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Roberto Álvarez Rodrigo Fuentes

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Agustinas 1180
Teléfono: (56-2) 6702475; Fax: (56-2) 6702231

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PATHS OF DEVELOPMENT, SPECIALIZATION, AND NATURAL RESOURCES ABUNDANCE

Roberto Álvarez
Economista Senior
Gerencia Investigación Económica
Banco Central de Chile

Rodrigo Fuentes
Economista Senior
Gerencia Investigación Económica
Banco Central de Chile

Resumen

En este trabajo se analizan tres preguntas principales. Primero, como un país inicialmente especializado en la producción de bienes primarios se puede convertir en un exportador de bienes manufacturados. Segundo, como la abundancia de recursos naturales afecta las posibilidades de adquirir ventajas comparativas en manufacturas. Tercero, si el tipo de abundancia de recursos naturales importa para la senda de desarrollo. Basados en un modelo de especialización determinando por la abundancia relativa de factores productivos, se estudian los patrones de comercio a medida que las economías de desarrollan (definido como acumulación de capital) para una muestra grande de países en las últimas cuatro décadas. La evidencia es, en general, consistente con la idea que los países están localizados en diferentes conos de diversificación. Se encuentra que las exportaciones netas de 4 agregados manufactureros son una función no lineal de la razón capital a trabajador de la economía. Los resultados muestran que las posibilidades de adquirir ventajas comparativas en manufacturas no sólo dependen de la abundancia de recursos naturales, sino también del tipo de recurso natural. De hecho, países abundantes en recursos mineros se encuentran localizados en un cono de diversificación caracterizado por una baja relación capital a trabajador, y son importadores netos de los 4 agregados manufactureros. En general, se puede concluir que países abundantes en recursos minerales, en comparación a aquellos abundantes en recursos forestales y agrícolas, son los que tienen una menor probabilidad de cambiar su patrón de especialización hacia manufacturas. Por otro lado, usando acumulación de capital humano en vez de capital físico, se encuentra que países abundantes en recursos minerales podrían moverse a un cono de diversificación donde producen y exportan manufacturas intensivas en capital. En cambio, los países abundantes en recursos forestales se especializarían en maquinaria. Finalmente, analizando más en detalle los países abundantes en minerales, se encuentra que existen diferencias en las sendas de desarrollo entre exportadores y no exportadores de petróleo.

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 (defined as capital accumulation) 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 find that net exports are a non-linear function of the capital/labor ratio of the economy. The pattern of gaining comparative advantages in manufacturing goods as a country develops depends not only on whether it is natural resource abundant or not, but also on its type of natural resources abundance. This paper shows that mineral-abundant countries are positioned in a diversification cone with low levels of capital per worker and 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. On the other hand when we use human capital instead of physical, we find that mineral abundant countries will move to a cone where they produce and export capital intensive manufactures. The forest abundant countries will attain comparative advantages in machinery as they accumulate human capital. Looking at the mineral abundant countries we find some differences in the path of development for oil exporters and non-oil exporters.

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E-mails: ralvarez@bcentral.cl; rfuentes@bcentral.cl.

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[1].

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".[2]

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.

[1] Other important research is on the impact of factor endowments on institutions and growth. Engerman and Sokoloff (1997) and (2000) have argued and presented evidence that differences in factor endowments were responsible for differences in development paths among new world economies. Acemoglu and Robinson (2001) present also evidence on this regard, but exploiting differences in settler mortality as source of variation in institutions quality.

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

Several papers have explored the relationship between country specialization and factor endowment.[3] This work, however, is the first to assemble the following four features: First, we use net exports per worker as a measure of comparative advantage, in line with Leamer (1984). Second, we employ panel data to study the relationship between manufacturing net exports and factors endowment. Third, we analyze the existence of a non-linear relationship between net exports and factor endowments. This empirical approach is based on the idea 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.[4] Fourth, we study how the development paths—or movements across cones of diversification—depend on the type of natural resource abundance. To keep things simple, we estimate the relationship between net exports and capital accumulation to be dependent on three types of resource abundance; 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 the data and we also present preliminary evidence on specialization dynamics. By computing transition probability matrices for different manufacturing aggregates, we investigate if there are differences in specialization dynamics across products and countries factor abundance. In general, the results suggest that mobility tends to be different for different groups of manufacturing goods. In addition, we do not find evidence that natural resource abundant countries experience less mobility in their patterns of specialization than resource scarce countries. In section 4, we present the main estimates and we discuss the results on development paths. These findings are consistent with the idea that countries are located

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

in different cones of diversification, a conclusion that is consistent with previous evidence provided by Leamer (1987) and Schott (2003). However, one distinction in this 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.

Our main finding is that the development paths of resource abundant countries also vary depending on the type of resource 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 that favor 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. Then, our results suggest that for mineral abundant economies seem to be more difficult to gain comparative advantage in the so-called industrial goods.

In section 5 we present a robustness check of our main results. First, we use human capital instead of physical capital as the factor to be accumulated. Second, we estimate the model using different definitions of natural resources abundance. Third, we introduce a role for trade policy variables, which could also have some effect on comparative advantage. Fourth, we study if the classification of mining abundant hides significant differences between petroleum and non-petroleum abundant countries. Finally, in section 6 we summarize the main results.

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[4] 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.

2. Factor-Endowment-Driven Specialization

In this section, we discuss the main implications for specialization in an economy rich in natural resources. The 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).[5] 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.[6] 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 resource-abundant country like Chile, for example, could be 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 cone A. 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 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

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

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 it may be emphasized. 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 concerning changes in comparative advantages for a large sample of countries. The measure of specialization is net exports for four manufacturing aggregates. To analyze changes in specialization patterns, we compute a number of transition probability matrices for each of the four aggregates. We are particularly interested in studying whether significant variations occur in specialization patterns and, if so, whether these changes are different depending on the abundance of natural resources.

3.1 Data Description

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 the data in two dimensions. 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 factor 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

[6] 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.

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 per worker (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. we follow an alternative strategy in this paper using information on net exports of the resource-intensive Leamer's aggregates to capture the impact of resource abundance on specialization patterns. Following Leamer's (1984), the equilibrium condition in factor markets can be written as:

$$AX = V \tag{1}$$

Where A is a square matrix of input requirements or the factor intensity matrix (assuming equal number of factors and goods), X is the vector of output and V is the vector of endowment. We have the same relationship for the rest of the world assuming same technology (matrix A) but different factor endowments. Assuming that individuals have identical and homothetic utility function, then total consumption for each country is a constant proportion of the world output $C = sX_w$, where s is the share country's consumption on total world consumption (X_w). The trade vector *(T)* can be written as the difference between production *(X)* and consumption *(C)* and using equation (1) we derive:

$$
\begin{aligned}
T &= X - C = A^{-1}V - sA^{-1}V_w \\
AT &= V - sV_w
\end{aligned}
\qquad (2)
$$

Where V_w represents the world endowments of factors. According to equation (2) the sign of the trade flows are an indicator of the relatively abundance of factor endowment. In order to maintain the estimates tractable, we only characterize three types of natural resource abundance: mining, forestry, and agriculture. 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 forestry 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. We calculate the sign of this trade flow for each five-year time period. 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 the four manufacturing aggregates, namely: labor-intensive, capital-intensive, machinery, and chemicals.

It must be acknowledged that using net exports as a measure of factor abundance is far from being a perfect measure of natural resources endowments. It can be the case that, due to trade policies or other distortions, countries abundant in some natural resource do not exploit their comparative advantages. Second, aggregating in three types of natural resources may hide some significant heterogeneity within the different products[7]. In our defense we can argue that it is difficult, in absence of very detailed information on inputs requirements, to identify for which natural resources we would need information for estimating the model. Even having this information, data on resources endowments is not readily available for a large sample of countries over time. One advantage of defining resources abundance in this way is that we can discuss differences on development paths depending on the type of natural resources. This is a

[7] See Schott (2003) for a discussion on this heterogeneity issues when using output of manufacturing industries for testing the factor abundance model.

considerable improvement respect to other paper distinguishing natural resources abundance using land endowments. Finally, given that the mapping between net exports and endowments could be not perfect, we check the robustness of our results for different definitions of resources abundance and for different control variables.

3.2 Export Transitions

In this section, we address the question of how specialization has evolved in the last four decades. We construct 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.[8] 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.[9]

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:

$$\mathrm{NX}_{\mathrm{jt+1}} = P \cdot N\mathrm{X}_{\mathrm{jt}} \tag{3}$$

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 (3) 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

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

[9] 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.

illustrative way of showing how common, for example, it is that a country moves from being a net importer to a 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.

These TPMs 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. First, we investigate 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 forestry 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 the mobility pattern 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.[10]

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

[10] 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.

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 on Comparative Advantage and Factor Endowments

In this section, we deal with the question of how patterns of comparative advantage evolve with changes in factor endowments. We are particularly interested in studying how trade patterns differ according to differences in natural resources abundance. In the context of the theoretical framework discussed in the previous section, trade patterns are determined by factor abundance, but specialization dynamics may be different depending on the type of natural resources abundance. Then, the main objective of this empirical exercise is to determine whether resources abundance countries display specialization patterns different from resources poor countries, and whether, within resources abundant countries, there are differences according to type of natural resources.

We construct a panel data with eight time periods corresponding to the five-year period from 1962 to 2000 for 73 countries.[11] The dependent variable to be analyzed is net exports per worker for four manufacturing aggregates: labor-intensive goods, capital-intensive goods, machinery, and chemicals.

Natural resources abundance is defined according to net exports of three resource-intensive goods as follows[12]:

- $D_M = 1$, if the country has positive net export of mining products.
- $D_F = 1$, if the country has positive net exports of forestry products.
- $D_A = 1$, if the country has positive net exports of agricultural products.

The model to be estimated for commodity *i* is the following:

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

$$\frac{NX_{itc}}{L_{tc}} = \alpha_c + \lambda_t + \beta_1 \frac{K_{tc}}{L_{tc}} + \beta_2 \left(\frac{K_{tc}}{L_{tc}} \right)^2 + \sum_{j=M,F,A} \gamma_0 \, D_{tj} + \sum_{j=M,F,A} D_{tj} \left\{ \gamma_1 \frac{K_{tc}}{L_{tc}} + \gamma_2 \left(\frac{K_{tc}}{L_{tc}} \right)^2 \right\} + \varepsilon_{itc} \quad (4)$$

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_{tj} for the dummy variables previously defined based on the natural resource abundance for each period t[13].

In estimating this equation, we are interested mainly in studying how capital accumulation affects net exports of each manufacturing good. In the 3xN case that we are exploring, there are different cones of specialization and therefore we expect net exports to be a no-linear function of the economy capital per worker. For low capital per worker ratios, countries are producing the labor-intensive goods. In this cone, an increase in capital per worker may increase production, and net exports, of this good, under the assumption that this economy produces other even less capital-intensive good (for example, handicrafts). In such a case, the derivative for net exports of labor-intensive good respect to capital per worker would be positive (and the derivative for handicrafts would be negative). A further increase in capital per worker could change the specialization pattern of this economy, reducing the production, and net exports, of the labor-intensive good, and expanding the production, and net exports, of the capital-intensive good (or machinery). In such a case, the derivative of net exports of labor-intensive good respect to capital per worker turns to be negative, and the derivative for net exports of the capital-intensive good (or machinery) would be positive.

These non-linear relationships seem to be present in the data. In Figures 3 through 5, we show the evolution of manufacturing net exports for three different countries. A typical natural resource-scarce country, like Korea, displays a development pattern relatively consistent with the theoretical model discussed in section 2. Net exports of the labor-intensive good have increased over time until late eighties, but then it has tended to reduce significantly. As a contrast net exports of machinery and chemical tend to decrease at the beginning of the time frame, and then to increase (Figure3). This pattern

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

is very different to the one followed by a natural resource-abundant country like Chile. In this case, net exports of the four manufacturing goods have declined over time (Figure 4). This is not, however, a typical pattern followed by a other natural resources rich country like Finland, which is relatively rich in forestry (Figure 5) we also find evidence of a non-linear behavior for manufacturing net exports. The net exports of the labor-intensive good are increasing at the beginning of the period, but at some point they tend to reduce. The inverse evolution is experienced by the capital-intensive good and machinery.

As it is explicitly considered in equation (4), the relationship between net exports and capital per worker depends on the relative abundance of natural resources in each country. Testing that a natural resources abundant country changes its specialization patters in a different way compared to a natural resources scarce country implies a joint null hypothesis that all interactive terms between the indicator of natural resource abundance and capital per worker are zero. This is:

$$\begin{aligned} D_j \gamma_1 &= 0 \\ D_j \gamma_2 &= 0 \end{aligned} \qquad \text{For all j=M, F, A.} \qquad (5)$$

We also test that for the pairwise differences between resources poor countries and each type of resources abundance. By testing these three hypotheses, we are able to analyze not only whether resources abundance matter, but also which type of resource abundant countries have development paths statistically different from resources scarce countries. Then, we test separately if:

$$D_M \gamma_1 = 0 \text{ and } D_M \gamma_2 = 0 \qquad (6)$$

$$D_A \gamma_1 = 0 \text{ and } D_A \gamma_2 = 0 \qquad (7)$$

$$D_F \gamma_1 = 0 \text{ and } D_F \gamma_2 = 0 \qquad (8)$$

Table 6 and Table 7 show the estimation results of equation (4) using fixed effects by country and time, and with two different proxies for human capital. From columns (1) to (4), we show results for labor-intensive (LAB), capital-intensive (CAP), machinery (MACH), and chemicals (CHEM), respectively. In the last four rows, we present the F-

[13] In section 5, we check the robustness of our results by including net exports of natural resources as a continuous variable.

test for the hypotheses on differences in development paths indicated by equations (5), (6), (7) and (8), respectively.

First, comparing Table 6 and 7, we find that results do not change very much by including secondary or tertiary schooling as a proxy for human capital. Second, the findings in both cases are consistent with the expected signs for capital per worker and squared capital per worker. In both specifications, the coefficient for K/L is always positive for the labor-intensive good, but negative for the other more capital intensive manufacturing goods. The exception is the manufacturing aggregate chemicals in which most of the variables are not significant and the R^2 is very low.

The different F-tests performed suggest that resources abundant and poor countries follow different development patterns. The joint hypotheses that all interactive terms between resources abundance and capital per worker are zero are rejected to standard significance levels for the four manufacturing aggregates (at 1% for LAB, CAP and MACH, but at 5% for CHEM).

In terms of differences depending on the type of resources abundance, the evidence is mixed. Tables 6 and 7 show that for the labor-intensive good (LAB) the hypothesis that agricultural-abundant countries follow a similar development path of natural resource scarce countries cannot be rejected – the p-values are 0.290 and 0.721 respectively. For CAP and MACH most of pair-wise hypotheses are rejected at standard levels of significance. For chemicals, there is a strong reject of the null hypothesis only for mining-abundant countries with p-values of 0.700 and 0.704, respectively.

To better understand these findings, we use the results from these estimations to illustrate the evolution of net exports as a function of capital per worker for the four manufacturing aggregates. This will tell us how the comparative advantages evolve as the country accumulates capital depending on countries factor abundance. Figures 6, 7, 8 and 9 show the fitted values of the regressions from table 6 for four special 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 forestry abundant countries ($D_M = D_A = 0$, $D_F = 1$)[14].

Figure 6 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. This is consistent with the theoretical model described in section 2. For low levels of capital per worker, capital accumulation reduces the production and net exports of labor intensive goods not included in LAB (for instance handicraft or services), but increases the production and net exports of relatively more capital intensive goods represented by LAB. 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 10). 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

[14] To isolate the pure impact of the type of resources abundance, we focus in the cases of countries that are, according to our period-specific definition, abundant in only one of the three natural resources considered. The development paths for all the other combinations of abundance are available upon request.

the net exports of this good will continue to decrease. This story is consistent with results shown in figure 3, and the theoretical model illustrated in figure 10.

Figure 7 shows the development paths for mineral abundant countries. It's worthy to note that most of countries in this group are characterized by a low capital/labor ratio. Given this combination of capital scarceness and mineral abundance, the relevant part of the curve for all manufacturing goods seems to be downward sloping. Only few countries have been able to increase consistently their capital per worker and net exports of manufacturing goods. If any, mineral abundant countries would gain comparative advantage in machinery and chemicals, but the evidence is limited to a few cases.

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 11, 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 and being net importer of every manufacturing good.

The agricultural abundant countries follow a different pattern than the other two groups (Figure 8). Consistent with the F-tests in tables 6 and 7, these results show that net exports of LAB display a similar behavior of the natural resource scarce countries. In contrast, the relationship between net exports and capital per worker seems to be monotonically negative for CAP, and monotonically positive for MACH and CHEM, though for MACH some non-linearity can not be ignored.

In Figure 9, we illustrate the pattern of net exports as a function of capital accumulation for forestry abundant countries. Net exports of LAB and MACH exhibit an inverted u-shape trajectory as a function of the capital per worker. The inverse relationship between net exports and capital per worker is found for CAP. In the case of CHEM, the relationship is monotonically negative. This suggests that capital accumulation if forestry abundant countries tend to change the specialization pattern from labor-intensive goods, MACH and CHEM to the capital-intensive manufacturing activity (CAP).

5. Robustness Checks and Extensions

In this section we analyze how robust are our results to three major modifications. First, we use human capital instead of physical capital as the factor to be accumulated. Second, we estimate the model using different definitions of natural resources abundance. Third, we introduce a role for trade policy variables, which could also have some effect on comparative advantage. Fourth, we study if our classification of mining abundant hides significant differences between petroleum and non-petroleum abundant countries.

5.1 Role for Human Capital

It may be argued that paths of development may depend on human capital rather than physical capital accumulation. There are two reasons to think that human capital could be as important as physical capital to explain comparative advantages. First, under the assumption of free physical capital mobility, it may be argued that capital per worker is not a source of comparative advantage. In contrast, human capital is lees mobile internationally. Second, from a theoretical point of view, capital should be understood widely as physical and human capital. Although in previous results, two measures of human capital were introduced as explanatory variables for net exports of manufactures, their squares terms and their interactions with resources abundance were not included in the estimation. In this section, we estimate a similar model to equation (4), but only considering resource abundance and human capital as sources of comparative advantage. In other words, we estimate the following equation:

$$\frac{NX_{itc}}{L_{tc}} = \alpha_c + \lambda_t + \beta_1 HK_{tc} + \beta_2 HK_{tc}^2 + \sum_{j=M,F,A} \gamma_0 D_{tj} + \sum_{j=M,F,A} D_{tj} \left\{ \gamma_1 HK_{tc} + \gamma_2 HK_{tc}^2 \right\} + \varepsilon_{itc} \qquad (9)$$

We estimate equation (9) using secondary school as proxy for countries human capital per worker (HK_{tc}). The results are shown in Table 8. It can be appreciated that, consistent with our previous findings, there is evidence of a non-linear relationship between net exports of manufactures and human capital per worker. For the labor-intensive good, β_1 is positive and β_2 is negative, showing the net exports of the goods increase with human capital for low levels of human capital. Then, after some level, human capital accumulation reduces next export of LAB. In contrast, for the most capital intensive goods – CAP, MACH, and CHEM - β_1 is negative and β_2 is positive, suggesting that the relationship between net exports and human capital is the inverse to that described for LAB[15].

In terms of the tests for the interactive terms between human capital (and squared human capital) and dummy for natural resources abundance, most of them show that resource abundance countries follow a development path different from resources scarce countries. The hypothesis that all interactive terms are zero is rejected for all manufacturing good, except for chemicals. For pairwise hypothesis of similarity between resources scarce countries and each definition of resources abundance, this is not rejected for forestry abundant countries (see last rows in Table 8).

To illustrate the development paths implied by these estimations, Figures 12, 13, 14 and 15 show the relationship between net exports of manufactures and human capital. The results for resource scarce countries are generally consistent with the evidence for capital per worker. The development paths plotted in Figure 12 are very similar to those in Figure 6. For mining abundant countries, the evidence in Figure 13 suggests that these countries can change their comparative advantage towards the capital-intensive good (CAP). Although some positive relationship between net exports of CHEM and human capital is found for high levels of human capital per worker, this is given by a reduced number of observations. The case for agricultural abundant countries plotted in Figure 14 reveals that the relationship between net exports of the four manufacturing products and human capital is mostly linear. This is consistent with what we have found when considering physical capital per worker. The only difference, however, is for MACH

[15] It is worthy to note that the model including human capital also is less successful in explaining net exports of chemicals. As it is shown in Table 8, the R-squared is very low compared to the other three

where net exports are negatively associated to human capital, but they were positively associated to accumulation of physical capital. Finally, Figure 15 shows the development paths for forestry abundant countries. This group follows very closely the pattern exhibited by resource scarce countries: for relatively large levels of human capital, accumulation of this factor reduces net exports of LAB and increase the net exports of the more capital intensive goods (CAP, MACH and CHEM).

5.2 Alternative Definitions of Factor Abundance

The results may be affected by alternative definitions of natural resources abundance. In our base regressions, we considered net exports equal to zero as a natural candidate for this classification. This threshold to define a country as natural-resource-abundant may seem arbitrary. Nevertheless, it is not difficult to argue that countries with comparative advantage in some good must have positive net exports of that good. On the other hand, the definition is hard to justify for countries that have net exports close to zero. In this case, it may be difficult to be certain that a country with slightly positive net exports effectively have significant differences in comparative advantage with a country with slightly negative net exports. Then, we check the robustness of our results by including net exports of the three resource-intensive goods as a continuous variable[16].

Due to space considerations, we only report here the significance tests for the hypotheses that resources abundant countries follow a different development path that scarce resources countries for the three cases discussed above. For each manufacturing good, the P-value of the corresponding F-test is shown in Table 9. We are particularly interested in analyzing whether alternative definitions of factor abundance change the main findings from the simple model. In general, we find that the null hypothesis that capital accumulation has the same effect on scarce and abundant resources countries is mostly rejected. There are some differences across specifications, but the main message is similar to the one in the previous section.

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manufactures, and most of the coefficients are not significant.

[16] we also define the dummy variables using mean or median for net exports of natural resources. Results are very similar to those using zero as a threshold for abundance.

5.3 Role of Trade Policy variables

In this section, we extend the basic model for incorporating the role of trade policy variables. In their more simple formulation, the neoclassical trade model assumes free trade in goods across countries. This is, of course, a very strong assumption. However, one of the main difficulties to control for differences in trade policy is that measure of trade barriers by sectors for all the countries and years in the sample are non-existent. In this paper, we include an aggregate trade openness variable, though imperfect, it may be useful to check if the development paths presented here are still valid after controlling for impediments to free trade. As a measure of openness, we include the percentage of years that a country is classified as "open" according to Sachs and Warner (1995)'s classification updated by Wacziarg and Horn Welch (2003).

The results of estimating equation (4) are shown in Table 10 and they are strictly comparable with those in Table 6. Openness is "beneficial" for LAB and CAP goods and negative impact on MACH and CHEM, but it is not significant. More importantly, the sign of the coefficients is not affected by including this variable and the F-tests for the interactions between capital per worker and the dummy variables for resources abundance show a pattern very similar to those found in Table 6. For most of the cases, we cannot reject the hypothesis that these interactive terms are different from zero. In sum, even controlling for trade openness, there is evidence that resource abundant countries follow a different specialization pattern than resources scarce countries.

5.4 Mining Abundant Countries: Petroleum versus Other Minerals

To check whether development patterns may be different among mining countries depending on whether they are rich in petroleum or other minerals, we divide these countries in two groups. Petroleum abundant countries are those with positive net exports of petroleum, and other minerals abundant countries are those with positive net exports of raw materials[17].

[17] In the appendix on Leamer's aggregates, we show that the aggregate petroleum includes Petroleum and derivatives (33), and raw materials include crude fertilizers & minerals (27), Metalliferous ores (28), Coal, coke (32), Gas, natural & manufactured (34), Electrical current (35), and Nonferrous metal (68).

To illustrate the existence of differences, we plot in Figure 16 the patterns of development implied by the estimation of equation (1). In general, we find that there are some differences between these two groups of countries. For LAB the relationship between net exports and physical capital accumulation for petroleum abundant countries seem to be positive, but it's negative for other minerals abundant countries. The inverse is found for MACH. In contrast, the relationship between net export and capital per worker is the same for both petroleum and other minerals abundant countries.

6. Conclusions

This paper studies the connection between comparative advantage and capital accumulation, with special focus on how natural resources abundance implies differences in development paths. In a panel data of countries for the period 1962-2000, we compute for manufacturing industry 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. All these conclusions are still valid when we control for openness in the net export functions. Also they are not sensitive to different alternatives for defining natural resources abundance.

To check our results we estimate the net exports per worker as a function of the human capital accumulation. The idea is that capital – labor ratio could endogenous due to international capital mobility, but human capital is less mobile. Using human capital, there are four – out of sixteen - paths of development that change. This is the case of net export of machinery and capital intensive manufactures for mineral abundant countries, and the case of machinery for agriculture and forestry abundant countries. Then, we conclude that differences in development paths are not depending on which measured of capital is used.

Exploring the path of development within the mineral abundant group we find some differences between the oil exporters and other minerals net exporters. The former tend to have low capital labor ratio and therefore have little chance to become net exporter of machinery and capital intensive manufactures. On the other hand the other minerals exporters have the chance to become net exporters of machinery. While the petroleum abundant countries increase the net exports of labor intensive manufactures as they accumulate capital, the other mineral abundant countries tend to reduce the net exports of labor intensive manufactures.

Finally, the evidence presented here suggests that the idea that developing countries should move toward exporting higher value added products couldn't 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 advantage.

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Figure 1

Path of Development in a Two-Factors and Three-Goods Model

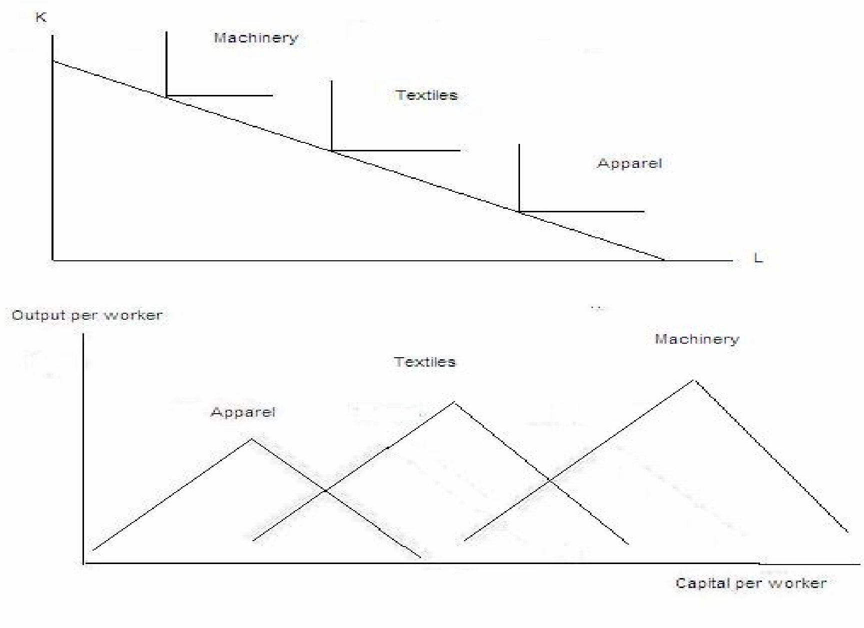

Figure 2

Path of Developments in Leamer's Triangle

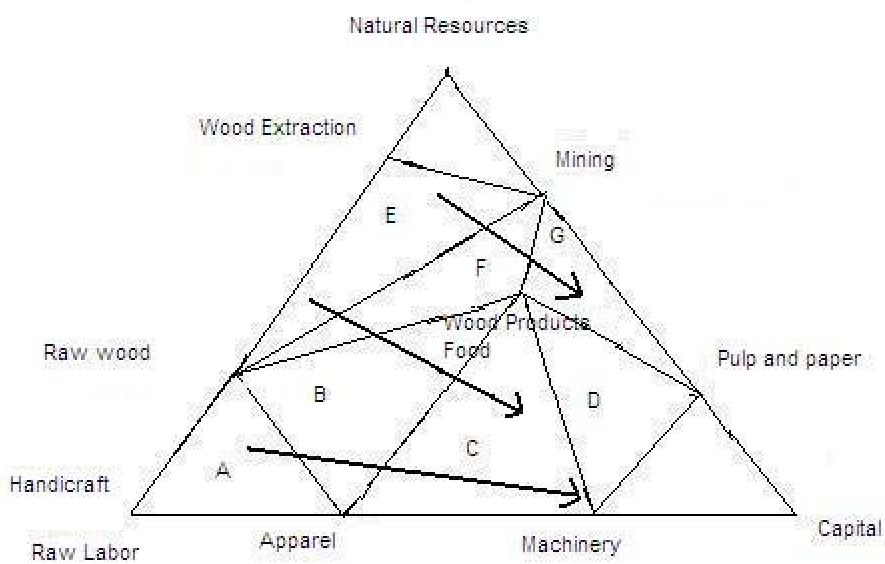

Figure 3

Korea: Net Exports of Manufacturing Goods

(Thousands of US dollars per worker)

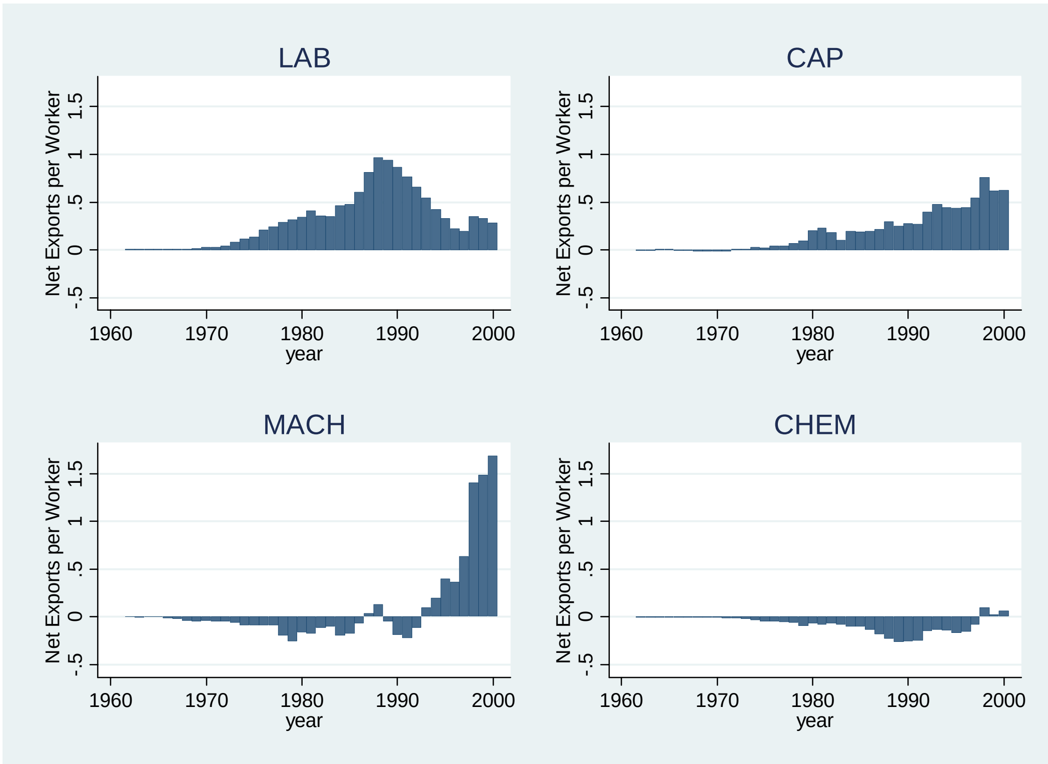

Figure 4

Chile: Net Exports of Manufacturing Goods

(Thousands of US dollars per worker)

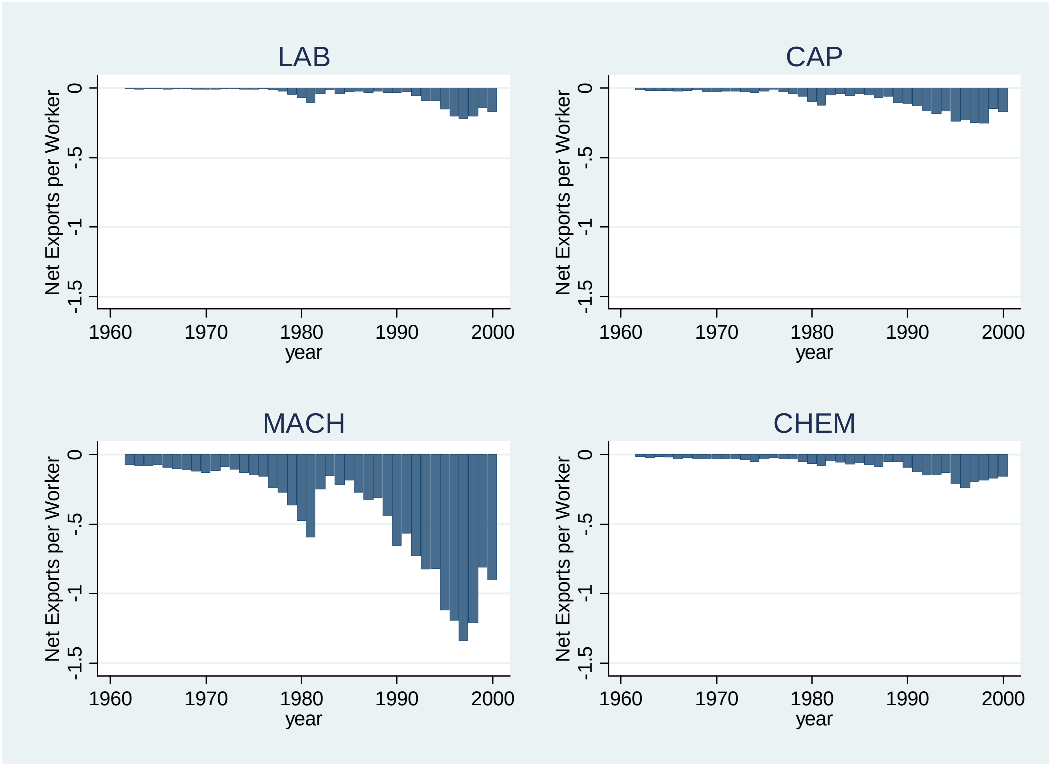

Figure 5

Finland: Net Exports of Manufacturing Goods

(Thousands of US dollars per worker)

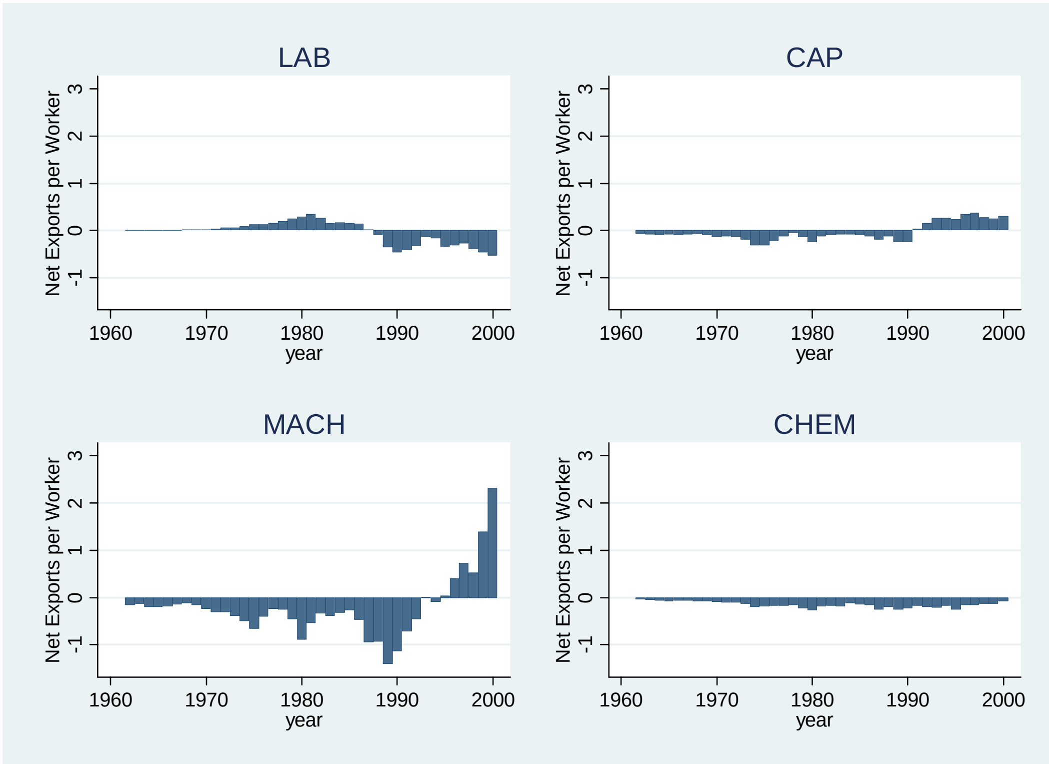

Figure 6

Net Exports of Manufacturing Goods and Capital per Worker

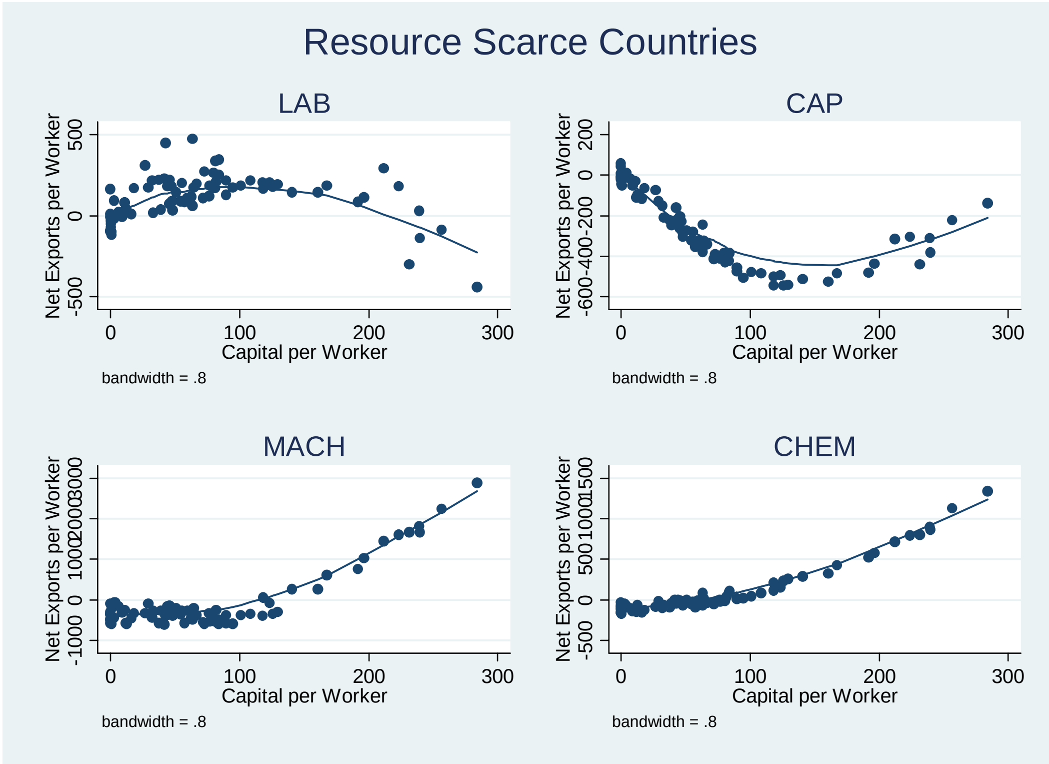

Figure 7

Net Exports of Manufacturing Goods and Capital per Worker

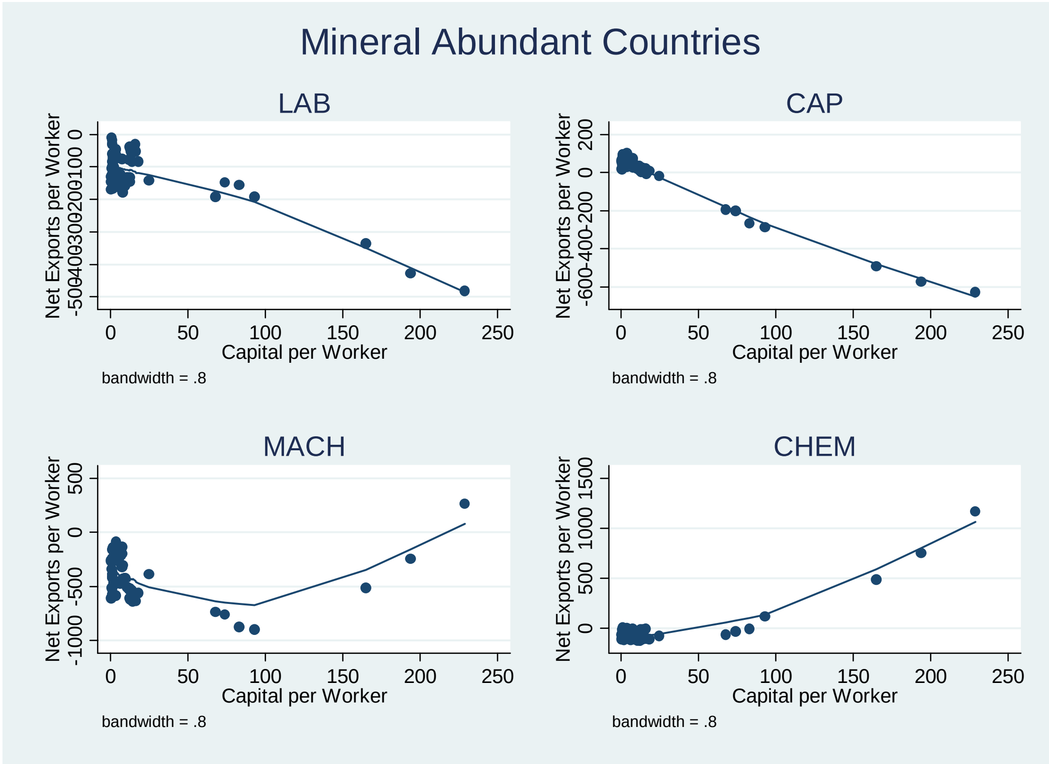

Figure 8

Net Exports of Manufacturing Goods and Capital per Worker

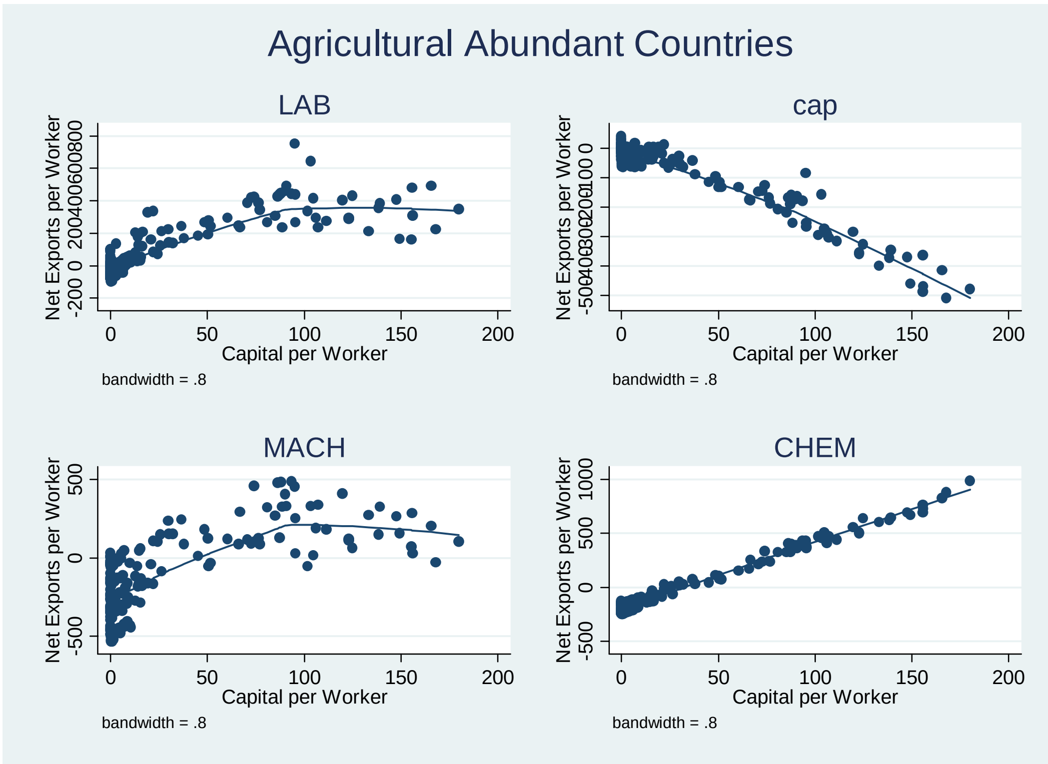

Figure 9

Net Exports of Manufacturing Goods and Capital per Worker

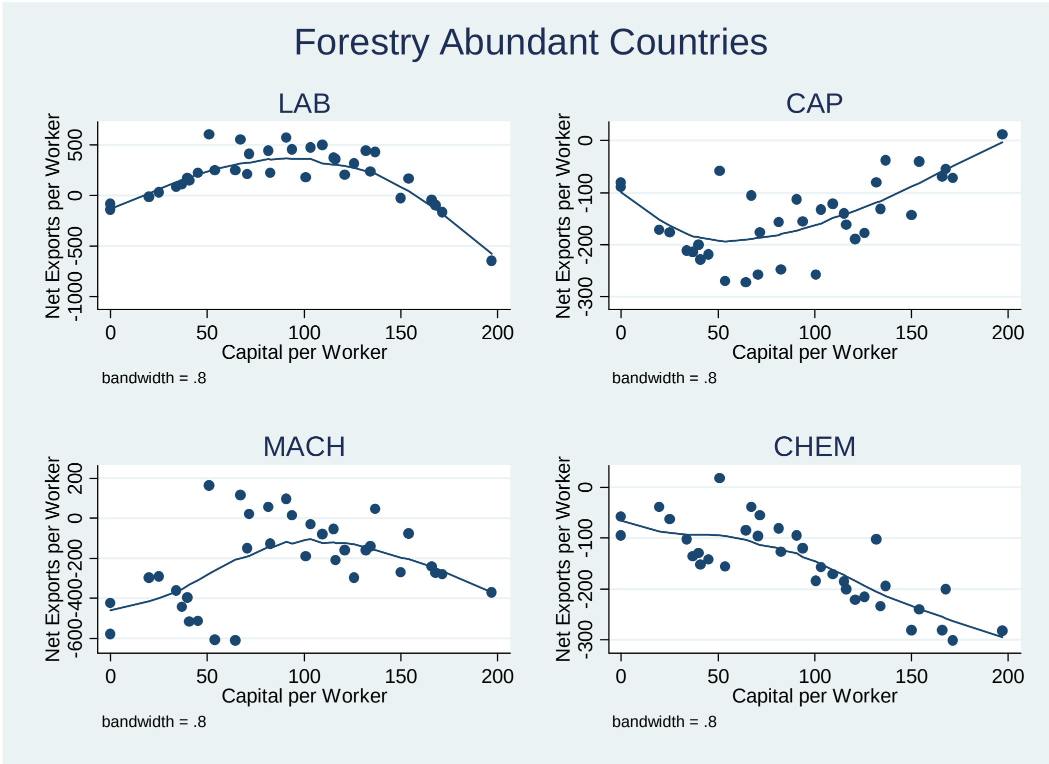

Figure 10

The Theoretical Case for Natural Resource Scarce Countries

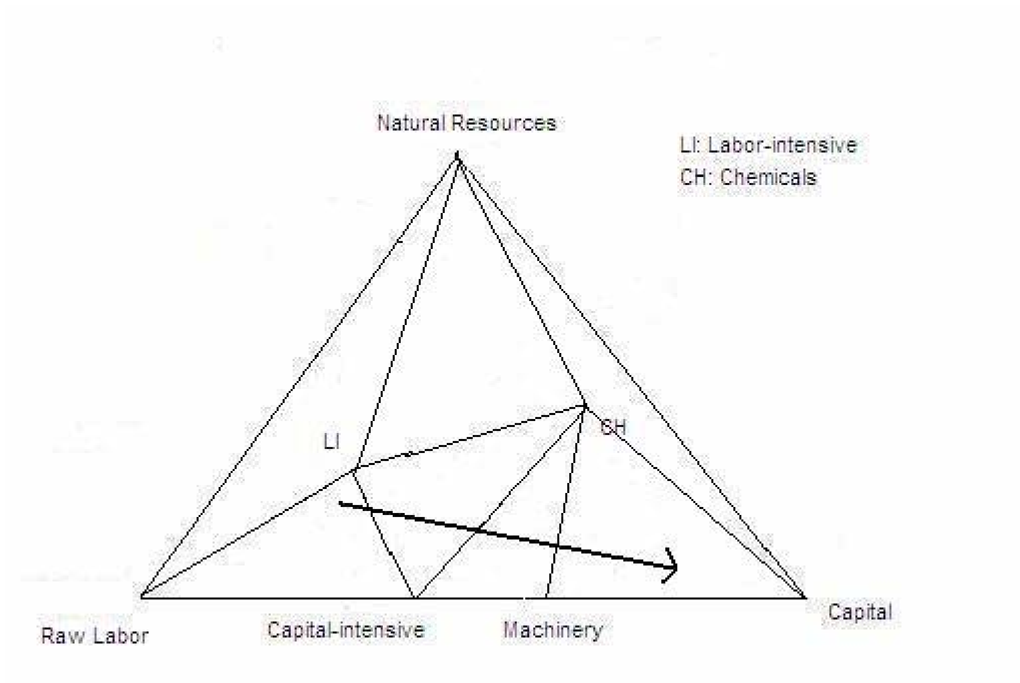

Figure 11

The Theoretical Case for Mining Abundant Countries

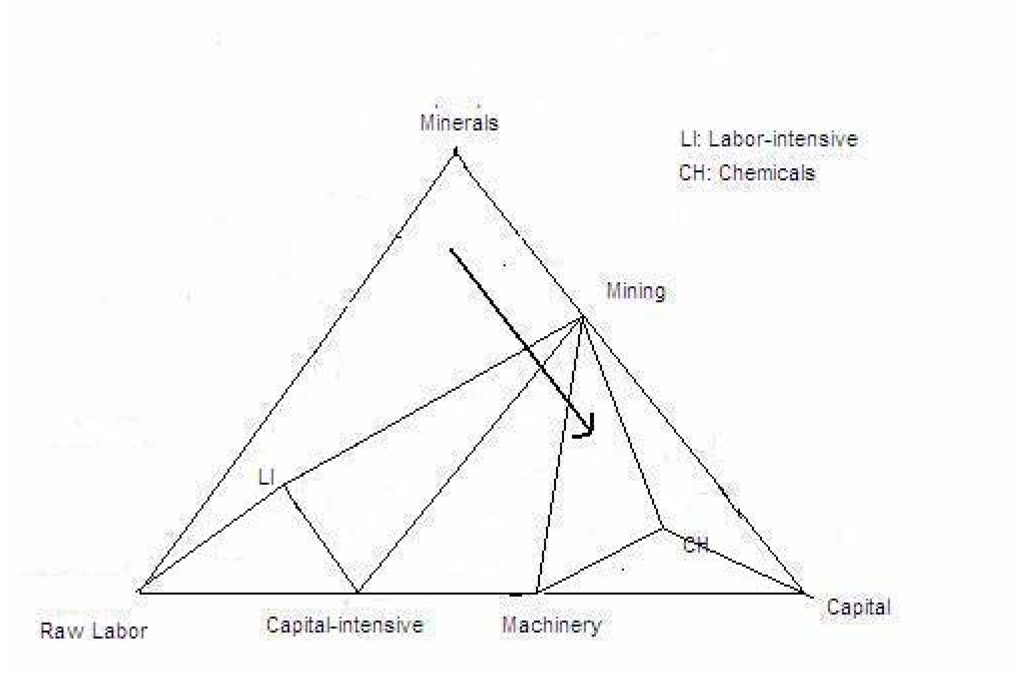

Figure 12

Net Exports of Manufacturing Goods and Human Capital per Worker

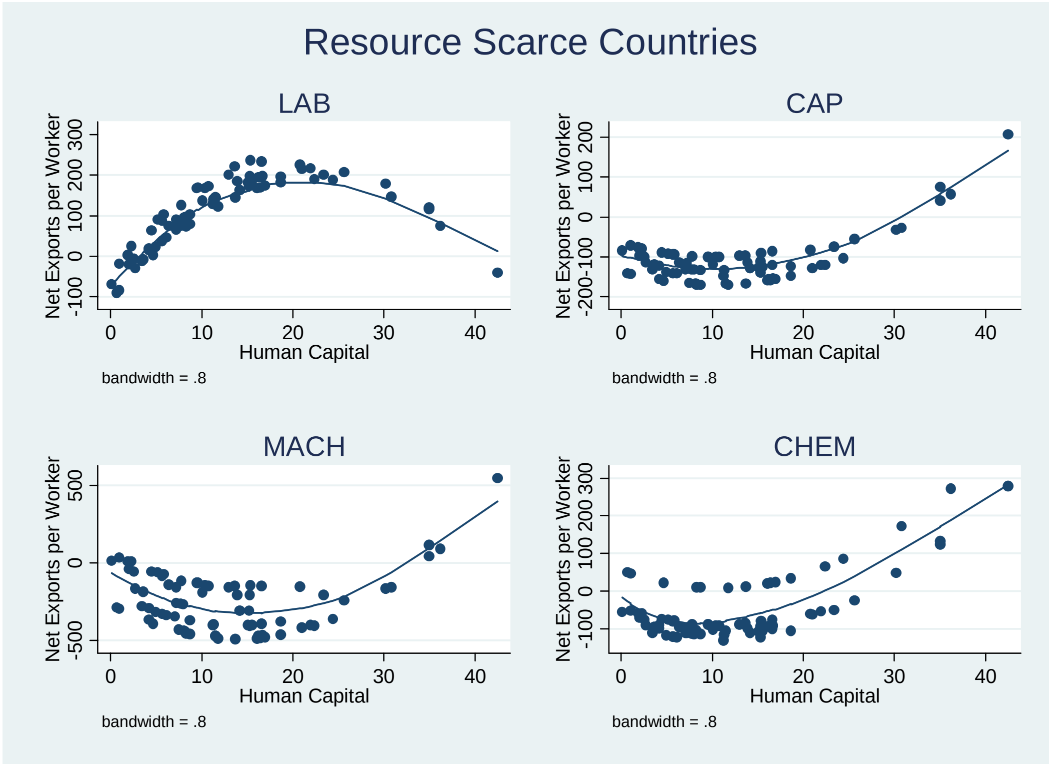

Figure 13

Net Exports of Manufacturing Goods and Human Capital per Worker

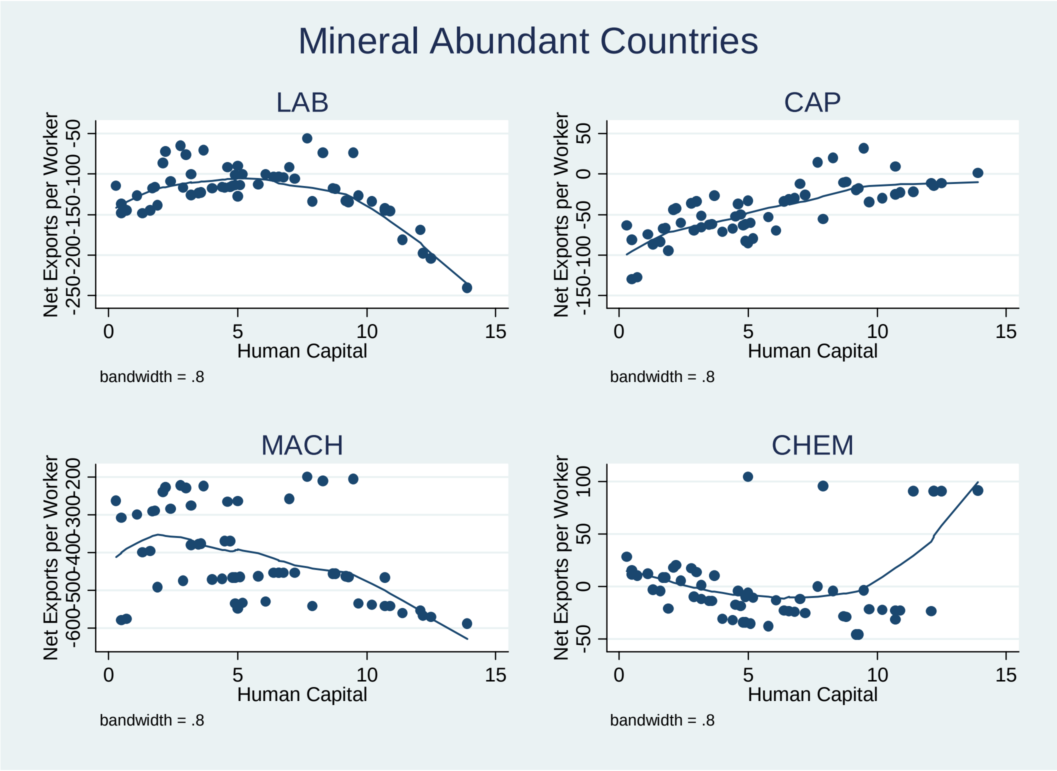

Figure 14

Net Exports of Manufacturing Goods and Human Capital per Worker

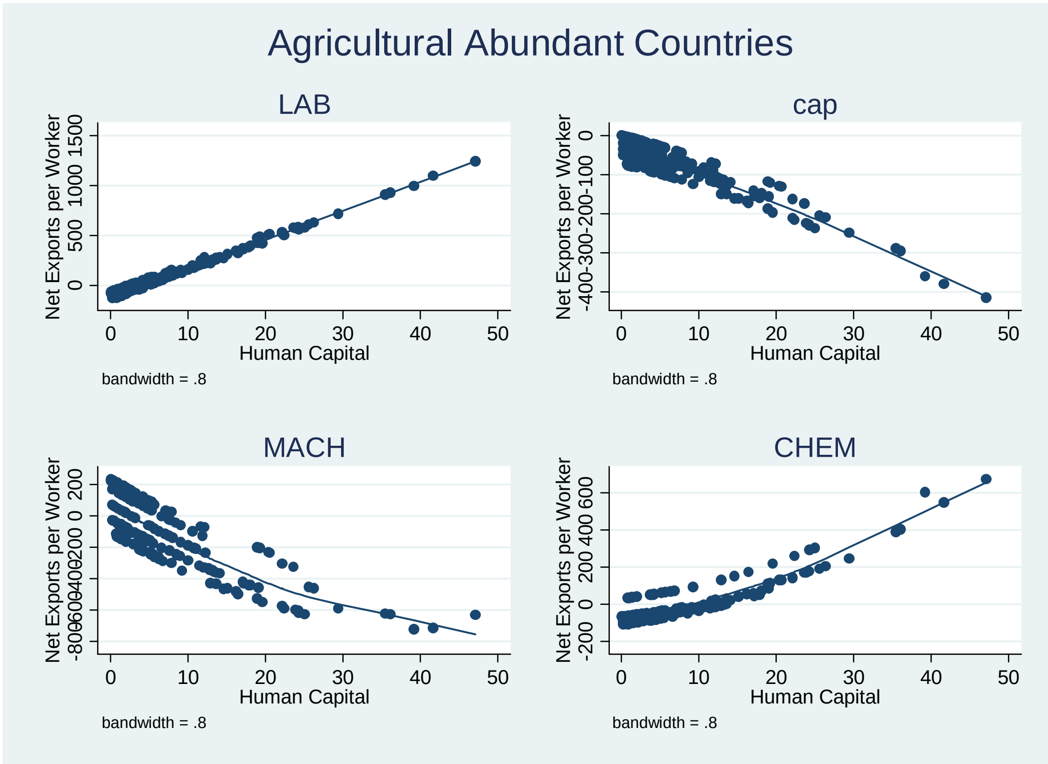

Figure 15

Net Exports of Manufacturing Goods and Human Capital per Worker

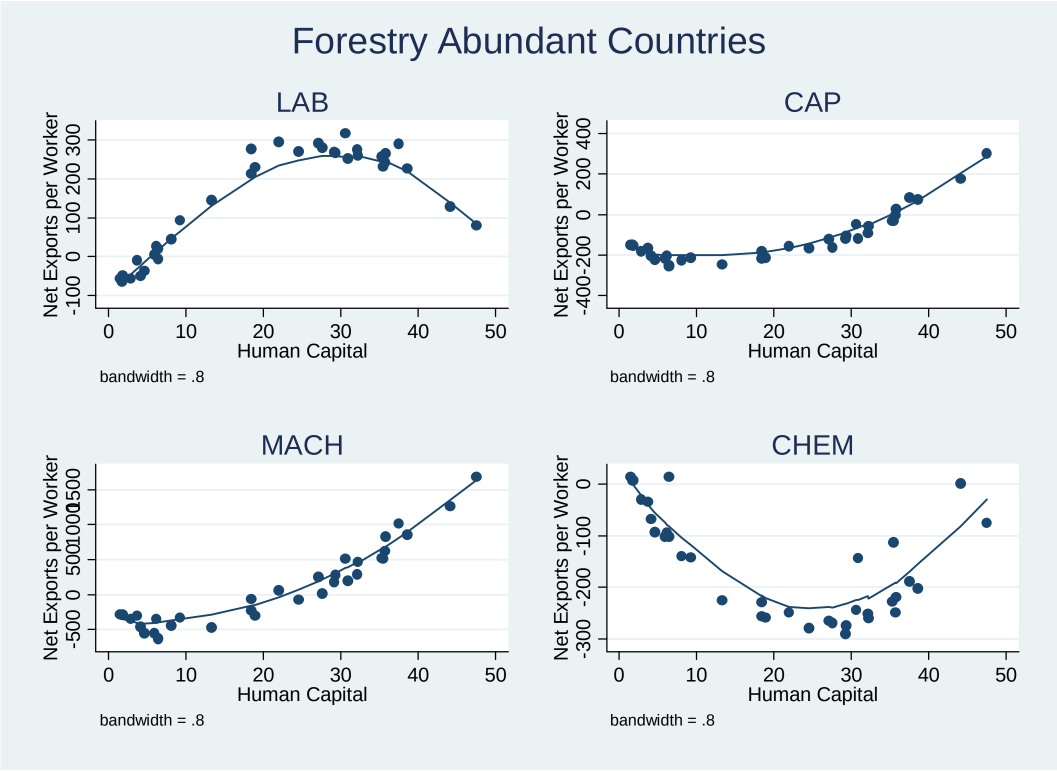

Figure 16

Net Exports of Manufacturing Goods and Capital per Worker

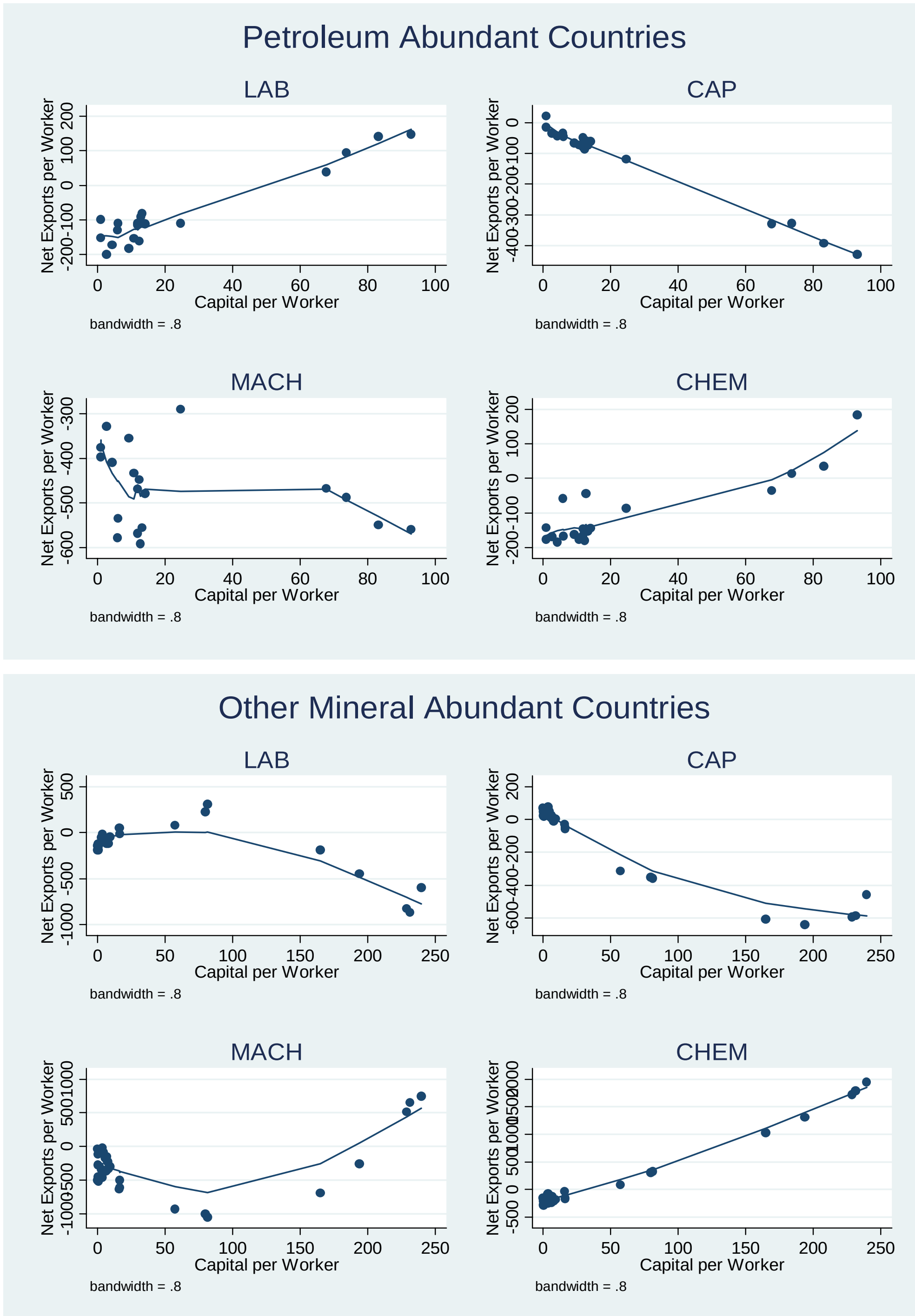

Table 1. Transition Matrix for Net Exports of labor-intensive Goods

LABOR-INTENSIVE
Natural Resource Scarce Countries

Quartile: 62-65	Quartile: 95-00 1	2	3	4	N	%
1	42.9	14.3	0.0	42.9	7	38.9
2	0.0	66.7	0.0	33.3	3	16.7
3	0.0	0.0	100.0	0.0	1	5.6
4	28.6	0.0	0.0	71.4	7	38.9
N	5	3	1	9	18	
%	27.8	16.7	5.6	50.0		

LABOR-INTENSIVE
Natural Resource Abundant Countries

Quartile: 62-65	Quartile: 95-00 1	2	3	4	N	%
1	34.6	38.5	15.4	11.5	26	23.2
2	13.3	53.3	26.7	6.7	30	26.8
3	32.3	12.9	35.5	19.4	31	27.7
4	24.0	0.0	12.0	64.0	25	22.3
N	29	30	26	27	112	
%	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

Quartile: 62-65	Quartile: 95-00 1	2	3	4	N	%
1	71.4	14.3	14.3	0.0	7	38.9
2	0.0	100.0	0.0	0.0	1	5.6
3	0.0	50.0	0.0	50.0	2	11.1
4	0.0	0.0	12.5	87.5	8	44.4
N	5	3	2	8	18	
%	27.8	16.7	11.1	44.4		

CAPITAL-INTENSIVE
Natural Resource Abundant Countries

Quartile: 62-65	Quartile: 95-00 1	2	3	4	N	%
1	52.0	24.0	16.0	8.0	25	22.5
2	16.1	38.7	41.9	3.2	31	27.9
3	12.9	29.0	41.9	16.1	31	27.9
4	8.3	8.3	8.3	75.0	24	21.6
N	24	29	32	26	111	
%	21.6	26.1	28.8	23.4		

Table 3. Transition Matrix for Net Exports of Machinery

MACHINERY Natural Resource Scarce Countries						
	Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%
1	66.7	16.7	16.7	0.0	6	33.3
2	33.3	66.7	0.0	0.0	3	16.7
3	0.0	0.0	0.0	100.0	1	5.6
4	12.5	0.0	0.0	87.5	8	44.4
N	6	3	1	8	18	
%	33.3	16.7	5.6	44.4		

MACHINERY Natural Resource Abundant Countries						
	Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%
1	64.0	32.0	4.0	0.0	25	22.5
2	30.0	43.3	26.7	0.0	30	27.0
3	9.4	18.8	50.0	21.8	32	28.8
4	4.2	0.0	20.8	75.0	24	21.6
N	29	27	30	25	111	
%	26.1	24.3	27.0	22.5		

Table 4. Transition Matrix for Net Exports of Chemicals

CHEMICALS Natural Resource Scarce Countries						
	Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%
1	60.0	20.0	0.0	20.0	5	27.8
2	33.3	33.3	33.3	0.0	3	16.7
3	0.0	0.0	50.0	50.0	2	11.1
4	25.0	0.0	0.0	75.0	8	44.4
N	6	2	2	8	18	
%	33.3	11.1	11.1	44.4		

CHEMICALS Natural Resource Abundant Countries						
	Quartile: 95-00					
Quartile: 62-65	1	2	3	4	N	%
1	48.0	28.0	12.0	12.0	25.0	22.5
2	20.0	50.0	23.3	6.7	30.0	27.0
3	6.5	12.9	54.8	25.8	31.0	27.9
4	32.0	12.0	16.0	40.0	25.0	22.5
N	28	29	31	23	11	
%	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

Table6: Panel Data Estimation Controlling for Secondary Education

	LAB	CAP	MACH	CHEM
KL	3.541	-7.399	-7.536	0.346
	(2.08)*	(6.81)**	(1.85)	(0.11)
$(KL)^2$	-0.019	0.024	0.068	0.016
	(3.21)**	(6.31)**	(4.73)**	(1.43)
D_M	-51.278	76.488	-53.311	70.958
	(0.96)	(2.23)*	(0.41)	(0.70)
D_A	23.138	-1.424	47.112	-73.782
	(0.47)	(0.05)	(0.40)	(0.79)
D_F	-124.325	-114.165	-293.308	55.138
	(2.09)*	(3.01)**	(2.06)*	(0.49)
D_M * KL	-5.763	2.685	-1.229	-2.120
	(2.82)**	(2.05)*	(0.25)	(0.55)
D_M * $(KL)^2$	0.022	-0.017	-0.018	0.016
	(2.00)*	(2.36)*	(0.66)	(0.75)
D_A * KL	2.828	4.951	13.793	5.711
	(1.38)	(3.77)**	(2.79)**	(1.47)
D_A * $(KL)^2$	-0.017	-0.029	-0.095	-0.017
	(1.55)	(4.13)**	(3.53)**	(0.81)
D_F * KL	7.751	4.135	11.859	-1.029
	(2.72)**	(2.27)*	(1.73)	(0.19)
D_F * $(KL)^2$	-0.058	-0.007	-0.084	-0.021
	(4.57)**	(0.82)	(2.75)**	(0.86)
Secondary	12.051	4.915	10.079	2.485
	(4.11)**	(2.62)**	(1.43)	(0.45)
Constant	-100.658	-7.243	-96.688	-82.663
	(1.82)	(0.20)	(0.73)	(0.79)
Observations	584	584	584	584
Countries	73	73	73	73
R-squared	0.23	0.20	0.24	0.07
F-test				
All interactive terms are zero	0.000	0.000	0.000	0.047
Mining interactive terms are zero	0.006	0.059	0.063	0.700
Agricultural interactive terms are zero	0.290	0.000	0.000	0.077
Forestry interactive terms are zero	0.000	0.000	0.003	0.030

Notes: Absolute value of t statistics in parentheses. * significant at 5%; ** significant at 1%. For F-test, p-value is reported. KL is capital per worker, $(KL)^2$ is squared of capital per worker, D_M is a dummy variable for net exporters of mineral products, D_A is dummy for net exporters of agricultural products, and D_F is dummy for net exporters of forestry products. Secondary is the percentage of population aged over 25 years with complete secondary school.

Table7: Panel Data Estimation Controlling for Post-Secondary Education

	LAB	CAP	MACH	CHEM
KL	5.566	-6.969	-3.565	0.581
	(3.23)**	(6.32)**	(0.88)	(0.18)
$(KL)^2$	-0.023	0.023	0.059	0.016
	(3.90)**	(6.01)**	(4.20)**	(1.38)
D_M	-13.531	82.377	32.851	74.362
	(0.25)	(2.37)*	(0.26)	(0.73)
D_A	29.570	-2.130	71.611	-73.990
	(0.60)	(0.07)	(0.62)	(0.80)
D_F	-142.587	-117.399	-332.778	53.314
	(2.38)*	(3.07)**	(2.37)*	(0.47)
D_M * KL	-6.381	2.596	-2.681	-2.173
	(3.09)**	(1.97)*	(0.55)	(0.56)
D_M * $(KL)^2$	0.025	-0.017	-0.011	0.016
	(2.21)*	(2.32)*	(0.40)	(0.75)
D_A * KL	1.539	4.513	12.212	5.486
	(0.75)	(3.44)**	(2.53)*	(1.42)
D_A * $(KL)^2$	-0.009	-0.026	-0.085	-0.015
	(0.81)	(3.73)**	(3.27)**	(0.74)
D_F * KL	8.582	4.001	15.268	-1.076
	(2.97)**	(2.16)*	(2.25)*	(0.20)
D_F * $(KL)^2$	-0.059	-0.006	-0.094	-0.020
	(4.61)**	(0.68)	(3.11)**	(0.84)
Post-secondary	-22.607	-0.763	-67.472	-0.765
	(3.36)**	(0.18)	(4.26)**	(0.06)
Constant	5.566	-6.969	-3.565	0.581
	(3.23)**	(6.32)**	(0.88)	(0.18)
Observations	584	584	584	584
Countries	73	73	73	73
R-squared	0.22	0.19	0.27	0.07
F-test				
All interactive terms are zero	0.000	0.000	0.000	0.052
Mining interactive terms are zero	0.002	0.062	0.048	0.704
Agricultural interactive terms are zero	0.721	0.001	0.001	0.077
Forestry interactive terms are zero	0.000	0.000	0.002	0.032

Notes: Absolute value of t statistics in parentheses. * significant at 5%; ** significant at 1%. For F-test, p-value is reported. KL is capital per worker, $(KL)^2$ is squared of capital per worker, D_M is a dummy variable for net exporters of mineral products, D_A is dummy for net exporters of agricultural products, and D_F is dummy for net exporters of forestry products. Post-secondary is the percentage of population aged over 25 years with complete post-secondary school.

Table8: Panel Data Estimation Using Human Capital

	LAB	CAP	MACH	CHEM
HK	26.798	-6.973	-32.345	-8.664
	(2.82)**	(1.15)	(1.38)	(0.49)
$(HK)^2$	-0.600	0.341	1.166	0.405
	(2.45)*	(2.18)*	(1.94)	(0.89)
D_M	-74.611	-2.501	-332.679	74.456
	(1.21)	(0.06)	(2.19)*	(0.65)
D_A	-33.905	64.702	161.974	-24.613
	(0.54)	(1.61)	(1.04)	(0.21)
D_F	-68.521	-69.340	-345.203	90.525
	(0.91)	(1.45)	(1.87)	(0.65)
D_M * HK	-6.886	18.077	47.894	2.582
	(0.75)	(3.07)**	(2.11)*	(0.15)
D_M * $(HK)^2$	-1.124	-0.416	-2.226	-0.163
	(3.64)**	(2.11)*	(2.93)**	(0.28)
D_A * HK	1.527	1.645	2.503	13.145
	(0.17)	(0.28)	(0.11)	(0.78)
D_A * $(HK)^2$	0.619	-0.394	-0.808	-0.148
	(2.31)*	(2.30)*	(1.23)	(0.30)
D_F * HK	3.459	-3.681	20.534	-14.876
	(0.33)	(0.56)	(0.81)	(0.78)
D_F * $(HK)^2$	0.072	0.097	0.065	0.054
	(0.26)	(0.55)	(0.09)	(0.10)
Constant	-33.051	-64.253	75.438	-41.925
	(0.49)	(1.48)	(0.45)	(0.33)
Observations	584	584	584	584
Countries	73	73	73	73
R-squared	0.17	0.14	0.14	0.03
F-test				
All interactive terms are zero	0.000	0.000	0.000	0.722
Mining interactive terms are zero	0.000	0.009	0.014	0.956
Agricultural interactive terms are zero	0.000	0.000	0.096	0.578
Forestry interactive terms are zero	0.551	0.848	0.235	0.422

Notes: Absolute value of t statistics in parentheses. * significant at 5%; ** significant at 1%. For F-test, p-value is reported HK is the percentage of population aged over 25 years with complete secondary school. D_M is a dummy variable for net exporters of mineral products, D_A is dummy for net exporters of agricultural products, and D_F is dummy for net exporters of forestry products.

Table 9: Panel Data Estimation Using Net Exports as Continuous Variable

	LAB	**CAP**	**MACH**	**CHEM**
Capital per worker				
All interactive terms are zero	0.034	0.464	0.000	0.000
Mining interactive terms are zero	0.175	0.207	0.001	0.003
Agricultural interactive terms are zero	0.030	0.399	0.002	0.000
Forestry interactive terms are zero	0.160	0.545	0.248	0.273
Human capital per worker				
All interactive terms are zero	0.000	0.000	0.140	0.375
Mining interactive terms are zero	0.100	0.230	0.617	0.536
Agricultural interactive terms are zero	0.000	0.000	0.631	0.266
Forestry interactive terms are zero	0.004	0.216	0.020	0.506

Table 10: Panel Data Estimation Controlling for Secondary Education and Trade Openness

	LAB	CAP	MACH	CHEM
KL	5.008	-5.650	-3.973	0.334
	(3.14)**	(5.75)**	(0.97)	(0.10)
$(KL)^2$	-0.022	0.019	0.061	0.017
	(3.90)**	(5.71)**	(4.28)**	(1.41)
D_M	0.265	140.444	-27.609	46.157
	(0.00)	(4.26)**	(0.20)	(0.40)
D_A	20.333	42.641	129.548	-89.492
	(0.39)	(1.34)	(0.97)	(0.81)
D_F	-87.063	10.914	-90.238	51.160
	(1.43)	(0.29)	(0.57)	(0.39)
D_M * KL	-2.619	1.973	7.149	1.453
	(1.27)	(1.55)	(1.34)	(0.33)
$D_M * (KL)^2$	0.013	-0.015	-0.047	0.003
	(1.19)	(2.31)*	(1.74)	(0.13)
D_A * KL	1.875	3.699	10.411	5.680
	(0.96)	(3.07)**	(2.07)*	(1.35)
$D_A * (KL)^2$	-0.011	-0.024	-0.076	-0.015
	(1.07)	(3.68)**	(2.83)**	(0.66)
D_F * KL	7.253	2.098	8.205	-1.287
	(2.73)**	(1.28)	(1.20)	(0.23)
$D_F * (KL)^2$	-0.058	0.001	-0.074	-0.021
	(4.88)**	(0.07)	(2.41)*	(0.84)
Secondary	9.371	1.751	5.624	2.956
	(3.43)**	(1.04)	(0.80)	(0.50)
Trade Openness	27.036	12.256	-3.685	-55.303
	(0.70)	(0.51)	(0.04)	(0.67)
Constant	(0.46)	(1.69)	(3.96)**	(0.20)
	-166.684	-90.028	-259.162	-61.894
Observations	(2.91)**	(2.55)*	(1.76)	(0.50)
Countries	536	536	536	536
R-squared	0.23	0.26	0.26	0.08
F-test				
All interactive terms are zero	0.000	0.000	0.000	0.020
Mining interactive terms are zero	0.449	0.023	0.176	0.506
Agricultural interactive terms are zero	0.559	0.000	0.004	0.070
Forestry interactive terms are zero	0.000	0.003	0.002	0.025

Notes: Absolute value of t statistics in parentheses. * significant at 5%; ** significant at 1%. For F-test, p-value is reported. KL is capital per worker, $(KL)^2$ is squared of capital per worker, D_M is a dummy variable for net exporters of mineral products, D_A is dummy for net exporters of agricultural products, and D_F is dummy for net exporters of forestry products. Secondary is the percentage of population aged over 25 years with complete secondary school. Trade openness is the percentage of year that a country is classified as "open" according to Sachs and Warner (1995)'s classification updated by Wacziarg and Horn Welch (2003).

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
Forestry 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	Forestry
ARG	Argentina	2	8	0
AUS	Australia	8	8	0
AUT	Austria	0	0	8
BOL	Bolivia	8	1	5
BRA	Brazil	0	8	8
CAN	Canada	8	8	8
CHE	Switzerland	0	0	0
CHL	Chile	8	5	8
CMR	Cameroon	8	8	8
COL	Colombia	6	8	0
CRI	Costa Rica	0	8	0
CYP	Cyprus	3	5	0
DNK	Denmark	0	8	0
DOM	Dominican Republic	1	8	0
DZA	Algeria	8	2	0
ECU	Ecuador	6	8	0
ESP	Spain	0	2	0
FIN	Finland	0	0	8
FRA	France	0	6	0
GBR	United Kingdom	4	0	0
GHA	Ghana	7	8	8
GRC	Greece	0	5	0
GTM	Guatemala	0	8	0
GUY	Guyana	8	8	5
HND	Honduras	0	8	5
HTI	Haiti	3	4	0
IDN	Indonesia	8	8	7
IND	India	0	7	0
IRL	Ireland	0	8	0
IRN	Iran, Islamic Rep.	8	2	0
ISL	Iceland	3	8	0
ISR	Israel	0	2	0
ITA	Italy	0	0	0
JAM	Jamaica	7	4	0
JOR	Jordan	6	0	0
JPN	Japan	0	0	0
KEN	Kenya	0	8	0
KOR	Korea, Rep.	0	0	0
LKA	Sri Lanka	0	8	0
MEX	Mexico	8	5	1
MLI	Mali	0	7	0
MOZ	Mozambique	6	5	2
MUS	Mauritius	0	8	0
MWI	Malawi	1	8	0
MYS	Malaysia	8	8	8
NIC	Nicaragua	0	8	1

Continue…

WB code	Country Name	Minerals	Agricultural	Forestry
NLD	Netherlands	3	8	0
NOR	Norway	8	7	8
NZL	New Zealand	0	8	8
PAK	Pakistan	0	5	0
PAN	Panama	0	8	0
PER	Peru	8	8	0
PHL	Philippines	1	7	6
PRT	Portugal	0	0	8
PRY	Paraguay	0	8	8
RWA	Rwanda	8	8	0
SEN	Senegal	6	8	0
SGP	Singapore	3	1	1
SLE	Sierra Leone	6	5	0
SLV	El Salvador	0	8	0
SWE	Sweden	0	0	8
THA	Thailand	0	8	0
TTO	Trinidad and Tobago	8	1	0
TUN	Tunisia	6	2	0
TUR	Turkey	0	8	0
TWN	Taiwan	2	4	6
UGA	Uganda	3	8	0
URY	Uruguay	0	8	0
USA	United States	0	8	1
VEN	Venezuela, RB	8	0	0
ZAF	South Africa	8	8	3
ZMB	Zambia	8	3	0
ZWE	Zimbabwe	8	8	3

Notes: It correspond to the number of periods – over 8 periods - that a country is classified as abundant in each of the three natural resources considered. 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.

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