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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 (NICs) and their major developed trading partners since the 1960s. In particular, we analyze their factor endowments in the 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 are diversified economies, 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.

1. 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) and Debaere and Demiroglu (2003) 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 (HO) 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 (not even in productivity equivalents) worldwide.

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 that we study is especially critical for the part of the research that has tried to integrate HO-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

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products. In Solow's world, capital accumulation in a country induces lower capital returns and hence lower growth rates. If countries produce the same products and trade, however, the familiar Rybczynski effect occurs and production shifts in the accumulating country towards capital-intensive sectors. Moreover, there is no drop in the capital return in the countries that grow relative to the rest of the world, since factor prices are set at the world level and not 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. Responsible for this interest is, in part, the "neoclassical revival" (Klenow and Rodriguez-Clare, 1997) in growth with its re-evaluation of the neoclassical growth model and the role of factor accumulation. Mankiw (1995) and Ventura (1997) pointed out that the rapid growth between 1960 and the 1990s in Hong Kong, Singapore, Taiwan, and South Korea was accompanied by a gradual shift toward more capital-intensive sectors *without diminishing returns*, and argued that this might be due to the Rybczynski effect in diversified economies. It is no coincidence that the East Asian countries are relatively open and characterized by massive capital accumulation and drastically expanding (capital-intensive) manufacturing production and exports since the 1960s.

We show that the condition that characterizes diversified economies is not violated for the newly industrialized countries (NICs) and their major developed trading partners since the 1960s. This condition is essential for the factor accumulation and growth without diminishing returns that Mankiw and Ventura consider, since it ensures that the NICs' factor prices are not determined at the country level. Instead, factor prices are set for the entire group of countries. Our finding links the growth debate with the recent empirical trade literature. There is a growing consensus in that literature that all countries cannot produce the same goods because of the substantial differences in the factor proportions. Some countries specialize in goods that are different from those that others produce and trade is not the critical integrating factor of their factor markets. However, within such a world, it is perfectly possible that a more limited set of countries are diversified and able to produce the same set of goods.

To empirically check the necessary conditions for diversified production, we use Deardorff's (1994) lens condition 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.

2. Deardorff's Lens Condition

In the standard $2 \times 2 \times 2$ Heckscher–Ohlin 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.[2] 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 the 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 using vectors $z_i = (K_i, L_i)$ whose coordinates are respectively the capital and labor used in sector *i* in all countries for which 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 and 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 they are the same for all countries. Figure 2 shows a violation of the lens condition. Endowments are not similar enough and the same set of goods are not 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

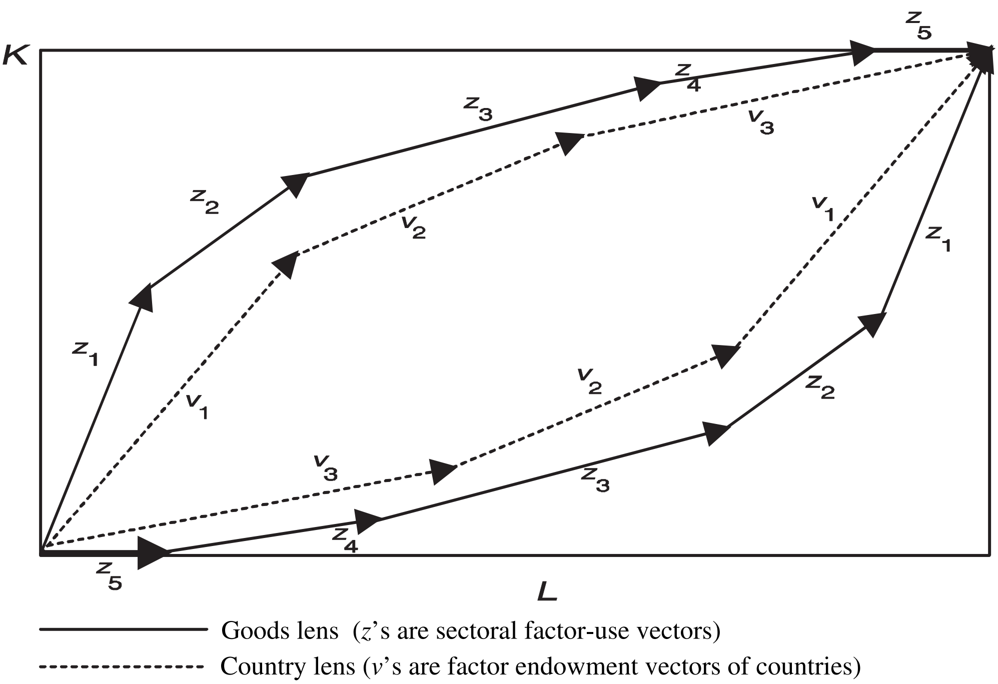

Figure 1. The Goods and Country Lenses Satisfying Deardorff's (1994) Lens Condition

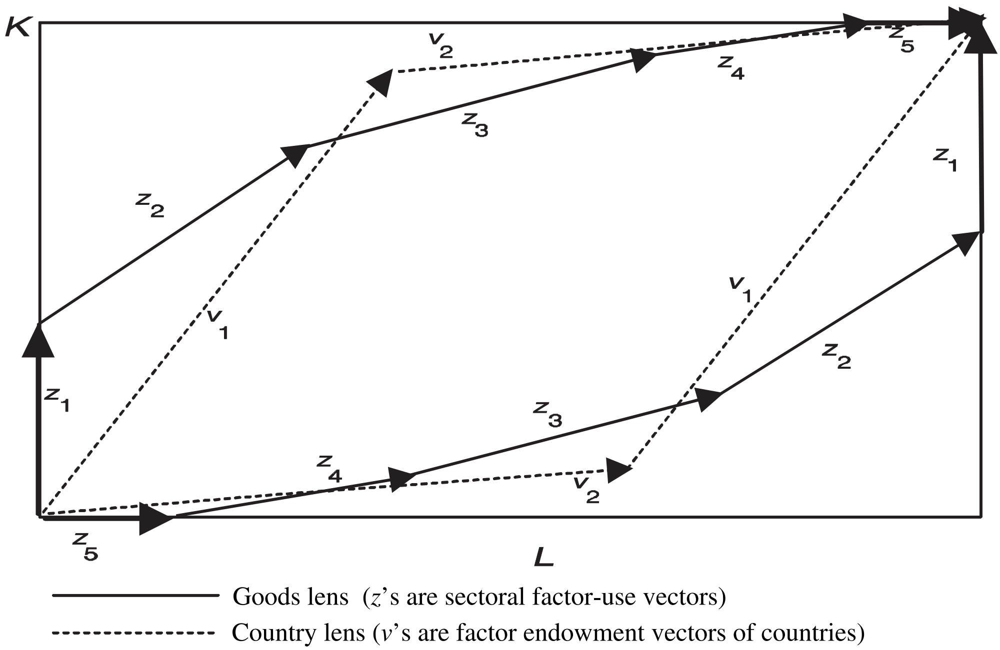

Figure 2. The Goods and Country Lenses Violating the Lens Condition

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 lens condition even if the range of the capital–labor ratios of the goods is wider than that of the endowments. In sum, the absolute size of sectors also matters when there are 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.[3] We express each country's production factors in US productivity equivalents. (We multiply country c's factors f by π_{cf}, where π_{cf} is country c's productivity 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. Equations (1) are for the vectors with which we draw the lenses (i's for sectors, c's for countries):

$$\begin{aligned} \boldsymbol{z}_i &= [L_i \quad K_i] \qquad \boldsymbol{K}_i = \sum\nolimits_c \pi_{ck} K_{ic} \qquad \boldsymbol{L}_i = \sum\nolimits_c \pi_{cl} L_{ic} \\ \boldsymbol{v}_c &= [L_c \quad K_c] \qquad \boldsymbol{K}_c = \sum\nolimits_i \pi_{ck} K_{ic} \qquad \boldsymbol{L}_c = \sum\nolimits_i \pi_{cl} L_{ic}. \end{aligned} \tag{1}$$

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 case with and without productivity adjustments, however. In the latter case, the (immobile) factors, when given the chance, have no incentive to move since factor prices are equal everywhere. With adjustments, however, this may no longer be true. In particular, if factor-augmenting productivity differences are not *completely* inherent to factors, but at least in part due to institutional differences, factors in less-paying countries will be eager to move abroad in order to earn a higher return. To avoid any confusion, we talk about integrated economies only in the 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 for both cases—independent of these adjustments. Note that one can implement the lens condition for a world with nontraded goods. As implied by Helpman and Krugman (1985) one should then only consider the total factors used for the traded goods to construct the lenses. This is the route that we take in the implementation.

3. The Empirical Implementation of the Lens Condition

Deardorff (1994) develops a lens condition for the entire world. Debaere and Demiroglu (2003) show that this condition can be used for any set of countries. The latter clears the way for empirical analyses of the production factors of various country groups. 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 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 total 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 must have accumulated capital at a slower rate than NICs, so that the total capital stock for the entire group (including the NICs) 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. Suppose that the NICs were specialized among themselves. Then, as they accumulated capital rapidly, they would experience diminishing returns to capital as a group, which would make it difficult for them to sustain such high rates of capital accumulation and growth.

We investigate whether the NICs and their major trading partners (the US, the UK, Germany, Japan, and Canada) are diversified economies. These countries fulfill both conditions. The NIC economies are only a fraction of the combined size of our developed countries, which constitute over 50 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 from 1965 to 1990. (Even Japan grew at a slower pace.) Note that there is some discretion in how we delineate the group of countries that we analyze. For our purpose, what matters is that the group is sufficiently large—it is not essential that the set of countries is complete. This does not imply, however, that our choice is arbitrary. The rich OECD countries are particularly appropriate because their endowments have been found to be similar enough to produce the same set of goods (see Debaere and Demiroglu, 2003). We could easily include other 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.[4] Moreover, OECD countries and the NICs are relatively open economies, whereas many developing countries are not. Consequently, to credibly make an argument that hinges on openness, the group of countries must be chosen carefully. To check Deardorff's condition for 1965–90 and get vectors (1) we need sector-level capital and labor data as well as measures of factor-augmenting productivity differences. We first discuss the sources for capital and labor and then present human capital and factor price data as proxies for factor-augmenting technological differences.

The *United Nations Industrial Statistics* (UNIDO) provide for manufacturing employment figures and investment flows with which we construct capital stocks. Hence, the relevant country endowments (with nontradable goods) amount to all factors used in manufacturing. We use the UNIDO data to obtain the distribution of factor use across the industries in a country. To ensure that the magnitudes of the endowments are internationally comparable, we link UNIDO with the Penn World Tables. Specifically, we infer the capital–labor ratio of a country's manufacturing sector k_{Mc} from the strong correlation in the Penn World Tables between k_c, a country's overall capital per worker, and y_c, its real GDP per worker.[5] First, we run the cross-country regression (2) merely for predictive purposes with the Penn World Data for 62 countries.[6] The period is 1965–90:

$$\ln k_{ct} = \alpha_c + \alpha_t + trend_c + \beta \ln y_{ct} + \varepsilon_{ct}. \tag{2}$$

The high R^2 of 0.97 is no surprise, especially since the regression also includes year effects and also country-specific time trends.[7] The β-coefficient takes the value of 1.1 and is significant at the 95 percent level. All variables are in 1985 international prices.

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_c and

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									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

Notes:
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.

predicted k_M. We report predicted k_{Mc} in levels instead of logs and correct for the bias from the logarithmic transformation in the usual way.[8,9] 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 1976–90 and 1963–77. The initial capital in a sector is based on the investment flow of the first year of the period in 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 US:

$$K_c = k_{Mc} x L_c \quad K_{ic} = K_{UNic} \big/ K_{UNc} x K_c \quad K_i = \sum\nolimits_c K_{ic}. \tag{3}$$

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. Plots of a country's share in the total capital stock in a sector, K_{ic}/K_i, versus its share in the total labor employed in that sector, L_{ic}/L_i, display a cloud of capital–labor ratios, even though all the points should in theory lie on the 45-degree line. There are various reasons why (productivity-adjusted) sectoral capital to labor ratios can vary. One reason is, of course, that countries may lie in different cones. Aggregation also matters. We use fairly aggregate sectoral data that may contain subsectors with varying factor intensity. Whenever countries produce more/less in these subsectors, the aggregate capital–labor ratio varies. Finally, there is also measurement error in the data. We discuss these concerns in more detail below.

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's (1994) cross-country survey evidence on the returns to schooling to construct human capital stocks. In their analysis, human capital-augmenting labor is $H_i = e^{\varphi(E_i)}L_i$ 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 is estimated in a Mincerian wage regression. Based on Psacharopoulos's 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 and 6.8 for the years beyond year 8. Hall and Jones provide for 1988 human capital–labor ratios for all countries with which we upgrade the labor force. 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), wages are drawn from the *Yearbook of Labour Statistics* for 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 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 Tables. The values are reported in Table 1. From a theoretical point of view, differences in factor returns are the appropriate 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 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.

4. The Empirical Results

Figures 3–5 present our main result. We also analyze 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 that 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.[10] Figure 5 shows for 1990 the country and the goods lenses for Hong Kong, Singapore, South Korea, and their main developed-country trading partners (the United States, Japan, Germany, the United Kingdom, and Canada). For 1977 (Figure 4) and 1965 (Figure 3) we consider the same group minus Hong Kong due to data limitations. The

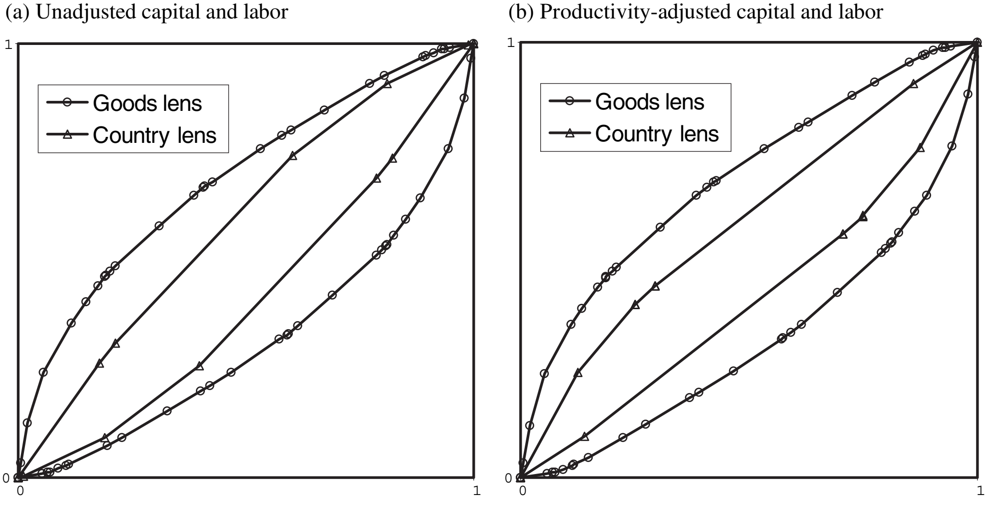

Figure 3. Lenses in 1965

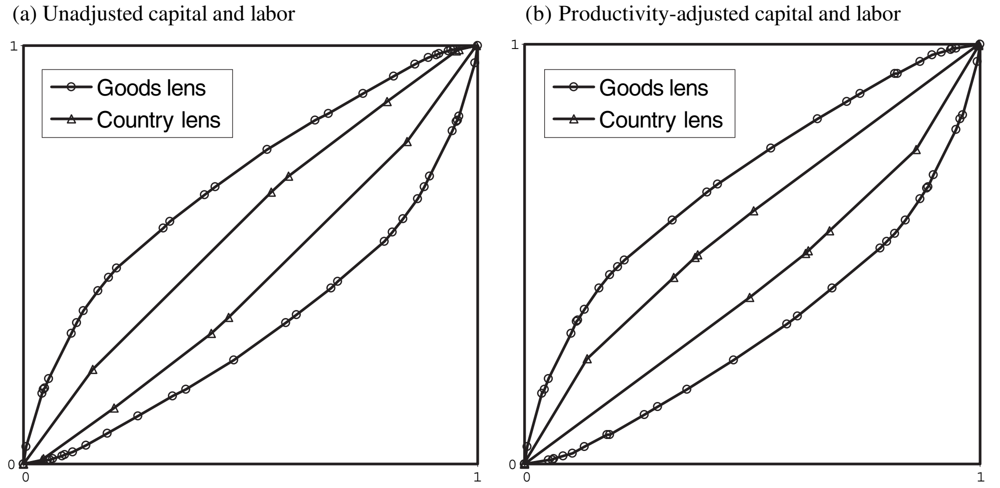

Figure 4. Lenses in 1977

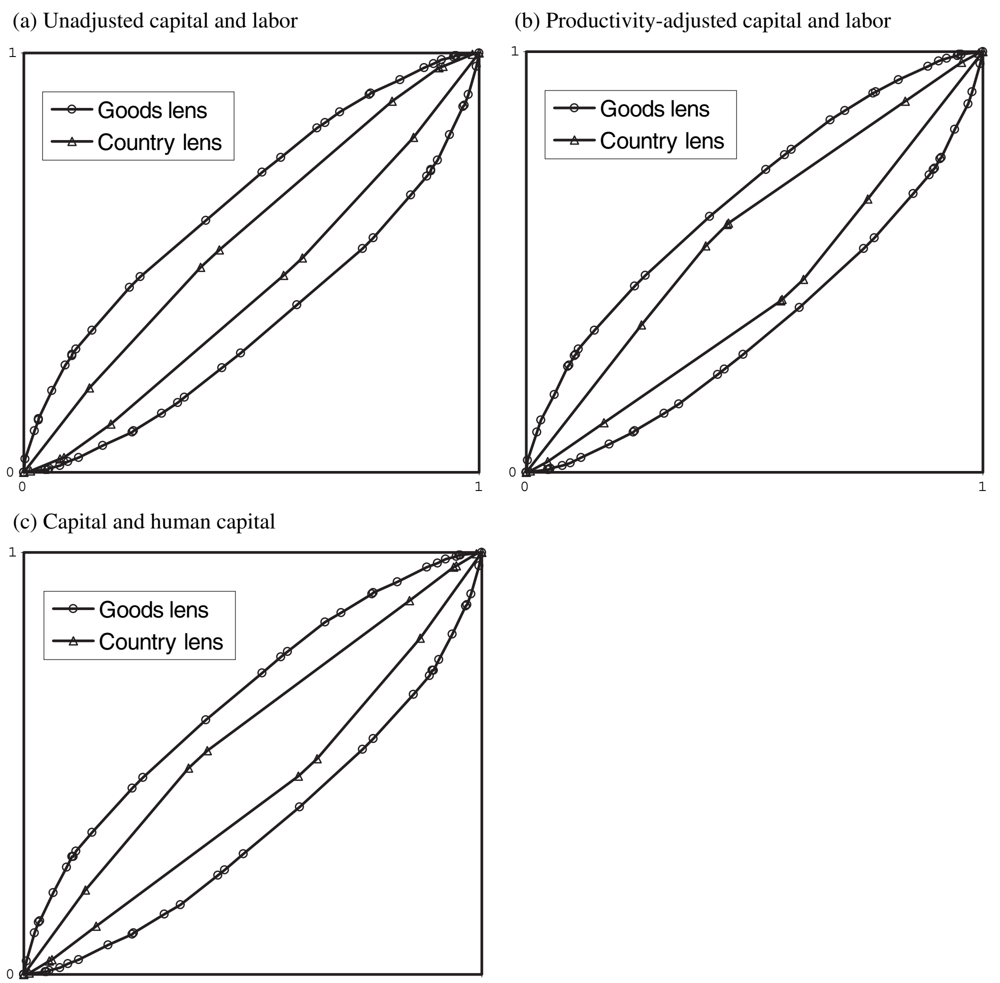

Figure 5. Lenses in 1990

figures to the left show the lenses without factor productivity corrections. These figures are included for expositional purposes. They allow us to assess the impact of the factor productivity corrections.[11] 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 for these corrections; 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 is for the lens in 1965 when we do not correct for differences in productivity; this violation is easily undone with productivity adjustments.[12]

To compare the results, we introduce a measure to 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 useful when a (non-) violation is not so easily observed on the graph as in Figure 3a where one can hardly see whether Singapore violates the goods lens or not. A positive value indicates a violation. When the measure is 1, it implies the country lens is the diagonal. A very small positive number indicates that the two lenses are close and a negative one implies a violation. The measure is derived as follows. Through *any* point x on the diagonal of the endowment box, draw a perpendicular to the diagonal. Call the point at which the perpendicular intersects the country and the good lens respectively point $c(x)$ and $g(x)$. If $d(x, y)$ is the distance between any two points x and y, the measure is defined as

$$\min_x \left\{ 1 - \frac{d(x, c(x))}{d(x, g(x))} \right\}. \tag{4}$$

Note that our measure also works well at the corners of the lenses. The measures for the NICs and their trading partners are reported in Table 2. (We also report the results separately for the subgroup of the trading partners and the NICs.)

Next, we assess how robust our results are.[13] One may wonder whether measurement error, especially for capital data, would change our basic results. 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 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 clearly not the case. As mentioned before, there are several reasons why these ratios may differ: aggregation across different subsectors, a violation in the lens condition, and measurement error. To analyze the impact of measurement error, we (for now) make the generous assumption (that does not favor our analysis) that all cross-country variation in sectoral capital–labor ratios is 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. (Sigma of 0.50 implies that one standard deviation of measurement error increases or decreases capital or labor by 35 percent.[14])

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	1990	Unadjusted	0.20	5.55	0.26	0.64
		Adjusted	0.26	3.85	0.35	0.56
		Human capital	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 capital	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 capital	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

We run a Monte Carlo simulation with 2000 repetitions for each lens. We perturb capital and labor for a sector in a country by randomly drawn errors, distributed normally with the above variance. We count the number of times this triggers a violation of the lens condition and report the frequency as the probability of a violation.[15] Column two presents the results. Except for the 1965 unadjusted lens, these probabilities are very low. As mentioned, all variation in sectoral capital–labor ratios across countries is attributed to measurement error in the exercise. This most likely overstates the actual errors because part of that variation is certainly due to aggregation. Each sector contains various subsectors with different capital–labor ratios, and variation in the within-sector composition across countries will result in unequal capital–labor ratios. On the other hand, our analysis ignores the potential within-country correlation of measurement errors. Another concern is the aggregation issue mentioned above: each sector in UNIDO consists of many subsectors. As shown in Debaere and Demiroglu (2003), sectoral aggregation makes the goods lens thinner. (If all sectors are aggregated, the goods lens is the diagonal.) This means that aggregation can cause a spurious violation of the lens condition. At the same time, aggregation reinforces the significance of obtained non-violations of the lens condition. An aggregate non-violation implies a non-violation with more disaggregated data that make the goods lens wider.[16]

To study the effect of disaggregation, we undertake a disaggregation exercise with firm-level data from US Compustat. From Compustat we take the average within-industry variation in firm-level log capital–labor ratios at the three-digit level.[17] We make the extreme assumption that this within-industry variation is only due to aggregation. We investigate how the goods lens would look 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 Compustat. (We normalize the new firm-level vectors so that they add up to countries' original factor-use vectors.) We finally re-draw the lenses for the hypothetical "disaggregate" goods lens (see Table 2, "Measure after disaggregation"). Overall, disaggregation does not have a big impact. The disaggregation effect is strong enough, however, to overturn the only violation we had.

5. 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 they were part of a world in which factor prices were a function of the world factor endowments and 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 those of their main developed-country trading partners with the sectoral factor use at different points in time. We adjust factor endowments and factor-use data for factor-augmenting productivity differences. We study the years 1965, 1977, and 1990. It is found that Deardorff's lens condition is satisfied for those three years.

References

Deardorff, Alan, "The Possibility of Factor Price Equalization Revisited," *Journal of International Economics* 36 (1994):167–75.

Debaere, Peter and Ufuk Demiroglu, "On the Similarity of Country Endowments," *Journal of International Economics* 59 (2003):101–36.

Hall, Robert and Charles Jones, "Why Do Some Countries Produce So Much More Output Per Worker Than Others?" *Quarterly Journal of Economics* 114 (1999):83–116.

Helpman, Elhanan and Paul Krugman, *Market Structure and Foreign Trade*, Cambridge, MA: MIT Press (1985).

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

Leamer, Ed and Jim Levinsohn, "International Trade Theory: the Evidence," in Gene Grossman and Ken Rogoff (eds), *Handbook of International Economics*, New York: Elsevier (1995).

Mankiw, G., "The Growth of Nations," *Brookings Papers on Economic Activity* 25 (1995): 275–310.

Psacharopoulos, George, "Returns to Investment in Education: a Global Update," *World Development* 22(9) (1994):1325–43.
Schott, P., "One Size Fits All," mimeo, Yale University (2001).
Stiglitz, J., "Factor Price Equalization in a Dynamic Economy," *Journal of Political Economy* 78(3) (1970):456–88.
Trefler, D., "International Factor Price Differences: Leontief Was Right!" *Journal of Political Economy* 101 (1993):961–87.
Ventura, J., "Growth and Interdependence," *Quarterly Journal of Economics* 112 (1997):57–84.

Notes

1. With small countries, goods prices are given and the return to capital does not change. If countries are big, goods prices may change with capital accumulation in one country and the return to capital is a function of the marginal change in *world* factor endowments.
2. Deardorff's condition is a necessary condition that is also sufficient when there are only two factors of production.
3. Factor-augmenting productivity differences account for international differences in factor prices (Leamer and Levinsohn, 1995) and sectoral capital–labor ratios. With them, capital shares in fast-growing countries do not necessarily increase more rapidly.
4. The lens condition is unlikely to hold for the NICs and India or China.
5. UNIDO employment data are more reliably compared internationally than UNIDO investment data.
6. For full country list, see the working paper version available upon request.
7. If one relates the regression to a Cobb–Douglas production function, the time trend and the country effects allow for technological differences between countries.
8. $\exp\beta = \exp(b - \text{var}(b)/2)$, with b an estimate of true β.
9. To predict Singapore's k_{Mc} (not in Penn tables), we run (2) with a common trend and dummy for East Asia and plug in Singapore's y_{Mc}.
10. How we draw the lenses generates a violation if countries produce different sets of goods (say, because of very different endowments). This is true also for a subset of countries. In addition, if there is factor intensity reversal (making FPE impossible) our methodology is likely to generate a violation since it makes the sector lens thinner. Similarly, averaging factor intensities from countries in different cones leads to a violation when the lenses are drawn the way we propose.
11. The uncorrected lenses are the theoretically correct condition to use only with factor-augmenting productivity differences that are the same across factors. Debaere and Demiroglu (2003) show that the uncorrected and the corrected lenses have the same shape in this case.
12. Note that disaggregation also undoes this violation; see below.
13. We also used the data from the Michigan model for the same set of countries (with Taiwan instead of Singapore) for 1990. No violation was obtained.
14. We compute the standard deviation of log capital–labor per sector across countries and take the average as the standard deviation of measurement error for all observations, which arises from either error in capital, labor, or both. (Attributing error to one or the other does not make a significant difference; the reported numbers have capital and labor equally responsible.) 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 correct for the bias that log-normal disturbances generate by dividing by $\exp(\text{Var}(error)/2)$.
15. For clarification: if the capital 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 is the fraction of all cases in which the obtained lenses generate a violation.

16. Aggregation issues are also one reason for why it is not useful to merely check whether all countries produce in the chosen industries—they may well produce in different subsectors.
17. The average standard deviation of log K_{if}/L_{if} of firms in three-digit industry is substantial: 0.47.
18. The result is not sensitive to the magnitude of the number, as long as it is larger than 30.