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STAGES OF DIVERSIFICATON AND SPECIALIZATION IN AN HECKSCHER-OHLIN WORLD, 1976-2000

Catia Batista and Jacques Potin

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Manor Road Building, Oxford OX1 3UQ

Stages of diversification and specialization in an Heckscher-Ohlin world, 1976-2000*

Catia Batista† and Jacques Potin‡

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Abstract

Recent research has documented a U-shaped industrial concentration curve over an economy's development path. How far can neoclassical trade theory take us in explaining this pattern? Building on Schott (2003), we estimate the production side of the Heckscher-Ohlin (HO) model with industry data on 50 developed and developing countries covering the period 1976-2000. We allow for multiple cones of specialization, and give special attention to intra-industry factor heterogeneity and to the potentially indeterminate nature of production. For each year, national industries are grouped in one of two HO aggregates: an aggregate of labor-intensive industries and an aggregate of capital-intensive industries. Decomposing changes in industrial concentration over time, we show that at least 30% of these changes seems to be explained by the diversification or concentration patterns at the HO-aggregate level. As the combined effect on specialization of changes in technology and relative prices seems to be small, the mechanism we identify is the textbook Rybczynski effect: poor countries accumulating capital have diversified their industrial production by producing more capital-intensive goods, while rich countries accumulating capital have made their production more concentrated by specializing in the production of capital-intensive goods.

JEL Codes: F11; O40

Keywords: Economic Growth and International Trade; Heckscher-Ohlin; Multiple Cones; Diversification; Specialization; Industrial Concentration; Structural Change

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†University of Oxford. E-mail: catia.batista@economics.ox.ac.uk

‡ESSEC, Paris. E-mail: potin@essec.fr

1 Introduction

Recent work shows that countries grow through two stages of industrial development. In the first stage of development, as a country's per capita income increases, the country's manufacturing sector becomes more diversified. In a second stage, while per capita income keeps rising, the country's industry becomes more concentrated (Imbs and Wacziarg, 2001). This phenomenon has major macroeconomic consequences. For instance, Koren and Tenreyro (2006) show that industrial concentration (inversely related to industrial diversification) is important in explaining the volatility of the growth of GDP per capita. At the beginning of their first stage of development, poor countries have a more concentrated industry, which contributes to the higher volatility of GDP in these countries. Understanding why these two stages of development are observed is therefore crucial to the design of economic policies aimed at reducing income fluctuations, particularly in less developed economies.

This paper uses the Heckscher-Ohlin (HO) model of international trade as a framework to study the evolution of industrial concentration over time. Our proposition is that the U-shaped curve might be explained as resulting directly from the Rybczynski effect. In the traditional HO model with a labor-intensive good and a capital-intensive good, when a country is below or at the lower edge of the cone of diversification, it produces none of the capital-intensive good and specializes in the production of the labor-intensive good. With constant product prices and state of technology, a country that accumulates capital will at some point enter the cone of diversification: it starts producing the capital-intensive good, and the country goes through a stage of diversification. As the country keeps accumulating capital, its production of the capital-intensive good should increase while the production of the labor-intensive good should decrease: this is the well-known Rybczynski effect. When the country reaches or goes beyond the upper edge of the cone of diversification, its manufacturing sector will be fully specialized in the capital-intensive good. Using data on 50 developed and developing countries over the 1975-2000 period, we aim at quantifying the importance of factor accumulation in explaining structural change within the industrial sector.

To validate our hypothesis, we must first check that observed production patterns are consistent with the HO model. That is confirmed in the first part of the paper. More precisely, using industry-level data for the 50 countries, we provide strong evidence that the production patterns observed in 1975–2000 are consistent with the production side of the 2×2 HO model. The two factors we consider are labor and physical capital, measured in effective units. The two goods find their counterpart in two "HO aggregates", which we construct following Schott (2003): one aggregate of labor-intensive industries (with a capital-labor ratio below a certain threshold or cutoff) and another aggregate of capital-intensive industries (with a capital-labor ratio above the cutoff). By doing so, we reduce the number of goods, and we also obtain sets of underlying industries with similar capital intensities, and thereby get closer to the theoretical HO model. In addition, this aggregation helps us solving the problem of production indeterminacy that appears in HO models with more goods than factors.[1] We allow countries to belong to one of three cones: the cone of diversification in which countries produce both aggregates, and two cones of specialization in which countries produce only one of the two aggregates.

The simple HO model described above is estimated using panel data. The cutoff between the two HO aggregates and the cone cutoffs are determined empirically. We also introduce multiplicative country fixed effects to account for country heterogeneity not only in terms of total factor productivity (TFP), but also in terms of differentiated impacts in the specialization pattern of factor accumulation. This is important because in a pure cross-section, as in Schott (2003), a positive correlation between the capital-labor ratio and productivity is likely to produce estimates of the marginal product of capital that are biased upward. Therefore, the first part of the paper shows that (1) the traditional 2×2 model with fixed cutoffs explains specialization at the HO aggregate level over the whole period, and that (2) capital accumulation and the Rybczynski effect are key in explaining the evolution of specialization across HO aggregates.

In the second part of the paper, we introduce and apply a decomposition methodology to the fraction of the overall change in the degree of specialization that can be explained by shifts of specialization across HO aggregates. Koren and Tenreyro (2007) show that, when one is interested in the volatility of growth rates, an appropriate measure of concentration is the Herfindahl index. This is the measure of concentration we focus on. We introduce a decomposition of its change over time in two components: a between-aggregate change and a within-aggregate change. The *between-aggregate change* is positive when the shares of the aggregates become more unequal, and negative when the opposite occurs. So, for instance, when a relatively poor country starts accumulating capital and enters the cone of diversification, the Rybczynski effect implies that the share of the capital-intensive aggregate should go up from zero to a non-negative level. This makes the aggregates shares more equal and, because the country starts producing capital-intensive goods, this should reduce industrial concentration. In that case, the between-aggregate change is found to be negative. On the contrary, the *within-aggregate change* is positive when each HO aggregate becomes more concentrated, something *a priori* unexplained by our 2×2 model. As a result, our decomposition enables us to isolate the contribution of the neoclassical factors (mainly capital accumulation according to our results, but also changes in technology and relative prices[2]) to the evolution of industrial concentration: it is measured by the between-aggregate change.[3] Using this decomposition of the change in

[1] See Melvin (1968). As discussed later, Bernstein and Weinstein (2002) find evidence of production indeterminacy at the industry level. The results in Schott (2003) can also be interpreted as a confirmation of this indeterminacy.

[2] Our thesis is that capital accumulation, through the Rybczynski effect, is a major explanation for the two stages of development. To distinguish the Rybczynski effect from the price effect, we shall focus on the *average* price of the labor-intensive goods relative to the ù*average* price of the capital-intensive goods. In this paper, a change in relative prices will always refer to this price ratio. We do not discuss price changes of any particular good within an HO aggregate.

[3] Note that this decomposition is especially relevant when there is production indeterminacy at the HO-

the Herfindahl index over time, we find that neoclassical factors (mainly capital accumulation through the Rybczynski effect) have contributed significantly to the evolution of industrial concentration. Our most conservative estimate indicates that, on average, at least 30% of the evolution in industrial concentration can be explained by these effects.

The paper is organized as follows. Section 2 discusses alternative theories that may explain the U-shaped concentration curve. Section 3 estimates the production side of the traditional Heckscher-Ohlin model. Section 4 decomposes the changes in industrial concentration over time. The last section summarizes and concludes.

2 Other hypotheses for the two stages of diversification

Quite surprisingly for us the existing literature on the stages of diversification, most notably Imbs and Wacziarg (2001) and Koren and Tenreyro (2006), has not put forward the neoclassical factors (and especially capital accumulation) as a source of explanation for the U-shaped industrial concentration curve. To the best of our knowledge, there is no empirical work that directly tests this hypothesis. Imbs and Wacziarg (2001) discuss two reasons that might explain the first stage of development. First, with non-homothetic preferences, the consumption and production patterns change with real income, and it is generally observed that consumers diversify their consumption as their income grows. While the role of demand is likely to be important in reality, our paper does not attempt to incorporate this type of explanation. Second, in line with Acemoglu and Zilibotti (1997), when risk-averse agents can invest in imperfectly correlated projects and when investing in a project requires a minimal investment, the degree of sectoral diversification will increase with the aggregate stock of capital and income. This will allow investment in risky, high-return projects. The present paper also studies the relationship between the national stock of capital and sectoral diversification. But differences arise: the emphasized mechanism is not the same; the exact relationship is between the stock of capital per worker and industrial concentration, rather than between the stock of capital only and industrial concentration; the relationship is non-monotonic.

Imbs and Wacziarg also discuss three alternative reasons that might lead to the specialization observed in the second stage. They suggest that falling transportation costs (related in some way to income) allow countries to specialize according to their comparative advantages, as predicted by Ricardian models with a continuum of goods.[4] Falling transportation costs might also lead to the clustering of economic activity in specific regions or countries. Finally, Saint-Paul (1992) models a situation in which countries facing incomplete markets diversify their

aggregate level or when natural endowments or Ricardian productivity differences explain specialization within an HO aggregate.

[4]The same result obtains in HO models with a continuum of goods like the one of Dornbusch *et al.* (1980). By contrast this paper does not put the emphasis on decreasing transportation costs, but rather on the Rybczynski effects associated with capital accumulation and on the effect of changes in relative prices.

output in order to reduce the volatility of their income. Financial market deepening reduces the incentive for industrial diversification, and leads to industrial concentration.[5]

All these five forces are likely to be at play simultaneously, but we should have a diversification phenomenon when the first two forces dominate, and specialization when the last three prevail. In contrast, the Rybczynski effect provides a single explanation for the two stages of development: rapid capital accumulation might explain the diversification of industrial output, and the same capital accumulation might also drive the specialization phenomenon. Obviously, all explanations are likely to have an impact on the evolution of industrial concentration. It is therefore essential to measure the contribution of the Rybczynski and other neoclassical effects emphasized in this paper. Our methodology is a first attempt to address this issue.

The work by Acemoglu and Guerrieri (2005) is closely related to ours, as they also explain the non-balanced nature of growth with a factor-proportions model. However, they model a closed economy, and empirical work is not tackled, but only called for in their conclusion. Recent papers on the dynamics of industrial concentration include Redding (2002), Xu (2003), Volpe Martincus and Pédussel Wu (2005), and Debaere and Demiroglu (2003b). None of these papers is directly interested in the diversification-concentration phenomenon in the world economy. The first three papers use the methodology introduced by Kohli (1978), which is appropriate for a world with at least as many factors as goods. We rather believe that there are more goods than factors, and therefore use the better suited methodology introduced by Schott (2003).[6]

3 The production side of the Heckscher-Ohlin model

3.1 The theoretical framework

Our general theoretical framework is the traditional 2×2 Heckscher-Ohlin model. We shall explain in this section how we make it empirically operational. We will also give arguments for selecting this particular model.

Consider N countries, $n = 1, \ldots, N$. At date t, country n is endowed with a quantity K_n^t of capital and a quantity L_n^t of labor. There are two goods that can be produced in each country, $i = l, k$. Good l is labor-intensive, and good k is capital-intensive. There is no factor intensity reversal. Both goods are produced with constant returns to scale (CRS) by competitive firms, and the marginal product of each factor is positive and decreasing at the firm (and industry) level. All countries have access to the same technology. Each country is small and can freely trade goods on the world market at date-t prices.

In a competitive equilibrium, countries with a low capital-labor ratio ($K_n^t/L_n^t \in (\tau_0 = 0, \tau_1^t)$) specialize in the production of the labor-intensive good. Countries with an intermediate capital-

[5]Kalemli-Ozcan *et al.* (2003) provide regional and international evidence of a causal relation from risk sharing to industrial specialization.

[6]Debaere and Demiroglu (2003b) is another paper studying the multiplicity of the cones of specialization.

labor ratio ($K_n^t/L_n^t \in (\tau_1^t; \tau_2^t)$) produce the two goods. Countries with a high capital-labor ratio ($K_n^t/L_n^t \in (\tau_2^t, \tau_3 = +\infty)$) specialize in the production of the capital-intensive good.

More precisely, the countries with a low capital endowment produce only the labor-intensive good, and production per worker therefore becomes:

$$\frac{Q_{nl}^t}{L_n^t} = F^l(K_n^t, L_n^t)/L_n^t = f^l\left(\frac{K_n^t}{L_n^t}\right), \tag{1}$$

where n denotes a country (or "nation"), t a date and $i = l, k$. F^l denotes the production function for the labor-intensive good, and $f^l(k) \equiv F^l(k, 1)$ makes use of its CRS property and inherits concavity.

For the countries in the cone of diversification, the value-added per worker for good i is given by:

$$\frac{Q_{ni}^t}{L_n^t} = \alpha_{2i}^t + \beta_{2i}^t \frac{K_n^t}{L_n^t}, \tag{2}$$

with $\alpha_{2l}^t > 0$, $\beta_{2l}^t < 0$, $\alpha_{2k}^t = 0$, and $\beta_{2k}^t > 0$. The countries with a high capital endowment specialize in the production of the capital-intensive good:

$$\frac{Q_{nk}^t}{L_n^t} = F^k(K_n^t, L_n^t)/L_n^t = f^k\left(\frac{K_n^t}{L_n^t}\right) \tag{3}$$

where F^k denotes the production function for the capital-intensive good, and f^k is concave.

Figure 1 represents the theoretically implied patterns of specialization.[7] The dashed line represents value-added per worker for the labor-intensive good over a country's "development path". The solid line represents value-added per worker for the capital-intensive good. The *Rybczynski effect* says that, with fixed prices and technologies, capital accumulation in the cone of diversification leads to a reduced production of the labor-intensive good and to an increased production of the capital-intensive good. The thin straight line that is tangent to the two curves determines the capital-labor ratios in the two industries (equal to τ_1^t and τ_2^t). Figure 2 shows total value-added per worker for the various levels of capital per worker. One can also easily show that the slope of the value-added per capita curve (in Figure 2) is equal to the rental cost of capital, and that the intercept of the tangent to this curve with the vertical axis is the compensation per worker.

Figure 3 shows how industrial concentration varies with a country's capital-labor ratio. As Koren and Tenreyro (2006) make clear, a particularly adequate measure of concentration is the Herfindahl index. This is presented in Figure 3.[8] We do find a U-shaped curve for industrial concentration when a country moves along its "development path", i.e. when it accumulates capital (more rapidly than the rest of the world).

[7] See Deardorff (1974, 1999) for further details.

[8] With 2 goods only, denoting by s_l the share of the labor-intensive good in total value-added, and by s_k the share of the capital-intensive good, the Herfindahl index is simply $HI = s_l^2 + s_k^2$. It attains a maximum of 1 when only one good is produced, and a minimum of 0.5 when the two shares are equal to 50%.

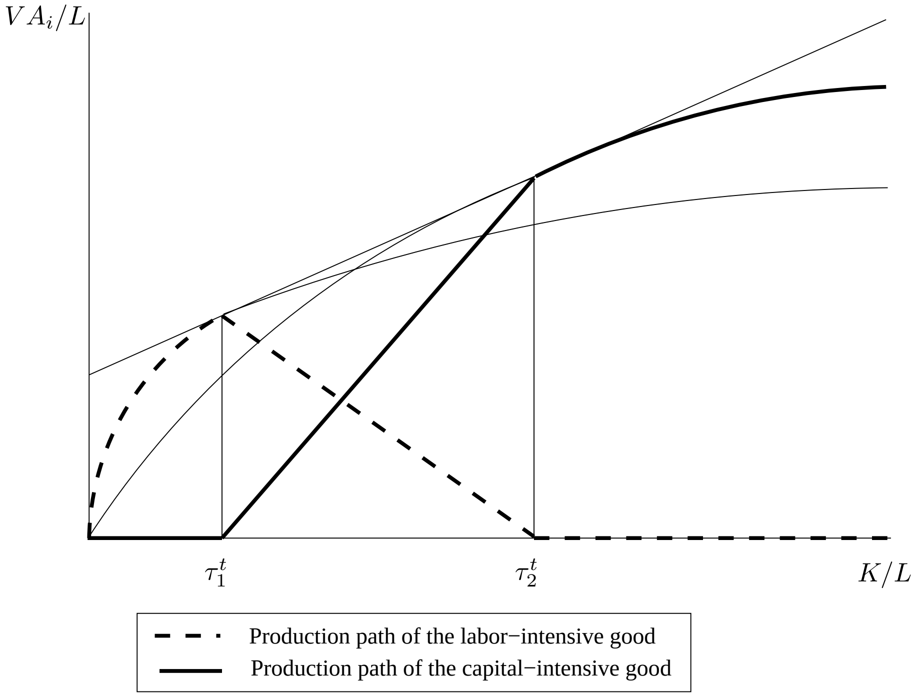

Figure 1: Production patterns in the 2×2 HO model.

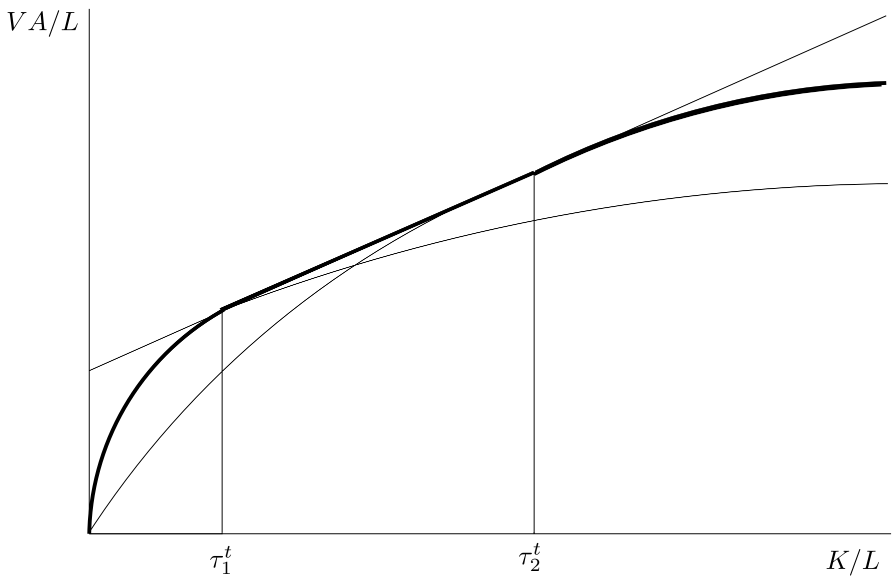

Figure 2: Value-added per worker in the 2×2 HO model.

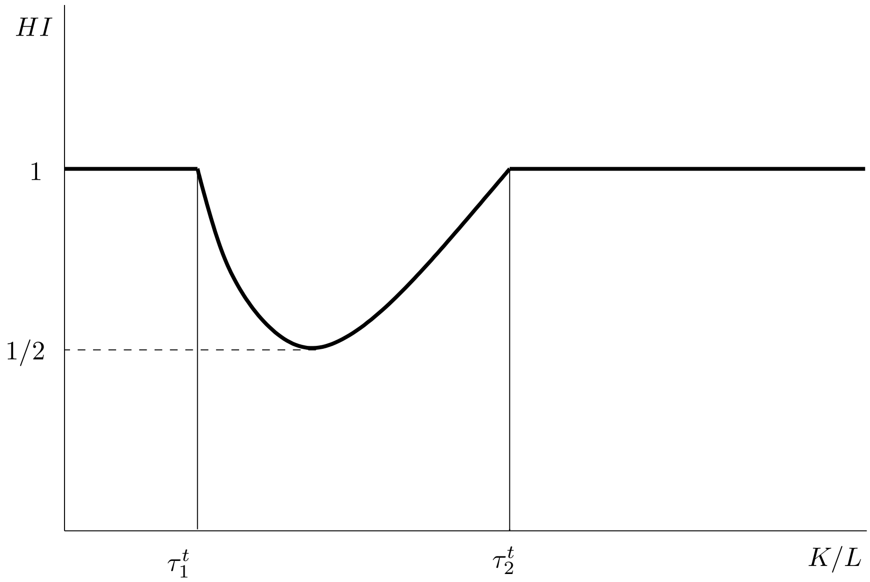

Figure 3: The Herfindahl index in the 2 × 2 HO model.

It is also well-known that a change in the relative price of the two goods or a biased technological progress should modify the structure of industrial production. For instance, if the relative price of the capital-intensive good goes up or if technological progress is biased in its direction, then the two cone cutoffs should move to the left, with more countries producing the capital-intensive goods and each country in the cone of diversification producing relatively more of the capital-intensive goods. The contribution to specialization of these two effects will have to be isolated from the impact of capital accumulation.

3.2 Empirical approach

In order to validate our hypothesis, we first check that observed production patterns are consistent with the HO model described above. We focus on the manufacturing sector as it should contain fewer non-tradables than other sectors of the economy, such as the agricultural sector or the services. On the one hand, it makes more reasonable the assumption that, whatever their location, all firms producing similar goods can sell these goods at the same price. On the other hand, including the agricultural and service sectors might provide a stricter test of the model at stake.

To empirically evaluate the model, we shall assume that production within the cones of specialization, given by Equations 1 and 3, is linear and can be expressed, respectively, as:

$$\frac{Q_{nl}^t}{L_n^t} = \beta_{1l}^t \frac{K_n^t}{L_n^t} \tag{4}$$

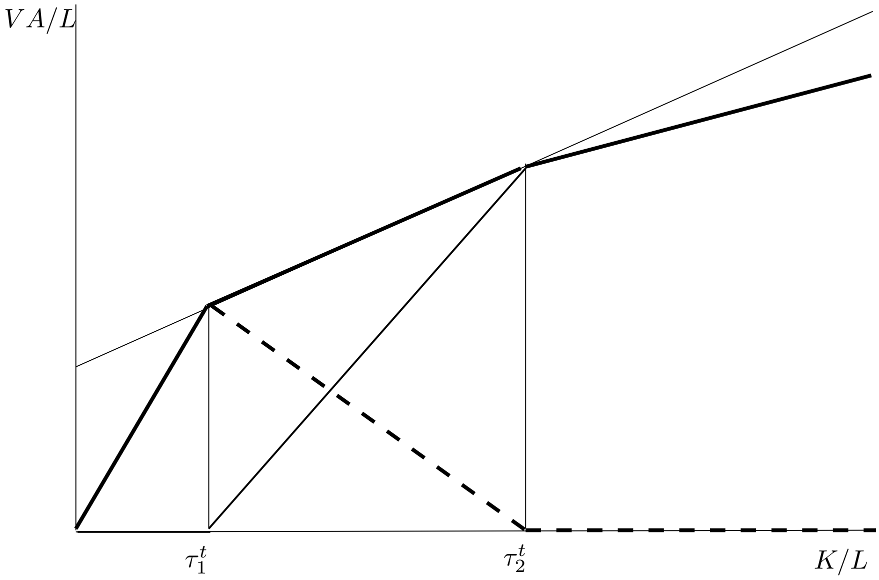

Figure 4: Production patterns and value-added per worker with our simplifying assumptions.

$$\frac{Q_{nk}^t}{L_n^t} = \alpha_{3k}^t + \beta_{3k}^t \frac{K_n^t}{L_n^t} \tag{5}$$

Recall that Equation 4 describes production in the first cone of specialization, whereas Equation 5 refers to the last cone in an economy's development path. Note that this is what we get in the HO model with fixed coefficients.

It follows from Equations 2, 4 and 5 that value-added per worker at the manufacturing level is piecewise linear:

$$\frac{Q_{nm}^t}{L_n^t} = \sum_{c=1}^{3} \left[\alpha_{cm}^t + \beta_{cm}^t \frac{K_n^t}{L_n^t} \right] I_{\left[\tau_{c-1}^t < \frac{K_n^t}{L_n^t} < \tau_c^t\right]} \tag{6}$$

Figure 4, that combines the information in Figure 1 with the linearization assumptions in Equations 4 and 5, shows that we keep the overall nonlinearity implied by theory.

As reality is much more complex than the 2×2 model, let us momentarily turn to a model that is more realistic, while still highly simplified. This is the "uneven" $2 \times m$ model, with 2 factors (capital and labor) and $m > 2$ goods. In such a model with more goods than factors, production is indeterminate, as there are many ways to maximize GDP (Melvin, 1968). Figure 5 represents possible production patterns when there is one labor-intensive good, and two capital-intensive goods. In the cone of diversification, a capital-accumulating country might maximize its GDP by having the production patterns represented by the black lines (solid and dashed): in that case, the country specializes in the production of the first capital-intensive good. But a country might as well specialize in the production of the second capital-intensive good (green or grey lines), and still maximize its GDP. One can also imagine that a country

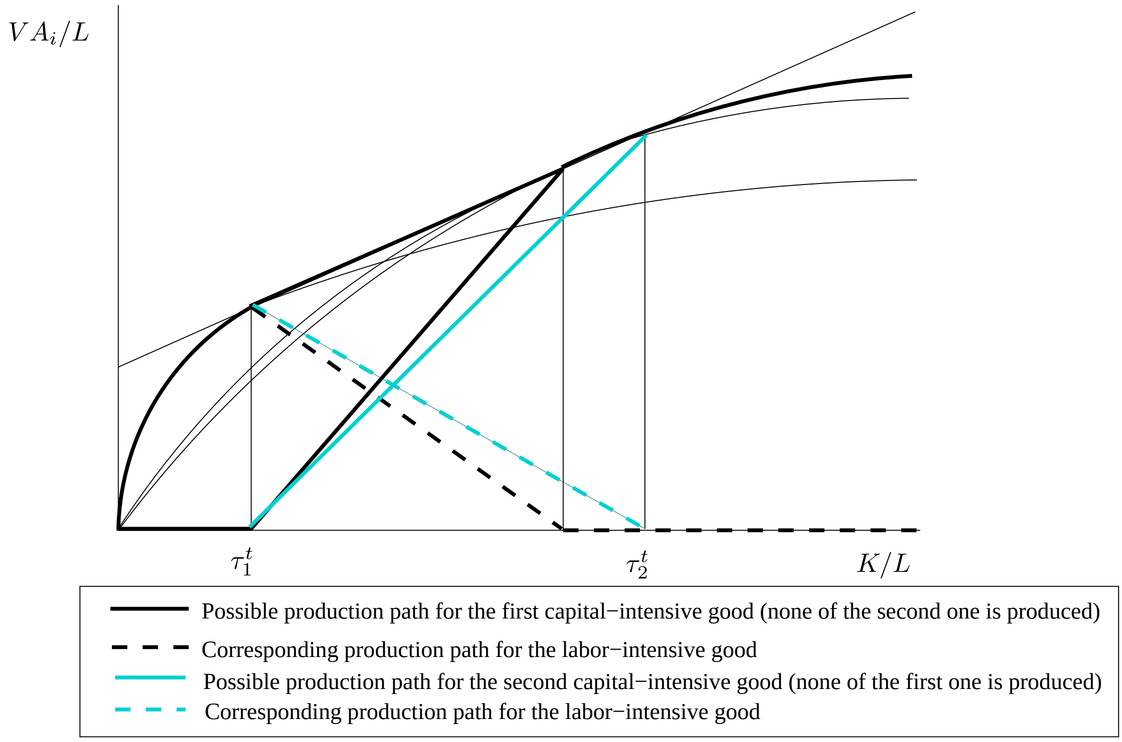

Figure 5: Production indeterminacy in the cone of diversification: two development paths.

does not specialize, and produces the two capital-intensive goods: production is indeterminate at the good level.[9]

The model considered here (with more goods than factors) is therefore different from the one underlying most of the empirical literature estimating Rybczynski relationships (including Kohli, 1978, Harrigan, 1995, 1997, Redding, 2002) that assumes production to be determinate at the industry level and runs regressions at the industry level. We therefore require a different empirical approach.

We consider that the basic 2×2 model might provide a good description of the world. First, we can group industries in "Heckscher-Ohlin" aggregates, as done by Schott (2003): we gather industries according to their capital-intensity, instead of using classifications such as

[9]Bernstein and Weinstein (2002) find substantial evidence of production indeterminacy using data from Japanese prefectures and from OECD countries. The evidence is stronger at the regional level. Bernstein and Weinstein suggest that this discrepancy might be explained by the high trade costs incurred for international trade. If this argument is correct, the reduction in transportation costs associated with globalization should make production patterns more indeterminate over time. With a wider cross-section of countries, Schott (2003) reports results that indicate a major indeterminacy of production at the industry level. Bernstein and Weinstein (2002) also argue that "aggregation can resolve production indeterminacy arising from the existence of more goods than factors only in exceptional cases" (p. 60). While this statement is true in a literal sense, our example in Figure 5 indicates that aggregation *can* significantly *reduce* production indeterminacy.

the International Industrial Classification (ISIC) as collections of goods with similar end use. For instance, in Schott's (2003) preferred model, the footwear industry in Panama is classified as belonging to a labor-intensive aggregate, while the Italian footwear industry belongs to an aggregate with a higher capital intensity.[10] For any ISIC industry, cross-country differences in factor intensity might reflect the fact that countries specialize in goods that differ in quality. It might also be the result of an international fragmentation of the production process, with the labor-rich countries specializing in the production stages that are labor-demanding. The aggregation has important consequences: goods are defined according to their capital intensity as in the production side of the HO model (when there is no factor intensity reversal as assumed in this paper); we reduce the number of "goods". In addition, Figure 5 shows that, at least in our example, production indeterminacy greatly vanishes when we consider the two capital-intensive goods together: the production level of this capital-intensive "aggregate" and the production level of the labor-intensive good are almost determinate. By grouping industries in HO aggregates, we might partially solve the indeterminacy problem. Figure 5 indicates that the linearity of the basic model is generally lost, but is likely to remain a good approximation.

Second, following Trefler (1993), we want to take into account factor-augmenting international productivity differences. Let π^t_{fn} be the productivity of factor $f = K, L$, in country n at date t. If K^t_n is the measured quantity of capital, then the effective quantity of capital and labor are:

$$K^{*t}_n = \pi^t_{Kn} K^t_n,$$
$$L^{*t}_n = \pi^t_{Ln} L^t_n.$$

As we try to be as close as possible to the traditional 2×2 model, the relevant quantities of labor and capital are the ones used in the manufacturing sector: in the cone of diversification, the production of each aggregate is dictated by the factor proportion in each sector and the quantity of factors employed in manufacturing.[11]

We form HO aggregates as in Schott (2003). For each country, all the industries with a capital-labor ratio below a certain HO cutoff q are grouped into a labor-intensive HO aggregate, and all the industries with a capital-labor ratio above the HO cutoff are grouped into a capital-intensive HO aggregate. In country n at date t, the production of the labor-intensive aggregate is therefore:

$$Q^t_{nl} = \sum_{i:\frac{K^{*t}_{ni}}{L^{*t}_{ni}} \leq q} Q^t_{ni},$$

while the production of the capital-intensive aggregate is equal to:

$$Q^t_{nk} = \sum_{i:\frac{K^{*t}_{ni}}{L^{*t}_{ni}} > q} Q^t_{ni}.$$

[10]With product-level U.S. import data, Schott (2004) finds that factor heterogeneity also exists at the product level, with capital and skill abundant countries specializing in high value products.

[11]This is also the approach followed by Schott (2001).

We assume that the HO cutoff does not change over time: this is why q does not depend on t.

Following our assumptions, a good approximation of the value-added per worker for each HO aggregate should be of the form:

$$\frac{Q_{na}^t}{L_n^{*t}} \approx \sum_{c=1}^{3} \left[\alpha_{ca} + \beta_{ca}\frac{K_n^{*t}}{L_n^{*t}}\right] I_{\left[\tau_{c-1}^t < \frac{K_n^{*t}}{L_n^{*t}} < \tau_c^t\right]}, a = k, l. \tag{7}$$

We further assume that the cone cutoffs do not change over time. This requires that the relative price of the two aggregates does not change or that this change is compensated by a biased technological change. The validity of this assumption will be checked *ex post*.

As explained above, we have computed estimates for factor-augmenting productivity differences across countries and adjusted the capital and labor quantities accordingly. Despite this adjustment, there might still be total factor productivity (TFP) differences remaining. We take this possibility into account by incorporating time-invariant Hicks-neutral productivity differences in our empirical model. The effect of such productivity differences can be seen in Figure 6: for a relatively productive country, the production level of each aggregate is multiplied by the same factor. This is a pure scale effect. Note that, for this country, the cone cutoffs do not change, while all the intercepts and slopes are multiplied by the same factor. Equation 7 then becomes:

$$\frac{Q_{na}^t}{L_n^{*t}} \approx \sum_{c=1}^{3} \left[(1+\delta_n)\alpha_{ca} + (1+\delta_n)\beta_{ca}\frac{K_n^{*t}}{L_n^{*t}}\right] I_{\left[\tau_{c-1} < \frac{K_n^{*t}}{L_n^{*t}} < \tau_c\right]}, a = k, l. \tag{8}$$

In order to measure the effect of changes in global technological progress, we also introduce multiplicative time dummies specific to each aggregate but common to all countries. We finally obtain the empirical model we estimate:

$$\frac{Q_{na}^t}{L_n^{*t}} = (1+\delta_a^t)(1+\delta_{na}) \sum_{c=1}^{3} \left[\alpha_{ca} + \beta_{ca}\frac{K_n^{*t}}{L_n^{*t}}\right] I_{\left[\tau_{c-1} < \frac{K_n^{*t}}{L_n^{*t}} < \tau_c\right]} + \epsilon_{na}^t, a = k, l. \tag{9}$$

As can be seen in the above expression, we do not impose at the estimation stage that the δ_{na}'s are the same for both aggregates. We will check *ex post* that they are of the same order of magnitude. Estimating two different national productivity factors for the two aggregates is also informative about the impact of land or natural resources on specialization.[12]

[12]See Schott (2003) for a short discussion and Leamer (1987) for a more advanced treatment. We do not explicitly include land and natural resources in our empirical analysis for two types of reasons. First, these are likely time-invariant or nearly so, and therefore included and indistinguishable from other country specific, time invariant factors included in fixed effects. We must use these effects as there is a likely correlation between an economy's level of capital per worker and the sort of time invariant factors that would be omitted if fixed effects were not used. Second, because we examine only industrial production and not all sectors (notably the primary sector), land and natural resources are not likely to play a major role in explaining the dynamics of industrial concentration.

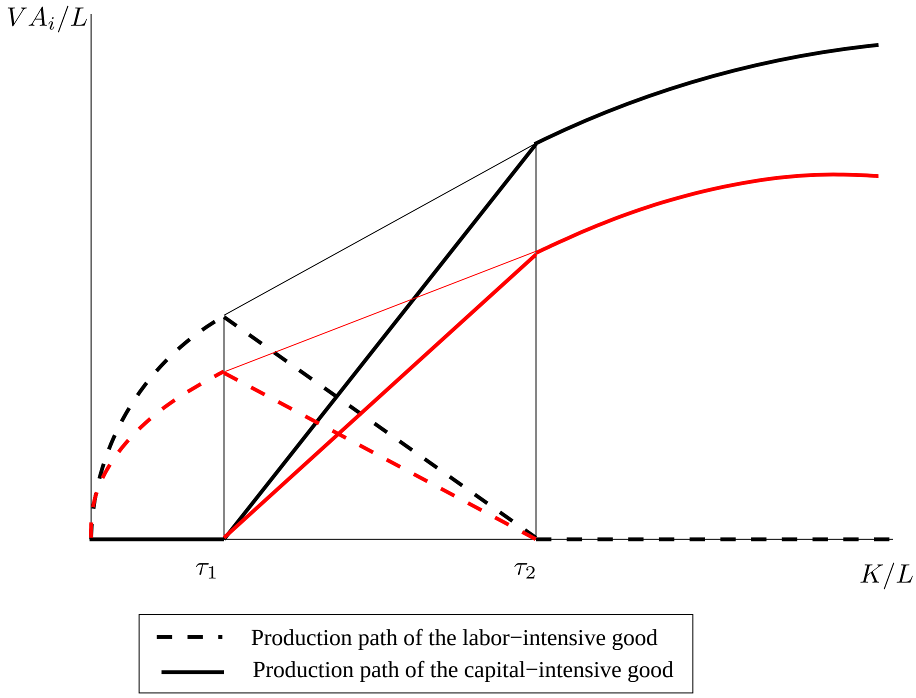

Figure 6: Production patterns in the 2×2 HO model and the scale effect.

While the approach followed by Schott (2003) is very close to the canonical HO model of production, the approach taken in our paper gets even closer to it: we can check that the return to effective capital are decreasing (when moving from one cone to another) as in neoclassical trade theory; .we allow for the possibility of cones of full specialization, which makes sense particularly when taking HO aggregates in place of the traditional goods or industries; we introduce factor-augmenting as well as Hicks neutral productivity differences between countries.

At this stage, a few words on model selection are essential.[13] We favor the standard HO model with 2 goods and 2 factors. Instead, Schott (2003) studies models with 2 factors and even cones of diversification that produce two goods, but finally he selects the model with 2 factors and two diversification cones. We want to emphasize that the 2×2 model is not simply assumed against the model with two diversification cones and three goods. The reason for choosing this model is that, as will be seen shortly, it provides a very good description of world production. But for the one willing to get closer to the model selected by Schott, our approach might be refined: we might be able to divide our capital-intensive HO aggregate between a middle HO aggregate and a (more) capital-intensive HO aggregate, as in Schott (2003). But finding the cutoff between these last two aggregates is less immediate than finding the first cutoff. A way to tackle the question is the following. As theory indicates, the countries around the cutoff

[13]Batista and Potin (2007) analyze this issue in detail.

between the middle aggregate and the more capital-intensive aggregate is impossible, then we know that the world behaves like in the HO model with two goods, and not three. Whatever the outcome of this work, our results should not be not affected for reasons exposed later.

Estimation procedure
An HO cutoff q has to be selected as well as the associated cone cutoffs. To do that, we proceed as follows:

- **Selection of the cone cutoffs**: For the HO cutoffs $q_1 = 2,500$, $q_2 = 5,000$, ..., $q_6 = 15,000$, we search for the corresponding cone cutoffs. For many cone cutoffs (τ_1, τ_2), Equation 9 is estimated with constrained Non Linear Least Squares (constrained NLLS) on the panel data we construct. The total Sum of Squared Residuals (SSR) is then computed for each set (q_i, τ_1, τ_2) by summing the SSRs for both HO aggregates. For the HO cutoff q, we select the pair $(\tau_1(q_i), \tau_2(q_i))$ such that the total SSR is minimized.

- **Selection of the HO cutoff**: We then select the HO cutoff q_i such that the total SSR associated with $(q_i, \tau_1(q_i), \tau_2(q_i))$ is minimized.

A drawback of this method is that it favors extreme (very small and very large) HO cutoffs q. With such extreme cutoffs, there is one of the two HO aggregates that gets very small. For instance, with a very small HO cutoff, the labor-intensive HO aggregate is almost empty, with just a few industries belonging to it. As a result, there is only one source of residuals (in this case, the capital-intensive HO aggregate) and the total SSR is almost automatically smaller. We therefore rely on complementary measures of model fit. First, we check that the explanatory power of the model remains high for both HO aggregates. Second, we check that, for each country, the estimated productivity differences (δ_{nl} and δ_{nk}) are of the same order of magnitude (as required).

Denoting by $\mathbf{X}$ the matrix of explanatory variables, we assume:

$$E[\epsilon_{na}^t|\mathbf{X}] = 0;\ E[\epsilon_{na}^t\epsilon_{na}^t|\mathbf{X}] = \sigma_a^2;$$

$$E[\epsilon_{na}^t\epsilon_{n'a'}^{t'}|\mathbf{X}] = 0, \text{if } n \neq n' \text{ and/or } t \neq t' \text{ and/or } a \neq a'.$$

Note that we do not assume that the error term is multiplicative and that we do not take logs in Equation 9. Actually, there is no clear reason to have heteroscedastic residuals with a variance that increases with K^*/L^*. In addition, working with logs would give more weight to the countries with a low K_n^*/L_n^* and might lead to a downward bias in the estimation of the first cone cutoff.

1	Food products; beverages; tobacco
2	Textiles
3	Wearing apparel, except footwear
4	Leather products
5	Footwear, except rubber and plastic
6	Wood products, except furniture
7	Furniture, except metal
8	Paper and products
9	Printing and publishing
10	Industrial chemicals; petroleum refineries; petroleum and coal products
11	Rubber products
12	Plastic products
13	Pottery, china, earthenware; glass; other non-metallic mineral products
14	Iron and steel; non-ferrous metals
15	Fabricated metal products; machinery, except electrical
16	Machinery, electric
17	Transport equipment
18	Professional and scientific equipment
19	Other manufactured products

Table 1: List of sectors.

3.3 Data and construction of the main variables

We use data from the United Nations Industrial Development Organization (UNIDO, 2005a,b) and the Penn World Table version 6.1 (PWT) (Heston et al., 2002).

The UNIDO data set (revision 2 at the 3-digit level) presents data for 28 sectors, but several countries aggregate data for two or more sectors (like "food products" and "beverages") into a larger one. To appropriately recognize missing data and to make data comparable across countries, we follow Koren and Tenreyro (2005) and aggregate sectors so as to obtain a consistent classification across countries. This leaves us with the 19 sectors or industries listed in Table 1. To estimate the model, we use 5-year averages for the periods 1976-1980, 1981-1985, 1986-1990, 1991-1995, and 1996-2000. We use the data for a country in a given period when they are available and when the country is reasonably open to international trade (as documented in Sachs and Warner, 1995).

Capital

To compute the stocks of capital at the industry level, we use investment data from the UNIDO at the 3-digit (UNIDO, 2005a) and 4-digit (UNIDO, 2005b) levels. The first database provides data for the period 1963-2001, and the second database covers the period 1985-2001. The second database contains data missing in the first one. The two matrices were merged.[15] We

[15]Even after merger, the database contains many holes. In order to compute stocks of capital, we had to make assumptions about these missing values. When there are holes within a sequence and when there are less than 6 consecutive years of missing data, the sequence was completed using a linear interpolation. When the

took investment in current U.S. dollars, and used exchange rates from the PWT to translate these numbers in the current national currency. Implicit national investment deflators were computed as the ratio value of national investment in current national currency units (ICUR) / value of national investment in 1996 national constant prices (IKON). We then used the perpetual inventory method to compute stocks of capital at the sectoral level. The exact formula is the one used by Leamer (1984, p. 233).[16]

In this paper, as in all works with international cross-sections involving quantities of factors, one of the main difficulties is to build data comparable across countries, which is especially true for the stocks of capital (Leamer, 1984). The approach, since Trefler (1993), is to correct for the heterogeneity in the productivity of capital. The work by Trefler (1993) is usually interpreted as indicating a strong correlation between the purchasing power parity-adjusted price of investment goods (as measured by the PWT) and their productivity. Following these results, Debaere and Demiroglu (2003a,b) used the price of investment goods given in the PWT as a measure of capital productivity. The idea is that a higher price indicates a higher quality, poorly measured by the PWT. With this method, measured investment is adjusted *upward* when investment is reported to be *costly*.

Instead, we think it is more natural to rely on Eaton and Kortum (2001) to derive estimates for the productivity of capital. They study the international trade of *equipment* goods[17] in 1985. Among other things, they try to understand why a few rich countries are the main exporters of these goods and why poor countries import so few of them. The first fact can be well explained by standard comparative advantage arguments. Eaton and Kortum (2001) explain the second fact as the result of barriers to trade, among which a low level of skills in poor countries appears to be especially important. We interpret their results as indicating that international differences in educational levels result in international productivity differences for capital goods. As a result, their estimates for the price of equipment goods for a given country can be understood as the real price of an *effective* unit of equipment good. As prices are normalized so that the U.S. price is equal to one, we can find for each country a proxy for the productivity of equipment goods (relative to the U.S.) by computing the inverse of the reported price of capital.[18] As a result, we use the measured price of equipment capital to

beginning (end) of a sequence is missing, we replaced the last (first) three missing values with an average of the first (last) three available values.

[16]We finally kept capital stock estimates only when we have at least 8 consecutive years of investment data (once holes are filled as explained in the previous note).

[17]Electrical machinery, nonelectrical machinery, and instruments.

[18]More precisely, Eaton and Kortum (2001) conduct a structural estimation of the national prices of equipemnt goods. Their empirical model is a Ricardian model with "transportation costs" and a continuum of heterogeneous goods. They estimate the costs parameters that are consistent with their model and with observed bilateral trade data. This theoretical approach and ours are notably different. Our assumption of identical selling prices might be contradicted by the existence of transportation costs. (See Deardorff (1979) on the consequence of transportation costs in the HO model.) Nevertheless, according to the reasoning exposed in the body text above, the contradiction is more apparent than real. We interpret their model as one with productivity differences that act as barriers to trade. This interpretation is consistent with the production side of the HO model and with

adjust reported investment *downward* when investment is *costly*.

Ideally we should use price estimates for each year, rather than the Eaton-Kortum's (2001) estimates for 1985. Nevertheless, this measure is broadly appropriate. First, as long as the relative GDPs per capita and the relationship between GDP per capita and the cost of capital remain constant over time, we can use relative prices in any year, including 1985. Second, for countries that catch up with the richest countries during the whole period, we should overestimate real investment in the years before 1985, and underestimate it for the years after 1985, with the measurement errors cancelling each other at least partially for the latest years. Eaton and Kortum (2001) provide estimates for many countries, but not for all the countries in our sample. For the countries without estimates, we use a predicted value based on their results.[19] Finally, investment in equipment goods is only part of the total capital investment. Our adjustment is appropriate if the real cost of the other capital goods (taking into account differences in absolute prices and productivity) is well approximated by the real cost of the equipment goods. [20]

In order to evaluate the impact of adjusting for the absence of purchasing power parity (PPP), we redo all our estimations using PPP adjusted data. The results are not significantly affected, although the overall fit is poorer, as detailed in the Appendix.

Labor

To measure the quantity of labor in a given industry and at the manufacturing level, we use data from the UNIDO database. These data are corrected for the heterogeneity of human capital using the method proposed by Hall and Jones (1999) and used, for instance, by Debaere and Demiroglu (2003a,b).[21] Data on educational achievement are from Barro and Lee (2000).

Value-added

We computed numbers for value-added in 1996 U.S. dollars, using the exchange rates and national deflators implicitly given by the PWT. Again we prefer not to use PPP-adjusted values: we assume that all goods produced with the same capital-labor ratio can be sold at the same price on international markets, as in the HO model. We conjecture that the observed deviations from absolute PPP at the retail level can be well explained by differences in distribution costs across countries. Distribution services (local land and labor) are mostly nontradable, and can therefore differ importantly across countries. As these distribution costs account for 50% of

our empirical implementation.

[19] The estimated relationship is $P_{Kn} = 4.53 - 0.70\ln(y_n^{1985})$, where y_n^{1985} is country n's real GDP per capita relative to the US in 1985 (100 for the US). We then use $\pi_{Kn} = 1/P_{Kn}$ when a price estimate is missing in Eaton-Kortum (2001).

[20] Interestingly, the strong (negative) correlation between the cost of capital and real GDP per capita suggests using trade data as Eaton and Kortum (2001) to solve the "endowments paradox" exposed by Trefler (1995).

[21] The correction factor for labor in country n at date t is $\pi_{ln}^t = \phi(s_n^t) = s_{n0}^t + s_{n2}^t e^{2\times 0.134} + s_{n4}^t e^{4\times 0.134} + s_{n6}^t e^{4\times 0.134+2\times 0.101} + s_{n8}^t e^{4\times 0.134+4\times 0.101} + s_{n10}^t e^{4\times 0.134+4\times 0.101+2\times 0.068} + s_{n12}^t e^{4\times 0.134+4\times 0.101+4\times 0.068}$, where s_{ne}^t is the fraction of the population over 25 with e years of education.

			1976-	1980	1981-	1985	1986-	1990	1991-	1995	1996-	2000
Country	Abbr.	$\frac{\pi_{K,\hat{U}SA}}{\pi_{Kn}}$	K_n^*/L_n^*	$\hat{\Pi}_{Ln}$	K_n^*/L_n^*	$\hat{\pi}_{Ln}$	K_n^*/L_n^*	$\hat{\pi}_{Ln}$	K_n^*/L_n^*	$\hat{\pi}_{Ln}$	K_n^*/L_n^*	$\hat{\pi}_{Ln}$
Australia	AUS	1.63	2.23	7,462	2.24	8,743	2.25	9,761	2.28	12,332		
Austria	AUT	1.36	2.08	17,366	2.15	20,957	2.14	25,532	2.16	31,534	2.2	32,371
Bangladesh	BGD	3.32					1.31	352	1.33	271	1.35	304
Bolivia	BOL	2.88	1.48	2,905	1.51	4,260	1.56	6,019	1.62	4,394	1.66	4,306
Bulgaria	BGR	2.18									2.14	1,737
Cameroon	CMR	2.84			1.21	5,470					1.34	8,995
Canada	CAN	1.24	2.31	9,256	2.35	12,283	2.34	14,673	2.44	19,369		
Chile	CHL	2.42	1.71	4,972	1.75	5,810	1.84	4,167	1.93	5,515	1.97	8,846
Colombia	COL	2.51	1.53	2,620	1.55	3,462	1.58	3,806	1.62	3,649	1.67	2,573
Cyprus	CYP	1.96	1.81	8,185	1.94	8,066	2.06	7,369	2.1	7,815	2.13	8,127
Denmark	DNK	1.15	2.17	19,659	2.21	19,622	2.29	19,395	2.3	18,042	2.31	18,030
Ecuador	ECU	2.52	1.6	6,316	1.69	7,664	1.74	9,372	1.79	9,523	1.83	10,673
Egypt	EGY	4.46					1.43	3,310	1.51	2,462	1.62	3,261
El Salvador	SLV	2.68					1.43	3,700	1.47	3,571	1.52	2,210
Finland	FIN	1.61	2	14,207	2.03	15,559	2.14	19,234	2.26	24,167	2.31	23,504
France	FRA	1.13									2.1	49,408
Greece	GRC	2.55	1.77	12,201	1.86	13,586	1.94	12,548	2.01	12,839	2.08	13,620
Guatemala	GTM	2.65					1.31	3,301	1.34	3,255		
Hong-Kong	HKG	1.6	1.73	4,282	1.83	4,654	1.93	6,301	2.05	10,780	2.11	17,680
Hungary	HUN	2.03							1.93	5,916	1.95	6,440
India	IND	2.07					1.36	2,029	1.4	2,678	1.46	3,989
Indonesia	IDN	2.91	1.33	1,225	1.4	1,395	1.41	1,446	1.46	1,907	1.55	5,193
Ireland	IRL	1.84	1.90	8,293	1.97	11,004	2.04	13,238	2.11	15,093	2.15	15,575
Israel	ISR	1.82	2.03	9,159	2.11	11,071	2.11	12,603	2.12	13,152	2.15	16,916
Italy	ITA	1.11	1.7	28,961	1.73	31,610	1.79	34,551	1.85	33,952	1.9	34,348
Japan	JPN	0.99	1.99	29,076	2.07	30,500	2.15	34,176	2.22	41,369	2.25	48,760
Kenya	KEN	3.69									1.37	330
Korea (Rep.)	KOR	1.47	1.81	8,718	1.97	11,575	2.14	13,590	2.28	25,239	2.37	40,988
Malawi	MWI	2.49			1.22	3,904	1.22	4,136				
Malaysia	MYS	2.33	1.49	2,378	1.55	3,167	1.62	4,269	1.81	5,680	1.94	9,607
Mexico	MEX	2.08					1.66	4,359	1.77	6,422	1.83	8,519
Netherlands	NLD	1.54	1.99	20,397	2.04	24,637	2.08	30,564	2.13	35,466	2.18	36,386
New-Zealand	NZL	2.14	2.3	6,672	2.33	10,228	2.32	13,366				
Norway	NOR	1.78	2.02	14389	2.07	17,482	2.28	19,276	2.43	20,036	2.45	18,231
Panama	PAN	2.33	1.68	5,726	1.77	4,847	1.9	4,116	1.99	4,110	2.02	4,903
Peru	PER	2.46							1.88	3,739	1.98	4,438
Philippines	PHL	2.45	1.81	1,904	1.9	2,606	1.98	2,325	2.05	2,751	2.1	3,234
Poland	POL	2.22							2.09	2,570	2.12	2,865
Portugal	PRT	1.95	1.48	6,844	1.53	8,460	1.61	7,906	1.68	7,639	1.73	8,195
Singapore	SGP	1.73	1.46	10,258	1.49	15,280	1.61	17,689	1.82	19,103	1.96	27,814
Spain	ESP	1.55			1.72	13,442	1.8	14,735	1.88	15,471	1.96	16,495
Sri Lanka	LKA	2.29			1.68	867	1.69	1,006	1.71	781	1.75	969
Sweden	SWE	1.09	2.1	21,376	2.15	24,667	2.16	27,842				
Thailand	THA	2.7							1.62	9,473	1.67	10,197
Trin. and Tob.	TTO	1.83					1.72	5,409			1.82	17,301
Turkey	TUR	2.78							1.62	6,736	1.67	7,992
U. Kingdom	GBR	0.99	1.91	12,842	1.94	17,157	1.98	19,564	2.03	23,464	2.07	27,750
USA	USA	1.00	2.48	11,025	2.58	14,454	2.61	16,378	2.65	19,100	2.67	22,360
Uruguay	URY	2.26							1.81	2,969	1.85	5,553
Venezuela	VEN	2.15							1.68	12,333		
Number of obs.	50		29		33		39		42		43	

Notes: Capital and labor are measured in effective units. Capital is in 1996 U.S. dollars.

Table 2: Geographic coverage and some key variables.

Sector	1976-1980	1981-1985	1986-1990	1991-1995	1996-2000
Wearing apparel	1581	2014	2398	2663	3905
Footwear	1,885	2,693	3,738	4,442	5,461
Furniture	3,900	4,644	4,985	5,458	5,854
Leather	3,093	4,611	5,712	6,644	7,378
Other manufactured products	5,219	6,938	7,121	7,719	9,426
Fabricated metal products	5,949	7,319	8,196	8,767	11,095
Printing and publishing	6,908	8,456	10,025	11,585	12,136
Textiles	7,405	9,121	10,353	11,668	15,380
Wood products	9,866	12,493	11,127	11,168	13,510
Professional and scientific equipment	7,807	10,585	10,660	14,834	17,602
Plastic products	10,447	12,279	12,839	14,918	17,805
Rubber products	12,431	15,413	16,074	17,075	19,341
Machinery, electric	8,122	11,615	17,660	21,647	29,832
Food products	12,816	16,815	19,299	21,082	23,589
Transport equipment	10,585	16,392	18,645	23,109	27,619
Pottery, china, earthenware	15,119	19,893	19,789	20,712	23,880
Iron and steel	20,362	29,334	32,078	33,979	35,725
Paper and products	22,823	30,740	38,563	45,946	49,697
Industrial chemicals	40,545	50,644	54,584	65,892	75,552

Notes: Capital and labor are measured in effective units. Capital is in 1996 U.S. dollars.

Table 3: United-States, industry capital-labor ratios (in increasing order).

the retail prices (Burstein *et al.* (2003)), differences in distribution prices can generate huge differences in retail prices.[22] Thus we do not assume that the law of one price holds at the retail level, but we assume that it holds at the producer level.

Correcting for the productivity and costs differences for the two factors has a significant impact on the relative capital-labor ratios: Table 2 reveals that the correction factor for capital is the most important. As a result, the relative capital-labor ratio for the typical less developed country shrinks.

3.4 Estimation of the development paths: results

Table 4 presents our results for the selection of cutoffs $(q;\tau_1(q);\tau_2(q))$. As anticipated, we find the smallest SSR when $q = q_1 = 2,500$ (1996) U.S. dollars per effective worker. But we know that this is due to the fact that, with such a small cutoff, there is only one source of residuals, the capital-intensive HO aggregate. In fact, we find that almost all of the residuals come from this second aggregate. We also find that the fit of the model is rather poor for the labor-intensive aggregate, and that the country dummies vary a lot across aggregates (δ_{nl} much

[22]Studying the behavior of real exchange rates after large devaluations, Burstein *et al.* (2005) find that deviations from *relative* PPP are well explained by the slow adjustment in the price of nontradable goods and services.

HO cutoff q	Selected cone cutoffs $\tau_1(q) - \tau_2(q)$	Total SSR
$q_1 = 2,500$	$500 - 6,500$	7.0×10^8
$q_2 = 5,000$	$2,000 - 11,500$	8.8×10^8
$q_3 = 7,500$	$3,000 - 21,000$	7.4×10^8
$q_4 = 10,000$	$3,000 - 29,500$	9.4×10^8
$q_5 = 12,500$	$3,500 - 38,500$	11.7×10^8

Notes: Details on the cone selection method are provided in the text.

Table 4: HO cutoffs and the selected cone cutoffs.

larger than δ_{nk} for most countries). Table 4 shows that the total SSR is almost as small for the HO cutoff at $q_3 = 7,500$. We can also check that, with this cutoff, the model fit is good for both aggregates and the country dummies are of the same order of magnitude. As a result, our preferred HO aggregate cutoff is $q_3 = 7,500$, with associated cone cutoffs $\tau_1(q_3) = 3,000$ and $\tau_2(q_3) = 21,000$. In the next section, we shall decompose the evolution of the national Herfindahl indexes using this cutoff of $q_3 = 7,500$, but other HO cutoffs will also be used to check the robustness of our results.

Table 5 presents the results of our estimation for the cutoffs ($q_3 = 7,500$; $\tau_1(q_3) = 3,000$; $\tau_2(q_3) = 21,000$). The period dummies appear to be small and not statistically significant. There is little change in the absolute price of each HO aggregate, or any price change has been almost exactly compensated by a biased technological progress. As a result, the relative price of the two HO aggregates does not seem to vary significantly over the 1976-1995 period. It is only in the last period (1996-2000) that there seems to be an increase in the relative price of the *labor*-intensive goods (by more than 10% compared to the 1976-1980 period). We interpret this finding as a validation of our hypothesis that the cone cutoffs do not move too much over time between 1976 and 2000.

Table 5 also shows that the Rybczynski effect is significant. In the cone of diversification, countries that accumulate capital produce less and less of the labor-intensive goods ($\hat{\beta_{1l}} > 0$ implies $\hat{\beta_{2l}} < 0$) and more and more of the capital-intensive goods ($\hat{\beta_{2k}} > 0$). As a result, capital-accumulating countries have produced more and more of the capital-intensive goods. Without the late increase in the relative price of the labor-intensive goods, countries would have produced even more capital-intensive goods, and the diversification-concentration phenomenon would have been stronger. Nevertheless, in our decomposition of the evolution of industrial concentration, what really matters is the level of the HO aggregate cutoff.

Our results indicate that the cone of diversification is fairly large, with most countries in that cone during the period 1976-2000. Contrary to Schott (2003), we find the concavity of the value-added per worker implied by the HO model.

Coefficient	Labor-intensive HO aggregate	Capital-intensive HO aggregate
$\delta_a^{1981-1985}$	-0.007	-0.007
	(0.057)	(0.029)
$\delta_a^{1986-1990}$	0.050	0.032
	(0.059)	(0.031)
$\delta_a^{1991-1995}$	-0.011	-0.040
	(-0.059)	(0.032)
$\delta_a^{1996-2000}$	0.064	-0.061
	(0.066)	(0.037)
β_{1a}	5.678***	
	(0.667)	
β_{2a}		2.237***
		(0.087)
β_{3a}		0.841***
		(0.179)
Constraints	$\alpha_{1l} = 0$	$\alpha_{1k} = 0$
	$\alpha_{3l} = 0$	$\alpha_{2k} = 0$
	$3,000\beta_{1l} = \alpha_{2l}$	$18,000\beta_{2k} = \alpha_{3k}$
	$\alpha_{2l} + 18,000\beta_{2l} = 0$	

Notes: The Table reports the estimates of Equation (9) with constrained Non Linear Least Squares. The estimates of the (country*HO aggregate) dummies are not reported. Standard errors are reported in parentheses. *** indicates statistical significance at the 1% level. These estimates take the HO aggregate cutoff $q_3 = 7,500$ to define the two HO aggregates, and the cone cutoffs $\tau_1(q_3) = 3,000$ and $\tau_2(q_3) = 21,000$ to define the cones.

Table 5: Cutoff and coefficient estimates for the 2×2 model.

4 Heckscher-Ohlin and the U-shaped industrial concentration curve

4.1 Decomposing the change in the Herfindahl index

We now turn to the main object of this paper: the evolution of industrial diversification and specialization patterns. To measure the concentration of a country's manufacturing sector, we focus on the Herfindahl index (HI), defined for country n at date t as:

$$HI_n^t = \sum_{u=1}^{S} \left(\frac{VA_{nu}^t}{\sum_{v=1}^{S} VA_{nv}^t} \right)^2,$$

with VA_{nu}^t the value-added of sector u. This concentration index is shown by Koren and Tenreyro (2006) to be one of the main components of a country's GDP variance: indeed, everything else equal, the countries with most concentrated manufacturing sectors are the ones with the most volatile growth rates.

To isolate the effect of the neoclassical factors, we proceed as follows. With two HO aggregates, we can decompose the HI as:

$$HI_n^t = \left(s_{nl}^t\right)^2 HI_{nl}^t + \left(s_{nk}^t\right)^2 HI_{nk}^t$$

with

$$s_{nl}^t = \frac{\sum_{i=1}^{S_l^t} VA_{nl_i}^t}{\sum_{j=1}^{S} VA_{nj}^t} \text{ and } HI_{nl}^t = \sum_{i=1}^{S_l^t} \left(\frac{VA_{nl_i}^t}{\sum_{j=1}^{S_l^t} VA_{nl_j}^t} \right)^2$$

and similarly for the k aggregate. The total HI is a weighted sum of the HI's at the HO aggregate level, with the weights equal to the shares of the aggregates raised to the square. It is straightforward to show that:

$$\Delta HI_n^{t,t+1} \equiv HI_n^{t+1} - HI_n^t = \underbrace{\sum_{a=l,k} \overline{s_{na}^2} \left(HI_{na}^{t+1} - HI_{na}^t\right)}_{\text{within-aggregate change}} + \underbrace{\sum_{a=l,k} \left[\left(s_{na}^{t+1}\right)^2 - \left(s_{na}^t\right)^2\right] \overline{HI_{na}}}_{\text{between-aggregate change}}, \quad (10)$$

with

$$\overline{s_{na}^2} = \frac{s_{na}^{t^2} + s_{na}^{t+1^2}}{2} \text{ and } \overline{HI_{na}} = \frac{HI_{na}^t + HI_{na}^{t+1}}{2}.$$

We now study four hypothetical cases serving as examples to provide simple intuition about this decomposition.[23] In all cases, there are two aggregates with two industries in each aggre-

[23] This decomposition is different from, but reminiscent of the decomposition used by Bound et al. (1994) or Bernard and Jensen (1997) to study changes in the composition of the workforce in U.S. manufacturing (unskilled versus skilled workers).

gate.

Case 1: The Rybczynski effect

This is the mechanism exposed in Subsection 2.1. Value-added in the four industries changes as follows:

$$(VA^t_{l_1}, VA^t_{l_2}, VA^t_{k_1}, VA^t_{k_2}) = (10, 10, 10, 10) \rightarrow (VA^{t+1}_{l_1}, VA^{t+1}_{l_2}, VA^{t+1}_{k_1}, VA^{t+1}_{k_2}) = (10, 10, 20, 20).$$

Concentration does not change within each aggregate and therefore there is no within-aggregate change. We have $\Delta HI^{t,t+1}_n = 0.278 - 0.250 = \sum_{a=l,k} \left(s^{t+1^2}_{na} - s^{t^2}_{na} \right) \times \frac{1}{2} = -0.069 + 0.097$. The concentration index goes up as the shares of the two aggregates become more unequal. The between-effect can be considered to be an "Heckscher-Ohlin effect": it is due to a shift of production to a set of goods that use a factor intensively. Such a shift can be explained by the neoclassical trade model and its direct extensions: Rybczynski effects, biased technological progress, change in relative prices, or a decline in transportation costs combined with comparative advantages *à la* HO.

Case 2: The effect of the heterogeneity in HI_a

In the above example, the Herfindahl indices were the same for the two aggregates. By doing so, we could isolate the mechanism introduced at the beginning of the paper. But one must recognize that it is the interaction between the changes in shares and the concentrations of the aggregates that matters. Everything else equal, the HI for manufacturing increases when the share of the most concentrated HO aggregate goes up.

As a result, the between-effect can be positive even though the two aggregate shares become more equal: this can happen when the growing aggregate is more concentrated than the other one. This is the case when, for instance, the structure of production changes like this:

$$(VA^t_{l_1}, VA^t_{l_2}, VA^t_{k_1}, VA^t_{k_2}) = (5, 25, 30, 30) \rightarrow (VA^{t+1}_{l_1}, VA^{t+1}_{l_2}, VA^{t+1}_{k_1}, VA^{t+1}_{k_2}) = (10, 50, 30, 30).$$

This result contradicts our initial intuition, but once again this is specialization *à la* HO (combined with the unequal concentration of the two aggregates) that drives the results.

Our empirical results show that the later particular situation is unusual: in a vast majority of cases, the shares of the two aggregates become more unequal when the between effect is positive, and the shares become more equal when the between effect is negative.

Case 3: Within effect only

Suppose that value-added changes as follows:

$$(VA^t_{l_1}, VA^t_{l_2}, VA^t_{k_1}, VA^t_{k_2}) = (10, 10, 10, 10) \rightarrow (VA^{t+1}_{l_1}, VA^{t+1}_{l_2}, VA^{t+1}_{k_1}, VA^{t+1}_{k_2}) = (10, 20, 10, 20).$$

The share of each aggregate does not change: there is no between effect. The Herfindahl index changes by $\Delta HI^{t,t+1}_n = 0.278 - 0.250 = \sum_{a=l,k} \frac{1}{4} \times (HI^{t+1}_{na} - HI^t_{na}) = 0.014 + 0.014$. The concentration index rises as each aggregate becomes more concentrated. A significant within effect can be due to a decline in transportation costs combined with comparative advantages *à la* Ricardo, or with economies of scale as studied in the new economic geography literature.

Case 4: Between effect and within effect together

What's happening when a relatively large sector grows in a given HO aggregate? There should be both a within effect and a between effect: the HO aggregate that contains this good becomes more concentrated, and the share of this HO aggregate goes up. This can be observed with the following hypothetical case:

$$(VA^t_{l_1}, VA^t_{l_2}, VA^t_{k_1}, VA^t_{k_2}) = (10, 10, 10, 10) \rightarrow (VA^{t+1}_{l_1}, VA^{t+1}_{l_2}, VA^{t+1}_{k_1}, VA^{t+1}_{k_2}) = (10, 10, 20, 10).$$

The Herfindahl index changes by $\Delta HI^{t,t+1}_n = 0.280 - 0.250 = 0.017 + 0.013$, where 0.017 is the within effect and 0.013 is the between effect.

The composition effect

When computing this decomposition, we rely on one of two procedures: either we take the actual composition of the HO aggregates at each date, or we keep it constant over time to get rid of a "composition effect", due to the fact that some ISIC sectors move across aggregates over time. When this occurs, we might have a case in which the share of each sector remains constant over time, and one sector moves to the largest aggregate. In such a situation, the overall HI does not change, but the measured between effect tends to be positive. To control for this "composition effect", we define:

$$\widetilde{HI}^{t+1}_{na} = \sum_{i=1}^{N^t_a} \left(\frac{VA^{t+1}_{na_i}}{\sum_{j=1}^{N^t_a} VA^{t+1}_{na_j}} \right)^2, \qquad a = l, k$$

meaning that we keep the composition of the HO aggregates constant over time.Note that in the above examples, industries are supposed to remain in the same aggregate over time: there is no composition effect, and the two measures (with and without correction for the composition effect) coincide.

The two measures are complementary and it is not obvious that the second one (with the correction) is better than the first one. When one industry moves from one aggregate to another, this is of interest as this indicates a shift to the production of another type of products within the same ISIC industry, which is also a kind of Heckscher-Ohlin specialization. As a result, we shall insist on the countries for which the two measures have the same sign: when they are both positive for a given country, this shows that the between-effect made the country's industry more concentrated, while two negative measures indicate that the between-effect lead to a more diversified industry. Nevertheless, one should keep in mind that the measure taking into account the composition effect is much easier to interpret.

One might argue that we obtain the U-shaped curve because we assume that there are two HO aggregates. The situation looks different in the case with three aggregates, like in Schott's (2003) preferred model. In that case, a country starting with a very small K^*/L^* that accumulates capital will first diversify producing goods in both the labor-intensive HO aggregate and the middle HO aggregate, but will then exhibit a concentration of its manufacturing sector, producing only the middle HO aggregate. Thus, when one plots the Herfindahl index at the HO aggregate level $(s_l^2 + s_m^2 + s_k^2)$, there is a U-curve when the country moves across the first cone. If the country then moves across the second cone, there will be a second U-curve. This seems to contradict the single U-curve observed in the data. We might still reconcile this implication of theory with the observed facts: we still get the U-curve when the middle aggregate is much more diversified than the two extreme ones, which is likely to be true. Equation 7 makes that mechanism clear.

It must also be noted that our empirical approach fails to measure changes in specialization within an HO aggregate due to changes in factor proportions (like a move towards capital-intensive goods within the capital-intensive HO aggregate when there is capital accumulation).For that reason, the results that follow should be interpreted as lower bounds to the total concentration/diversification effect of factor accumulation.

Results of the decomposition

Using the methodology just proposed, we decompose changes of industrial concentration over 10-year intervals. Namely, we consider changes in the Herfindahl index (ΔHI) and its between (BE) and within components(WE) over three moments in time: 1976-1980, 1986-1990 and 1996-2000. Tables 6 and 7 present results for both unadjusted and adjusted (for compositional effects) data.

We observe important differences (namely an average reduction in the relative contribution of the between effect to the overall HI change) due to the compositional adjustment of HO aggregates. This is evidence of significant movements of ISIC industries across HO aggregates over time, as their capitalistic intensity varies.

For the adjusted case, we find that the between effect is positive for approximately one half of the countries from 1976 to 1990, indicating a positive contribution to industrial concentration. This effect has a magnitude of roughly 30% of the observed contributions to concentration changes. On the contrary, from 1986 to 2000, the between effect takes a negative sign for most countries, thereby generally contributing to industrial diversification. Its relative magnitude attained 27% of the total (absolute) magnitudes of between and within effects.

		Including Composition Effect			Corrected for Composition Effect		
Country	ΔHI x1000	WE x1000	BE x1000	|BE| as % |BE|+|WE|	WE x1000	BE x1000	|BE| as % |BE|+|WE|
Australia	-2.1	-13.0	10.8	45.5%	-3.2	1.0	24.9%
Austria	-0.1	-5.7	5.5	49.4%	-1.7	1.5	47.7%
Bolivia	159.6	264.8	-105.2	28.4%	152.5	7.0	4.4%
Canada	1.9	6.1	-4.3	41.0%	1.5	0.4	19.6%
Chile	25.4	1.2	24.2	95.3%	12.9	12.4	49.1%
Hong-Kong	-14.6	38.0	-52.6	58.1%	-12.8	-1.9	12.9%
Colombia	5.2	-4.0	9.2	69.6%	6.4	-1.4	17.5%
Cyprus	9.5	12.3	-2.8	18.5%	9.4	-0.1	1.1%
Denmark	2.2	-3.6	5.8	61.8%	0.6	1.7	74.4%
Ecuador	-19.1	-147.5	128.5	46.5%	-8.7	-10.4	54.3%
Egypt	-20.6	-25.7	5.1	16.4%	-24.5	3.6	12.8%
Finland	7.8	2.8	5.0	63.7%	7.4	0.4	5.1%
Greece	6.2	8.5	-2.3	21.5%	8.3	-2.1	19.9%
Guatemala	9.4	6.7	2.7	29.0%	6.7	2.7	28.9%
Hungary	3.9	0.9	3.0	75.8%	3.8	0.0	1.2%
Indonesia	-47.0	-47.0	0.0	0.0%	-47.2	0.0	0.0%
Ireland	7.6	-18.4	26.0	58.5%	17.1	-9.4	35.4%
Israel	12.1	-17.4	29.4	62.9%	14.3	-2.0	12.4%
Italy	2.9	-5.2	8.1	60.9%	3.5	-0.5	13.4%
Japan	11.7	11.0	0.7	6.2%	10.9	0.7	6.3%
Jordan	36.7	10.1	26.6	72.6%	19.7	17.0	46.3%
Korea, Rep.	-9.9	-40.9	31.0	43.1%	-0.6	-9.3	93.6%
Malaysia	-11.8	22.6	-34.4	60.4%	-12.0	0.0	0.0%
Netherlands	14.9	7.9	7.0	47.0%	10.5	4.3	29.0%
New Zealand	5.4	-61.9	67.3	52.1%	-2.2	7.5	77.5%
Norway	14.1	1.8	12.3	87.1%	15.4	-1.2	7.3%
Pakistan	-26.2	-25.7	-0.6	2.1%	-25.3	-0.8	3.0%
Panama	9.8	-24.0	33.8	58.5%	-30.9	41.0	57.0%
Philippines	34.6	49.9	-15.3	23.5%	34.5	0.0	0.0%
Portugal	-0.1	-9.3	9.2	49.6%	1.3	-1.5	53.3%
Singapore	44.8	10.1	34.6	77.3%	33.9	10.7	24.0%
Sweden	0.1	-2.7	2.8	51.2%	-47.6	-8.1	14.5%
Turkey	15.3	-27.6	42.9	60.8%	-6.4	21.6	77.3%
UK	-3.1	-6.1	2.9	32.7%	-0.1	-3.0	96.5%
Tanzania	22.2	22.2	0.0	0.0%	22.3	0.0	0.0%
USA	-3.0	-20.7	17.7	46.1%	-1.7	-1.2	41.6%
Venezuela	-7.3	-14.0	6.7	32.3%	-18.6	11.2	37.5%
Average (N=37)	8.1	-1.2	9.2	46.1%	4.0	2.5	29.7%

Table 6: Decomposition of ΔHI, 1976-1980 to 1986-1990.

		Including Composition Effect			Corrected for Composition Effect		
Country	ΔHI x1000	WE x1000	BE x1000	|BE| as % |BE|+|WE|	WE x1000	BE x1000	|BE| as % |BE|+|WE|
Austria	-1.1	-1.1	0.0	0.0%	-1.1	0.0	0.0%
Bangladesh	-48.9	-48.9	0.0	0.0%	-48.7	0.0	0.0%
Bolivia	-46.2	-214.2	168.0	44.0%	-180.8	134.7	42.7%
Chile	4.7	5.4	-0.7	12.0%	-40.8	45.4	52.7%
Hong-Kong	-11.5	-87.8	76.3	46.5%	-1.6	-9.8	85.7%
Colombia	18.0	12.4	5.6	31.3%	13.0	5.1	28.1%
Cyprus	39.1	-1.5	40.7	96.3%	38.4	1.0	2.4%
Ecuador	135.6	76.8	58.9	43.4%	169.5	-33.7	16.6%
Egypt	10.7	-17.8	28.4	61.5%	3.7	7.2	66.4%
El Salvador	-44.4	-44.4	0.0	0.0%	-44.6	0.0	0.0%
Finland	15.8	12.5	3.3	20.6%	27.0	-11.1	29.2%
Greece	20.9	26.8	-5.9	18.1%	38.3	-17.6	31.5%
Hungary	23.6	13.4	10.2	43.3%	23.7	0.0	0.1%
India	12.0	45.5	-33.5	42.4%	11.9	0.0	0.0%
Indonesia	-28.6	7.8	-36.4	82.4%	-28.5	0.0	0.0%
Ireland	36.7	33.4	3.3	9.0%	19.7	17.2	46.6%
Israel	-3.8	-2.5	-1.4	35.9%	12.7	-16.7	56.7%
Italy	17.6	17.6	0.0	0.0%	17.6	0.0	0.0%
Japan	4.7	3.5	1.2	26.5%	12.9	-8.1	38.6%
Jordan	-10.2	117.3	-127.5	52.1%	34.0	-44.4	56.6%
Korea, Rep.	20.3	7.4	12.9	63.5%	35.5	-15.2	30.0%
Malaysia	40.9	-71.5	112.4	61.1%	45.1	-4.2	8.6%
Mexico	-2.9	18.2	-21.1	53.7%	0.3	-3.1	92.1%
Netherlands	2.1	2.1	0.0	0.0%	2.1	0.0	0.0%
Nigeria	16.0	16.0	0.0	0.0%	16.1	0.0	0.0%
Norway	-9.5	-5.3	-4.2	43.8%	-3.1	-6.4	67.5%
Pakistan	-8.6	-116.4	107.8	48.1%	-20.1	11.4	36.2%
Panama	66.1	195.7	-129.7	39.9%	65.9	0.0	0.0%
Peru	27.0	40.1	-13.2	24.7%	27.1	0.0	0.0%
Philippines	-49.4	-25.2	-24.2	49.0%	-49.9	0.5	1.0%
Poland	-13.7	-10.5	-3.2	23.2%	-13.7	0.0	0.0%
Portugal	-13.7	-17.8	4.1	18.8%	-13.3	-0.4	2.7%
Singapore	40.3	26.2	14.1	34.9%	77.6	-37.0	32.3%
Spain	-1.8	2.3	-4.1	63.8%	14.3	-16.0	52.9%
Sri Lanka	-88.5	-88.5	0.0	0.0%	-88.7	0.0	0.0%
Turkey	-17.0	-46.7	29.7	38.9%	-4.3	-12.6	74.4%
UK	0.5	-0.6	1.1	65.4%	6.5	-6.0	48.1%
USA	3.3	0.8	2.5	75.2%	21.9	-18.6	45.9%
Venezuela	48.8	-155.1	203.9	56.8%	48.0	0.9	1.9%
Average (N=39)	5.3	-7.0	12.3	36.6%	6.2	-1.0	26.9%

Table 7: Decomposition of ΔHI, 1986-1990 to 1996-2000.

Overall, our results point to neoclassical factors (namely factor accumulation, changes in relative prices, biased technological change) explaining at least one third of observed changes in industrial concentration. This is only a lower bound to the actual impact of these factors: indeed, including compositional effects implies an increased contribution of a share of 46% and 37% in the first and second periods considered, respectively; moreover, these numbers abstract from the fact that factor accumulation likely impacts within effects. Nevertheless, it is clear that there is plenty of room for other types of explanations for changes in patterns of industrial diversification and specialization.

4.2 The shares of the HO aggregates and the Rybczynski effect

In this section we investigate what fraction of changes in industrial specialization between aggregates is due to neoclassical factors (change in K/L, change in relative prices, biased technological change). We compute the shares of both aggregates as predicted by our estimates:

$$\widehat{\left(\frac{Q_{na}^t}{L_n^{*t}}\right)}_{HO} = (1+\widehat{\delta_a^t})(1+\widehat{\delta_{na}}) \sum_{c=1}^{3} \left[\widehat{\alpha_{ca}} + \widehat{\beta_{ca}} \frac{K_n^{*t}}{L_n^{*t}}\right] I_{\left[\hat{\tau}_{c-1} < \frac{K_n^{*t}}{L_n^{*t}} < \hat{\tau}_c\right]}, a = k, l. \tag{11}$$

The predicted share of aggregate l is computed as:

$$\widehat{\left(s_{nk}^{t+1}\right)}_{HO} = \frac{\widehat{\left(\frac{Q_{nk}^{t+1}}{L_n^{*t+1}}\right)}_{HO}}{\widehat{\left(\frac{Q_{nl}^{t+1}}{L_n^{*t+1}}\right)}_{HO} + \widehat{\left(\frac{Q_{nk}^{t+1}}{L_n^{*t+1}}\right)}_{HO}}. \tag{12}$$

We can then compute the change in shares for both aggregates explained by our model:

$$\widehat{\left(s_{nk}^{t+1}\right)}_{HO} - \widehat{\left(s_{nk}^{t}\right)}_{HO}.$$

Figures 11 and 12 report the actual changes in the share of the labor-intensive aggregate, as well as the changes predicted by the neoclassical factors. Changes of specialization across aggregates are indeed well explained by the neoclassical factors emphasized here (Rybczynski effect, change in the relative price of the two HO aggregates, technological change biased towards an HO aggregate). As a result, when computing the between-aggregate change, we get a good estimate of the change of HI due to the neoclassical factors.

Our final objective is, however, to evaluate the role played by factor accumulation in determining diversification-concentration patterns. This type of factor accumulation implies a Rybczynski effect that should mainly cause between-aggregate changes. Because there are other factors leading to between-aggregate changes, it is important to isolate the Rybczynski effect.[24]

For this purpose, we compute an estimate of the value-added per worker in country n that would have been observed without any change in the coefficients of the model or in the country residuals, but with changes in K_n/L_n:

$$\widehat{\left(\frac{Q_{na}^t}{L_n^{*t}}\right)}_{RYB} = (1+\widehat{\delta_{na}})\sum_{c=1}^{3}\left[\widehat{\alpha_{ca}}+\widehat{\beta_{ca}}\frac{K_n^{*t}}{L_n^{*t}}\right] I_{\left[\hat{\tau}_{c-1}<\frac{K_n^{*t}}{L_n^{*t}}<\hat{\tau}_c\right]}, a = k, l. \tag{13}$$

The new predicted share of aggregate k is given by:

$$\widehat{\left(s_{nk}^{t+1}\right)}_{RYB} = \frac{\widehat{\left(\frac{Q_{nk}^{t+1}}{L_n^{*t+1}}\right)}_{RYB}}{\widehat{\left(\frac{Q_{nl}^{t+1}}{L_n^{*t+1}}\right)}_{RYB}+\widehat{\left(\frac{Q_{nk}^{t+1}}{L_n^{*t+1}}\right)}_{RYB}}. \tag{14}$$

We then compute the change in shares for both aggregates explained by the Rybczynski effect only:

$$\widehat{\left(s_{nk}^{t+1}\right)}_{RYB} - \widehat{\left(s_{nk}^{t}\right)}_{RYB}.$$

It turns out that the Rybczynski effect is by far the most important factor explaining the evolution of industrial specialization across HO aggregates. Figures 11 and 12 show that the Rybczynski effect is indeed important in explaining changes in specialization at the HO aggregate level: for many countries, the change in the share of the first HO aggregate is close to the observed changes, both for the 1975-1985 period and the 1985-1995 period (i.e. close to the 45-degree line). For 1985, we tend to slightly overestimate the share of the labor-intensive aggregate: one explanation is that its relative price went down during the period. By taking this change into account, the change estimated based on the neoclassical factors is closer to the actual one. This is rather the opposite for the 1985-1995 period: in that case, the relative price of the labor-intensive goods went down, and the estimated share in 1995 is higher when using all the neoclassical factors. Nevertheless, those results indicate that, among the neoclassical factors, the Rybczynski effect is hugely dominant. It is therefore changes in the countries capital-labor ratios that explain most of the switch of production from one HO aggregate to the other one.

Focusing on 14 developing countries over the 1982-1992 period, Xu (2003) runs Rybczynski regressions at the industry level. He finds that developing countries tend to specialize in *labor*-intensive goods when they accumulate capital. Even if we find this to be true for Colombia

[24] Production of each HO aggregate is also determined by the relative price of the aggregates, and by the technology used to produce each aggregate. In our framework, it turns out that these two effects are empirically equivalent.

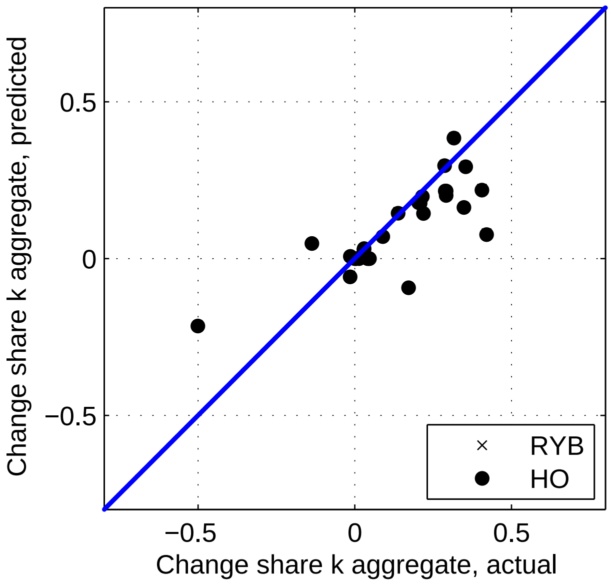

Figure 7: Changes in the share of the capital-intensive HO aggregate, actual, attributed to HO factors, and attributed to the Rybczynski effect only, (1976-1980) - (1986-1990).

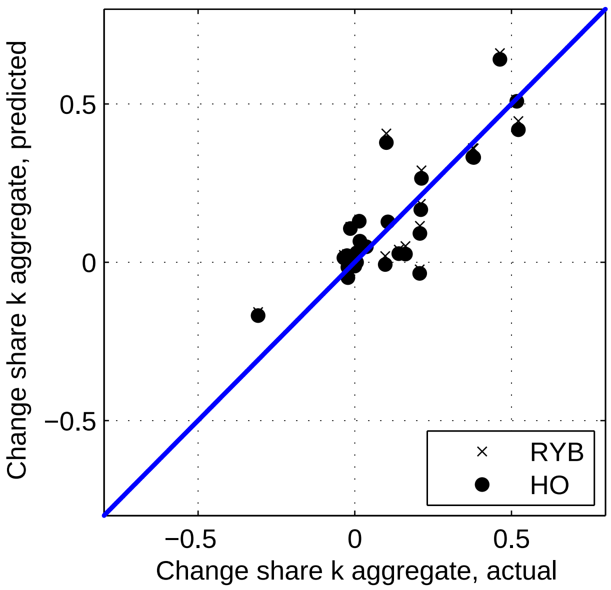

Figure 8: Changes in the share of the capital-intensive HO aggregate, actual, attributed to HO factors, and attributed to the Rybczynski effect only, (1986-1990) - (1996-2000).

between the late 1970s and the late 1980s, our results confirm that, on average, the Rybczynski effect seems to explain specialization even for developing countries. Why such a difference? First, we measure the capital/labor ratio in the manufacturing sector while Xu takes the national one. Second, the period under consideration is different, our being much broader. Third, ranking industries according to their average capital-intensity in the 1982-1992 period cannot take into account important changes in factor intensity, whereas we allow industries to move across aggregates. And, finally, running regressions at the industry level might hide the fact that, on average, the overall share of the capital-intensive goods went up, something we can measure because we construct HO aggregates.

5 Conclusion

In this paper, we make contributions in two directions. First, we build on Schott (2003) to develop a more complete test of the production side of the HO model. Special attention is given to intra-industry heterogeneity in factors of production and to the potentially indeterminate nature of production. Using data for 50 countries during the period 1976-2000, we find that countries do produce as predicted by the model. By comparing our estimates for the different years, we can study the actual development path of each country.

Second, we argue that the HO model provides possible explanations for the two stages of development documented by Imbs and Wacziarg (2003): the U-curve for industrial concentration may be the direct result of neoclassical factors such as capital accumulation (Rybczynski effect), biased technological progress or changes in relative prices. We develop a methodology to measure the contribution of those neoclassical factors. We find that these factors, and mainly capital accumulation, explain at least 30% of the evolution of industrial concentration. While this is a substantial (loer bound to the) impact, it indicates that a significant part of that change remains unexplained by the standard neoclassical factors: specialization with economies of scale, risk diversification or other forces are also part of the story. In this paper, we propose a first measure of the total contribution of these non-neoclassical elements. Their respective contributions remain to be determined.

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