PATHS OF DEVELOPMENT, SPECIALIZATION, AND NATURAL RESOURCES ABUNDANCE*

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Abstract

This paper addresses three main questions; how can a country specialized in primary goods become an exporter of manufacturing goods? How does factor abundance affect the possibilities of achieving comparative advantages in manufactures? Does the type of natural resource abundance make any difference to the path of development? Based on factor-endowment-driven specialization, we study the trade patterns along the paths of development for a large sample of countries in the last four decades. Consistently with the idea that countries are located in different cones of diversification, we found that net exports are a non-linear function of the capital/labor ratio of the economy. The pattern of the creation of comparative advantages as a country develops depends not only on whether it is natural resource abundant or not, but also on the type of natural resources that abound. For instance, mineral-abundant countries are positioned in a diversification cone with low levels of capital per worker and where they are net importers of all manufacturing goods. In contrast to countries with comparative advantages in forestry and agricultural products, mining countries are the least likely group to change their specialization pattern towards manufacturing goods.
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1. Introduction

The strategy of development based on natural resources is particularly controversial. Several decades ago, the ideas of Singer (1950) and Prebisch (1950) on secular deterioration of international prices of raw materials and commodities had a great impact on the development strategies followed by the developing world. A large number of less developed countries implemented an industrialization strategy based on import substitution that had profound damaging effects on their economic performance (Edwards, 1993; Taylor, 1998).

More recently, the so-called *natural resources curse* has revived the old debate concerning the growth consequences of natural resource abundance. This debate was greatly influenced by the empirical evidence provided by Sachs and Warner (1995), showing that countries rich in natural resources have experienced lower economic growth rates than poorly endowed ones. Later evidence provided by Sachs and Warner (2001), Gylfason (2001) and Kroneberg (2004) has confirmed the existence of a negative relationship between natural resource abundance and economic growth. The issue, however, remains in dispute. Some authors have analyzed the robustness of these results to alternative econometric techniques, while others have focused on explaining what are the factors underlying this negative relationship (Rodriguez and Sachs, 1999; Leite and Weidman, 2002; Lederman and Maloney, 2002; Hausmann and Rigobon 2003, Mehlmun, et. al. 2005; Hodler, 2005).

A country's specialization in natural resources has been indicated as not only harmful for economic growth, but also as having negative consequences for income distribution. Leamer et al. (1999), for example, have shown that resources rich countries may exhibit a specialization pattern that increases income inequality. They argue that specialization based on natural resources would explain why Latin America, a region so abundant in natural resources, at the same time has some of the highest inequality indices around the world. The idea is that natural-resource-intensive sectors absorb the scarce capital in these economies, delaying industrialization. The absence of incentives to accumulate human capital increases inequality and makes the surge of manufacturing industries that require skilled labor more difficult.

Perhaps based on these considerations, many scholars and policy makers have argued that developing economies should change their specialization patterns toward manufacturing goods to achieve higher economic growth and a more equitable income distribution. Edwards (1997), for example, has argued that a key challenge for Latin American policy makers is to increase net exports of higher-value-added manufactures. In the same vein, Gylfason (2004) claims that "an important challenge to policy makers in many developing countries with abundant natural resources is to find ways to reduce their dependence on these resources, through successful diversification of economic activity".[1]

This challenge generates important questions for developing countries. How can a country specialized in primary goods become an exporter of manufacturing goods? How does factor abundance affect the possibilities of achieving a comparative advantage in manufactures? Does the type of natural resource abundance make any difference to the path of development? These are the main questions that we try to answer in this paper. Based on factor-endowment-driven specialization, we study the trade patterns along the paths of development for a large sample of countries in the last four decades. To do that, we focus on the relationship between net exports of four manufacturing aggregates and factor endowments. We are particularly interested in analyzing whether resource abundant countries follow a different path of development from that of resource scarce countries. In addition, we examine whether the type of resource abundance matters for the pattern of specialization.

Several papers have explored the relationship between country specialization and factor endowment.[2] Our work, however, is the first to assemble the following four features: First, using net exports as a measure of comparative advantage, in line with Leamer (1984); Second, using panel data to study the relationship between this variable and factors endowment; Third, analyzing the existence of a non-linear relationship between net exports and factor endowments. This empirical approach is based on the idea

[1] World Bank (2001) presents a more optimistic view arguing that what matters is not what goods countries produce, but how they produce. Scandinavian countries that have been able to grow based on their natural resource abundance, however, have motivated most of this view. Bravo-Ortega and De Gregorio (2005) present both a theoretical model and empirical evidence on how economic growth and factor abundance is possible for economies with high levels of human capital.

[2] For a survey, see Harrigan (2003).

that countries inhabit different cones of diversification depending on their abundance of natural resources. Leamer (1987) has estimated a non-linear relationship between manufacturing industry shares and endowments. Schott (2003) also looks for the existence of diversification cones with a different econometric methodology. In both cases, by using cross-section data, they only exploit the cross-country differences in specialization. By using panel data and fixed effects techniques, we consider within-country variations in specialization.[3] Fourth, studying how the development paths—or movements across cones of diversification—depend on the type of natural resource abundance. We estimate the relationship between net exports and capital accumulation to be dependent on three types of resource abundant economies; mining, agricultural and forestry products. In contrast, most of previous evidence has controlled for resource abundance using simple measures of land abundance.

This paper is structured as follows. In section 2, we discuss the conceptual framework for studying specialization patterns. In section 3, we describe our data and present preliminary evidence on specialization dynamics. By computing transition probability matrices for different manufacturing aggregates and resource abundance, we investigate if there are differences in specialization dynamics across products and factor abundance. In general, our results suggest that mobility tends to be different for different groups of products. In addition, we find no evidence that natural resource abundant countries experience less mobility in their patterns of specialization than resource scarce countries. In section 4, we present our estimates and discuss our results on development paths. Our results are consistent with the idea that countries are located in different cones of diversification, a conclusion that is consistent with previous evidence provided by Leamer (1987) and Schott (2003). However, one distinction in our work is that we uncover differences according to the type of resource abundance. Natural resource scarce countries follow a completely different development path from the one followed by resource abundant countries. For poor natural resource countries, initial comparative advantage in labor-intensive industries changes to more capital-intensive goods. The experience of resource abundant countries also varies depending on the type of resource

[3] Lederman and Xu (2001) also use panel data and net exports, but they do not study whether countries follow different development paths according to their abundance of natural resources.

abundance. Countries endowed with resources amenable to the production of agricultural products develop comparative advantages in labor-intensive goods and chemicals. By contrast, countries endowed with factors amenable to the production of forestry goods are able to change their specialization patterns first towards labor-intensive goods and machinery, and then to the capital-intensive manufacturing aggregate. Mineral abundant countries, however, given their low levels of capital per worker, are positioned in a diversification cone where they are net importers of all manufacturing goods. Finally, in section 5 we summarize the main results.

2. Factor-endowment-driven specialization

In this section, we discuss the main implications for specialization in an economy rich in natural resources. Our theoretical approach is based on the Heckscher-Ohlin model that explains production and trade patterns by differences in countries' factor endowments. This model predicts that a country has comparative advantages in those goods that use more intensively its more abundant productive factor. The basic model with two goods and two factors (capital and labor) is, however, too simple for discussing differences in development paths. In this model, according to the Rybczynski theorem, capital accumulation increases output in the more capital-intensive good and it reduces output in the labor-intensive good.

Leamer (1987) extends the traditional model to a case with three factors and *n* goods. In this context, it is possible to analyze how countries with different endowments experience dissimilar development paths. One interesting feature of this model is that economies are located in different diversification cones, which are defined by the mix of products in which the economy specializes. This model predicts different development paths depending on natural resource abundance. By contrast, the *2xn* model indicates that all countries follow the same development path. With only two factors, capital accumulation changes the output mix from labor-intensive goods to more capital-intensive goods.

In Figure 1, we illustrate the case of 2 factors and 3 goods. In panel A, using a Lerner-Pearce diagram, we show a "poor" capital economy specialized in apparel and

textiles, and a "rich" capital economy producing textiles and machinery. The Rybczynski theorem predicts that capital accumulation in the poor economy increases output in textiles and reduces output in apparel. Further increases in capital could make the production of machinery profitable; thus, this economy would stop producing apparel and shift its specialization to more capital-intensive goods. Panel *b* illustrates these changes in output of each good as long as the economy increases its capital per worker.

By introducing a third factor, Leamer (1987) has shown that development paths will be different depending on the relative abundance of natural resources. The output mix of resource-rich economies will be different from that in resource-poor economies. Consequently, capital accumulation will generate transitions to different diversification cones across countries.

Figure 2 displays one specialization triangle suggested by Leamer (1987).[4] The corners of this triangle represent three factors of production: labor, natural resources and capital. Points inside this triangle represent both factor endowments of countries and factor requirements of productive sectors. Every endowment point and factor requirements on a straight line emanating from one corner have the same ratio of the other two factors.[5] A movement in the direction of the corresponding vertex depicts an increase in a factor endowment. For instance, if a country originally located in cone A increases its capital endowment, it moves to cone B.

A country like Chile, for example, is illustrated by an endowment point located in cone F, producing three goods (i) mining an agricultural products, (ii) wood, and (iii) food. In contrast, a labor-abundant country (for example, China) would be located in the A cone. Clearly, the output mix in both economies is very different.

Three arrows in Figure 2 represent three different development paths. The bottom arrow illustrates the development path experienced by economies relatively scarce in natural resources. As long as they accumulate capital, they move from cone A toward cones B, C and D, reducing output in labor-intensive goods and increasing output in capital-intensive goods. An economy rich in natural resources follows a different development path, changing its specialization from cone E to F, G and D. Initially, these

[4] A more detailed discussion is presented by Leamer et al., (1999).

economies are specialized in primary agricultural and forestry products, and extractive mining. Capital accumulation is accompanied by changes in the specialization pattern to elaborated goods based on those natural resources that are more physical- and human-capital intensive (cone F). Only if these countries are able to make large increases in their capital endowments, they will produce machinery (cone D), a predominant sector in more developed countries.

In the extreme, this model predicts that resource-rich countries will not produce labor-intensive goods (e.g., textiles and apparel), which can be produced at much lower costs in labor-abundant countries such as China and India. Trade barriers and non-tradable goods may explain why resource-abundant economies produce goods in which they appear to have no comparative advantage. There are two main messages from this model, however, that we would like to emphasize. First, in a natural-resource-rich country, capital accumulation should reduce the importance of labor-intensive sectors. Second, natural resource abundance may retard the specialization of capital-intensive sectors.

3. Exploring the data

In this section, we first describe the data set and then we analyze the evidence about changes in comparative advantages for a large sample of countries. Our measure of specialization is net exports for four manufacturing aggregates. To analyze changes in specialization patterns, we compute transition probability matrices for each of the four aggregates. We are particularly interested in studying if significant changes occur in specialization patterns and, if so, whether these changes are different depending on the abundance of natural resources.

[5] For example, capital per worker used for producing one machinery unity value is higher than capital per worker used for producing one apparel output unit value.

3.1 The data set

Trade data comes from the World Trade Flows compiled by Feenstra et al. (2004). This data set contains information of bilateral exports and imports, disaggregated by industries at 4-digit SITC (rev. 2). We proceed to aggregate in two levels. First, we obtain trade flows for 10 goods according to Leamer's aggregates (see appendix 1). Second, we obtain exports and imports at the country level by summing up across importers and exporters.

The resource endowments come from different sources. Capital stock is taken from Bosworth and Collins (2003). Figures in 1995 local currency are translated into dollars by using the 1995 nominal exchange rate. For human capital, we use the percentage of population above 25 years of age with at least secondary education from Barro and Lee (2004). Alternatively, we use the percentage of population with at least tertiary education.

The main problem encountered by most studies trying to analyze specialization patterns is the difficulty in obtaining precise measures of abundance of natural resources for a large sample of countries over time. Leamer (1984) is the most complete study, collecting information for seven types of natural resources. However, this information is impossible to obtain for many countries over a long time horizon. Other papers studying specialization patterns typically use arable land (in hectares) as a proxy for natural resource abundance (see for example, Redding, 2002 and Leamer et. al., 1999). The path of development, however, could be very different depending on the type of natural resources abundance. For instance, mining tends to be much more capital intensive than agriculture or forestry. Thus the capital accumulation process will expand the mining sector, while it may be contracting sectors like traditional agriculture, thereby generating a completely different path of development from that followed by forestry or agricultural abundant countries.

For many of these natural resources, however, the absence of information is less limiting in a panel of countries. It may be argued that as long as this abundance changes little overtime, its effect will be captured by country fixed effects. In this paper, we use information on net exports of the resource-intensive Leamer's aggregates to capture the

impact of resource abundance. In order to maintain our estimates tractable, we only characterize three types of natural resource abundance. Firstly, if net exports of two aggregates—petroleum and raw materials—are positive, we define a country as abundant in natural resources related to the mining sector. On the other hand, if net exports of forest products are positive, we define the economy to be endowed with forestry resources. Finally, if the net exports of tropical products, animal products, and cereals are positive, we define the country as relatively rich in land suitable for agricultural production.

Given that we are using trade data on resource-intensive industries to define the natural resources abundance, the analysis on patterns of trade will be concentrated on four manufacturing aggregates, namely: labor-intensive, capital-intensive, machinery, and chemicals.

3.2 Transition process: a first sight

In this section, we address the question of how specialization has evolved in the last four decades. We constructed a transition matrix for each aggregate, following the analysis pioneered by Quah (1993, 1996a and 1996b) for studying economic growth, and recently applied by Proudman and Redding (2000) and Redding (2002) for analyzing trade specialization dynamics.[6] In contrast to these studies, we have a large sample of developed and developing countries and we use net exports, which is a traditional measure of comparative advantage.[7]

Consider a cross-country distribution of net exports for aggregate j in a year t given by NX_{jt}. The following law of motion describes the evolution of this distribution over time:

$$\mathrm{NX}_{\mathrm{jt+1}} = P \cdot N\mathrm{X}_{\mathrm{jt}} \qquad (1)$$

[6] Mancusi (2001) applies the same methodology for studying technological specialization in industrial countries.

[7] Proudman and Redding (2000) use a revealed-comparative-advantage-based measure of specialization, which it is not derived from any particular trade model. Redding (2002), by the contrary, draws in a theoretically consistent measure—the share of the industry in the country's GDP—which is derived from an aggregate translog revenue function. Industry shares are available from the UNIDO dataset. However, it contains a very incomplete coverage of countries, and for some countries there is a lot of missing information.

Where *P* is an operator mapping one distribution into another between two time periods, *t* and *t+1*. Although the law of motion for *NX* needs not be first order or the relationship needs not be time-invariant, it is useful to assume both for analyzing the intra-distribution dynamics of *NX*.

The law of motion described by (1) is generally simplified by making discrete the set of possible values of the variable of interest. In such a case, the operator *P* becomes just a transition matrix probability. Each cell of this matrix shows the conditional probability of moving between states over time. This is a particularly useful and illustrative way of showing how common, for example, it is that a country moves from net importer to net exporter of manufacturing goods. Moreover, by computing these probabilities, we may investigate whether there are differences across countries depending on their factor abundance.

To simplify the analysis, we define 4 states that correspond to the four quartiles of the distribution of *NX* for each manufacturing aggregate. It is the case that countries in the first quartile are net exporters of the corresponding manufacturing aggregate, and countries in the fourth quartile are net importers. Since we are particularly interested in illustrating differences between resource abundant and resource scarce countries, we compute the transition probability matrices (TPM) for both groups of countries. To better illustrate the issue and not present as many TPMs as there are types of resource abundance, we define only two main groups: (i) resource scarce countries: those countries that are net importers of the three resource aggregates, and (ii) resource abundant countries: those countries that are net exporters of at least one resource-intensive aggregate.

Our results are shown in tables 1 trough 4 for labor-intensive goods, capital-intensive goods, machinery, and chemicals, respectively. Each cell in the TPM shows the probability of moving from one quartile to another between 1962-1965 and 1995-2000. We are interested in discussing two main issues. One relates to how resource-rich countries differ from resource-poor ones in terms of their position in the world distribution of net exports. The other issue is about how mobility patterns differ according to manufacturing goods and according to countries' factor abundance.

The last row in every TPM shows the percentage of countries that are classified in every quartile, from 1 (largest net exports) to 4 (largest net imports), in 1962-1965. For the period 1995-2000, this percentage is shown in the last column of TPM. It can be appreciated that, with the exception of chemicals, natural-resource-scarce countries are mostly positioned in the first quartile of the distribution, i.e., they are large net exporters of manufacturing goods. This is the case mainly at the beginning of the period. In the case of labor-intensive goods, 38.9 percent of resource-scarce countries were in the first quartile of the distribution in 1962-1965. In contrast, this was the case for only 23.2 percent of resource-abundant countries. The difference had been reduced in 1995-2000, the percentage of countries in the first quartile for resource-scarce countries (27.8 percent) was slightly larger than resource-abundant countries (25.9 percent). There is similar evidence for capital-intensive goods and machinery.

In the case of chemicals, even at the beginning and at the end of the period, the (unconditional) probability of resource-scarce countries being in the first quartile of the distribution is larger than for resource-abundant countries, there are differences at the bottom of the distribution; nearly half of the countries (44 percent) are among the largest net importers of these products.

What these TPMs reveal is that, unsurprisingly, resource abundance seems to be barely consistent with comparative advantage in manufacturing goods. It is the case that for all manufacturing goods, the percentage of countries at the top of the distribution—first quartile—is larger for resource-scarce countries. However, as we illustrate in more detail above, these TPMs show some differences in specialization dynamics that are interesting to analyze.

The first dynamic issue that we explore is across manufacturing goods. Is there any evidence that changes from comparative disadvantage to advantage are more difficult to achieve in some products than in others? Surprisingly, researchers have been rarely interested in investigating this issue. As factor abundance is difficult to change, it is expected that comparative advantage tends to be persistent. The degree of persistence, however, would tend to be different across manufacturing goods. Consider, for example, manufacturing goods that require highly specialized skills. It is not easy for a country to change in a short period the qualification of its labor force in order to make the

production of these goods profitable. In a more extreme case, a country that is not endowed with minerals will never change from net importer to net exporter of mining products. Leamer (1995) presents graphical evidence for the phenomenon of persistence in comparative advantage. Comparing forest products and labor-intensive products, he shows that labor-intensive goods tend to be more "footloose" than other aggregates, with a large number of countries changing from being net importers to net exporters.

A second issue that we investigate relates to mobility patterns across countries. We explore whether resource abundance inhibits changes in specialization. Is it more difficult to go from net importer to net exporter of manufactures for a resource abundant or for a resource scarce country? It is argued that exports of primary goods may retard the production of modern manufacturing goods because they either absorb all of the physical capital accumulation or do not stimulate human capital accumulation.

To analyze these issues, we compare mobility underlying the transition probability matrix for both groups of countries, resource-scarce and resource-abundant, and the four manufacturing goods. We use two mobility indices developed by Shorrocks (1978). These indices attempt to summarize information about the mobility patterns in the estimated transition probability matrix (*P*), and are computed as follows:

$$MI_1 = \frac{q - tr(P)}{q - 1} \qquad \text{and} \qquad MI_2 = 1 - \det(P)$$

Where *P* is the transition probability matrix, *q* is the number of states, *tr(P)* is the trace of the matrix, and *det(P)* is its determinant.

A simple way of looking at mobility issues is to analyze the diagonal of *P*. This diagonal shows how absorbent the different states are. In the extreme, when all states are absorbent—the case of no mobility—each element in this diagonal will be equal to 1, and *tr(P)* will reach a maximum. This idea is captured by the mobility index MI_1. The mobility index MI_2 considers not only the diagonal of *P*, but also the elements off diagonal.[8]

Firstly, we analyze differences across manufacturing goods to analyze whether comparative advantage tends to be more persistent in some goods than others. In general,

[8] A simple intuition for MI_2 is regarding a 2 by 2 to matrix with each element equal to 0.5, which would be the case of perfect mobility, i.e., it would be equally likely to move between two states. In such a case, *det(P)* is zero and MI_2 takes a maximum value of 1.

the evidence shows that comparative advantage in labor-intensive goods seems to be less persistent than in other manufacturing aggregates. However, this is true only in the case of resource-scarce countries. For these countries, both mobility indices are lower for labor-intensive goods than for the other three manufacturing goods. In contrast, for resource-rich economies the mobility index for labor-intensive goods is relatively similar –(in the case of MI_2) or indeed larger (in the case of MI_1) than the index for the other three manufacturing aggregates.

In terms of differences between resource-scarce and abundant countries, the evidence shows that, with the exception of machinery, resource-abundant countries display higher mobility. Hence, these results are not consistent with the idea that resource-abundant countries are less likely to change their specialization patterns in manufacturing goods. There is an interesting dynamic in comparative advantage even in resource-abundant countries that are traditionally assumed to specialize in primary commodities and trapped in this specialization pattern. In the next section, we explore more in detail how factor accumulation is responsible for these changes and how specialization patterns differ according to factor abundance.

4. Evidence

In this section, we deal with the question of how patterns of trade evolve for countries that are abundant in different types of natural resources. In the context of the theoretical framework discussed in the previous section, both variables—trade pattern and natural resource abundance— are intimately related. Countries experiencing changes in their relative factor endowments should also experience changes in their specialization patterns and therefore in their trade structures.

We constructed a panel data with eight time periods corresponding to the five-year period from 1960 to 2000 for 73 economies.[9] The dependent variable to be analyzed is net exports per worker for four manufacturing aggregates: labor-intensive goods, capital-intensive goods, machinery, and chemicals.

Using the definition for natural resources presented in the previous section, three dummy variables were defined:

D_M = 1, if the country has, on average, positive net export of petroleum and raw materials aggregates.

D_F = 1, if the country has, on average, positive net exports of forest products.

D_A = 1, if the country has, on average, positive net exports of tropical goods, animal products and cereals and other food products.

Note that the threshold to define a country as natural-resource-abundant is totally arbitrary. However, we considered net exports equal to zero as a natural candidate for this.[10] The model to be estimated for commodity *i* is the following:

$$\frac{NX_{itc}}{L_{tc}} = \alpha_c + \lambda_t + \beta_1 \frac{K_{tc}}{L_{tc}} + \beta_2 \left(\frac{K_{tc}}{L_{tc}} \right)^2 + \sum_{j=M,F,A} D_j \left\{ \gamma_0 + \gamma_1 \frac{K_{tc}}{L_{tc}} + \gamma_2 \left(\frac{K_{tc}}{L_{tc}} \right)^2 \right\} + \varepsilon_{itc}$$

where NX_{itc} represents the net exports of commodity *i* at time *t* in country *c*, *K* stands for capital, *L* for labor, and D_j for the dummy variables previously defined based on the natural resource abundance. Table 6 and Table 7 show the estimation results using fixed effects by country and time, and with two different proxies for human capital. The results do not change very much. What matters is how capital accumulation will affect net exports in each case. In the 2x2 case, net exports are a linear function of the economy's capital/labor ratio (Leamer, 1984). In case of complete specialization, it is possible to find some non-linear relationship. In the 3x*N* case, there are different cones of specialization and therefore net exports are not a linear function of the relative endowment of factors. For this reason, we include squared terms in the regression. Interestingly, the coefficient for the square of *K/L* is negative only in the labor-intensive manufacturing sector. But for the other three sectors, which are more capital intensive than the first one, this coefficient is positive. Thus, there exists a *K/L* threshold that makes net exports an increasing

[9] In contrast with evidence in the previous section, in this part we consider only 73 countries because of two reasons. First, many countries do not have information on capital stock. Second, we clean the sample by eliminating those countries for which there is not information for all of the eight periods analyzed.

[10] The list of countries with the corresponding definition of natural resource abundance is presented in Appendix 2.

function of this ratio for the more capital-intensive sector in the economy. As we will show below, this depends on the relative abundance of natural resources in each country.

To better understand our finding, we use the results from our estimations to draw the evolution of net exports as a function of capital per worker, for the four aggregates. This will tell us how the comparative advantages evolve as the country accumulates capital.

Figures 3, 4, 5 and 6 show the fitted values of the regressions from table 6 for four cases: natural-resource-scarce countries ($D_M = D_A = D_F = 0$), mineral abundant countries ($D_M = 1$, $D_A = D_F = 0$), agricultural countries ($D_M = 0$, $D_A = 1$, $D_F = 0$) and forest abundant countries ($D_M = D_A = 0$, $D_F = 1$). The dependent variable is net exports per worker. Therefore, when the economy accumulates capital we are capturing the effect on both variables: production (Rybczynski effect) and consumption.

Figure 3 shows the evolution of net exports for the natural-resource-scarce countries. The net exports of labor-intensive sectors in the manufacturing industry have an inverted U-shape, showing that at a low level of *K/L*, the relation between this ratio and net exports is positive. The reason for this is that we are not taking into account some other sectors that could be more labor intensive than those included in this group. On the other hand, net exports of capital-intensive sectors like machinery and chemicals show a negative relationship with capital per worker at the very earliest stage of development. The net exports of the capital-intensive good display a more pronounced U-shaped relationship, which means that net exports start increasing around a threshold of 150 dollars per worker. Above that value, it is very likely that countries that are scarce in natural resources will be in a cone of diversification where they produce chemicals, machinery and capital-intensive goods, and importing natural-resource-intensive commodities.

The result obtained for natural-resource-scarce countries could be explained in terms of the Leamer's triangles introduced in section 2 (see figure 7). For instance a country that is natural resource scarce but labor abundant will produce handicraft, the labor-intensive and the capital-intensive manufacturing goods (diversification cone closest to labor-vertex). At the beginning, this economy will probably be a net exporter of handicrafts and labor-intensive goods, and a net importer of the capital-intensive good.

When capital increases, the economy will move into the next cone of diversification, where it will produce the labor-intensive good, the capital-intensive good, and chemicals. A larger increase in capital per worker would be consistent with an increase in net exports of the capital-intensive good and chemicals. Finally, in the cone of diversification closest to the capital vertex, this economy will not produce the labor-intensive good, and the net exports of this good will continue to decrease. This story is consistent with our results in figure 3, and the theoretical model illustrated in figure 7.

The group of mineral-abundant countries is characterized by a low capital/labor ratio. It is important to notice, looking at the x-axis, that the capital/labor ratio is below 20 dollars per worker, therefore the shape of the net export curve corresponds to the left-hand part of any other group of graphs. Given this combination of capital scarceness and mineral abundance, the curve for all manufacturing goods is downward sloping.

This is consistent with the idea that the mining sector is capital intensive and it takes the extra capital accumulated by the country. On the other hand, if the relative price of the mining good in each country is very high (Dutch disease hypothesis), this good is always produced. Thus when a country accumulates capital, it reduces net exports of all goods and increases the production of the primary mineral commodities. The theoretical case is presented in figure 8, where a mineral-abundant country always produces mining products. The price effect mentioned before could be seen in this figure by noting that mining is at the vertex of all cones of diversification, meaning that the price of that commodity is very high.

This result has important implications for the trade structure of mineral-abundant countries. It seems that they never could reach the minimum threshold to become net exporters of more capital-intensive goods, and they get trapped in a long-term equilibrium of low capital/labor ratio.

The agricultural abundant countries follow a different pattern than the other two groups (Figure 5). Our results show that these countries display a monotonic relationship between net exports per worker and capital per worker. While for the labor intensive manufacturing products and chemicals the relationship is upward sloping, for machinery and capital intensive manufacturing industry the relationship is always downward sloping. The path of development tend to move toward the K vertex in the Leamer's

triangle passing around the cone of diversification that include machinery and capital intensive manufacturing goods, probably producing capital-intensive agricultural products as opposed to traditional crops.

The pattern of net exports as a function of the capital accumulation, for forest abundant countries, is illustrated in Figure 6. Net exports of labor intensive manufacturing industry exhibit an inverted u-shape trajectory as a function of the capital per worker. The net exports of capital intensive manufacturing goods show a monotonic upward sloping relation while the net export of machinery and chemical products show downward sloping relationship with capital accumulation. The difference is that chemical product for very high K/L starts turning around the relationship. This pattern would be consistent with a path of accumulation of different countries with different levels of forest resources abundance and with two types of forestry products. One forestry sector is timber and the other is pulp and high quality paper. The first sector is relatively less capital intensive than the second, but more natural resources intensive. Then a more forest abundance country will move first into more capital-intensive manufacturing products than the other.

5. Conclusions

This paper studies the connection between comparative advantage and capital accumulation in a 3-factors and n-goods framework. In a panel data of countries for the period 1962-2000, we compute net exports per worker and explore if countries with different type of natural resources abundance behave differently. In contrast to previous evidence using simple measures of factor abundance, most commonly arable land per worker, we define natural resources abundance using data on net exports of agricultural, forestry and mining products. This data allows us to group countries according to different type of natural resources abundance.

First we compare net exports between 1962-1965 and 1996-2000. Using transition probability matrices for different manufacturing aggregates and resources abundance, we found that there is no evidence that natural resources abundant countries experience less mobility in their patterns of specialization than resource scarce countries. However, the patterns of mobility differ for different types of products.

Second, we estimate net exports per worker as a function of the capital/labor ratio and the proxy for natural resources. We find evidence that non-linearities are important to explain net exports. In particular, net exports of the labor-intensive manufacturing industry have an inverted U-shape as a function of the country's capital/labor ratio. On the other hand, the function of net exports of capital-intensive manufacturing sectors (i.e., chemical products, machinery and capital-intensive goods) is U-shaped.

The path of comparative advantages followed by countries depends on whether the economy is natural-resource abundant or not, but it also depends on what type of natural resources it possesses. For example, countries that are mineral abundant tend to be relatively capital scarce and, for those low levels of capital per worker, they cannot become industrialized. On the other hand, the industrialization pattern of natural-resource-scarce countries is similar to forestry-abundant countries', but different from that of countries rich in minerals and agriculture.

Finally, the evidence presented here suggests that the idea that developing countries should move toward exporting higher value added products cannot be taken as

a one-size-fits-all recommendation. The type of natural resource abundance heavily influences both the structure and the dynamics of comparative advantages.

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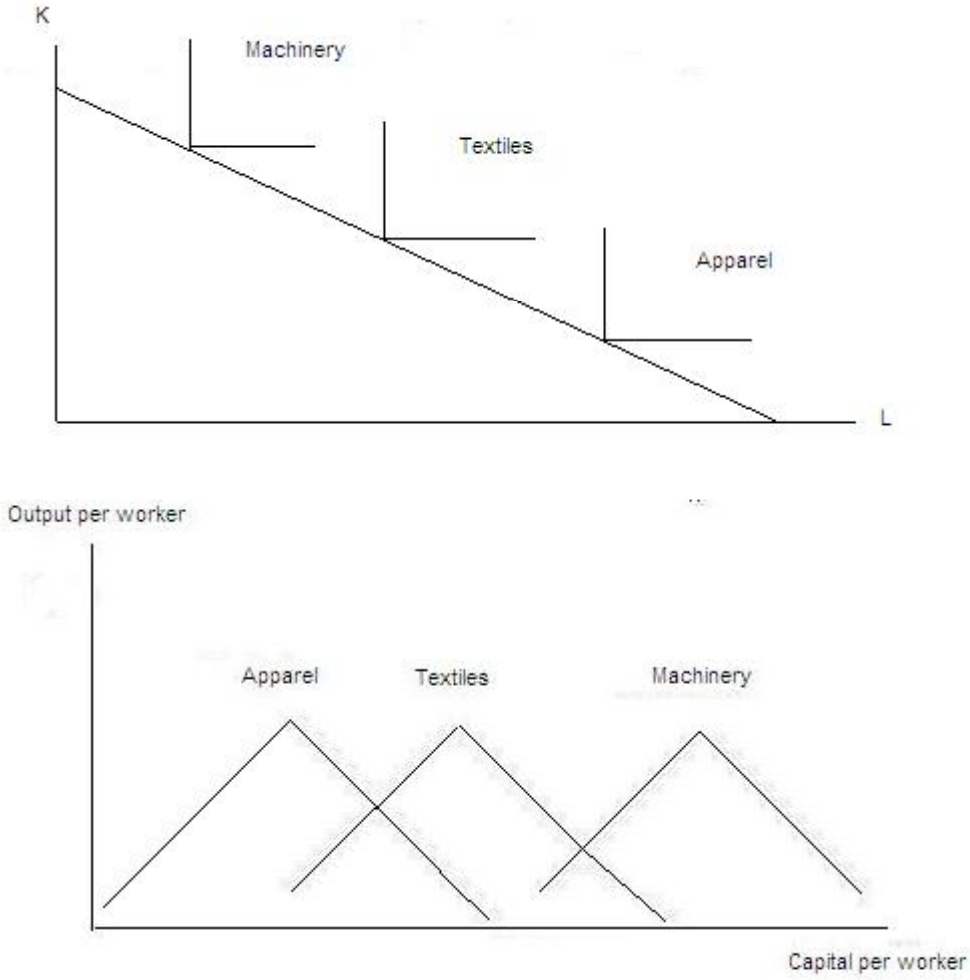

Figure 1. Path of Development in a Two-Factors Three-Goods Model

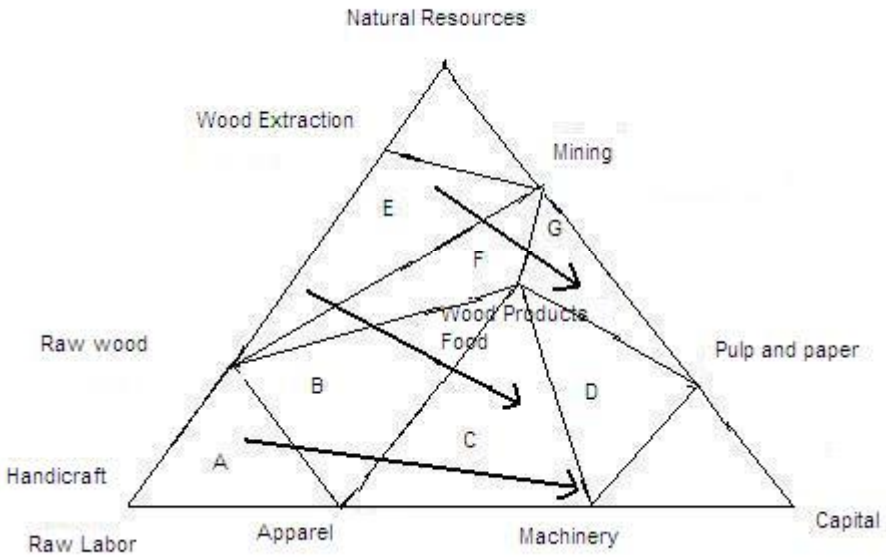

Figure 2. Path of Developments in Leamer's Triangle

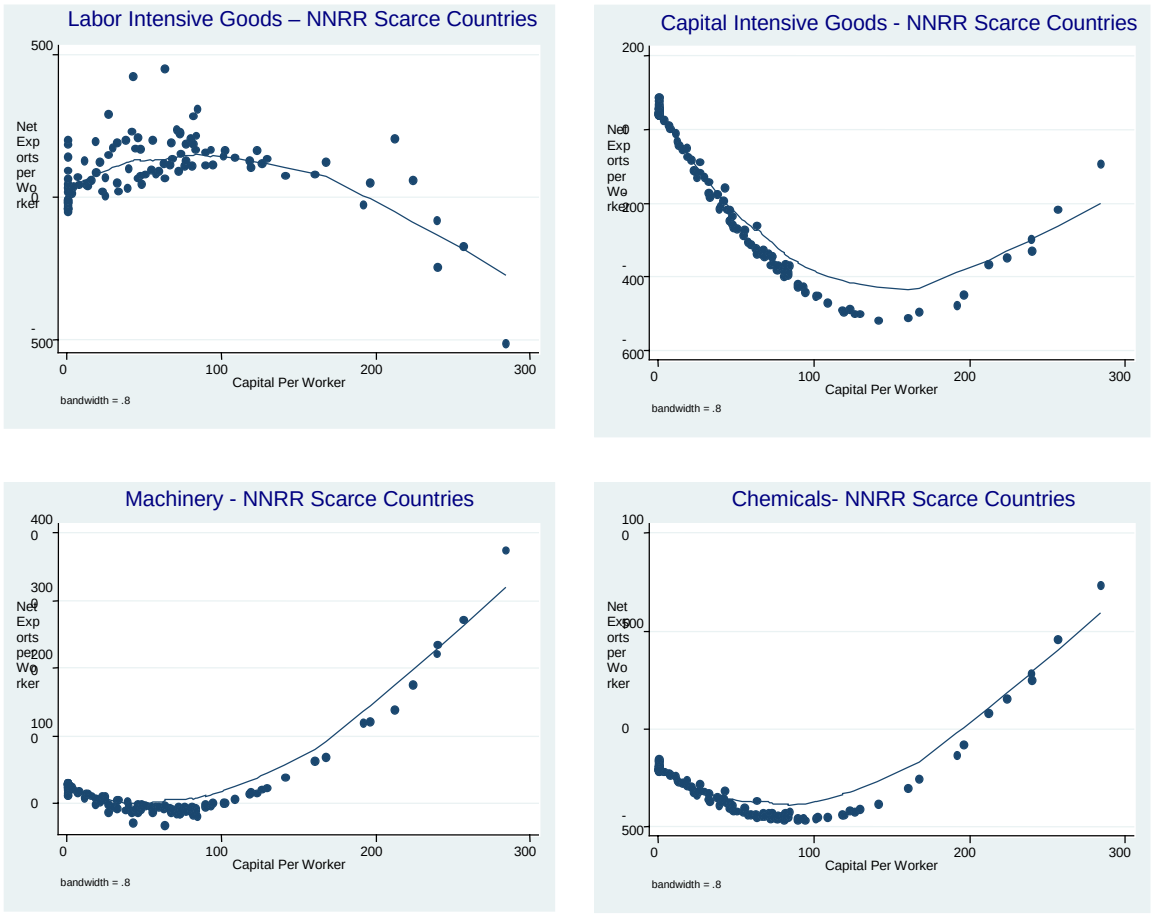

Figure 3. Net Exports of Natural Resource Scarce Countries

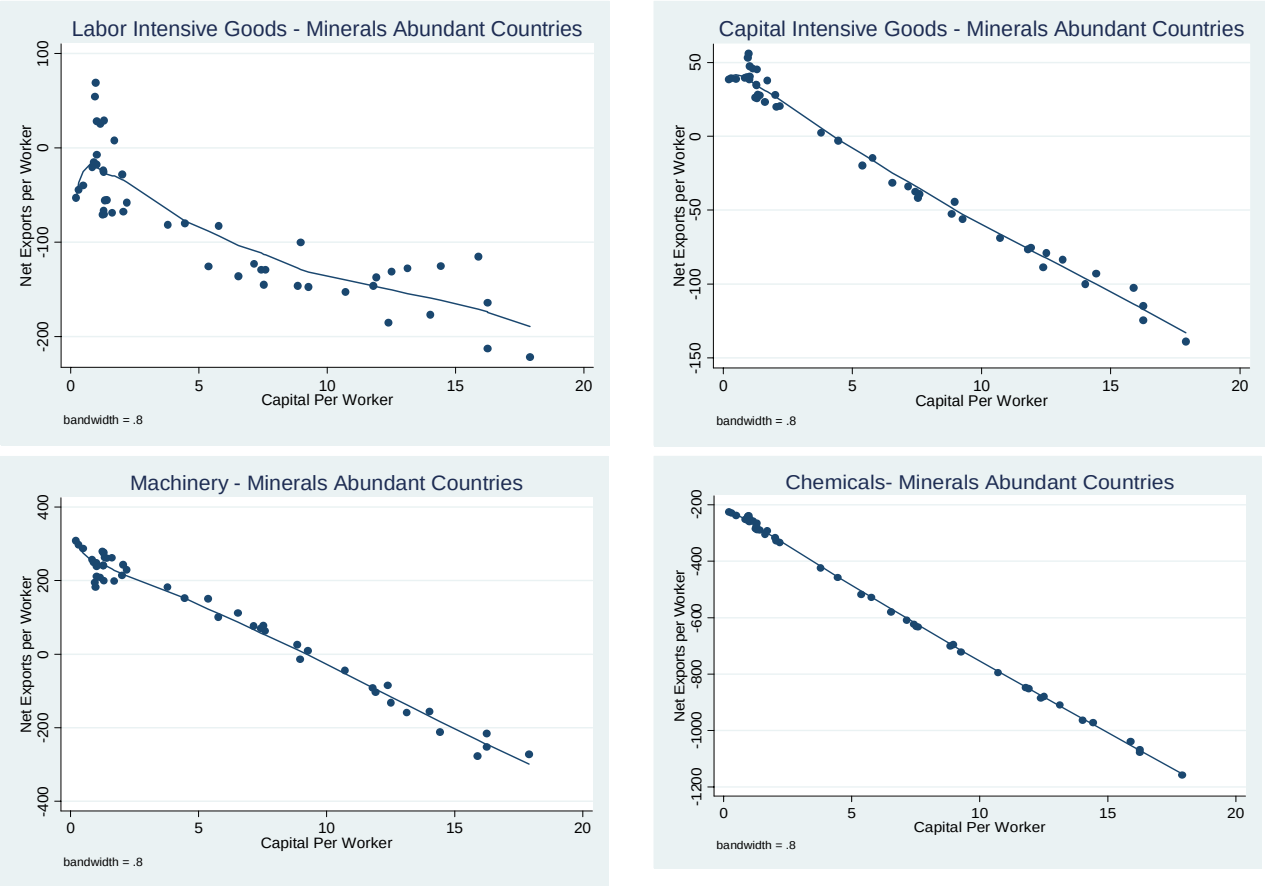

Figure 4. Net Exports of Mineral Abundant Countries

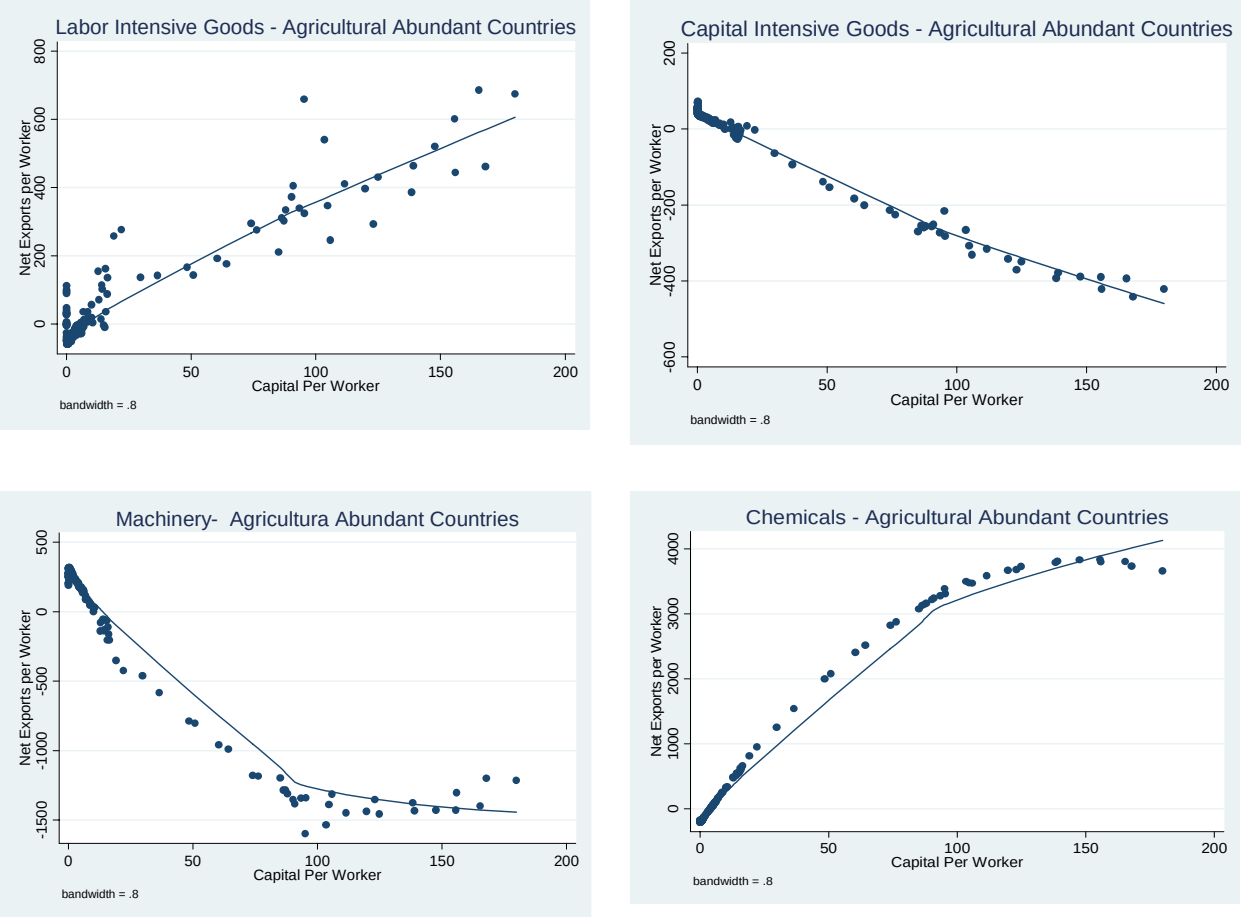

Figure 5. Net Exports of Agricultural Abundant Countries

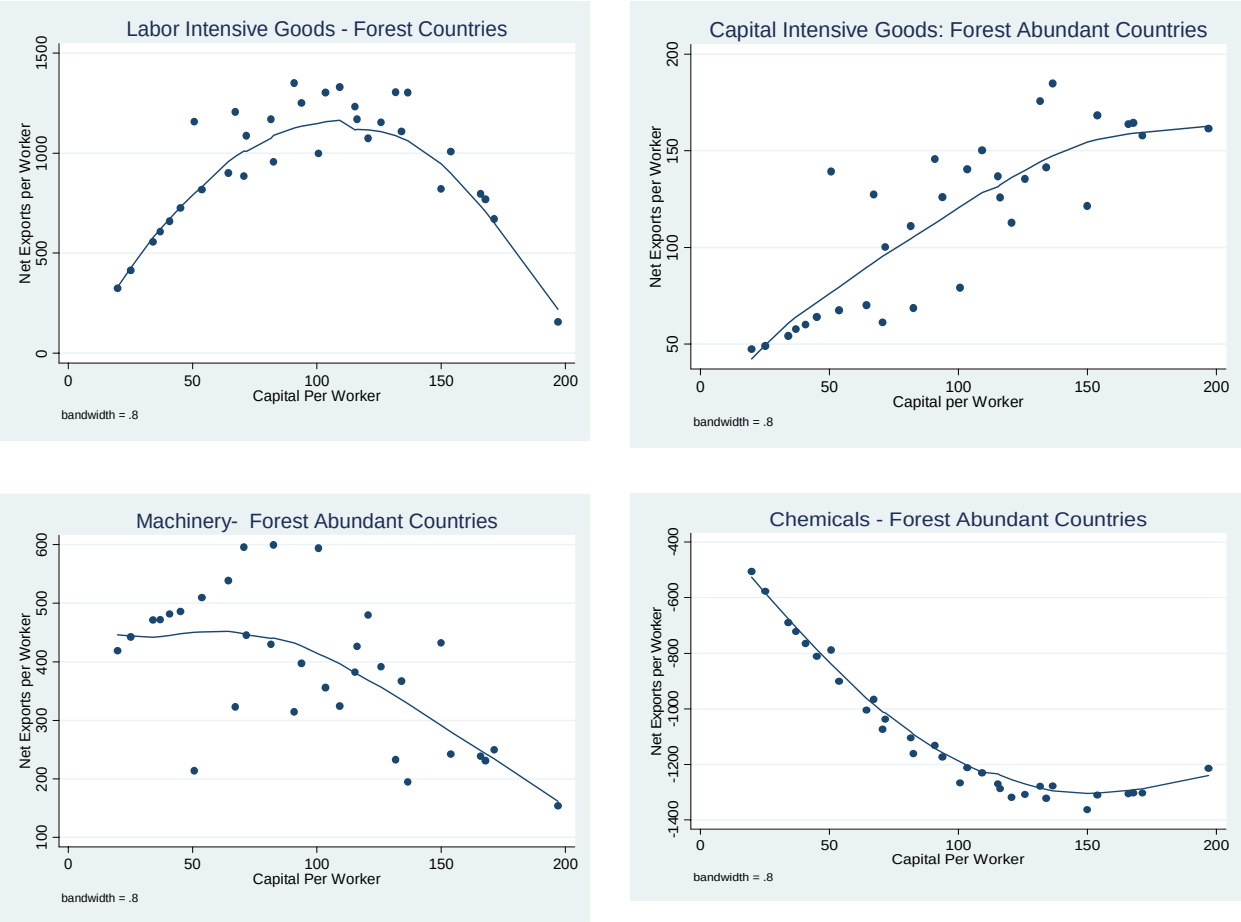

Figure 6. Net Exports of Forest Abundant Countries

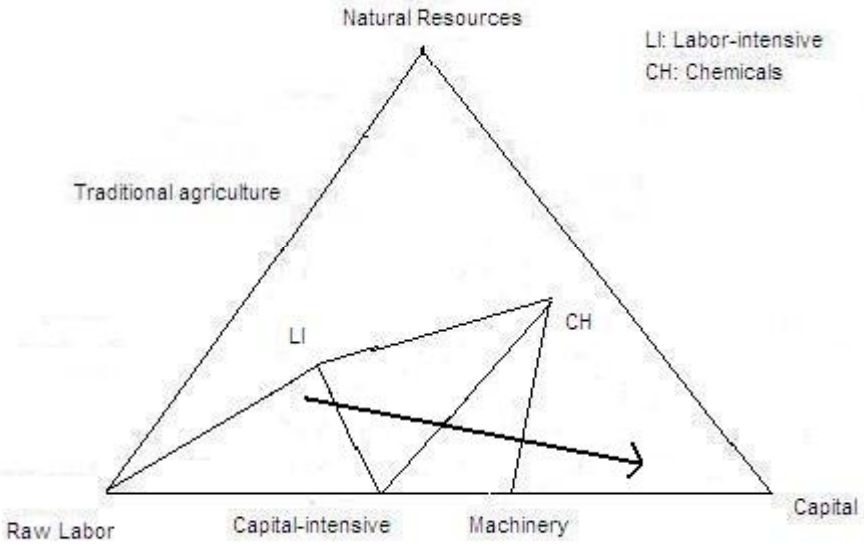

Figure 7. The Theoretical Case for Natural Resource Scarce Countries

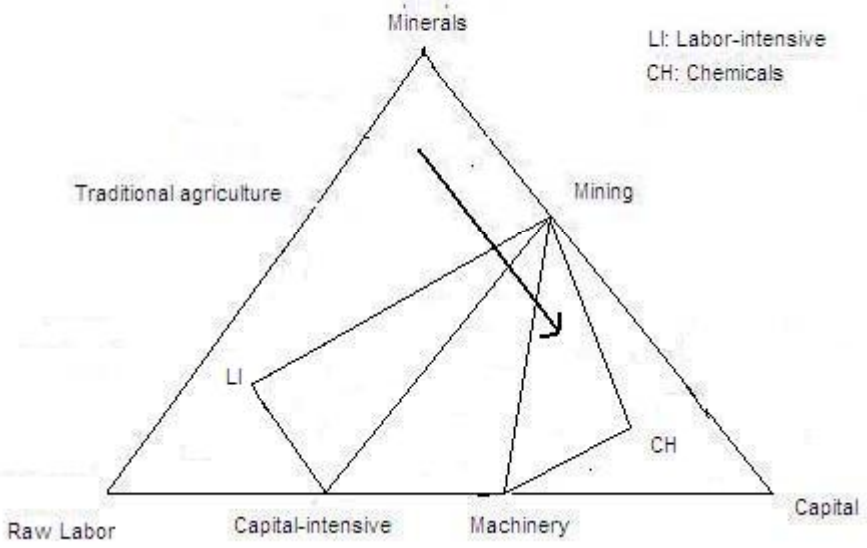

Figure 8. The Theoretical Case for Minerals Abundant Countries

Table 1. Transition Matrix for Net Exports of labor-intensive Goods

LABOR-INTENSIVE Natural Resource Scarce Countries							LABOR-INTENSIVE Natural Resource Abundant Countries						
	Quartile: 95-00							Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%	Quartile: 62-65	1	2	3	4	N	%
1	42.9	14.3	0.0	42.9	7	38.9	1	34.6	38.5	15.4	11.5	26	23.2
2	0.0	66.7	0.0	33.3	3	16.7	2	13.3	53.3	26.7	6.7	30	26.8
3	0.0	0.0	100.0	0.0	1	5.6	3	32.3	12.9	35.5	19.4	31	27.7
4	28.6	0.0	0.0	71.4	7	38.9	4	24.0	0.0	12.0	64.0	25	22.3
N	5	3	1	9	18		N	29	30	26	27	112	
%	27.8	16.7	5.6	50.0			%	25.9	26.8	23.2	24.1		

Table 2. Transition Matrix for Net Exports of Capital-Intensive Goods

CAPITAL-INTENSIVE Natural Resource Scarce Countries							CAPITAL-INTENSIVE Natural Resource Abundant Countries						
	Quartile: 95-00							Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%	Quartile: 62-65	1	2	3	4	N	%
1	71.4	14.3	14.3	0.0	7	38.9	1	52.0	24.0	16.0	8.0	25	22.5
2	0.0	100.0	0.0	0.0	1	5.6	2	16.1	38.7	41.9	3.2	31	27.9
3	0.0	50.0	0.0	50.0	2	11.1	3	12.9	29.0	41.9	16.1	31	27.9
4	0.0	0.0	12.5	87.5	8	44.4	4	8.3	8.3	8.3	75.0	24	21.6
N	5	3	2	8	18		N	24	29	32	26	111	
%	27.8	16.7	11.1	44.4			%	21.6	26.1	28.8	23.4		

Table 3. Transition Matrix for Net Exports of Machinery

MACHINERY Natural Resource Scarce Countries							MACHINERY Natural Resource Abundant Countries						
	Quartile: 95-00							Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%	Quartile: 62-65	1	2	3	4	N	%
1	66.7	16.7	16.7	0.0	6	33.3	1	64.0	32.0	4.0	0.0	25	22.5
2	33.3	66.7	0.0	0.0	3	16.7	2	30.0	43.3	26.7	0.0	30	27.0
3	0.0	0.0	0.0	100.0	1	5.6	3	9.4	18.8	50.0	21.8	32	28.8
4	12.5	0.0	0.0	87.5	8	44.4	4	4.2	0.0	20.8	75.0	24	21.6
N	6	3	1	8	18		N	29	27	30	25	111	
%	33.3	16.7	5.6	44.4			%	26.1	24.3	27.0	22.5		

Table 4. Transition Matrix for Net Exports of Chemicals

CHEMICALS Natural Resource Scarce Countries							CHEMICALS Natural Resource Abundant Countries						
	Quartile: 95-00							Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%	Quartile: 62-65	1	2	3	4	N	%
1	60.0	20.0	0.0	20.0	5	27.8	1	48.0	28.0	12.0	12.0	25.0	22.5
2	33.3	33.3	33.3	0.0	3	16.7	2	20.0	50.0	23.3	6.7	30.0	27.0
3	0.0	0.0	50.0	50.0	2	11.1	3	6.5	12.9	54.8	25.8	31.0	27.9
4	25.0	0.0	0.0	75.0	8	44.4	4	32.0	12.0	16.0	40.0	25.0	22.5
N	6	2	2	8	18		N	28	29	31	23	11	
%	33.3	11.1	11.1	44.4			%	25.2	26.1	27.9	20.7		

TABLE 5: Mobility Indices

Manufacturing Aggregate	Index MI_1		Index MI_2	
	NR Scarce	NR Abundant	NR Scarce	NR Abundant
Labor-intensive	0.40	0.71	0.86	0.98
Capital-intensive	0.47	0.64	0.96	0.99
Machinery	0.60	0.56	0.99	0.96
Chemicals	0.61	0.69	0.97	0.98

Table 6: Panel Data Estimation Using Secondary Education

	LAB	CAP	MACH	CHEM
KL	2.44	-7.60	-10.05	-5.93
	(1.40)	(6.50)**	(2.38)*	(1.88)
$(KL)^2$	-0.02	0.02	0.08	0.03
	(2.73)**	(6.03)**	(5.40)**	(2.92)**
D_M * KL	-16.41	-3.82	-21.05	-51.76
	(2.74)**	(0.95)	(1.45)	(4.80)**
D_M * $(KL)^2$	0.03	0.01	0.01	0.19
	(1.24)	(0.42)	(0.08)	(4.17)**
D_A * KL	-0.53	2.92	-15.84	59.87
	(0.11)	(0.87)	(1.31)	(6.64)**
D_A * $(KL)^2$	0.01	-0.02	0.03	-0.22
	(0.63)	(1.02)	(0.49)	(5.20)**
D_F * KL	18.38	7.86	16.08	-10.02
	(4.19)**	(2.68)**	(1.52)	(1.27)
D_F * $(KL)^2$	-0.09	-0.02	-0.11	0.02
	(5.43)**	(2.16)*	(2.61)**	(0.68)
Secondary	11.85	2.33	-9.19	2.64
	(4.64)**	(1.37)	(1.49)	(0.57)
Constant	-61.75	38.53	323.96	-215.52
	(1.38)	(1.29)	(3.00)**	(2.68)**
Observations	584	584	584	584
Countries	73	73	73	73
R-squared	0.22	0.12	0.23	0.15

Notes: Absolute value of t statistics in parentheses. * significant at 5%; ** significant at 1%. KL is capital per worker, $(KL)^2$ is squared of capital per worker, Minerals is a dummy variable for net exporters of mineral products, Agricultural is dummy for net exporters of agricultural products, and Forest is dummy for exporters of forest products. Secondary is the percentage of population aged over 25 years with complete secondary school.

Table7: Panel Data Estimation Using Post Secondary Education

	LAB	CAP	MACH	CHEM
KL	4.90	-7.19	-3.71	-4.87
	(2.71)**	(6.06)**	(0.90)	(1.53)
$(KL)^2$	-0.02	0.02	0.07	0.03
	(3.53)**	(5.79)**	(4.75)**	(2.71)**
D_M * KL	-13.31	-3.24	-20.22	-50.87
	(2.19)*	(0.81)	(1.46)	(4.74)**
D_M * $(KL)^2$	0.02	0.00	0.02	0.19
	(0.70)	(0.27)	(0.28)	(4.14)**
D_A * KL	-1.72	2.62	-6.68	60.12
	(0.33)	(0.78)	(0.57)	(6.64)**
D_A * $(KL)^2$	0.02	-0.01	-0.01	-0.22
	(0.99)	(0.89)	(0.24)	(5.20)**
D_F * KL	17.50	7.70	15.10	-10.32
	(3.91)**	(2.62)**	(1.48)	(1.31)
D_F * $(KL)^2$	-0.09	-0.02	-0.10	0.02
	(4.92)**	(2.05)*	(2.57)*	(0.76)
Post secondary	-2.84	0.10	-72.48	-5.30
	(0.57)	(0.03)	(6.35)**	(0.60)
Constant	-29.46	45.61	217.89	-213.40
	(0.65)	(1.54)	(2.11)*	(2.68)**
Observations	584	584	584	584
Countries	73	73	73	73
R-squared	0.19	0.12	0.28	0.15

Notes: Absolute value of t statistics in parentheses. * significant at 5%; ** significant at 1%. KL is capital per worker, $(KL)^2$ is squared of capital per worker, Minerals is a dummy variable for net exporters of mineral products, Agricultural is dummy for net exporters of agricultural products, and Forest is dummy for exporters of forest products. University is the percentage of population aged over 25 years with complete university school.

Appendix 1: Leamer's aggregates

Aggregate	SITC	Aggregate	SITC
Petroleum		Cereals	
Petroleum and derivatives	33	Cereals	4
		Feeds	8
		Miscellaneous	9
		Tobacco	12
		Oils seeds	22
		Textile fibers	26
		Animal oil & fat	41
		Fixed vegetables oils	42
Raw materials		Labor-Intensive	
Crude fertilizers & minerals	27	Nonmetal minerals	66
Metalliferous ores	28	Furniture	82
Coal, coke	32	Travel goods, handbags	83
Gas, natural & manufactured	34	Art apparel	84
Electrical current	35	Footwear	85
Nonferrous metal	68	Misc. products articles	89
		Postal packing, not classified	91
		Special trans., not classified	93
		Coins (nongold)	96
Forest Products		Capital-Intensive	
Lumber, wood, & cork	24	Leather	61
Pulp & waste paper	25	Rubber	62
Cork and wood manufactures	63	Textile yarn, fabric	65
Paper	64	Iron & steel	67
		Manufactured metal n.e.s.	69
		Sanitary fixtures & fittings	81
Tropical Agriculture		Machinery	
Vegetables	5	Power generating	71
Sugar	6	Specialized	72
Coffee	7	Metalworking	73
Beverages	11	General industrial	74
Crude rubber	23	Office & data processing	75
		Telecommunications & sound	76
		Electrical	77
		Road vehicles	78
		Other transp. vehicles	79
		Prof. & scientific instruments	87
		Photographic apparatus	88
		Firearms & ammunition	95
Animal Products		Chemicals	
Live Animals	0	Organic	51
Meat	1	Inorganic	52
Dairy products	2	Dyeing & tanning	53
Fish	3	Medical, pharmaceutical products	54
Hides, skins	21	Essences & perfumes	55
Crude animals & vegetables	29	Fertilizers	56
Processed animals & veg. oils	43	Explosives & pyrotechnics	57
Animal products n.e.s.	94	Artificial resin & plastics	58
		Chemicals material n.e.s.	59

Appendix 2: Natural Resources Abundance

WB code	Country Name	Minerals	Agricultural	Forest
ARG	Argentina	1	1	0
AUS	Australia	1	1	0
AUT	Austria	0	0	1
BOL	Bolivia	1	0	1
BRA	Brazil	0	1	1
CAN	Canada	1	1	1
CHE	Switzerland	0	0	0
CHL	Chile	1	1	1
CMR	Cameroon	1	1	1
COL	Colombia	1	1	0
CRI	Costa Rica	0	1	0
CYP	Cyprus	0	0	0
DNK	Denmark	0	1	0
DOM	Dominican Republic	0	1	0
DZA	Algeria	1	0	0
ECU	Ecuador	1	1	0
ESP	Spain	0	0	0
FIN	Finland	0	0	1
FRA	France	0	1	0
GBR	United Kingdom	0	0	0
GHA	Ghana	1	1	1
GRC	Greece	0	0	0
GTM	Guatemala	0	1	0
GUY	Guyana	1	1	1
HND	Honduras	0	1	1
HTI	Haiti	0	0	0
IDN	Indonesia	1	1	1
IND	India	0	1	0
IRL	Ireland	0	1	0
IRN	Iran, Islamic Rep.	1	0	0
ISL	Iceland	1	1	0
ISR	Israel	0	0	0
ITA	Italy	0	0	0
JAM	Jamaica	1	1	0
JOR	Jordan	1	0	0
JPN	Japan	0	0	0
KEN	Kenya	0	1	0
KOR	Korea, Rep.	0	0	0
LKA	Sri Lanka	0	1	0
MEX	Mexico	1	1	0
MLI	Mali	0	1	0
MOZ	Mozambique	0	1	0
MUS	Mauritius	0	1	0
MWI	Malawi	0	1	0
MYS	Malaysia	1	1	1
NIC	Nicaragua	0	1	0

Continue…

WB code	Country Name	Minerals	Agricultural	Forest
NLD	Netherlands	1	1	0
NOR	Norway	1	1	1
NZL	New Zealand	0	1	1
PAK	Pakistan	0	0	0
PAN	Panama	0	1	0
PER	Peru	1	1	0
PHL	Philippines	0	1	1
PRT	Portugal	0	0	1
PRY	Paraguay	0	1	1
RWA	Rwanda	1	1	0
SEN	Senegal	0	1	0
SGP	Singapore	0	0	0
SLE	Sierra Leone	1	1	0
SLV	El Salvador	0	1	0
SWE	Sweden	0	0	1
THA	Thailand	0	1	0
TTO	Trinidad and Tobago	1	0	0
TUN	Tunisia	1	0	0
TUR	Turkey	0	1	0
TWN	Taiwan	0	0	0
UGA	Uganda	0	1	0
URY	Uruguay	0	1	0
USA	United States	0	1	0
VEN	Venezuela, RB	1	0	0
ZAF	South Africa	1	1	1
ZMB	Zambia	1	1	0
ZWE	Zimbabwe	1	1	0

Notes: 1 means that country is abundant in natural resources used intensively in the production of such goods. The classification is based on net exports of resources-intensive Leamer's aggregates. Minerals include Petroleum and Raw material; Agricultural includes Tropical agriculture, Animal products, and Cereals; and Forest includes Forest products. Abundant and scarce countries are divided according if net exports are positive or negative.