NICs and their developed-country trading partners, we cannot reject the hypothesis that these countries were able to produce the same set of goods since the 1960s. This empirical evidence supports the theoretical analyses of the East Asian growth miracle of Mankiw (1995) and Ventura (1997) in an environment in which factor accumulation did not imply decreasing returns to capital.

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Introduction:

The distribution of world output has been at the forefront of recent debates in international economics. In particular, researchers have wondered about the extent to which there is production specialization across countries. From Schott (2001), Debaere and Demiroglu (2003) and Cunat (2000), we know that country endowments in the world are so different that it is unlikely that all countries of the world can produce a similar set of goods. Within the framework of the Heckscher-Ohlin model, still one of the major models used in trade analysis, this observation has important implications. Because of the very different factor endowments between developed and developing countries, it implies that trade cannot equalize factor prices (even not in productivity equivalents). As emphasized by Leamer (1996), the latter has important consequences. Whether or not developed and developing countries lie in the same cone has very different implications for the trade and wages debate.

In this paper, we revisit that debate. We explicitly study the condition that is critical for production specialization over time; the existing studies mainly focus on a cross section. In particular, we study this condition for the newly industrialized East Asian economies and their trading partners. This group of countries is of particular interest for a number of reasons. The rapid, yet sustained growth between 1960 and the first half of the 1990s of Hong Kong, Singapore, Taiwan and South Korea has been at the center of the debate in the growth literature. The condition for production specialization is especially critical for this part of the research that has tried to integrate Hechscher-Ohlin type trade into the discussion about the role of trade in the East Asian growth miracle.

In the growth literature, there is a consequential difference between Solow's one-sector, closed-economy model and its two-sector, open-economy counterpart by Stiglitz (1970) in which countries produce the same products. In Solow's world, capital accumulation leads to decreasing capital returns and hence to lower growth rates. When countries produce the same products and are allowed to trade, however, the familiar Rybczynski effect takes place and production shifts in the accumulating country towards capital-intensive sector. Moreover, there is no drop in the return to capital as countries grow, since factor prices are set at the world level instead of at the country level.[1] In recent years, this distinction between a one-sector world with complete specialization and a multiple-sector, diversified economy has gained attention. This interest is due in part to the "neoclassical revival" (Klenow and Rodriguez-Clare, 1997) in growth with its re-evaluation of the Solow model and the role of factor accumulation. Mankiw (1995) and Ventura (1997) pointed out that the rapid, yet sustained growth between 1960 and the 1990's in Hong Kong, Singapore, Taiwan and South Korea was accompanied by the gradual shift in production towards more capital-intensive sectors *without incurring diminishing returns*, and argued that this might be due to the Rybczynski effect. It is no coincidence that the East Asian countries are relatively open economies, characterized by

[1] If countries are small, prices for goods do not change and the return to capital in the world as a whole does not change. If countries are big, prices for goods may change due to capital accumulation in one country, yet the change in the return to capital will be a function of the marginal change in the factor endowments at the world level.

massive capital accumulation and a drastic expansion of their (increasingly capital-intensive) manufacturing production and exports since the 1960s.

In this paper, we show that the condition for specialization is not violated for the East Asian countries and their major developed trading partners since the 1960s. This condition is essential to make the factor accumulation and growth without diminishing returns that Mankiw and Ventura consider possible, since it ensures that East Asia's factor prices are not determined at the country level. Instead, factor prices are set for the entire group of countries as a whole. Our finding links the growth debate with the recent empirical literature in international trade. There is a growing consensus in that literature that because of the substantial differences in the factor proportions across the countries of the world, all countries cannot produce the same goods. Some countries have to specialize in goods that are completely different from the ones others produce and trade will not be the critical integrating factor of their factor markets.[2] However, within such a world, it is perfectly possible that a more limited set of countries are diversified and are able to produce the same set of goods.

To check the necessary conditions for specialized production empirically, we use Deardorff's lens condition (Deardorff, 1994) that relates the factor intensities of multiple sectors to the cross-country distribution of the endowments. The intuition behind this condition is fairly straightforward. Countries whose endowments are too different can never produce the same set of goods at the same factor prices. A very poor country with little capital per worker cannot produce highly capital-intensive goods competitively, because its scarce capital will be too expensive. Therefore, countries with very different factor endowments should specialize and produce different goods. Alternatively, the countries with similar endowments will be able to produce goods with similar factor intensities. We check the lens condition for 1965, 1977 and 1990 for the East Asian countries and their major trading partners. For each year, we allow for factor-augmenting productivity differences between countries as in Trefler (1993), so that factor returns across countries can differ. With Deardorff's condition, we study the (changing) international environment within which East Asian sustained growth and capital accumulation took place. This study highlights an aspect of interdependence that is not easily captured by cross-country growth regressions or by studies of the sectoral shifts within individual countries since it hinges on the changing distribution of endowments of multiple countries in conjunction with the changing factor intensities of multiple production sectors.

The paper proceeds as follows. Section one presents Deardorff's lens condition. In section two, we discuss the empirical implementation of the condition and the data. The third section discusses the results.

[2] There is ample evidence that factor prices are not the same (see Leamer and Levinsohn, 1995). Debaere and Demiroglu (2003), Schott (2001), Cunat (2000) and others all argue that there are multiple diversification cones.

1. Deardorff's Lens Condition

In the standard 2 x 2 x 2 Heckscher-Ohlin (HO) model, countries produce the same set of goods with factor price equalization if and only if their capital-labor ratios lie inside the diversification cone. The condition that +
Deardorff develops is a higher dimensional version of this cone of diversification and builds on the standard HO assumptions. In higher dimensions, the condition is perhaps most easily understood by example. In the example given in Figure 1 there are three countries and five sectors. The graph shows two lenses; the one in dashed lines is called the 'country lens' and the other one in solid lines the 'goods lens'. To draw the country lens, countries' capital K_c and labor L_c endowment vectors $v_c = (L_c, K_c)$ are first ranked according to capital-labor ratio. Next, these vectors are concatenated, first in increasing and then in decreasing order of their capital-labor ratios, both times starting from the origin. The goods lens is constructed in a similar fashion. This time we concatenate the sectoral factor use vectors $z_i = (K_i, L_i)$ whose coordinates are respectively the total amount of capital and labor used in sector i in all the countries for which the lenses are drawn.

In the example of Figure 1, Deardorff's lens condition is satisfied: the country lens lies inside the goods lens. In this case the endowments are similar enough so that all countries can produce the same set of goods. Because of this, countries are said to be diversified in production. The factor prices are set at the world level and the same for all countries.[3] Figure 2 shows a violation of the lens condition. Endowments are not similar enough and it is impossible that the same set of goods is made everywhere.

Consider the violation of the lens condition in Figure 2 in which the country lens does not entirely lie in the goods lens. Country 1 has too much capital. Even if the country only produced the most capital-intensive products (z_1 and z_2), it could never employ all its resources for a given set of factor prices. Consequently, countries will produce different sets of goods at different factor prices in the world. Figure 2 shows that one can obtain a violation of the diversification condition even if the range of the capital-labor ratios of the goods is wider than that of the endowments. In other words, the absolute size of sectors also matters in a setting that has more than two goods and more than two countries.

In the implementation, we adjust Deardorff's condition for factor-augmenting technological differences between countries as in Trefler (1993) to relax the all-too-strict assumption of identical technology across countries.[4] We express each country's

[3] Trading countries with immobile factors are said to replicate the integrated world economy (IWE), i.e. the hypothetical world equilibrium that would be obtained if all factors were perfectly mobile. See Dixit and Norman (1980).

[4] Introducing factor-augmenting differences is important to reconcile the model with some stylized observations. Factor augmenting differences allow for differences in factor prices across countries (see Leamer and Levinsohn, 1995), they are consistent with differences in sectoral capital-labor ratios across countries. Also, with factor-augmenting differences the capital shares in faster growing countries do not necessarily increase more rapidly.

production factors in terms of the US productivity equivalents. (We multiply country *c*'s factors *f* by π_{cf}, where π_{cf} is the productivity of country *c* in factor *f* relative to the US.) What is now required is that the surface or lens spanned by the productivity-adjusted country vectors lies inside the surface spanned by productivity adjusted goods vectors. The equations (1) are for the vectors with which we can draw both lenses (the *i*'s refer to sectors, the *c*'s to countries).

$$\begin{array}{lll} \boldsymbol{z_i} = [L_i \;\; K_i] & \text{and} & \boldsymbol{v_c} = [L_c \;\; K_c], \quad \text{where} \\ \boldsymbol{K_i} = \Sigma_c \;\; \pi_{ck} K_{ic} & & \boldsymbol{K_c} = \Sigma_i \;\; \pi_{ck} K_{ic} \\ \boldsymbol{L_i} = \Sigma_c \;\; \pi_{cl} L_{ic} & & \boldsymbol{L_c} = \Sigma_i \;\; \pi_{cl} L_{ic} \end{array} \qquad (1)$$

A note of caution is in order. If the productivity-adjusted lens condition holds, countries are able to produce the same set of goods (at productivity-equivalent factor prices). One should note an important difference between the productivity-adjusted case and the case with no factor augmenting productivity adjustments, however. In the latter case, the (immobile) factors would have no incentive to move even if they had the ability, because factor prices are the same everywhere. With adjustments, however, this absence of incentive may no longer be the case. In particular, if factor-augmenting productivity differences are not *completely* inherent to factors, but are, at least in part, due to institutional differences, factors in less-paying countries would be eager to move abroad in order to earn a higher return. To avoid any confusion, we will talk about integrated economies only in the first case (without factor-augmenting productivity differences) and use diversified economies (referring to the fact that countries can produce the same set of goods) as the more general term in both cases -- that is independent of whether these adjustments are made or not.

Note that one can specifically implement the lens condition for a world with non-traded goods. As implied by the work of Helpman and Krugman (1985) and Courant and Deardorff (1990), one should in that case only consider the total factors used in the production of traded goods to construct the lens condition. This is the route that we take in the empirical implementation.

2. The Empirical Implementation of the Lens Condition

Deardorff (1994) develops his lens condition for the world economy as a whole. Debaere and Demiroglu (1998) show that this condition can be used for any group of countries that does not encompass the entire world. The latter clears the way for an empirical analysis of the production factors of various groups of countries. In this paper, we study Deardorff's condition for Hong Kong, South Korea, Singapore and their major developed country trading partners.

There is a specific rationale for choosing this particular set of developed countries. As argued, diminishing returns to capital accumulation are not just a function of one country's individual capital accumulation. Factor prices are set for the entire group of countries. What matters is the factor accumulation among the group of diversified economies. Therefore, for an explanation of East Asian growth along the lines of Mankiw

(1995) and Ventura (1997) to make sense, there has to be a set of countries beyond the East Asian economies that fulfill two conditions. First, the countries (other than the East Asian economies) have to be relatively big and they must have accumulated capital at a slower rate than NICs, so that the total capital stock for the entire group (including the East Asian countries) grows at a moderate rate. Second, these countries should produce a similar set of goods as the East Asian economies. Suppose this were not the case. For example, assume that the East Asian countries were specialized among themselves. In that case, as they accumulated capital rapidly, the East Asian Tigers would have experienced diminishing returns to capital as a group, which would make it difficult for them to sustain such high rates of capital accumulation and growth.

In this study we investigate whether the NICs and their major trading partners (the US, the UK, Germany, Japan and Canada) are diversified economies. These countries fulfill the conditions mentioned above. The size of the NIC economies is only a fraction of the combined size of these developed countries, which constitute more than fifty percent of the world economy. Moreover, the trading partners of the NICs did not grow (and accumulate capital) at the same pace as the NICs did over the period 1965-1990. (Even Japan grew at a slower pace.) Note that there is a degree of discretion as to how we delineate the group of countries we choose to analyze. For our purpose, what matters is that the group is sufficiently large. It is not necessary that the set of countries includes all trading partners. This discretion does not mean, however, that countries are chosen arbitrarily. The rich OECD countries are particularly appropriate because their endowments have been found to be similar enough to allow them to produce the same set of goods (see Debaere and Demiroglu (2003)). Therefore, we could easily extend the study to other developed countries such as Belgium or Holland, without any impact. Other big countries such as India and China, if their data were available, could also be included, yet their inclusion is not necessary once we establish that the NICs and the developed country group are diversified economies that are able to produce the same set of goods.[5] Moreover, the OECD countries and the NICs are relatively open economies, whereas many developing countries are not. Consequently, to make a credible argument that hinges on openness, the group of countries must be chosen carefully.

The aim is to check Deardorff's condition empirically for the 1965-1990 period. This requires data on sector-level capital and labor as well as measures of factor augmenting productivity differences between countries in order to obtain the vectors in (1). In this section we discuss the sources of the capital and labor data that we use. We also introduce human capital measures and factor price data to proxy for factor-augmenting technological differences between countries.

[5] Furthermore, from Debaere and Demiroglu (2003), we know that developed and developing countries have too dissimilar endowments in order to be able to produce the same set of goods. It is unlikely that the lens condition for the NICs and India or China would hold.

2.1. The Capital and Labor Data

a. UNIDO and Penn World Data: For our group of countries *United Nations Industrial Statistics* (UNIDO) provide at the manufacturing level employment figures and investment flows with which we can construct capital stocks. Hence, the relevant country endowments (with non-tradable goods) amount to the sum of the factors used in manufacturing. We use the UNIDO data to determine the distribution of factor use across the industries within a country. To ensure that the magnitudes of the endowments are internationally comparable, we link the UNIDO data with the Penn World Tables. Specifically, we want to infer the capital-labor ratio of a country's manufacturing sector k_{Mc} from the strong correlation that is found in the Penn World Tables between k_c, a country's overall capital per worker ratio, and y_c, its real GDP per worker ratio.[6]

First, we run the cross-country regression (2) merely for predictive purposes with the Penn World Data for 62 countries. [7] The period is 1965-1990.

$$ln\, k_{ct} = \alpha_c + \alpha_t + trend_c + \beta\, lny_{ct} + \varepsilon_{ct} \qquad (2)$$

The high R^2 of 0.97 is no surprise, since the regression includes year effects and also country specific time trends and fixed effect. Moreover, there is a fairly strong correlation between lnk_{ct} and lny_{ct} in the Penn data.[8] The β-coefficient takes the value of 1.1 and is significant at the 95 percent level. All variables are in 1985 international prices.

In order to predict k_{Mc} , we plug a country's per worker GDP in manufacturing y_{Mc} in regression (2). We take y_{Mc} from the *UN National Accounts* and use the *Yearbook of Labour Statistics* to adjust the data for differences in hours worked. Table 1 provides y_M and the predicted k_M. We report the predicted k_{Mc} in levels instead of logs and correct for the bias arising from the logarithmic transformation in the usual way.[9,10]

[6] We presume that the UNIDO employment data can be more easily compared internationally than the UNIDO investment data. The methodology is similar to Debaere and Demiroglu (2003).

[7] The countries are: Switzerland, Luxembourg, Germany, Norway, Finland, Canada, Sweden, Australia, Belgium, Canada, Sweden, Australia, Belgium, Japan, France, USA, Austria, Denmark, New Zealand, Netherlands, Italy, Spain, Taiwan, Greece, Iceland, Ireland, Israel, United Kingdom, Venezuela, South-Korea, Ecuador, Iran, Syria, Panama, Mexico, Hong Kong, Colombia, Poland, Portugal, Argentina, Chile, Sri Lanka, Peru, Yugoslavia, Turkey, Dominican Republic, Bolivia, Botswana, Thailand, Honduras, Mauritius, Zimbabwe, Philippines, Guatemala, Swaziland, Jamaica, Morocco, India, Madagascar, Zambia, Ivory Coast, Paraguay, Kenya, Nigeria, Malawi and Sierra Leone.

[8] If one relates the regression to a Cobb-Douglas production function, one notices that the time trend and the country effects allow for technological differences between countries.

[9] $exp\ \beta = exp\ (b - var(b)/2)$, where b is an estimate of the true β. The latter implies the assumption that b, in our case $\ln k_c$, is distributed normally.

To construct capital stocks for the UNIDO data with the perpetual inventory method, we need 15 years of investment flows. To construct the 1977 and 1990 capital stocks, we use investment flows from 1976-1990 and 1963-1977. The initial capital in a sector is based on the investment flow of the first year of the period the following fashion: $I / (d+g)$, where I is the investment flow of the first year considered in a sector, d the depreciation rate and g the growth of investment. We always assume that the depreciation rate is 13.3 percent. We deflate a country's investment data into 1985 prices by its investment deflator taken from the *IMF World Economic Outlook* and *the UN National Accounts*. To construct the 1965 stock requires, due to data limitations a somewhat different procedure. We take the initial capital stock of 1963 to which we add the real investment flows of 1963, 1964 and 1965, with the appropriate depreciation.

Once we have the UNIDO capital stocks and the predicted k_{Mc}'s we construct internationally comparable capital stocks as follows. We take the total labor force of the UNIDO data, L_c, and multiply it by the predicted capital-labor ratio in manufacturing, $k_{Mc,}$ to obtain the capital stock of manufacturing in country c, K_c as in the first equation. We then use the sectoral distribution of the UNIDO capital stocks (K_{UNic}/K_{Unc} -- i stands for sector) to determine the sectoral capital stock in a country as in the second equation. And finally, the total stock of capital in a particular sector for the set of countries that we consider is obtained by adding all sectoral stocks across countries as in the third equation. Note that all labor data are adjusted for differences in hours worked versus the United States.

$$K_c = k_{Mc}\, x\ L_c$$
$$K_{ic} = K_{UNic}/K_{UNc}\, x\ K_c \qquad (3)$$
$$K_i = \Sigma_c K_{ic}$$

In theory, the capital-labor ratio of a sector should be the same in all countries that lie in the same cone. It is well known that this is not the case. A country's share in the total capital stock of a sector, K_{ic}/K_i, is usually not equal to its share in the total labor employed in that sector, L_{ic}/L_i, even though they should be the same in theory. There are various reasons why (productivity adjusted) sectoral capital to labor ratios can vary. One reason, of course, is that countries may lie in different cones. Aggregation also matters. We use fairly aggregate sectoral data that may contain subsectors with different factor intensities. Whenever countries produce more or less capital intensively in these subsectors, the aggregate capital-labor ratios will vary. Finally there is also measurement error in the data. We will discuss these concerns in more detail below.

b. Correcting for factor productivity differences and differences in human capital: It can be argued that there are differences in human capital across countries. We choose to adjust the data with proxies that should capture such differences. Our human capital measures are taken from Hall and Jones (1999). Hall and Jones used Psacharopoulos

[10] To predict k_{Mc} for Singapore we use a slightly different procedure, since k_c for Singapore is not part of the Penn World Tables. We run (2) with a common trend and dummy for the East Asian Economies and then plug in y_{Mc} of Singapore.

(1994) cross-country survey evidence on the returns to schooling to construct human capital stocks. In their analysis, human capital augmenting labor is given by $H_i = e^{\varphi(Ei)} L_i$ where $\varphi(E_i)$ reflects the efficiency of a unit of labor with E years of schooling relative to one with no schooling, $\varphi(0) = 0$. The derivative $\varphi'(E_i)$ yields the return to schooling that can be estimated in a Mincerian wage regression. Based on Psacharopoulos' survey, Hall and Jones assume that $\varphi(E_i)$ is piecewise linear with a return to education of 13.4 percent in the first four years of education, 10.1 for the next four years and 6.8 for the years beyond the 8th year. Hall and Jones provide for 1988 a human capital - labor ratios for all our countries with which we can upgrade the labor force. Note that, however imperfect these measures, the final outcome of our results hardly ever depends on them. The human capital corrections can be interpreted as a robustness check.

To correct for factor-augmenting productivity differences between a country and the US, we also rely on relative factor prices. As in Trefler (1993), the wages are drawn from the *Yearbook of Labour Statistics* for the years 1965, 1977 and 1990. They are made internationally comparable with the consumption PPP from the *Penn World Tables*. Most data are hourly wages. In case the latter are not available (e.g. with monthly wages), we divide the wage number by the hours worked from the same *Yearbook of Labour Statistics*. We follow Trefler (1993) in choosing the 1990 PPP-adjusted investment price index from the *Penn World Table*. The values are reported in Table 1. From a theoretical point of view, differences in factor returns are the appropriate factor productivity correction when there is factor price equalization. If countries are not lying in the same cone, the relative factor returns are likely to overstate technological differences, however. While this is a concern, correcting factors in this way is not critical for the final outcome. The corrections function more like robustness checks in the absence of other, better measures for factor-specific productivity measures of the countries (and time-period) involved.

3. The Empirical Results

In this section, we discuss our empirical evidence and address the robustness of the presented results. We analyze the issues of measurement error and aggregation, and check the lens condition for various subgroups. In Debaere and Demiroglu (2003), we address other, more conceptual issues that are related to the methodology. There we show how the lenses we draw are likely to produce a violation of the lens condition when there is no factor price equalization and when countries are not able to produce the same set of goods because of too different factor endowments.[11]

Figures 3-5 present our main result. Figure 5 shows the 1990 country and goods lenses for Hong Kong, Singapore, South Korea and their main developed country trading

[11] In particular, we show how the way we draw the lenses generates a violation if countries produce different sets of goods (say, because their endowments are too different). This is true even if one only focuses on a subset of countries. Also, if there is factor intensity reversal (making FPE impossible) our methodology is likely to generate a violation since it will make the lens condition thinner (and hence more prone to violations.) Similarly, averaging factor intensities from countries that produce in different cones should lead to a violation of the lens condition when the lenses are drawn the way we propose.

partners (the United States, Japan, Germany, the United Kingdom and Canada). For 1977 and 1965 we consider the same group minus Hong Kong due to data limitations. The figures to the left show Deardorff's lenses without corrections for factor productivity differences. These figures are included merely for expositional purposes. They allow us to assess the impact of the factor productivity corrections that we introduce.[12] The figures to the right show the impact of differences in factor-augmenting productivity. We use differences in factor returns in all cases but one; in Figure 5c for the year 1990 we make use of differences in the return to education instead. The NICs have lower capital-labor ratios than the developed countries in the group, their factor of production vectors are above the diagonal to the left of the upper right corner (and, under the diagonal to the right of the lower left corner). We normalize the total labor force and capital stock for this group of countries to one in the graphs, so that each side of the box has unit length.

In all but one of the cases, the country lens lies inside the goods lens. In other words, no violation of the diversification condition is obtained with and without factor productivity adjustments. The only violation that occurs is for the lens in 1965 when we do not correct for differences in productivity; this violation is easily undone with factor productivity adjustments.[13]

To compare the different results, we introduce as Debaere and Demiroglu (2003) a measure that should give an idea of how well the goods lens envelops the country lens, or how strong the violation of the lens condition is. This measure is especially useful when a (non-) violation is not so easily observed on the graph. The latter is the case for Figure 3a; one can hardly see that Singapore violates the goods lens. A positive value indicates that the lens condition is not violated. When the measure is exactly 1, it implies that the country lens is identical to the diagonal. A very small positive number indicates that the two lenses are very close to one another. The measure is negative when there is a violation. The measure is derived as follows. Through *any* point x on the diagonal of the endowment box, we draw a line that is perpendicular to the diagonal. Call the point at which the perpendicular intersects the country lens point and the good lens point, respectively $c(x)$ and $g(x)$. Letting $d(x,y)$ represent the distance between any two points x and y, the measure is defined as

$$\min_x \left\{ 1 - \frac{d(x, c(x))}{d(x, g(x))} \right\}$$

Note that the advantage of the measure is that it works well at the corners of the lenses. The measures for the NICs and their trading partners are reported in Table 2. (In addition

[12] The uncorrected lenses are the theoretically correct measure to use only in case of factor-augmenting productivity differences that are the same across factors. Debaere and Demiroglu (1998) show that the un-corrected and the corrected lenses have the same shape in this case.

[13] Note that the disaggregation also undoes this violation, see below.

to reporting the measure for the entire group of countries, we also report it for the subgroup of the trading partners and the NICs separately.)

In what follows, we provide different ways to assess the robustness of the presented results.[14] One may wonder whether measurement error would change our basic results. Especially the measurement error in our capital data may be a concern. We run Monte Carlo simulations to study its effect. For this exercise we use the cross-country variation in sectoral capital-labor ratios as a measure of the size of the measurement uncertainty. In theory, the capital-labor ratio for a sector must be the same across all countries with factor price equalization (in productivity equivalents), which is, as we pointed out, clearly not the case. As mentioned before, there are several reasons why these ratios may differ across countries: aggregation across different subsectors, a violation in the lens condition and measurement error in the data. In order to analyze the impact of measurement error, we temporarily make the generous assumption (that does not favor our analysis) that all the cross-country variation in sectoral capital-labor ratios is due to measurement error. This variation is substantial as one may note from Table 2 under Sigma, which is the average standard deviation of the log capital-labor ratio in a sector across countries. For example, a Sigma of 0.50 implies that one standard deviation of measurement error increases or decreases capital or labor by 35 percent.[15]

We run a Monte Carlo simulation with 2000 repetitions for each lens. We perturb the capital and labor data for a sector in a country by randomly drawn errors, distributed normally with the variance mentioned above. We count the number of times those generated data trigger a violation of the lens condition, and report the frequency as the probability of a violation.[16] The results are presented in column two of Table 2. Except for the unadjusted lens for 1965, the violation probabilities are very low.

As mentioned above, all of the variation in sectoral capital-labor ratios across countries is attributable to measurement error in that exercise. This most likely overstates the size of actual errors because part of that variation is certainly due to aggregation. Each sector

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[14] We also used the data from the Michigan model that are described in Debaere and Demiroglu (2002) for the same set of countries (with Taiwan instead of Singapore) for 1990. Here also no violation was obtained.

[15] We compute the standard deviation of log capital-labor ratio for each sector across countries, and use the average of these standard deviations as the standard deviation of measurement error for all observations. The error may arise from either measurement of capital or labor, or both. (Attributing the error to one or the other does not make a substantial difference in the result.) For the reported numbers it is assumed that capital and labor are equally responsible for the overall measurement error. When the standard deviation of $log\ K_{ic}/L_{ic}$ equals 0.5, the standard deviation of both *ln(K)* and *ln(L)* is *0.5/sqrt(2*). We also correct for the bias that log-normal disturbance generates by dividing the new figures by *exp(Var(error)/2*).

[16] We precisely mean with "probability of violation" the following. If our capital stock and employment data were the true values and if new data were observed based on these values (but after being perturbed by errors with the assumed stochastic characteristics), the probability of violation would be the fraction of all cases in which the obtained lenses generated a violation.

contains various subsectors with different capital-labor ratios, and variation in the within-sector composition across countries will result in unequal capital-labor. On the other hand, our analysis of measurement errors ignores the potential within-country correlation of measurement errors.

Another concern is the aggregation issue mentioned above: Each sector in the UNIDO data consists of many subsectors. As we show in Debaere and Demiroglu (2003), sectoral aggregation makes the goods lens thinner. (If all sectors were aggregated, the goods lens would become the diagonal.) This means that aggregation can cause a spurious violation of the lens condition. At the same time, the presence of aggregation reinforces the significance of obtained non-violations of the lens condition. If there is a non-violation at the aggregate level, there will definitely be a non-violation when the goods lens is drawn with more accurate and disaggregated data that make the goods lens wider. To get a sense for how disaggregation may affect our results, we provide the results from a disaggregation exercise based on firm-level data from COMPUSTAT for the US.

From COMPUSTAT we take the average within-industry variation in firm-level log capital-labor ratios at the 3-digit level.[17] We make the extreme assumption that this within-industry variation is only due to aggregation. We then investigate how the goods lens would look like if there were so much variation in each sector of every country in our datasets hidden behind the aggregate numbers. We break down all the factor use vectors of each country into 100 equal parts, as if there were 100 firms.[18] We perturb the capital-labor ratios so that they are distributed randomly around the industry's original capital-labor ratio with a cross-firm variance that equals the value from the COMPUSTAT data. (We normalize the new firm-level vectors to make sure that they add up to a country's original factor use vectors.) We finally re-draw the lenses for the hypothetical "disaggregate" goods lens. (See Table 2, the column under “Measure after Disaggregation.”) Overall, disaggregation does not have a big impact on our measure. The disaggregation effect is strong enough, however, to overturn the only violation that we had.

Conclusion

In this paper, we link the debate about factor accumulation and growth in East Asia to the recent empirical literature in international trade. Mankiw (1995) and Ventura (1997) have conjectured that East Asian countries could sustain rapid capital accumulation over long periods of time without incurring diminishing returns because factor prices were a function of the world factor endowments and were set for the world as a whole. An important necessary condition that has to be satisfied for Mankiw and Ventura’s conjecture is Deardorff's (1994) lens condition. We investigate whether that condition holds, which involves comparing the factor endowments of the NICs and of their main

[17] The average standard deviation of log K_{if}/L_{if} of firms f within their respective 3-digit industry i is 0.47, which is quite substantial.

[18] The result is not sensitive to the magnitude of the number, as long as it is larger than 30.

developed-country trading partners with the sectoral factor use at different points in time. To account for productivity differences across countries, we adjust factor endowments and factor use data for factor-augmenting productivity differences. We study the years 1965, 1977 and 1990. We find that Deardorff's lens condition is satisfied for those three years.

Bibliography

Courant, Paul and Alan Deardorff (1990), "On the Likelihood of Factor Price Equalization with Non-traded Goods," *Review of International Economics*, Vol. 31, No.3, pp. 589-596.

Cunat, Alejandro (2000), "Can Trade Equalize Factor Prices?," mimeo, Harvard University.

Deardorff, Alan (1994), "The Possibility of Factor Price Equalization Revisited," *Journal of International Economics*, Vol. 36, pp. 167-175.

Deardorff, Alan and Robert Stern (1990), *Computational Analysis of Global Trading Arrangements*, The University of Michigan Press, Ann Arbor.

Debaere, Peter and Ufuk Demiroglu (1998), "On the Similarity of Country Endowments," *Journal of International Economics*, mimeo, University of Michigan.

Debaere, Peter and Ufuk Demiroglu (2003), "On the Similarity of Country Endowments," *Journal of International Economics*, Vol. 59, No. 1, pp. 101-136.

Debaere, Peter (2003), "Does Lumpiness Matter in an Open Economy? Studying International Economics with Regional Data," forthcoming, *Journal of International Economics.*

Demiroglu, Ufuk and Kwan Koo Yun (1999), "The Lens Condition for Factor Price Equalization,"*Journal of International Economics*, Vol. 47, No. 2, pp. 449-456.

Dixit, A.K. and V. Norman (1980), *The Theory of International Trade*, Cambridge University Press.

Hall, R. and C. Jones (1999), "Why do Some Countries Produce So Much More Output Per Worker Than Others?", *Quarterly Journal of Economics*, Vol. 114, No. 1, pp. 83-116.

Helpman, E. and P. Krugman (1985), *Market Structure and Foreign Trade*, MIT Press, Cambridge, MA.

Klenow, P. and Andres Rodriguez-Clare (1997), The Neoclassical Revival in Growth Economics: Has It Gone Too Far?" In B. Bernanke and J. Rotemberg (eds.), *NBER Macroeconomics Annual 1997*, MIT Press, Cambridge, MA, pp. 73-103.

Leamer, E. (1996), "In Search of Stolper-Samuelson Effects on US-wages," NBER Working Paper, No. 5427.

Leamer, E. and J. Levinsohn (1995), "International Trade Theory: The Evidence" in G. Grossman and K. Rogoff, eds., Handbook of International Economics, vol. III, Elsevier, New York.

Mankiw, N. Gregory (1995), "The Growth of Nations," *Brookings Papers on Economic Activity*, Vol. 25, pp. 275-310.

Psacharopoulos, George (1994), "Returns to Investment in Education: A Global Update," World Development, Vol. 22, No. 9, pp. 1325-1343.

Schott, Peter (2001), "One Size Fits All?", mimeo, Yale University.

Stiglitz, Joseph (1970), "Factor Price Equalization in a Dynamic Economy," *Journal of Political Economy*, Vol. 78, No. 3, pp. 456-488.

Trefler, Daniel (1993), "International Factor Price Differences: Leontief Was Right!", *Journal of Political Economy*, Vol. 101, pp. 961-987.

Ventura, Jaume (1997), "Growth and Interdependence," *Quarterly Journal of Economics*, Vol. 112, No. 1, pp. 57-84.

Yearbook of Labour Statistics, various years, United Nations.

Table 1. Per Worker Capital and Income and the Factor Returns Relative to the US

	1965				1977				1990			
	y_c	k_{Mc}	w_c	r_c	y_c	k_{Mc}	w_c	r_c	y_c	k_{Mc}	w_c	r_c
Canada	22,245	7,744	0.80	1.26	28,779	10,300	0.99	1.32	34,380	14,168	1.14	1.05
Germany	17,282	8,774	0.49	0.85	25,406	15,065	0.71	1.16	29,509	19,023	0.96	1.48
Japan	7,333	3,017	0.41	0.88	14,436	8,408	0.70	1.15	22,624	16,246	1.02	1.50
Korea	3,055	1,335	0.09	0.57	7,358	2,622	0.19	0.70	16,022	5,958	0.58	0.91
Hong Kong[a]									22,827	3,287	0.64	1.40
Singapore	5,476	886	0.13	1.11	13,764	4,066	0.15	1.20	24,369	6,028	0.50	1.34
UK	16,645	2,970	0.54	0.98	20,654	7,914	0.63	0.94	26,755	10,384	1.16	1.42
US	28,051	6,653	1.00	1.00	31,869	10,857	1.00	1.00	36,771	12,856	1.00	1.00

y_c	per capita income in country *c*
k_{Mc}	capital per worker in manufacturing in country *c*
w_c	wage in country *c* relative to the US
r_c	return to capital in country c relative to the US

[a] Data for Hong Kong is available for 1990 only

Table 2. The Measure, Probability of Violation, and the Measure after Disaggregation

Country Group	Year	Adjustment	Measure	Probability of violation (%)	Measure after Disaggregation	Sigma
All Countries[a]	1990	Unadjusted	0.20	5.55	0.26	0.64
		Adjusted	0.26	3.85	0.35	0.56
		Human-cap	0.27	2.60	0.32	0.58
	1977	Unadjusted	0.19	10.25	0.21	0.71
		Adjusted	0.44	0.30	0.46	0.63
	1965	Unadjusted	-0.04	40.70	0.09	0.94
		Adjusted	0.45	0.45	0.47	0.69
Asian Countries	1990	Unadjusted	0.54	0.00	0.58	0.51
		Adjusted	0.60	0.15	0.62	0.57
		Human-cap	0.36	0.30	0.43	0.56
	1977	Unadjusted	0.64	0.55	0.68	0.58
		Adjusted	0.19	14.75	0.29	0.74
	1965	Unadjusted	0.55	1.50	0.64	0.87
		Adjusted	0.72	0.55	0.79	0.80
Trading Partners	1990	Unadjusted	0.59	0.10	0.65	0.46
		Adjusted	0.28	2.45	0.37	0.49
		Human-cap	0.39	1.00	0.46	0.40
	1977	Unadjusted	0.59	0.00	0.63	0.46
		Adjusted	0.44	0.05	0.47	0.50
	1965	Unadjusted	0.24	2.40	0.34	0.58
		Adjusted	0.45	0.05	0.48	0.52

[a] The countries are the United Kingdom, the United States, Canada, Japan, Germany, Korea, Singapore and, only for 1990, Hong Kong.

Figure 1. The goods and country lenses satisfying Deardorff's (1994) lens condition

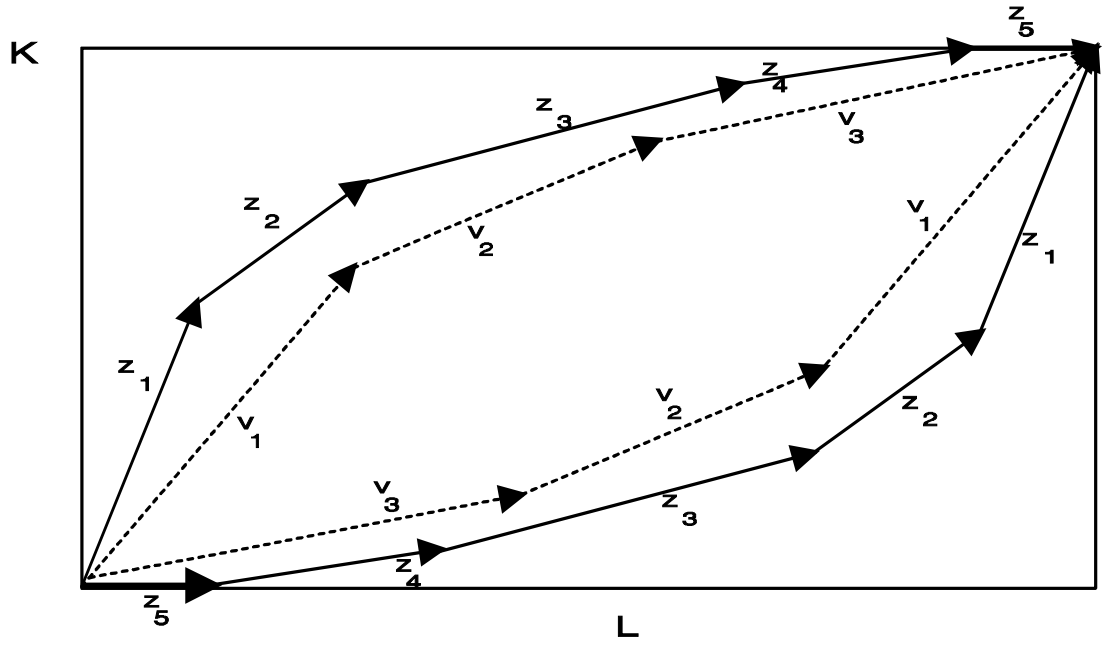


Figure 2. The goods and country lenses violating the lens condition

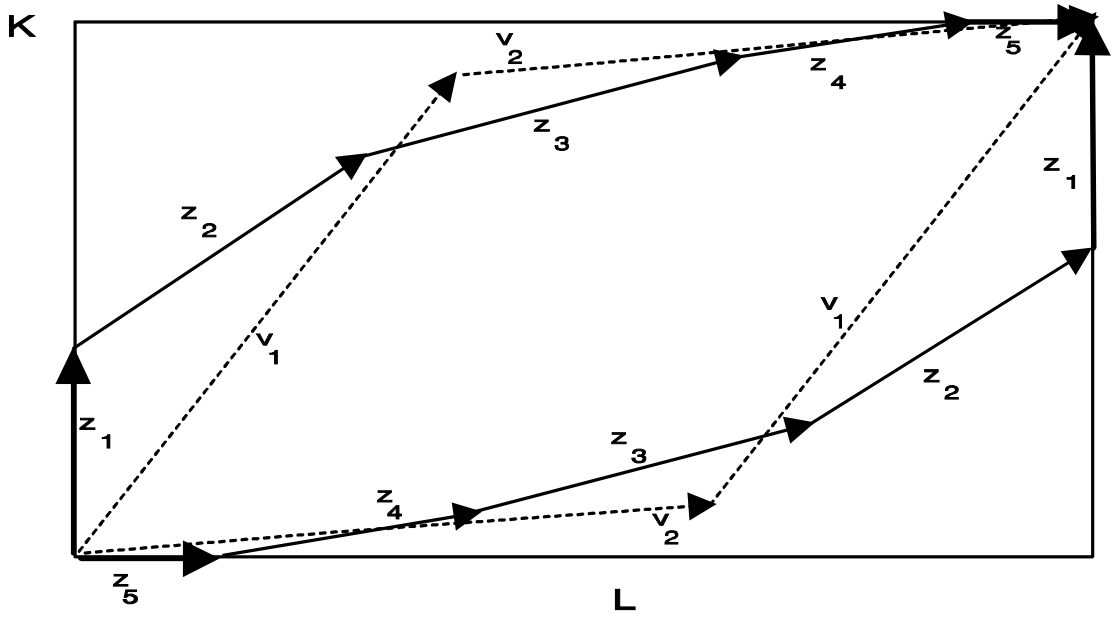
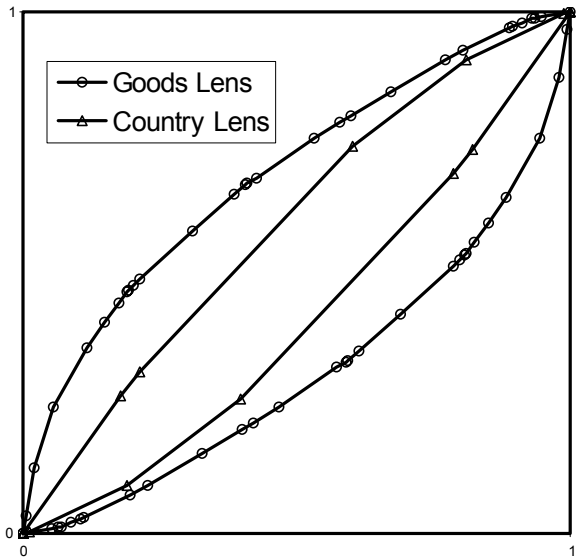


Figure 3. Lenses in 1965

a. Unadjusted Capital and Labor



b. Productivity Adjusted Capital and Labor

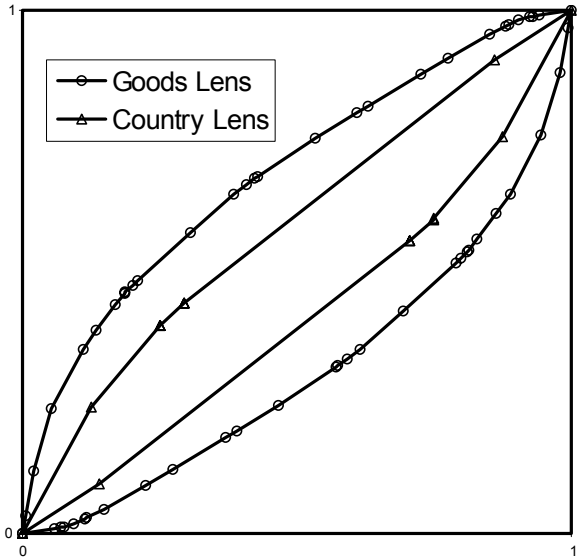
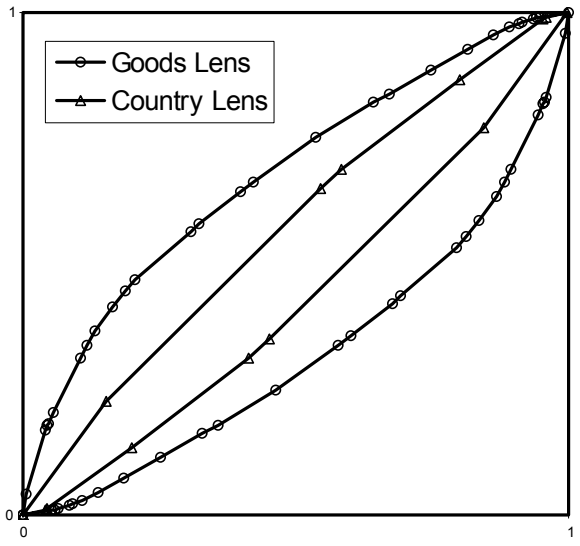


Figure 4. Lenses in 1977

a. Unadjusted Capital and Labor



b. Productivity Adjusted Capital and Labor

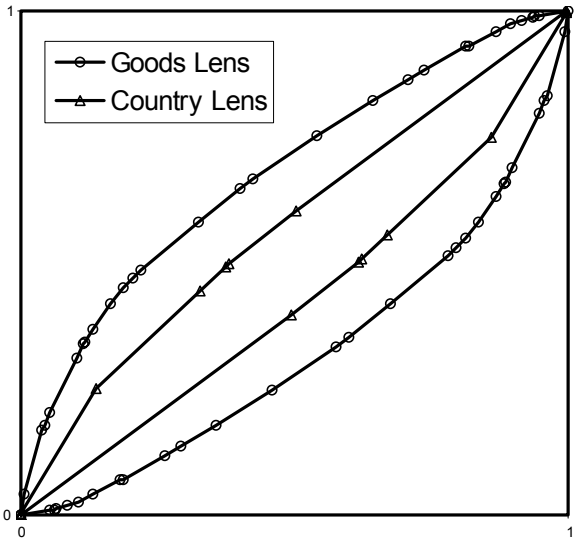
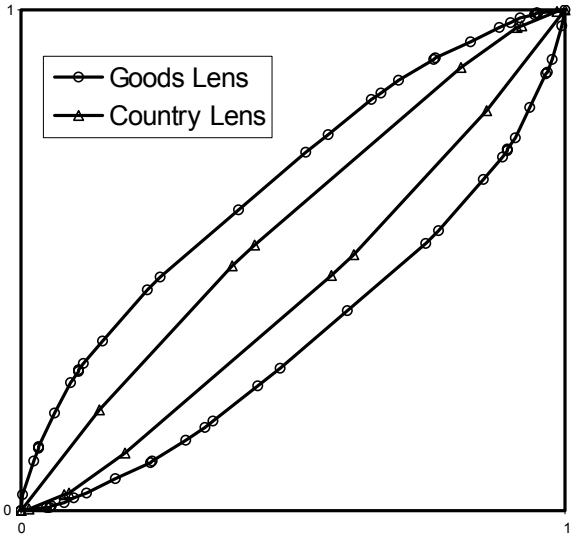
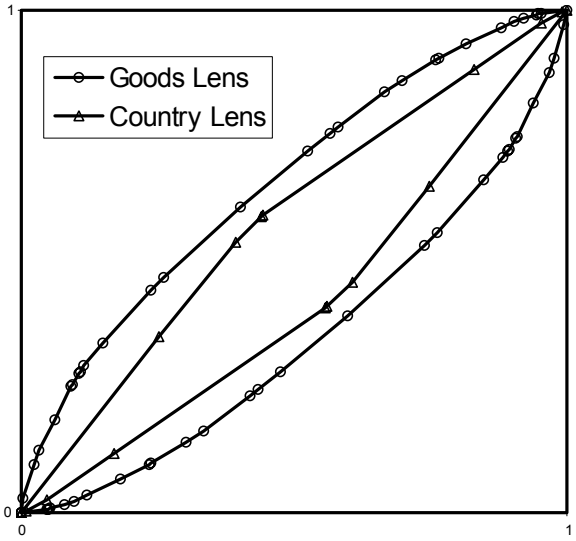


Figure 5. Lenses in 1990

a. Unadjusted Capital and Labor



b. Productivity Adjusted Capital and Labor



c. Capital and Human Capital