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Trade in Mineral Resources

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Background paper to the 2010 World Trade Report

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Introduction

This paper provides a review of current thinking on the economics of international trade in mineral resources. There is not a great deal written on this topic, and so my review is necessarily broad rather than deep. In some cases I am only able to cite related and even tangential literature.

I first define what is meant by trade in mineral resources. I then discuss patterns of trade in mineral resources. The paper then moves on to the five topics requested by the World Trade Organization: theoretical and empirical literature on international trade in minerals; trade impacts of mineral abundance and the resource curse; the political economy of mineral trade in resource-abundant states; non-economic considerations associated with strategic mineral resources; and the impact of domestic market structure and regulation on production and trade in minerals.

Defining Mineral Resources

Natural resources are both renewable and non-renewable. Renewable resources are fish and forest products and renewable energy. Non-renewable resources include both non-renewable energy and minerals. References to "energy" can include solid fossil energy and uranium. Typically, however, energy refers to oil and natural gas. References to "mineral" commodities typically refer to solids that must be mined. The energy minerals coal and uranium are mined, and so can fall in either the energy or mineral category. For present purposes the term mineral resources includes all solids that must be mined, including coal and uranium.

Economic theories associated with non-renewable resource production and exhaustion do not differentiate between energy and minerals. The one characteristic that distinguishes the energy group is the lack of competitive markets. But this is not the reason for the traditional distinction between the flowing and solid minerals. Rather, the distinction is a result of the fact that certain firms tend to extract energy, while others tend to extract minerals.[1] Each sector supports the education of its own engineers, and so engineers are

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[1] Some firms extract both. A foray by the major energy companies into mining in the 1980s was quickly reversed when it became clear that there was little technological spillover.

trained either in energy or minerals in separate departments at universities. The professional energy societies hold separate meetings from the professional mining societies. Likewise, academic energy economists have their own societies and journals, and attend separate, focused meetings about energy, while academic mineral economists attend their own set of society meetings about minerals and mining. Coal and uranium are discussed in both camps.

The first saleable product of mining is concentrates, which are manufactured from mineral ores. Ores are a concentration of mineralization located either proximate to the surface or underground. They are liberated from surrounding rock and brought to the surface via energy-intensive and capital-intensive mechanical means. These techniques range from relatively low-technology loaders and scrapers in the case of some industrial minerals to extreme high-technology processes to mine gold several kilometers underground. The creation of concentrates from ore requires additional applications of energy, labor, and capital at the surface. Mining is therefore very similar to manufacturing. The main difference is that with manufacturing raw materials are brought to fixed locations where they are combined with labor and capital, while in mining labor and capital are brought to the raw materials and combined at the location of the rock.

In accordance with the Alchian-Allen conjecture (Hummels and Skiba 2004), international trade in ore is rare. Due to its relatively low price per ton, ore undergoes at least some processing at or near the extraction site in order to increase its value per unit weight prior to shipment. Coal is crushed and washed, iron is upgraded and lumped or pelletized into iron ore, copper is concentrated to a concentrate containing some 30% copper, and industrial minerals are washed, ground and sized. It is these processed materials, called “ores and concentrates” in the Standard International Trade Classification (SITC), that are then traded. The prices per unit weight of iron ore and steam coal, at roughly $0.02/kg (Radetzki 2008), are a fraction of the price of coffee and wool, and yet are sufficient to warrant that these commodities are transported internationally given current bulk transportation costs. The prices of industrial minerals are even lower, meaning that there are limits to how far these materials can be profitably transported even given local upgrading. Sized sand and gravel, for example, is not shipped more than a few hundred miles from its source due to its low value per unit weight.

That minerals require the application of energy, labor, and capital in order to liberate their services is an important point to note. Many academic models of the mining sector have minerals flowing from the ground at no direct cost and then being exported or added as an input to final goods production. This has implications in models of endogenous growth, in which factor reallocations away from manufacturing and into mining within a booming minerals economy are asserted to lead to slower economic growth (e.g., Sachs and Warner 1997, van Wijnbergen 1984).

Patterns of Trade in Minerals and Metals

In trade studies, "minerals" are often classified as those commodities in SITC 2-digit sections 27 (crude industrial minerals) and 28 (metalliferous ores and scraps).[2] The latter includes concentrates. Metals are found in SITC categories 67 (iron and steel) and 68 (non-ferrous metals). These four sections are often combined in studies of mineral and metal trade (e.g., Radetzki 2008). SITC section 66 (non-metallic mineral manufactures) includes lime, cement, building stone, clays, and precious stones such as diamonds. Non-monetary trade in coin is found in SITC 96, and non-monetary trade in gold is found in SITC section 97.[3] Though sections 66, 96 and 97 are normally excluded from common minerals and metals aggregations, they should be included since they are no different from including the value-added products of iron and steel (SITC 67) and metals such as copper and silver (SITC 68). Furthermore, the value of trade in precious stones (SITC 667) is greater than that of aluminum and copper ores and metals combined (Radetzki 2008, p. 28), and so leaving it out of the calculus risks highly distorting the analysis.

Secondary supply, such as recycled scrap, is included in sections 27 and 28, which distorts to some degree the usefulness of these classifications for studying link between factor abundance in ores and trade in minerals. Given the rising international trade in recycles, this is becoming an increasingly problematic issue with using these data aggregations to infer domestic production.

The energy mineral uranium is included in section 28, but coal is found in section 32, and so is excluded from studies of mineral and metal trade that include sections 27 + 28 + 67 + 68. One would think that for consistency either uranium and coal would both be excluded from the aggregation because they are energy minerals, or both included because they are mined. I suggest that a complete listing of mineral ores and concentrates would be SITC 27 + 28 + 32 + 66 + 97. I include gold metal here because most gold mines concentrate the gold to refined bars on site, a fairly simple process requiring only small furnaces and one laborer. To exclude section 97 would be to exclude gold mineral flows altogether.

Metal products would include SITC 67 + 68 + 96. A minerals and metals aggregate would include the sum of the two groupings: SITC 27 + 28 + 32 + 66 + 67 + 68 + 96 + 97. The iron and steel group (SITC 67) is sometimes thought to be a manufacture (e.g. UNIDO 1981, p. 68, n 13), and so may be excluded from this group.

Worldwide mineral export volume grew by 4.1% annually from 1950 to 2003 (Maxwell 2006). Production grew at only 2.7%, indicating an increasing degree of specialization across countries during this period; more production was traded and less was consumed domestically as an input to the production of value-added goods. In 1965 minerals and metals (SITC 27+28+67+68) accounted for 12.4% of the value of global exports (Radetzki 2008). By 2005 this had shrunk to 6.6%, though the value of annual mineral

[2] SITC tracks trade in merchandise. The UN is developing a new system, SITS, to track trade in services.
[3] Unfortunately, trade data in this category is missing for many gold producing nations. Some of the data that does exist combines monetary (i.e., central bank) and non-monetary shipments of gold.

and metal exports rose from $23 billion to $671 billion over the period, mainly due to increases in tonnages shipped. This increase in tonnage reflects both the impacts of reductions in trade barriers and the reduction in bulk transportation costs (Maxwell 2006). The top mineral and metal commodities traded over the 2003-2005 period were iron and steel ($249 billion/yr.), precious stones ($74 billion/yr.), copper concentrates and metals ($35 billion/yr.), coal ($33 billion/yr.) and aluminum concentrates and metals ($30 billion/yr.) (Radetzki 2008, p. 28). To put this in perspective, average annual exports of aircraft were $116 billion over this same period. By weight, coal and iron ore are by far the most extensively traded minerals.

It has long been held that developing countries tend to export raw materials and import manufactures. In a study of the trade patterns of 60 developed and developing countries in 1958 and 1975, certain countries did demonstrate a higher concentration of trade in minerals and energy per unit of GNP than other countries (Leamer 1984). The extreme exporters were Indonesia, Columbia, Ecuador, Nigeria, Libya (petroleum products), and Canada, Chile, Australia, and Netherlands (raw materials including ores, metals and natural gas). The extreme importers were the US, UK, France, Italy, Belgium-Luxembourg, and Japan. Countries abundant in labor and capital tended to export manufactures, and countries abundant in natural resources tended to export raw materials. In what he calls the "development ladder," Leamer (1984, Tables 4.4 and 4.5) shows that the developed countries are predominately the net exporters of labor and capital-intensive manufactured goods (SITC 6 through 9) and importers of raw materials and resource-intensive manufactures (SITC 0 through 6), while the developing countries are net importers of manufactured good and exporters of raw materials. UNIDO (1981) confirms that in 1975, 62% of the manufacturing exports from developing countries were resource-based manufactures, SITC 6.[4]

As of 2005, Latin America and the Former Soviet Union were the main exporters of minerals and metals. The OECD countries, China, and India were the main importers. Chile is the world's dominant copper exporter, Australia coal, Brazil and Australia iron ore, and Indonesia tin (Radetzki 2008, pp. 34-35).

It is of interest whether certain groups of raw materials tend to be traded together and whether the same countries that produce and export ores and concentrates also export value-added products such as refined metals. Leamer (1984, Tables 3.1 and 3.2) determines that between 1958 and 1975 country net exports in SITC 2-digit sections 23 (crude rubber), 24 (cork and wood), 27, 28, 68 and 96 were highly correlated. He does not include section 97 (non-monetary gold) in his analysis. Primary ores and concentrates (section 28) and their metals (section 68) are thus often exported simultaneously, the mix depending perhaps on how far each is being transported and how this drives the benefit of value-added processing. Commodities that are sent to neighboring countries for processing may be shipped in concentrate form, while commodities sent further afield may be processed into a final metal form to conserve on transportation costs. Since primary ore and concentrate exports are indicative of domestic production, this is early

[4] The resource-based industries of interest to this study included mineral tar (SITC 522), fertilizers (SITC 562), tin (SITC 687), silver and platinum group metals (SITC 681), and aluminum (SITC 684).

evidence that metal exports require as their source domestic mining production. One exception is iron ore, which is exported independently of iron and steel exports (section 67). Iron and steel exports are instead correlated with capital-intensive goods exports. Another exception is manufactured industrial minerals and diamonds (section 66), which are correlated with labor-intensive goods exports. Coal exports are, curiously, correlated with cereals exports.

The 3-digit level trade data for 1978 provides greater detail as to these trade patterns, and reveals the flaws with two-digit sectoral analysis (Leamer 1984, Table 3.5). Coal export patterns are now shown to be correlated with the exports of mineral ores and concentrates. Diamond exports are shown to be correlated with oil exports (no doubt the influence of oil-producing countries like Australia, Canada, and the Netherlands in Leamer's sample, who also have diamond cutting and finishing facilities). Precious metal jewelry exports are shown to be correlated with other net exports of labor-intensive manufactures rather than exports of precious metals and stones, indicative of a geographical separation of precious stone production from value-adding activities like jewelry fabrication.

Wright and Czelusta (2004, 2007) argue that it is no coincidence that countries' exports of minerals and metals tend to emerge across multiple commodities in concert. Many countries have multiple and various mineral endowments that are there for the taking, and it is a matter of domestic public interest in mineral extraction, supported by sufficient country-specific technological knowledge and in some cases technological advance, that causes production and export across the broad range of endowments to occur. The potential augmentation of the endowments is vast, and the noted ebb and flow of exports in resource-based economies is related to policy rather than changing endowments. Chile was a major exporter of copper in the 1800s, and then fell away as the high grade deposits were exhausted and there was no national consensus to support the industry. Production surged again in the mid 1900s as government support for mining was renewed. By that time, as well, its low grade deposits had become high grade in relation to other producers, and so one could argue that there were relative endowment (i.e., geological) reasons for the resurgence of Chilean copper production and exports.

In sum Leamer's data, which though dated is the best that we have for this type of analysis, is overwhelmingly supportive of the idea that developing countries tend to specialize in agriculture, energy and mineral exports, and developed countries tend to specialize in manufacturing exports. Countries that export any one mineral product tend to export other mineral, energy, and forest products, being broad-based resource-intensive economies. But these countries may not also produce and export value-added products such as refined metals or jewelry; there can be separation between the countries that mine and those that refine, since refining requires additional factors such as capital and labor. Iron and steel is an example, where at the three-digit SITC level only pig iron exports are correlated with iron ore exports from the same country (and by implication, iron ore production).

Topic 1: Summary of the Theoretical and Empirical Literature on the International Trade in Minerals

It is widely accepted that countries' specialization in production is due to comparative (cost) advantage. A comparative advantage in good *x* will result in production and export of good *x* along with the production of non-traded goods for domestic consumption, and the import of all other goods that can be traded.

There are two main theories that isolate two different sources of comparative advantage. The Ricardo (and Ricardo-Viner) models suggest that there are technological differences in production across countries. The second theory, the Heckscher-Ohlin model, ascribes differences in comparative advantage to exogenously given differences in factor supplies. Immobile and inelastically supplied endowments of natural resources form a source of comparative advantage that guides the flow of minerals between regions and nations. The Heckscher-Ohlin-Vanek version of the model emphasizes that it is actually flows of factor services that are predicted by the model, and goods are simply the vehicle by which these factor services flow. With respect to trade in minerals and metals this model posits, via the Rybczynksi Theorem, that an increase in the resource endowment will lead to either an initiation of production and export of the mineral and metal that uses the resource intensively (i.e., that provides the vehicle for resource service flows), or an increase in the output and export of the mineral and metal if such specialization had already been demonstrated.

The Heckscher-Ohlin model is of course a simplification of the world, and there has been much debate over its usefulness in explaining patterns of world production and trade (see, for example, Ohlin et al. 1977). On the one hand, the export of minerals must perforce be a result of a domestic endowment of a mineral resource:

> The most obvious factors that explain a good deal of international trade are 'natural resources'—land of different quality (including climate conditions), mineral deposits, etc. No sophisticated theory is required to explain why Kuwait exports oil, Bolivia tin, Brazil coffee and Portugal wine. (Haberler 1977, p. 4)

Or, as Moroney (1975, p. 142) puts it, "it seems reasonable that comparative advantage in primary products depends mainly on regional availability of natural resources." Several of the assumptions of the Heckscher-Ohlin model (Leamer 1984, p. 3) would seem to apply to minerals trade: production technologies for mining are more or less the same in each country; in-ground natural resources are immobile; and the factor and commodity markets are fairly competitive. Ohlin himself seemed to base his theory on observations relating abundance of mineral deposits to trade in minerals and metals, and in particular iron (Ohlin 1967, pp. 6-7). On the other hand, sophisticated theory *is* needed to explain why Kuwait for years exported crude oil rather than refined products, and in general why some countries export value-added mineral products and others unprocessed commodities (Brookfield 1977). Historical accident comes into play, as does the complexity created by an inability to define natural resources as some homogeneous factor (Brookfield 1977, Haberler 1977). The exhaustibility of natural resources and uncertainty about the total stock available in the first place and about future prices introduce additional complexities (Leamer 1984, p. 38). Kemp and Long (1984) address the first of these complexities and show that under certain assumptions about intertemporal prices and interest rates the trade predictions of Heckscher-Ohlin model are preserved even where one of the factor endowments is an exhaustible natural resource.

Then there are the many other real-world departures from the assumptions of the theory: dimensionality greater than 2 x 2, limited factor endowment dissimilarities, transportation costs, economies of scale, preference dissimilarity, dramatically unbalanced trade, factor mobility, factor endogeneity, and composite capital, to name a few (Leamer 1984, Findlay 1995, Lederman and Xu 2007). Ohlin (1967, p. 61) noted that policy, too, can affect comparative advantage, as can destructive frosts, plant diseases and floods, which favor manufacturing activities over agriculture. Frequent revolutionary upheavals cause the loss of buildings and machines, favoring agriculture over manufacturing. Geography (distance from markets) might also be a factor that determines comparative advantage, as transport costs and tariffs are substitutes (Venables 2007). Balassa (1989, p. 60) summarizes his empirical analysis of the theory as suggesting that "Comparative advantages appear to be the outcome of a number of factors, some measurable, others not, some easily pinned down, others less so."

All one can do given these complexities is to assume that a linear relationship between net exports and factor endowments is preserved even in the face of these violations of the model assumptions (Leamer 1984, p. 1).[5] This relationship may not be the relationship between factor input requirements, factor endowments, and trade flows recommended by the H-O-V theorem (Anderson 1987), but it would nevertheless be useful as a weakened hypothesis linking endowments to trade flows.

Empirical Tests of Trade Theory

The Ricardo models of trade have not been tested empirically, though the idea that there can be technological differences across countries has been incorporated into empirical studies of the Heckscher-Ohlin models. In a review of the extant empirical tests of the Heckscher-Ohlin models, Leamer and Levinsohn (1995, p. 1375) summarize the work as showing "a substantial effect of relative factor abundance on the commodity composition of trade." Technological differences and home-bias of consumption distort these factor-induced trade patterns, but not enough to completely weaken the predictions of a factor endowment model of trade, even if the strict predictions of the H-O-V model are not found in the data (Bowen et al. 1987, Trefler 1995). Other things that matter for trade are international technological differences, country size, distance between trading partners, economies of scale, and demand-side (or consumption) differences across countries. In other words, trade is a complex phenomenon.

[5] For an interesting discussion amongst top trade theorists about the role of trade theory in explaining real-world trade patterns, see Ohlin et al. (1977) starting on page 97 and running through page 102.

Wood (1999) proposes a fairly simple relationship between factors and trade. He suggests that the pattern of trade in processed and unprocessed primary factors and manufactures can be explained by differing endowments of skilled workers and land. The data appears to reveal that those countries with a lower level of skilled workers per acre tend to import manufactures and export primary products. Africa tends to export unprocessed products due to an abundance of land and lack of skilled labor, while Latin America exports processed primary products due to an abundance of land and an abundance of skilled labor. The prospect for value-added processing in Africa is conditional on their raising the skill level of workers relative to the rest of the world (Owens and Wood 1997).

In one of the most comprehensively documented tests of the relationship between endowments and trade flows to date, and the only one to date that explicitly considers mineral and energy endowments, Leamer (1984) tests the proposition that factor endowments adequately explain trade patterns for a set of 10 aggregate goods clusters given 11 aggregate factors. Of interest, two of the goods clusters are petroleum/petrochemicals and raw materials, the latter heavily weighted with mineral, metal, coal, and natural gas products. These two clusters are meant to represent flows of oil services, and minerals and gas services, respectively. Three of the factor endowment aggregates are coal, minerals, and oil and gas.[6] Factor endowment is defined as factor share of world production divided by GNP share. A ratio greater than 1.00 indicates relative factor abundance. In other words, a country is said to be abundant in coal, or minerals, or oil and gas resources if its share of world production of coal, or minerals, or oil and gas exceeds its share of world GNP. Examining trade patterns between 60 countries in both 1958 and 1975, Leamer indeed finds that a relative abundance in oil leads to net exports of petroleum and petrochemical products, and that coal and mineral abundance leads to net exports of raw materials. Leamer summarizes his empirical analysis by stating that there is “a surprisingly good explanation of the main features of the trade data in terms of relatively brief list of resource endowments,” and that “overall the simple linear model does an excellent job. It explains a large amount of the variability of net exports across countries, and it also identifies sources of comparative advantage that we all ‘know’ are there, thereby increasing the credibility of the results in cases when we do not ‘know’ the sources of comparative advantage” (p. 187). Wood (1994) interprets Leamer’s results as supporting the endowments model of trade in resources but not in manufactures. Deardorff (1984), in a contemporaneous review of extant tests of trade theory, views the evidence as favoring the Heckscher-Ohlin-Vanek model as long as human capital (skill) and natural resource endowments are included as endowments.

In a follow-up study to Leamer, Lederman and Xu (2007) find that the traditional endowments of crop land, forest land, and capital account for between 74% ad 84% of the variance in next exports in raw materials across countries and across time. In another extension of Leamer’s work, Trefler (1995) is less sanguine about the factor proportions theory of trade, noting that trade is *not* what is expected given factor endowments and the assumptions of factor proportions theory. The different view may be because Trefler does

[6] The minerals endowment is computed from the value of country production of bauxite, copper, fluorspar, iron ore, lead, manganese, nickel, potash, pyrite, salt, tin, and zinc. Notably, endowments of and trade in non-monetary gold and precious stones are omitted.

not include energy and minerals as factor endowments, and trade patterns related to these endowments are likely to be some of the most reliable in such analyses. In fact, when Trefler includes coal, oil and minerals as factor endowments the HOV theorem performs as expected with respect to resource-intensive products (Trefler 1995, p. 1045). Trefler argues that international productivity differences and domestic consumption biases are important determinants of trade in manufactured goods, but I find it hard to refute Haberler's observations with respect to trade in raw materials. Leamer (1995) suggests that technology differences and home bias effects are confined to the most capital-intensive manufactures. My own examination of the endowments and trade patterns in South Africa are consistent with a substantial mineral resource base leading to the predicted exports of minerals and metals and imports of manufactures (Davis 1994). The Spearman rank correlation between South Africa's world reserve ranking and export ranking across 17 minerals is 0.51, statistically significant at the 2.5% level. That is, not only are the patterns of mineral trade as expected, but so are the quantities.

In Leamer's analysis, exports of mineral and metal products tended to depend not only on endowments of minerals, but also on a scarcity of capital (as measured by cumulative investment flows) and a lack of professional and technical workers. In 1958 an abundance of unskilled labor also contributed to a tendency to export minerals and metals, though this relationship disappeared by 1970. Countries that imported minerals and metals, conversely, had a scarcity of mineral resources and an abundance of capital and skilled labor. Wood (1999) similarly finds that countries with a high concentration of unprocessed primary product exports had a high ratio of land per worker and a low ratio of skill per worker. Primary processing requires skilled labor in addition to primary endowments, as measured by land.

This is not to say that countries with mineral endowments do not need at least some human and invested capital to be able to produce and export minerals. Minerals do not freely flow from the ground, even though this is the way that some economists model mineral production (e.g. Sachs and Warner 1995). I have noted above that capital, labor, and energy must be applied to free the resource from the host rock. Vanek (1963) and Moroney (1975) were early proponents of the idea that natural resources and capital are complements in the production of raw material exports, based on their analysis of US production. Kenen (1965) argues that capital should not be thought of as a separate specific factor endowment, but as an agent that is applied to resource stocks to bring forth their flow of useful services. Wood (1994) develops this further, arguing that it is the *immobile* factors that determine trade patterns, and that capital is mobile, like an intermediate good. Findlay (1995, Chapter 5) provides a formal model whereby land is an endogenous endowment that is brought into being through the application of capital. The trade predictions of the traditional fixed factor model still hold, with trade being more sensitive to price signals. Tilton (1983, 1992, 2003) argues that relative resource abundance in minerals can be and has been undone via public policy that destroys investment. Conversely, relative resource scarcity, or impending scarcity as high-grade deposits are mined out, can be overcome via proprietary technological competence and good policy (Wright and Czelusta 2007).

Finally, in Leamer's study minerals abundance was not required for a comparative advantage in the export of capital-intensive manufactures. Of relevance here, iron and steel (SITC 67) and manufactures of metal (SITC 79) make up 76% of this trade category. Iron and steel production is capital and skill intensive (Wood 1994, p. 30). Lederman and Xu (2007), in their extension of Leamer's work, also find that the primary factor responsible for mineral exports (forest land) was not necessary for exports of value-added metal products.[7] This supports my earlier work disputing the purported idea by South Africa's Industrial Development Corporation that South Africa has a comparative advantage in value-added metal products such as jewelry simply because it has endowments of diamonds and gold (Davis 1994). Extraction is locationally tied, but further processing in other locations is possible and potentially efficient, especially as bulk transportation costs decline.

In sum, it is reasonable to propose that while there are many determinants of comparative advantage in production, and additional factors that govern the translation of comparative advantage into patterns of trade, a domestic endowment of mineral resources is necessary but not sufficient for the production and export of minerals and metals other than iron and steel. A supportive legislative framework, social license, and adequate natural or made infrastructure such as roads and ports, are all important to see the resource stock turned into production and exports (Tilton 1983, 1992). Where these complementary inputs are available, the country will tend to export mineral ores, concentrates, and metals to countries with a lower relative endowment in resources but abundance capital and skilled labor. It will import capital-intensive manufactures, machinery, and chemicals in return.

Measuring Mineral Endowments

One of the most vexing issues in endowment-based trade theory is the measurement of relative factor endowments. The measurement of mineral and energy endowments is particularly difficult. One approach is to infer endowments from a country's revealed comparative advantage. This approach assumes not only that the factor content theory of trade holds for all goods, but that it is possible to determine the factor content of the observed imports and exports mix. The more direct approach is to measure physical endowments, i.e., mineral resource stocks, directly.

Leamer (1984) measures coal, minerals, and oil and gas endowments as the value of production in a given year, and measures relative factor abundance as a production share in the world economy that exceeds GNP share. Moroney (1975) follows a similar strategy. Geologists and mineral economists do not, on the other hand, think of endowments as the value of current production. The upstream concept of exogenous geological abundance (i.e., quantity) comes into play, as does quality, location, and technical considerations such as extractability of metal from ore. Cost of extraction is a major factor in defining geological abundance. The profession has developed various definitions of quality and quantity, such as reserve, resource, and resource base, to convey these geological notions of abundance (Gocht et al. 1988, pp. 68-73).

[7] Lederman and Xu do not use production of oil and gas or minerals as factor endowments, but instead use forest land per worker as a proxy for the resource stock endowment.

Unfortunately, there is no standardization of these categorizations, with several mineral-producing nations deriving their own definitions (e.g., JORC in Australia, CIMVal in Canada, SAMVal in South Africa, and SME in the United States). The United Nations even has its own definitions in an attempt at harmonization. Within these disparate classifications there are common elements. Reserves are quantities that are relatively more certain geologically and more likely to be economic to extract. They are an intermediate capital, developed through capital investment in "proving up" resources. Production is generally related to reserves via a fairly steady flow/stock ratio known as the production/reserve ratio. The idea here is that optimization of capital spending on information about a mineral deposit determines that information (via drilling and sampling) about the resource should be performed incrementally, in stages. The staged approach results in reserves being proven up to form a given number of years of production, with that production/reserve remaining fairly constant over time for each mineral deposit type (Tilton 1983). Resources are less geologically certain and may never be economically extracted, and are more indicative of the natural endowment since they come into being with relatively little application of capital to nature.

Since reserves are a working inventory of raw materials in process, they are a reflection of, rather than a determinant of, comparative advantage. They are not truly what the Heckscher-Ohlin model implies by a separate endowment called natural resources. It is not surprising that Leamer finds that production from reserves (which indicates the prior application of sufficient investment and technically skilled labor) tends to be correlated with exports of these same products in a slightly refined form. Trefler (1995, p. 1045) voices this same concern with measuring resources endowments using resource production. For countries with sufficiently large resource endowments, production is only forthcoming if there is a hope of export. The possibility of export then leads to production, and not the other way around. My point is that production is endogenous, and as such may not be an appropriate measure of mineral abundance.

Resources would be a better measure of the H-O mineral resource endowment. I am not aware of any empirical trade research that takes this track. Some researchers use land area per capita as a proxy for mineral resource endowments (e.g., Lederman and Xu 2007, Wood 1999). Others use agricultural or forest land per capita. Leamer (1984) finds that net exports of minerals and agricultural products for the most part are not correlated, recommending against these practices.

Changing Mineral Endowments and Patterns of Mineral Trade

Appendix D in Leamer (1984) plots relative mineral abundance (i.e., production) for 60 countries in 1958 and 1975, shows that relative mineral endowments (i.e., production) change over time. Countries with dramatic increases in abundance include Australia, Dominican Republic, Honduras, Paraguay, and Philippines. Countries with dramatic decreases include Cyprus, Ghana, and Yugoslavia. As predicted, mineral net export levels change accordingly. I also find that the location of mineral production can change over time (Davis 1995). Between 1970 and 1991, nine countries became specialized in mineral production, while one diversified away from minerals.

It is not clear whether these changes in specialization are due to endowment changes or policy changes. David and Wright (1997) document how policy directly encouraged development of the United States' mineral resources into reserves, and then to production and export, replacing Britain and Germany as major producers in the late 1800s. The United States, Britain, and Canada are examples of early producers who have given way to Australia and Chile (Wright and Czelusta 2004). Wright and Czelusta (2007) discuss the rise of Latin America as a minerals producer, where the endowments were always there, but only became available to exploit as policy changed to focus on developing this sector. The implication, once again, is that a resource endowment is necessary but not sufficient for a comparative advantage in mineral-intensive goods. Policy providing the opportunity to employ appropriate complementary capital and labor must also be in place, making mineral endowments largely endogenous. Location-specific geological and technical knowledge may also be particularly relevant in gaining a comparative advantage in mineral production (Wright and Czelusta 2007).

Recent policy changes include the impositions of windfall profits taxes and new production royalties in Mongolia and Chile. Another is the sweeping threats of nationalization in Bolivia and Venezuela. One could anticipate that these policy changes will impair these nations' comparative advantage in minerals and their complementary factors, capital and skilled labor, with an impending reduction in net exports of minerals as a result.

Leamer (1984, Tables 4.4 and 4.5) notes that between 1958 and 1975 developing countries tended to climb the "development ladder," adding to the export mix more and more labor and capital intensive goods, forcing the developed countries to concentrate in exports of the most sophisticated trade aggregates, machinery and chemicals. As countries like Korea, Spain, and Brazil move up the ladder other countries like Afghanistan, Libya, and Malaysia fill the vacancy, moving from relatively autarkic states to oil and raw materials exporters. A study by UNIDO (1981) of changes in manufacturing trade patterns in the 1960s and 1970s shows that it is the resource-based manufactures that the developing countries first move into. Martin (2007) finds that developing countries as a group have continued to diversify their merchandise export mix away from raw materials and towards manufacturing over the past 40 years. The quantity shift began in earnest in the early 1970s. These manufacturing quantity additions are in addition to, rather than instead of, quantity increases in mineral and metal exports.

Transportation Costs

In the 1800s and early 1900s the high cost of bulk transport between nations meant that comparative advantage in iron and steel production, and in "heavy" industry, relied on factor abundance of iron and coal. As bulk transportation costs between nations decreased and fell below the cost of domestic rail costs, trade in raw materials became possible and even desirable, and previously immobile resources began to be traded as mildly processed raw materials between countries (Maxwell 2006). Even within the last few decades an increasing proportion of mineral and metal production has been exported

(Radetzki 1990, p. 9, Radetzki 2008, p. 30). As of 2005, 54% of iron ore production was exported rather than processed domestically (Radetzki 2008, p. 30). As a result of the increasing mobility of ores and concentrates, comparative advantage in heavy manufactures shifted from Europe and the United States to Japan and then to South Korea, the latter two countries being resource poor. Exports of raw materials, however, still depended on having a domestic resource stock, and so the shift in trade was really away from resources embodied in heavy manufactures to resources embodied in mildly processed raw materials. Radetzki (2008, Chapter 1) provides a review.

Findlay (1995, Chapter 6) proposes a 3 x 3 model of trade that illustrates the impact of transportation costs on comparative advantage. Decreasing transportation costs causes the resource-abundant country to loose its comparative advantage in heavy manufactures and instead export raw materials and the labor-intensive good, and then re-import the raw material as embodied in the final manufactured good, a form of deindustrialization that has in other contexts been referred to as the Dutch disease. A common domestic policy concern is that it may be more desirable to export the resources in a more value-added form. Traditional models do not support such worries – there is an optimal amount of domestic processing that should take place, and that amount is conditional on the availability of domestic technologies and on the terms of trade. Anything that makes trade in raw materials more attractive, such as an improvement in the terms of trade or the above noted drop in shipping costs, will result in reduced resource-based manufacturing (Findlay 1985). Policy to protect resource-based economies against the deindustrialization associated with otherwise beneficial falling transportation prices or improving terms of trade then comes into play. Strategies include export taxes on raw material exports and support for value-added manufacturing. It is curious here that worries about improving terms of trade in mineral exporting countries focus on the resulting deindustrialization, while declining terms of trade brings worries about the negative welfare effects of a falling relative price of net exports. The former is related to the discussions of the resource curse that follow, while the latter, according to Findlay (1985), is the more appropriate concern.

Topic 2: Mineral Abundance, The Resource Curse, and Trade Policy

For the past 20 years it has been widely held that economies specializing in natural resource extraction have suffered from a "resource curse," whereby their incomes per capita are higher than normal but their economic growth is slower than normal.[8] Empirical studies, and particularly those of Sachs and Warner (1995, 1997), support these assertions. The worry is that the slower growth is a result of some permanent structural change that will have long-run negative impacts on development.

The search for the mechanism behind the curse has led to a flurry of theoretical and empirical research, and it now appears that the resource curse was either a spurious statistical artifact (Alexeev and Conrad 2008, Lederman and Maloney 2007a) or a result of a depleting resource sector (Davis 2006). Nevertheless, the predominance of the

[8] See Stephens (2005) and Davis and Tilton (2005) and for a review of the literature and theories relating to the resource curse.

resource curse and its almost universal acceptance has the potential to impact trade policy in mineral abundant economies (Davis and Tilton 2008).

It is important at the outset to differentiate between discussions of the Dutch disease the resource curse.

Mineral Booms, the Dutch Disease, and the Resource Curse

I have previously described the Dutch disease as "a morbid term that simply denotes the coexistence of booming and lagging sectors in an economy due to a temporary of sustained increase in export earnings" (1995, p. 1768). Mineral exporting countries become ideal candidates for the disease. The mining industry booms while other tradable industries like manufacturing and agriculture shrink. This adjustment process tends to deindustrialize the economy in the medium term.

There are two kinds of mineral booms: a) an exogenous increase in international relative prices of raw materials and minerals, and b) an exogenous increase in the domestic availability of mineral resources. The first type of mineral shock is produced by sudden variations of the terms of trade of minerals. I noted above that this was one mechanism by which comparative advantage can change. In this case it is in favor of the production and export of minerals. The second type of mineral shock is produced by the increase in the relative endowment of minerals in a country either through exploration efforts or through policy. To avoid unnecessary repetition, I will focus on the effects of an increasing endowment. Nonetheless, much of the analysis applies with slight modifications to the trade effects on mineral-exporting countries of exogenous increases in the prices they can obtain for their products.

The large-scale exploitation of mineral discoveries generates an increase in mineral exports and a large external surplus. This creates a real shock to an economy, because its main impact falls on the level of real income and the intersectoral allocation of factors of production. The trade effects of a mineral boom are primarily transmitted into the economy by means of this *real transmission channel*.

In addition to the real effects generated by mineral booms, the literature recognizes that monetary effects also accompany the booms (Cuddington 1989). Since the booms usually stimulate a dramatic increase in mineral exports, a large influx of foreign exchange to the booming economy is commonly observed. This influx may affect the economy through the balance of payments. Thus, the trade effects of a mineral boom are also transmitted into the economy through a *monetary transmission channel*.

The most commonly used framework to understand the real effects of mineral booms is a small-open economy version of the static Ricardo – Viner model, better known as the specific factor model (Jones 1971, Snape 1977, Corden and Neary 1982).[9] The model assumes that an economy has two sectors: 1) a tradable sector, which is decomposed into a manufacturing industry and a mineral/energy industry; and 2) a non-tradable sector.

[9] A simple presentation of this model can be found in Markusen et. al. (1995).

Since the economy is assumed to be small in the world market, the economy faces fixed relative international prices for tradable goods. In addition, the price of the non-tradable good moves flexibly to equalize domestic supply and demand.[10]

Each sector uses a specific factor of production. The mineral sector uses a natural resource like mineral resources to produce concentrates or refined products, while the manufacturing and the non-tradable sector employ a different type of capital. Each sector also draws resources from a common pool of a perfectly mobile factor of production like labor. The endowments of the factors of production are assumed to be fixed. In addition, the model assumes that there are no distortions in commodity and factor markets. In particular, the real wage is perfectly flexible, which ensures that full employment is maintained at all times. This assumption rules out the occurrence of immiserizing growth.

The mineral boom has two static real effects, a spending effect and a factor reallocation effect (Corden and Neary 1982, Corden 1984, Neary and van Wijnbergen 1986). The spending effect refers to the short-run real effect generated by the sudden increase of domestic wealth as a consequence of a mineral boom. The higher level of national wealth during the boom increases domestic spending on both tradable and non-tradable goods. The excess demand for both goods causes an appreciation of the real exchange rate, defined as the ratio of the price of tradable commodities with respect to the price of non-tradable goods. The real appreciation means that the price of non-tradable goods raises in terms of the non-booming tradable commodities. This happens because the price of tradable goods is determined in international markets and does not change despite the extra domestic spending. In contrast, the price of non-tradable goods is set in the domestic market and does rise due to excess demand.

In this context, the higher relative price of non-traded goods makes the domestic production of non-booming tradable goods (like manufacturing and agricultural products) less attractive, generating a contraction of the non-booming tradable sector. When the traditional trading sector is manufacturing, the boom leads to deindustrialization. The spending effect is stronger when short-lived booms happen or when the booming sector is an enclave with no backward and forward linkages with other sectors.

The factor reallocation effect refers to the medium-run real effect associated with the reallocation of the mobile factors of production as a consequence of the mineral boom. The expansion of the booming sector increases the demand for mobile factors of production which tends to bid up their real prices. This outcome makes it more expensive to produce tradable and non-tradable goods. The real increase of mobile factor input prices and the increase in the relative price of non-tradable goods squeeze the profitability of the non-booming tradable industries that use mobile factors and non-traded goods as inputs. This resource movement effect reinforces the tendency toward the appreciation of the real exchange rate and the deindustrialization of the non-booming

[10]The Ricardo-Viner model can be seen as a short-run version of the Heckscher-Ohlin model in which specific factors like capital are not mobile across sectors in the short term, but they become mobile in the longer term as companies gain flexibility to adjust their production capacity.

tradable sectors. The empirical evidence shows that countries with booming mineral exports do have slower growth in manufacturing and services (Sachs and Warner 1997).

An important issue that should be highlighted here is that the spending and factor reallocation effects do not necessarily generate a "disease." The appreciation of the real exchange rate and the deindustrialization of the non-booming tradable sectors are efficient responses to the increase in mineral earnings (Davis and Tilton 2005). The real appreciation is essential to affect the reallocation of factors of production out of the non-booming industries and the non-traded sectors and into the minerals sector, such that the economy can accommodate the mineral export boom and enjoy the fruits of the increased wealth in the economy (Findlay 1985, Neary and van Wijnbergen 1986). Therefore, *a priori* there is in nothing in mineral export booms and any resulting Dutch disease phenomena that impedes economic growth and development. Within the specific factors model a resource boom must increase national welfare (Corden and Neary 1982).

The Dutch disease truly becomes a disease if there exists some market failure inhibiting an appropriate structural adjustment or if there is some existing distortion in the economy which is intensified by the mineral export boom (van Wijnbergen 1984, Neary and van Wijnbergen 1986). Sachs and Warner (1995), for example, provide a model where the manufacturing sector exhibits positive externalities in production. Deindustrialization will then lead a booming mineral economy to suffer slower economic growth as a result of the boom. Such slower growth has come to be called the Resource Curse. Roemer (1985) notes that in practice the most popular response to the deindustrialization associated with mineral booms is to tax those exports and subsidize the lagging sector. In fact, the booming countries with manufacturing sectors did have less trade openness (Sachs and Warner 1997). Trade protection for manufactures has for decades been South Africa's approach to dealing with deindustrialization (Davis 1994).

Policy considerations also arise from the monetary consequences of a resource boom. During a mineral boom the central bank's foreign reserves surge. The inflow of foreign exchange raises the domestic monetary base. Unless the central bank sterilizes the monetary impact of the boom, the expansion of the monetary base will generate short-run inflationary pressures and the appreciation of the real exchange rate, reinforcing the real effects of the boom described above (Neary and van Wijnbergen 1986).

If the domestic financial market is well developed, the central bank can sterilize the increase of foreign exchange during the boom by carrying out contractionary open market operations. Otherwise, an alternative to open market operations is to reduce the net credit from the central bank to the government in order to reduce the monetary base. This outcome can be achieved through repayments of public loans to the central bank, running a fiscal surplus, or increasing the reserve requirement ratio (to reduce the monetary multiplier) (Cuddington 1989).

The sterilization of the monetary effect of a mineral export boom may be more important when the economy exhibits sticky prices, because the boom can increase unemployment if there is wage rigidity. Without monetary accommodation during the boom, unemployment may be exacerbated (Neary and van Wijnbergen 1986).

In summary, both the spending and the resource movement effect generate an appreciation of the real exchange rate and a reallocation of the mobile factor of production from the non-booming sector to the booming and non-traded sectors. Trade protection for the shrinking sector, while commonplace, is only warranted on an efficiency basis if there is a market failure. In these cases the appropriate policy response is to raise the *existing* level of protection, since the market failure would have warranted some protection in the first place (van Wijnbergen 1984).

Mineral Booms and Depletion

Another explanation for the slow growth in mineral economies is resource depletion. Growth slows when the depletion of nonrenewable mineral resources and a growing population are not offset by technological progress (Jones 2002).[11] Nordhaus (1992) shows the relationship among economic growth, the rate of technological progress, an exogenous depletion rate and the population growth rate using an expanded version of the Solow growth model. The model has five factors of production: capital, labor, energy, natural resources, and land. In the steady-state equilibrium, the rate of economic growth is positively influenced by technological change and negatively affected by two terms: the drag on per-capita growth given by Malthusian diminishing returns and the drag from declining production of exhaustible resources. Boyce and Emery (2007) extend Nordhaus by including optimally declining production in the resource sector. The result is a growth path shown in Figure 1. In Davis (2006) I confirm that once one controls for change in level of resource production over the sample period, the resource curse identified by Sachs and Warner disappears. Those economies with shrinking minerals sector output saw slower growth, while those that had increasing mineral output saw faster growth. These cases are reflected in the growth path in years 2 through 10 in Figure 1 and years 1 and 2, respectively.

My results also explain why some find for and others find against a resource curse. Measuring the rate of minerals output only at the start of the growth period would tend to identify mineral producing countries as those that have heavy mineral production and are subject to depletion (years 2 through 10 in Figure 1). Likewise, measuring the rate of minerals output at the end of the period would tend to identify as mineral producing countries those whose mineral output has moved from low to high over the sample period (years 1 through 2 in Figure 1). This is why papers that measure mineral production (or some other measure of abundance, such as reserves, which is linearly related to production) near the *end* of the sample period find no evidence to support the resource curse (Brunnschweiler 2008, Brunnschweiler and Bulte 2008, Sala-i-Martin 1997a, 1997b, Sala-i-Martin, Doppelhofer, and Miller 2004), while Sachs and Warner (1995,

[11] Population pressure on fixed factors of production like land can lead to a decrease in the marginal productivity of other factors like labor and capital. Therefore, Malthusian diminishing marginal returns are possible when there fixed resources in an economy.

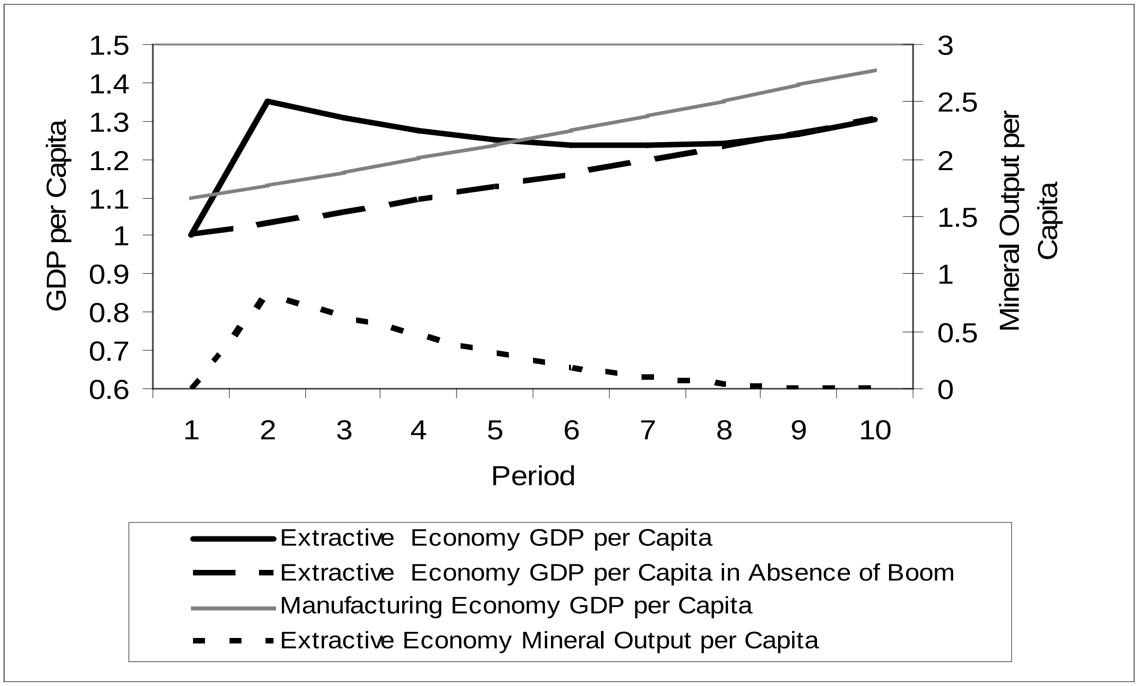

Figure 1: GDP per capita in a booming developing mineral economy (adapted from Davis 2006, 2009)

1997) and others who measure mineral production at the start of the sample period do find a resource curse.

In sum, I believe that there is indeed a tendency towards slower economic growth as booming mineral economies deplete their resources, but like the Dutch disease, this reflects optimal market choices and optimal depletion paths rather than lost external economies or some nefarious undertakings of politicians or multinationals. Economic replacement of reserves would prolong the booming economy, and may delay the return to the steady state path for GDP (Davis 2009). Open and stable, not protectionist and whimsical, trade policies are most likely to attract the necessary FDI into the sector to extend the mineral boom. Trade policy that subsidizes the shrinking manufacturing sector on the mistaken notion that it is lost economies in that sector that are inefficient and likely to shorten the length of the mineral boom by sterilizing what would otherwise have been economic mineral resources.

Topic 3: The Political Economy of Trade Policy in Mineral Abundant States

Mineral export booms may generate not only the direct boom and bust growth effects associated with the resource curse or depletion phenomena, but also indirect growth effects via the quality of institutions, the rate of human capital formation, increases in poverty, and civil wars. The indirect effects have been the subject of intense scrutiny by political scientists.

It is not easy to identify those economies that are particularly dependent on mineral and metal production and therefore subject to such political economy risks. Radetzki (2008, p. 190) identifies only 11 economies that are particularly susceptible. They are all small and developing. Their small size is not surprising, as there is a lack of geographic diversity that would allow diversification of production and exports. That they are developing economies is also not surprising given Leamer's observation that economies climb the development ladder to manufacturing production and export as they acquire capital and skilled labor over time. In fact, Radetzki makes a point of noting that the number of susceptible economies has shrunk over the past 20 years as economies climb the development ladder.

Consider institutional capabilities in these economies. According to Sachs and Warner (2001), Ross (2001), Acemoglu et al. (2001), and Bulte et al. (2005), a mineral boom deteriorates the quality of the institutions. This problem appears because of a mismanagement of the mineral rents generated during the boom. Mineral rents, generally captured by the government through taxes and royalties, may cater to the ruling elite in the booming country. In this context, a mineral export boom may accentuate income disparities between urban and rural areas, for the poor may be largely excluded from any benefits of the boom. In addition, political control over the mineral rents may make it profitable for individuals and organizations to spend considerable efforts and resources to appropriate an important share of those rents. This situation may cause the emergence of rent-seeking activities among the social groups associated with the domestic mining industry (for example, oligarchic elites). Such rent-seeking activities are totally unproductive, since they are carried out in order to increase the share of the mineral rents that a particular social group enjoys. Thus, rent-seeking actions may crowd out productive activities associated with economic growth.

Mineral rents can be easily appropriated by these groups because minerals are spatially concentrated. They can be easily protected and controlled at a relatively low cost. The case of Angola's oil and diamonds is a particularly clear example (Hodges 2004). Part of the rents can be used to bribe public officers in order to obtain support for mineral activities (for instance, new authorizations to exploit deposits, tax exonerations, weak laws to regulate the industry, etc.), and reduce the governmental interference in the mineral booming industry (for example, reductions of royalties and income taxes, the avoidance of windfall taxes, reductions in the enforcement of environmental laws, etc.). Hence, the mineral boom may tend to increase the level of governmental corruption. The increase in corruption may tend in turn to erode the credibility and the quality of institutions like the Congress, the Supreme Court, the Police, the local administrations, and so on.

Public enforcement of laws may also decrease as a consequence of the deterioration in the quality of institutions. Crime and violence levels may increase. There might be also a rise in drug smuggling. In the limit, the government may become an autocracy or a dictatorship, especially if the military power overthrows a democratic government.[12]

[12] For a summary and critique of these propositions, see Haber and Menaldo (2009).

These outcomes may in turn bring about a reduction in economic development in the booming economy.

The main thesis here is that weak developing country governments can be captured by a politically powerful mining elite. Even strong governments can be destabilized by mineral windfalls and the rent seeking that ensues. In these models any blame for natural resource mismanagement lies with the government, and not, as Stiglitz (2008) alternatively proposes, with the private foreign companies holding the licenses to extract. The political economy model, though often not formalized as such, has an irresponsible government at its core, with fiscal constraints preventing that government from financing questionable development efforts, enacting intraregional and intertemporal wealth transfers that impoverish the poor, and buying private sector cooperation in pursuing these and other objectives (Davis 1998). The sizeable rents from mineral extraction relax these constraints, and the resultant inappropriate governance ensues. Ascher (1999) provides one of the most interesting and well though-out analyses of this process.

Bulte et. al (2004) provide partial evidence of the existence of these indirect effects of mineral booms. The authors conducted an empirical exercise which consisted of running reduced-form development regressions which have human development and institutional quality indicators as dependent variables and initial GDP per-capita, resource intensity and other control variables as independent variables. The main findings of their empirical analysis were that natural resources are associated with less productive social institutions and that countries with unproductive institutions tended to score lower on various development indicators (such as the human development index and life expectancy). In this way, there might be an indirect relationship between natural resources and economic development that works through the quality of institutions. I have commented elsewhere (Davis 2009) that I have my suspicions that this finding is a result of incorrect model specification.

Davis and Tilton (2005) point out that good governance can impede the economic incentives that originate rent-seeking behavior, and ensure that mineral rents are invested in human capital and other kinds of assets that promote economic development. Good governance requires adequate incentives generated by an adequate allocation of property rights and a political framework that constrains inappropriate public sector behavior. They conclude that the debate should center not on whether or not minerals extraction creates institutional failure, but on whether most mineral developing countries can achieve the desired level of governance such that they can benefit from their endowments.

Moving on to the effect of a mineral booms on the formation of human capital, Sachs and Warner (2001) have argued that a mineral boom would crowd out entrepreneurial activity and innovation if wages in the domestic mineral industry are raised so high to encourage innovators and entrepreneurs to work in the mining sector. In addition, the incentives to invest in education in fields not related to the domestic mining industry would decrease, because a mineral booming sector does not need workers with high skills.[13] In this

[13] Expatriate labor tends to fill technical and managerial roles.

context, the need for high-quality education may decline during the boom, reducing the returns to education and the incentives to invest in education. Hence, the future expansion of other sectors that require high-qualified workers may be constrained and technical diffusion may be also retarded.

If one believes that the path to development and growth is through education and increasing human capital, then there is support for an educational push. But that supply side effort must be matched with increasing demand for skilled labor domestically, at least for skill levels that are below those that are internationally mobile. Wood (1999) uses the East Asian experience to argue that the demand pull for skilled labor could come from trade protection that promotes skill-intensive sectors such as, according to Leamer's (1984) analysis, iron and steel and manufactures of metal. I am less sanguine, as it appears that comparative advantages in unprocessed primary products are hard to break away from (Davis 1994). Many countries have failed in the promotion of these goods, but perhaps this is because they only supported the demand-side of the equation and failed to support the development of a skilled labor force. Even those who are advocates of active policy in this area suggest that more research needs to be done before specific policy measures can be recommended (Mayer 1999). Resource exporting countries tend to have less open economies. There is also the worry that resource exporting countries that experiment with closed trade policies suffer from slower growth than those with open trade policies (Sachs and Warner 1997, 2001). The original proponents of a resource curse note that the growing mineral economies—Botswana, Chile, Malaysia, and Mauritius—did not attempt to alter their exports away from natural resources, as did the slower growing mineral economies (Sachs and Warner 1999, p. 26).

Governmental worries over minerals abundance can also center around terms of trade declines and increased volatility associated with extensive minerals production and exports. The Stolper-Samuelson theorem is behind the terms of trade worries, since a decline in the relative price of resource-intensive goods will lead to decreased returns to the owners of resources. One has to be careful here, though, as general equilibrium effects are often complicated. Leamer (1995) relates the case of trade for Sweden, which was an exporter of forest products and raw materials and an importer of all other products as of 1958. By 1965 it had started to export machinery, no doubt as a result of increases in its capital stock as it climbed the "development ladder." But by 1974 its manufacturing exports per capita had soared. Leamer suggests that the increase in the price of petroleum created a reversed Dutch disease, where the high cost of petroleum imports could only be paid by increasing production and exports of forest products and the next step on the ladder of development for Sweden, machinery exports. Subsequent changes in endowments in the US and Japan resulted in their exports of machinery increasing greatly, reducing Sweden's comparative advantage in machinery and causing them to move backwards to capital-intensive exports of iron and steel by 1988.

While there is no agreement over whether the terms of trade has worsened for mineral exporters as a group over time (Davis and Tilton 2005), there are no doubt individual countries for which this is the case, either due to a trend or due to a stationary series with negative random deviations (Cuddington, Ludema and Jayasuriya 2007). Even so, the relevance of such an analysis is not clear. For one, income terms of trade is more relevant than price terms of trade, since it is possible that declining export prices have been met with increased export quantities. In addition, it is the full accounting statement, which measures costs of production against revenues from production, that matters (Davis and Tilton 2005).

Volatility of export revenue due to price volatility is the other concern, as minerals tend to have high price volatility (Claessens and Duncan 1993, de Ferranti et al 2000). If price volatility is supply driven, decreasing prices will be met with increasing quantities, stabilizing revenues. If it is demand driven, the two will reinforce each other. The latter is accepted (Yukawa 1988).

It is important to recognize that export revenue instability refers to revenues that have both downward and upward swings around the secular trend. It is commonly thought that a relatively certain export stream is preferred to an uncertain stream due to microeconomic and macroeconomic non-linearities. Roemer (1985, p. 246), for example, suggests that while a secular trend in terms of trade that results in de-industrialization or de-agriculturalization may not require counteracting policies, cyclicality in market prices may: "Both diversification and the realisation of linkages from the export sector are served by steady, long-term price signals to investors. This suggests a large stabilising role for government." In my view, Roemer does not give enough credit to the ability of capital markets to see their way through cyclicality. Nor does he devote adequate concern to the disincentives for investment that large government bureaucracies, and the resultant high tax rates, create. Moreover, recent advances in finance find that where there is flexibility to respond asymmetrically to rises and falls in income, instability can be beneficial. The permanent income hypothesis is an example, whereby savings (and growth) will be higher in a volatile income economy. For example, consider a poor economy with a flat export revenue profile. That profile is too low to allow effective development programs, and at best there is a minimal subsistence welfare program in place. A sudden spike in revenues may well allow such programs to be initiated and grow, whereby they become self sustaining by the time the spike has ended. Any subsequent drop in export revenues, even to below where they were before, has been more than offset by the "big push" initiated during the previous boom. The nonlinearity induced by a positive price and quantity correlation during boom and bust periods also creates a mean export revenue that is higher under instability than under stability. Empirical tests of the impact of price fluctuations have been viewed as either equivocal (Lim 1988, Sachs and Warner 1997) or confirming the models' predictions that volatility does not harm growth (Behrman 1987).

Even though the simulations and empirical data fail to show any firm relationship between export instability and economic growth, the multinational development agencies have been almost frenetic in their search for solutions (e.g., Claessens and Duncan 1993, de Ferranti et al. 2000). Stabilization schemes, buffer stocks, and international commodity agreements were all attempted in the 1970s and 1980s, and all failed to meet their goals. The only systems that appear to work are special reserve funds that deposit windfall earnings into accounts that cannot be raided by the treasury (Radetzki 2008).

While export volatility is probably not a problem for growth, export concentration is (Lederman and Maloney 2007b). Curiously, it is possible that the very trade barriers intended to reduce export concentration end up increasing it by overvaluing exchange rates and imposing an anti-export bias (de Ferranti at el. 2000). Trade also reduces the declining marginal product of capital associated with capital accumulation, since the economy shifts to more capital intensive production as its relative capital stock grows. As a result, growth is more easily sustained in open economies than in closed economies (Leamer 1995, Sachs and Warner 2001).

If policy can impact trade patterns, and in particular the pattern of trade with respect to minerals, then one has to ask whether it is desirable to export one type of good compared with another. East Asia's development success in the 1970s and 1980s are often heralded as coming from the benefits of an endowment in skill and a lack of endowment in land, leading to manufacturing exports. The main worry for countries heavily endowed with minerals is that any trade liberalization will result in increased specialization and de-industrialization, making these economies less like, rather than more like, the East Asian economies. It also makes them more susceptible to all of the possible impacts of mineral booms that this section has outlined. The United Nations Industrial Development Organization took up interest in optimal sectoral mix in the 1980s (UNIDO 1981, 1986). It was, and is, decidedly pro manufacturing, but for no empirically supportable reason. It is difficult to know whether this is in an effort towards efficiency or in an effort to protect capital earnings. Sarmiento (1988) is a late call for trade policy to foster and then protect manufacturing activity in mineral-based economies.

Circling back to trade and the influences of political economy on trade patterns, one might ask to what extent political economy worries about mineral booms have translated into policy actions. Mineral-abundant countries do in fact have restrictions on trade for both exports and imports. Anderson reports that as of 1995 low income countries had average tariff equivalents of around 10% for imports of manufactures and of 20% for imports of agricultural goods. Minerals and energy exports faced import tariffs of less than 0.5% in high income countries, and of around 5% in low income countries. This is preliminary evidence that mineral exporting economies may well be attempting to protect domestic manufacturing and agricultural sectors, or, conversely, stifle the minerals exporting sector. As Davis and Tilton (2008) emphasize, this is the resultant negative impact of popular belief in either a direct or indirect resource curse associated with minerals production.

Programs that seek to change the mix of production within a resource-abundant country are called resource-based industrialization (RBI). Roemer (1979) provides a review of RBI. He notes that as of 1979 RBI "has been advocated more than it has been analyzed." That statement is still true today. Several resource-based countries have tried to shift their comparative advantage away from minerals and into manufactures through dirigiste trade and domestic policies, but with little success (Davis 1994, Lederman and Xu 2007). Roemer notes that there are many barriers to RBI, including the fact that transportation costs per unit of value rise as one moves away from bulk transport. Tariff protection in importing countries also serves as a barrier to industrialization (Radetzki 2008). Lederman and Xu (2007) find that policy that reduces trade openness only weakens comparative advantage in raw material exports. It does not eliminate it. Martin (2007), while providing a roadmap for reducing comparative advantage in resource exports, argues that developing country trade openness actually enhances developing country exports of manufactures. In one of the most comprehensive studies of idiosyncratic trade policy to date, Davis (1994) finds that an industrialization scheme in South Africa had an export subsidy structure that ended up putting several of the targeted industries at a disadvantage. The perverse outcome was because of a reduction in support for those industries that imported a large fraction of inputs. As a result, wool and cotton exports were subsidized at a higher effective rate than fabricated and structural metal products. The subsidy scheme was also predicted to worsen the terms of trade for South Africa's regional trading partners.

Even worse, these efforts to direct the structure of the economy would seem to be ineffective. Lederman and Xu (2007) extend Leamer (1984) to test the extent to which raw material exports are affected by factors other than the traditional ones. They find that domestic institutional quality confers comparative advantage in raw materials exports, as does either an abundance of schooling or technical R&D. Even so, the traditional endowments—land (as a proxy for resource stock), labor, and capital—account for the majority of variance in raw materials trade patterns across countries and over time. Wood (1999) also finds that trade policy probably has a minor influence on trade patterns. Endowments matter, and are incontrovertible. That does not mean that extreme positions regarding trade policy do not emerge. Those that favor industrialization would find that the factor endowments theory of trade necessitates either the protection of manufactures in countries with low skill-land ratios, or an active attempt to change comparative advantage through education. Primary production is feared because of its alleged low income elasticity of demand, which will result in terms of trade losses, and slow technical progress, which will lead to a lack of endogenous skill creation. Interestingly, trade policy failure is not prevalent in Ascher's (1999) 16 resource-based economy case studies, two of which (India and Chile) relate to mineral extraction.

In sum, given evidence that the slow economic growth in mineral economies can be explained solely by depletion effects, trade policy with respect to things like institutional failure, terms of trade movements, and export revenue volatility is likely to be unnecessary. Nor is there much interest of late, given the commodities boom, in suppressing investment in mineral extraction; one only has to attend a regional meeting of mining ministers to see the intense interest by extractive nations in gaining foreign investments to foster the development of the mineral sector. This is not to claim that there are not governance problems and challenges in resource-abundant economies. While there may not be a resource curse, there is certainly resource disappointment. My point is that there is no obvious trade policy remedy to such disappointment.

Topic 4: Non-economic Considerations for Mineral Resources with Strategic Value

The advanced nations, through depletion of domestic sources, a secular decline in bulk transportation costs, and expanded needs due to industrialization and income growth, have increased their dependence on imported raw materials (Radetzki 2008). Concerns about this dependence have intensified. At the same time, rapidly growing developing countries that export minerals have increasingly adopted policies to ensure sufficient domestic supply of such minerals. In 2006, China increased to 15% export taxes on aluminum, copper, and nickel. In 2007, India created a 7% export tax on iron ore exports (Radetzki 2008, p. 51). A number of metals may be deemed "strategic," being vital in the manufacture of alloys and catalysts, and with concentrated supply and few substitutes: niobium (Brazil), tungsten (China), platinum (South Africa and Russia), palladium (South Africa and Russia), and vanadium (South Africa, China, and Russia) (Radetzki 2008). All are all metals with few sources of supply, none of which are in Japan, the United States, or the EU.

Certain minerals have production that is especially geographically concentrated. China accounts for 93% of production of the 17 rare earth elements as a group, and for 95% of neodymium alone. Such concentration creates obvious opportunities for using trade policy to guide the location of manufacturing activity. China's activity in neodymium markets provides a recent example. Each Prius electrical motor requires 2 to 4 pounds of neodymium. In each of the past three years China has reduced the amount of rare earths that can be exported, and recently announced plans to increase limits on rare earth exports, including neodymium, to 35,000 tons per year in an effort to ensure domestic supply and force manufactures requiring rare earths to locate within China (Bradsher 2009a, 2009b). Some exports would be banned altogether. Export restrictions will of course lower domestic prices and reduce incentives to extract, particularly if investors feel that the restrictions may be lifted in the future. The only way for domestic prices to be maintained via market forces is through additional flow of capital into manufacturing facilities in China such that domestic demand increases.

There is no information as to general trade policies for strategic minerals in either exporting or importing nations. As a result BIAC (2006) has called on the OECD, a region that is particularly susceptible to dependence on strategic mineral imports, to "Provide a fact-based analysis of the range of existing trade distortions affecting the movement of raw materials, such as minerals, metals, scrap, hydrocarbons…" The European Commission Enterprise and Industry Division has initiated a public consultation on future non-energy raw materials policy, and held a conference on Trade and Raw Materials in Brussels in 2008 (http://trade.ec.europa.eu/doclib/docs/2008/october/tradoc_140944.pdf). At that conference the European Commission made addressing trade barriers in raw materials a key priority for EU trade policy.

Despite China's hints at restrictions of rare earth exports, Radetzki (2008) notes that there has been only one man-made disruption of mineral flows in the past 40 years. In 1976, as a result of political upheavals in Zambia, global cobalt production fell by 20%. Prices rose from $5.40/lb. to $25/lb., and remained elevated for several years.

While there are many responses and strategies to alleviate the risks associated with import dependence, a main policy response is to attempt to increase domestic production. The challenge here is that geographical disparities in endowments do not always enable domestic production. Commodity stockpiling is the more usual measure of gaining a buffer against supply disruptions. It is not clear, however, that domestic supply is any more secure than diversified international supply. An artificially induced domestic supply is likely to be concentrated geographically and commercially, leaving open the risk of supply disruptions and market maneuvering by the supplier. There must also be prohibitions against export during world-wide production shortages, which reduce incentives for private investment in domestic production activities.

Topic 5: The Impact of Domestic Market Structure and Regulation on Production and Trade in Minerals

Until the 1980's trade theory based on the Heckscher-Ohlin, Ricardo, and Ricardo-Viner models was the main framework for understanding international trade. This theory is based on the assumption that industries exhibit constant returns to scale and that the market structure of those industries is perfectly competitive. International trade consists of each country exporting the goods most suited to its factor endowment, technology, and climate, while importing the goods least suited for its national characteristics. Such trade is called *inter-industry trade* because a country's exports are in a different industry than its imports.

The last three decades have witnessed the introduction of a new framework to understand international trade. This new approach breaks with classical trade theory by stressing the relevance of increasing returns to scale as an important, independent source of trade. A world economy characterized by increasing returns to scale will be one where imperfect competition predominates. Thus, the new approach has integrated international trade theory with the theory of industrial organization.

This new way of understanding international trade emerged due to the recognition that relatively few markets for industrial products, services and natural resources like minerals and crude oil meet the assumption of perfect competition required by classical trade theory. Except in markets for a select group of standardized commodities, companies do not generally perceive themselves as price takers. In many markets there are only a limited number of relevant competitors, and these firms are well aware of the interdependence of their actions in the market place. This point of view is acknowledged by Helpman and Krugman, with special emphasis on minerals, in the following quotation:

> What is true of the economy as a whole is true of international trade as well. More than half of world trade is in manufactured goods, where markets are often oligopolistic rather than competitive. Markets for

> minerals are also often oligopolistic (or oligopsonistic, where the processing stage is highly concentrated). …In other words, the study of international trade should be in part a study of international industrial organization. (1989, p.1)

Helpman and Krugman (1985) point out that there are mainly two ways in which traditional trade theory appears to be inadequate in accounting for empirical observations regarding international trade: a) its failure to explain the volume of trade between certain countries, and b) its failure to explain the composition of trade between certain countries. The standard theory associates the causes of trade with the intrinsic differences between countries. For instance, countries may be different with respect to their relative endowments of factors of production or their production technologies. This implies an inverse relationship between similar features of countries and the volume of trade between them. This is the usual explanation why mineral economies specialize in exporting ore and minerals: those countries are relatively abundant in mineral resources, so they possess comparative advantages in producing and exporting minerals. However, an important amount of world trade is between countries that are relatively similar in their relative factor endowments. In addition, the actual composition of trade patterns includes substantial two-way trade in goods of similar factor intensity. The intra-industry trade of goods is hard to explain *a priori* from the point of view of the standard trade theory.

According to van Marrewijk (2009), there are two different types of intra-industry trade. *Horizontal intra-industry trade* refers simultaneous exports and imports of goods categorized in the same sector and at the same stage of processing. This type of trade is based on product differentiation, such as Germany's simultaneous import and export of luxury cars. On the other hand, *vertical intra-industry trade* refers to simultaneous exports and imports of goods categorized in the same sector but at different stages of processing. This type of trade is explained by the increasing ability to fragment the production process into different stages, each performed at different locations in order to exploit local conditions. For instance, China imports technology-intensive computer components and uses its abundant labor force to assemble these components into desktop and laptop computers. In this scenario, manual assembly is the labor-intensive final production stage of computers. Then, China exports those components (as parts in the assembled computers) again to Europe, the U.S.A. or Latin America.

The New Trade Theory and Intra-industry trade

Intra-industry trade first received attention in the 1960s in studies by Verdoorn (1960) and Balassa (1966) on the large trade flows among European countries. Grubel and Lloyd (1975) provided one of the most important empirical studies on the importance of intra-industry trade and how to measure it. They proposed the Grubel-Lloyd index, which measures the percentage of a country's intra-industry trade in sector *i*:

$$GL_i = 1 - \left(\frac{|\text{export}_i - \text{import}_i|}{\text{export}_i + \text{import}_i} \right)$$

If a country does not import from the same sector in which it exports, the second term on the right-hand side of GL_i is equal to one, and the whole expression reduces to zero. If the export value within a sector is equal to the import value, the second term on the right-hand side of GL_i is equal to zero, and the whole expression reduces to one. The Grubel–Lloyd index therefore varies between zero (indicating pure *inter*-industry trade) and one (indicating pure *intra*-industry trade). Grubel and Lloyd showed that international trade is largely *intra*-industry within broad industrial classifications.

Solid theoretical foundations for explaining intra-industry trade appeared later in the 1980s and 1990s with the new trade literature pioneered by Krugman (1979, 1981) and structured by Helpman and Krugman (1985). This "new trade theory" relied to a large extent on the monopolistic competition framework with differentiated products.[14] A monopolistically competitive industry is one that manufactures the same generic good. Nonetheless, each company occupies a specific position or market niche due to product differentiation (for instance, goods can differ in quality, location of production, color, size, and so forth). There is free entry of new firms selling differentiated goods, and the seller of each variety has some control over price. The automobile industry has been considered in the literature as a prototypical monopolistically competitive industry. The number of products manufactured in the industry is supposed to be equal to the number of firms, although many of such companies may belong to the same conglomerate. There might not be free entry for the conglomerates, but there certainly will be for the market niches they choose. It is relatively easy for any of the large automobile companies to produce a particular type of sedan vehicle, for example.

Krugman (1979) used this framework to analyze trade when firms exhibit increasing returns to scale in production. Krugman pointed out that international trade is not necessarily explained by international differences in technology or factor endowments. He argued that international trade might simply be a way of extending firms' presence in foreign markets and a strategy that allows them to take advantage of economies of scale, which intensify the incentives to specialize in a limited variety of products. Imperfect competition arises, and firms are capable of differentiating their products so that their outputs become imperfect substitutes internationally. Thus, under international monopolistic competition, there will be a rationale for trade: because firms produce differentiated goods, they will export those products to other countries in order to expand their markets, gain a strategic position in different niches, and take advantage of economies of scale in production. In a world where economies of scale are relevant and monopolistic competition is the norm, it is natural to find countries exchanging goods produced with similar factor proportions. According to Helpman and Krugman, "If we were to aggregate groups of products into sectors defined by similarity of factor proportions, we would expect to find substantial amounts of two-way [intra-industry] trade" (1985, p. 132).

[14] This type of market structure was proposed in the literature by Chamberlin (1933) and formalized by Dixit and Stiglitz (1977).

According to Markusen et al. (1995), intra-industry trade characterizes an important amount of international trade among the majority of developed countries. However, intra-industry trade is not the only kind of trade that happens. Inter-industry trade is also observable, especially among developing and developed countries. In order to explain the joint existence of inter-industry and intra-industry trade, Krugman (1981) proposed a model in which trade is originated by both comparative advantage as well as economies of scale and imperfect competition.

Krugman's framework conceptualizes a view of trade in which comparative advantage drives specialization at the aggregative, sectoral, international level, but economies of scale cause specialization at the level of individual products. First, trade depends on how similar economies are with respect to their factor endowments. Second, as countries become more similar, international trade among them will become more and more intra-industry exchange. In this sense, economies can exhibit not only a Heckscher-Ohlin inter-industry trade specialization, but also an intra-industry trade specialization explained by internal increasing returns to scale and consumers' taste for a diversity of products. Krugman concluded that trade patterns and trade volumes are altered by the existence of economies of scale. The variety of goods produced in each country will mainly depend on firms' internal increasing returns to scale. Similar countries will have incentive to trade because they possess similar industries, which allow the specialization of each country. The bigger countries' similarities, the higher the possibilities of specialization will be. This means that the variety of goods will be higher as well.

Krugman's explanation of intra-industry trade patterns has been challenged by Donald Davis (1995), who points out that intra-industry trade could be also explained by comparative advantage.[15] The key of Davis's approach is to introduce elements of the Ricardian trade theory within the Heckscher-Ohlin framework. Within this approach essential characteristics of intra-industry trade imply that technological differences across countries matter. He develops the Heckscher-Ohlin-Ricardo model, which shows that even with constant returns to scale intra-industry trade could still occur. The Heckscher-Ohlin-Ricardo model predicts that countries of identical factor endowments would still trade due to technological differences. Those differences would encourage specialization and thus international trade in exactly the same matter that was set out in the Ricardian model. Therefore, Donald Davis concludes that increasing returns to scale are not necessary to account for intra-industry trade.

[15] The origin of this critical view of Krugman's approach is the evidence that scale economies are not the source of intra-industry trade. According to Donald Davis, "Empirical verification of the role of scale economies in giving rise to intra-industry trade, however, has proven elusive. Tests based on the Grubel-Lloyd measure of intra-industry trade have consistently shown a significant *negative* relation between intra-industry trade and proxies for scale economies. A recent test seeking to account for import shares by proxies for scale economies found a positive relation by some measures and a negative relation by another. The evidence advanced in Helpman's (1988) study of fourteen developed countries does not distinguish between a variety of models with specialization. In sum, the direct empirical support of the scale economies theory is, at best, mixed" (1995, p. 202).

Market Structure and Intra-industry trade of Mineral Resources

I have observed that intra-industry trade of final goods may be explained either by the existence of scale economies in production and imperfect competition or by simultaneous relative differences in factor endowments and technology. The relevant questions at this point regarding mineral trade are: is it possible to have intra-industry trade of minerals? If so, what would it be the main explanation to account for intra-industry trade of minerals?

Regarding the first question, suppose that we focus on the mineral industries of Peru and Chile. Intra-industry trade in minerals would occur, for example, if Chile exported copper concentrates to Peru and simultaneously imported copper concentrates from Peru. In fact, this kind of intra-industry trade actually occurs between those countries. According to DIRECON (2009), Chile exported to Peru copper concentrates worth US$ 31.8 million in 2008, while Peru exported to Chile copper concentrates worth US$ 94.6 million.

Krugman and Obstfeld (2003) show that the Grubel-Lloyd index for the US iron and steel sector is around 0.43, indicating a moderate level of intra-industry trade. van Marrewijk (2009) shows evidence regarding some intra-industry trade of minerals and natural resources between China and its trading partners. He used the factor intensity classification of the International Trade Center (UNCTAD/WTO) that distinguishes between five broad factor-intensity categories at the 3-digit level, namely

A. *Primary products*; e.g., meat, dairy, cereals, fruit, coffee, minerals and oil.
B. *Natural-resource intensive products*; e.g., leather, wood, pig iron, and copper.
C. *Unskilled-labor intensive products*; e.g., textiles, clothing, ships, and footwear.
D. *Human-capital intensive products*; e.g., perfumes, cosmetics, cars, and watches.
E. *Technology intensive products*; e.g., chemicals, electronics, tools, and aircraft.

Table 1 shows the Grubel-Lloyd intra-industry trade index for these sectors in China for selected years. The results provide evidence that intra-industry trade is particularly low for unskilled-labor intensive sectors, particularly high for technology intensive sectors, and intermediate for primary product and natural resource industries. The average Grubel-Lloyd indices for the latter industries are 0.27 and 0.38, respectively. This indicates that there was moderate intra-industry trade of minerals between China and its trading partners between 1980 and 2005, although the importance of this kind of trade would have declined over time as the shares of product type in total trade indicates.[16] The limitation of this approach is that different types of goods are lumped together in the primary product and natural resource sectors, so it may be possible that intra-industry trade patters appear because of the broad data aggregation for each sector.

[16] Due to China's economic development in the last decades, the composition of its trade flows have tended to move away from primary products, initially towards unskilled-labor intensive products, and then towards technology and human-capital intensive goods.

Table 1: Intra-industry trade and composition of trade flows in China
(Trade-weighted average Grubel-Lloyd index (3-digit level) and per cent of total trade)

Type of Products					
	Primary Products	Natural-resource intensive products	Unskilled-labor intensive products	Technology intensive products	Human-capital intensive products
Weighted average Grubel-Lloyd summary statistics for product type, 1980-2005					
average	0.27	0.38	0.16	0.56	0.36
st. dev.*	0.11	0.07	0.04	0.04	0.08
Share of product type in total trade (percentages)					
1980	51.4	3.4	27.8	8.1	9.2
1985	49.5	2.0	33.7	7.1	7.7
1990	19.4	2.9	46.5	15.6	15.5
1995	10.1	4.0	45.4	24.9	15.6
2000	7.5	3.2	39.2	35.5	14.6
2005	4.6	3.3	28.9	47.7	15.5

Source: van Marrewijk (2009). *st. dev. = standard deviation.

Bernatonyte (2009), in a study of intra-industry trade patterns between Lithuania and the European Union from 2001 to 2007, showed that the Grubel-Lloyd index for trade in mineral products, Category V of the EU's Combined Nomenclature classification, varied between 0.09 and 0.26 over the period. Intra-industry trade of mineral commodities was the lowest of any of the 12 sectors studied, even given the broad sectoral classification that a 12 sector classification generates. Wong (1995) shows that intra-industry trade is muted the higher international transportation costs, and this may be why intra-industry trade in the minerals sector is lower than that of other sectors.

While low, the fact that there appears to be intra-industry trade in minerals raises a second question: What is the main explanation to account for intra-industry trade of minerals? The answer would explain, for instance, why Chile is (at least partially) exporting copper concentrates in exchange for imported copper concentrates, or why the US, China and Lithuania are exhibiting some intra-industry trade of minerals. Unfortunately, these empirical studies do not address the causes of the observed intra-industry trade of minerals, and to the best of my knowledge, the available literature regarding market structure and intra-industry trade has not addressed that question either. There are neither theoretical studies nor empirical research attempting to directly explain the main cause of intra-industry trade in minerals.

One argument for mineral intra-industry trade is the possibility of having an oligopoly in a domestic mining industry that faces international competition. Suppose, for example, that in the domestic mining industry there is a dominant cartel which produces minerals that are sold domestically and abroad. There is also a fringe of mineral producers that competes with the dominant cartel. Under this scenario, the dominant cartel can exercise market power in the domestic market by charging higher prices domestically and lower prices abroad (this policy implies 3rd degree price discrimination). The dominant cartel will export mineral ores and final products facing international prices, and it will sell the ores domestically at a markup over the marginal cost of production (Helpman and Krugman 1985). If the dominant cartel controls the majority of mines in the country, the competitive fringe will need to import some ore concentrates to produce final products to be sold domestically or internationally. Intra-industry trade results when the domestic economy simultaneously exports and imports ore concentrates because of the imperfect market structure of the domestic mining industry.

According to Vasquez (2006), the Peruvian oil industry exhibits intra-industry trade of liquefied petroleum gas (LPG) because of the existence of an imperfect market structure in the LPG market characterized by the presence of a dominant group of refiners and a fringe of LPG importers. This argument has been not studied in the case of the mineral industries. The traditional resource economics literature that has studied the relationship between market structure and optimal nonrenewable resource extraction has tended to focus on energy production or extraction in the abstract (Stiglitz 1976, Dasgupta and Heal 1979, Dasgupta and Stiglitz 1982). This literature points out that imperfect market structures like monopolies, oligopolies and oligopsonies will generate a dynamically inefficient outcome with a bias towards initial conservation of the nonrenewable resources. This means that resources like minerals produced under imperfect competition will be depleted at a lower pace. The literature does not analyze market structure, optimal resource depletion, and trade patters simultaneously.

In the one study relating international trade to the structure of mineral markets, Kolstad and Abbey (1984) analyzed the relation between imperfect market structure and trade patterns in the international steam coal market through simple static monopoly and oligopoly models (e.g., Cournot duopoly). They found evidence that the exercising of market power by certain agents in the international steam coal market can lead to inter-industry trade patterns that are consistent with those observed in reality. However, Kolstad and Abbey only focused on inter-industry trade patterns and excluded from the analysis the fact that steam coal is an exhaustible resource.

In the absence of evidence of imperfect competition driving horizontal intra-industry minerals trade, vertical intra-industry trade remains a compelling argument to account for intra-industry trade patterns. For instance, different mineral ore concentrates at different stages of processing may be simultaneously exported and imported between two countries in order to be processed at specialized smelting facilities located in both countries. Firms tend not to smelt other firms' concentrates. Each firm may then export all of its worldwide concentrates to its own smelter locations. With smelters scattered across the world and located in regions where there are mines, there will appear to be intra-industry movement of concentrates.

High domestic transportation costs may also explain why certain ore concentrates or final mineral products are reciprocally traded between some countries. For example, country A may import minerals from a nearby region of a bordering country B (where many mines are located) in order to re-export those minerals to a region of country B where smelting and ore processing facilities are located. This scenario is likely if the costs of transporting minerals across country B are higher than the sum of costs of shipping the minerals to country A and the cost of re-exporting the minerals from country A to the country B. If this were driving the intra-industry trade in minerals, we should see higher ratios of intra-industry trade in large countries with poor internal transportation infrastructure and a large border to area ratio. Unfortunately there are no empirical studies examining these explanations for vertical intra-industry trade of mineral commodities.

In conclusion, there is not a clear explanation of how the market structure of mineral markets and the depletion of exhaustible minerals are related with intra-industry trade of mineral commodities. Are either Krugman's arguments or Donald Davis's viewpoints the explanations of the observed patterns of intra-industry trade of minerals? The claim by Krugman that domestic minerals production is oligopolistic, combined with high international transportation costs, could explain why intra-industry trade in minerals exists but at low levels. There is no evidence, however, that the industry is currently oligopolistic, aside from, possibly, diamonds, and I am aware of no regulatory framework that would restrict entry to protect a firm or conglomerate that is exercising market power domestically.

References

Acemoglu, Daron, Simon Johnson, and James A. Robinson (2001), The colonial origins of comparative development: an empirical investigation, *American Economic Review* 91 (5), 1369-1401.

Alexeev, Michael, and Robert Conrad (2008), The elusive curse of oil, forthcoming, *Review of Economics and Statistics*. Available at http://mypage.iu.edu/~malexeev/alexeev_conrad_restat_feb_08.pdf.

Anderson, James E. (1987), Review of *Sources of International Comparative Advantage: Theory and Evidence*, Cambridge, MA, MIT P. *Journal of Economic Literature* 25, 146-47.

Anderson, Kym (2003), Trade liberalization, agriculture, and poverty in low-income countries, Discussion Paper No. 2003/25, UNU/WIDER.

Auty, Richard (1994), Industrial policy reform in six large newly industrialized countries: The resource curse thesis, *World Development* 22, 11-26.

Balassa, Bela (1966), Tariff reductions and trade in manufacturers among the industrial countries, *American Economic Review* 56 (3), 466–73.

Balassa, Bela (1989), *Comparative Advantage, Trade Policy, and Economic Development*, New York, New York UP.

Behrman, Jere R. (1987), Commodity price instability and economic goal attainment in developing countries, *World Development* 15 (5), 559-73.

Bernatonyte, Dalia (2009), Intra-industry trade and export specialization: Lithuanian case, *Economics and Management* 14, 668-75.

BIAC (2006), Freedom for investment, and the challenges for energy and raw materials security, Discussion Paper for the Consultation with the OECD Liaison Committee, 12 December, 2006, Paris, France, Available at http://www.biac.org/statements/high_level/BIAC_Statement_to_LCM_2006.pdf.

Bowen, Harry P., Edward E. Leamer, and Leo Sveikauskas (1987), Multicountry, multifactor tests of the factor abundance theory, *American Economic Review* 77 (5), 791-809.

Boyce John R., and J. C. Herbert Emery (2007), What can exhaustible resource theory can tell us about per capita income growth and levels in resource abundant countries?, Working Paper, University of Calgary.

Bradsher, Keith (2009a), China tightens grip on rare minerals, *New York Times*, pp. B1+, Tuesday, September 1, 2009.

Bradsher, Keith (2009b), Backpedaling, China eases proposal to ban exports of some vital minerals, *New York Times*, p. B4, Friday, September 4, 2009.

Brookfield, Harold (1977), Dissent from the periphery, in Bertil Ohlin, Per-Ove Hesselborn, and Per Magnus Wijkman, eds., *The International Allocation of Economic Activity*, New York, Holmes & Meier Publishers, pp. 70-79.

Brunnschweiler, Christa N. (2008), Curse or blessing? Natural resource abundance, institutions, and economic growth, *World Development* 36 (3), 399-419.

Brunnschweiler, Christa N., and Erwin H. Bulte (2008), The resource curse revisited and revised: a tale of paradoxes and red herrings, *Journal of Environmental Economics and Management* 55, 248-64.

Bulte, Erwin H., Richard Damania, and Robert T. Deacon (2005), Resource intensity, institutions, and development, *World Development* 33 (7), 1029-44.

Chamberlin, Edward H. (1933), *The Theory of Monopolistic Competition*, Cambridge, MA, Harvard UP.

Claessens, Stijn, and Ronald C. Duncan, eds. (1993), *Managing Commodity Price Risk in Developing Countries*, Baltimore, John Hopkins UP.

Corden, W. Max (1984), Booming sector and Dutch disease economics: survey and consolidations, *Oxford Economic Papers* 36, 359-80.

Corden, W. Max, and J. Peter Neary (1982), Booming sector and de-industrialisation in a small open economy, *Economic Journal* 92, 825-48.

Cuddington, John (1989), Commodity export booms in developing countries, *World Bank Research Observer* 4, 143-65.

Cuddington, John T., Rodney Ludema, and Shamila A. Jayasuriya (2007), Prebish-Singer redux, in Daniel Lederman and William F. Maloney, eds., *Natural Resources: Neither Curse nor Destiny*, Palo Alto, CA, Stanford UP, and Washington, DC, The World Bank, pp. 103-40.

Dasgupta, Partha S., and Geoffrey M. Heal (1979), *Economic Theory and Exhaustible Resources*, Cambridge: Cambridge UP.

David, Paul A., and Gavin Wright (1997), The genesis of American resource abundance, *Industrial and Corporate Change* 6, 203-45.

Davis, Donald R. (1995) Intra-industry trade: A Heckscher-Ohlin-Ricardo approach, *Journal of International Economics* 39 (3-4), 201-26.

Davis, Graham A. (1994), *South African Managed Trade Policy: The Wasting of a Mineral Endowment*, Westport, CT, Praeger.

Davis, Graham A. (1995), Learning to love the Dutch disease: evidence from the mineral economies, *World Development* 23 (10), 1765-79.

Davis, Graham A. (1998), The minerals sector, sectoral analysis, and economic Development, *Resources Policy* 24 (4), 217-28.

Davis, Graham A. (2006), The resource curse: assessing the empirical evidence, Working Paper, Colorado School of Mines.

Davis, Graham A. (2009), Extractive economies, growth and the poor. In Jeremy Richards, ed., *Mining, Society, and a Sustainable World*, Berlin, Springer-Verlag, pp. 37-60.

Davis, Graham A., and John E. Tilton (2005), The resource curse, *Natural Resources Forum* 29, 233-42.

Davis, Graham A., and John E. Tilton (2008), Why the resource curse is a concern, *Mining Engineering* 60 (4), 29-32.

de Ferranti, David, Guillermo E. Perry, Indermit S. Gill, and Luis Servén (2000), *Securing our Future in a Global Economy*, Washington DC, The World Bank.

Deardorff, Alan V. (1984), Testing trade theories and predicting trade flows, in Ronald W. Jones and Peter B. Kenen, eds., *Handbook of International Economics*, Vol. I, Amsterdam, North-Holland, pp. 467-517.

DIRECON (2009), *Informe de Comercio Exterior de Chile, Segundo Trimestre 2009*, Direccion General de Relaciones Economicas Internacionales, Ministerio de Relaciones Exteriores de Chile. Available at http://cms.chileinfo.com/documentos/Informe_comercio_exterior_2trim_2009.pdf.

Dixit, Avinash K., and Joseph E. Stiglitz (1977), Monopolistic competition and optimum product diversity, *American Economic Review* 67 (3), 297-308.

Findlay, Ronald (1985), Primary export, manufacturing, and development, in Mats Lundahl, ed., *The Primary Sector and Economic Development*, London, Croom Helm, pp. 218-33.

Findlay, Ronald (1995), *Factor Proportions, Trade, and Growth*, Cambridge, MA, MIT P.

Gocht, Werner R., Half Zantop, and Roderick G. Eggert (1998), *International Mineral Economics*, Berlin, Springer-Verlag.

Grubel, Herbert, and Peter Lloyd (1975), *Intra Industry Trade: The Theory and Measurement of International Trade with Differentiated Products*, London, Macmillan.

Haber, Stephen, and Victor Menaldo (2009), Do natural resources fuel authoritarianism? A reappraisal of the resource curse, Working Paper, Stanford University.

Haberler, Gottfried (1977), Survey of circumstances affecting the location of production and international trade as analysed in the theoretical literature, in Bertil Ohlin, Per-Ove Hesselborn, and Per Magnus Wijkman, eds., *The International Allocation of Economic Activity*, New York, Holmes & Meier Publishers, pp. 1-24.

Helpman, Elhanan, and Paul R. Krugman (1985), *Market Structure and Foreign Trade*, Cambridge, MIT P.

Helpman, Elhanan, and Paul R. Krugman (1989), *Trade Policy and Market Structure*, Cambridge, MIT P.

Hodges, Tony (2004), *Angola: Anatomy of an Oil State*, 2nd ed., Oxford, The Fridtjof Nansen Institute in Association with James Curry, and Bloomington, Indiana UP.

Hummels, David, and Alexandre Skiba (2004), Shipping the good apples out? An empirical confirmation of the Alchian-Allen conjecture, *Journal of Political Economy* 112 (6), 1384-1402.

Jones, C. (2002), *Introduction to Economic Growth*, New York: W.W. Norton.

Jones, R. (1971), A three-Factor model in theory, trade and history, in J. Bhagwati, R. Jones, R. Mundell and J. Vanek, eds., *Trade, Balance of Payments and Growth. Papers in Honor of Charles P. Kindleberger*, Amsterdam, North-Holland, pp. 1-22.

Kemp, Murray C., and Ngo Van Long (1984), The role of natural resources in trade models, in Ronald W. Jones and Peter B. Kenen, eds., *Handbook of International Economics*, Vol. I, Amsterdam, North-Holland, pp. 367-417.

Kenen, Peter B. (1965), Nature, capital, and trade, *Journal of Political Economy* 73 (5), 437-60.

Kolstad, Charles D., and David S. Abbey (1984), The effect of market conduct on international steam coal trade, *European Economic Review* 24 (1), 39-59.

Krugman, Paul R. (1979), Increasing returns, monopolistic competition, and international trade, *Journal of International Economics* 9 (4), 469-79.

Krugman, Paul R. (1981), Intra-industry specialization and the gains from trade, *Journal of Political Economy* 89 (5), 959-73.

Krugman, Paul R., and Maurice Obstfeld (2003), *International Economics: Theory and Policy*, Boston, Pearson Education.

Leamer, Edward E. (1984), *Sources of International Comparative Advantage: Theory and Evidence*, Cambridge, MA, MIT P.

Leamer, Edward E. (1995), *The Heckscher-Ohlin Model in Theory and Practice*, Princeton Studies in International Finance, No. 77, International Finance Section, Department of Economics, Princeton University.

Leamer, Edward E., and James Levinsohn (1995), International trade theory: The evidence, in Gene M. Grossman and Kenneth Rogoff, eds., *Handbook of International Economics*, Vol. III, Amsterdam, Elsevier, pp. 1339-94.

Lederman, Daniel, and William F. Maloney, eds. (2007a), *Natural Resources: Neither Curse nor Destiny*, Palo Alto, CA, Stanford UP, and Washington, DC, The World Bank.

Lederman, Daniel, and William F. Maloney (2007b), Trade structure and growth, in Daniel Lederman and William F. Maloney, eds., *Natural Resources: Neither Curse nor Destiny*, Palo Alto, CA, Stanford UP, and Washington, DC, The World Bank, pp. 15-39.

Lederman, Daniel, and L. Colin Xu (2007), Comparative advantage and trade intensity: Are traditional endowments destiny?, in Daniel Lederman and William F. Maloney, eds., *Natural Resources: Neither Curse nor Destiny*, Palo Alto, CA, Stanford UP, and Washington, DC, The World Bank, pp. 289-322.

Lim, David (1988), Export instability and economic growth in resource-rich countries, in Miguel Urrutia and Setsuko Yukawa, eds., *Economic Development Policies in Resource-rich Countries*, Tokyo, United Nations University, pp. 66-89.

Lucas, Robert E. (1988), On the mechanics of economic development, *Journal of Monetary Economics* 22 (1), 3-42.

Markusen, James R., James R. Melvin, William H. Kaempfer, and Keith E. Maskus (1995), *International Trade: Theory and Evidence*, New York, McGraw-Hill.

Martin, Will (2007), Outgrowing resource dependence: theory and developments, in Daniel Lederman and William F. Maloney, eds., *Natural Resources: Neither Curse nor Destiny*, Palo Alto, CA, Stanford UP, and Washington, DC, The World Bank, pp. 323-55.

Maxwell, Philip (2006), Trade in minerals, in Philip Maxwell, ed., *Australian Mineral Economics: A Survey of Important Issues*, Carlton, Australia, The Australasian Institute of Mining & Metallurgy, pp. 27-34.

Mayer, Jörg (1999), Conclusions, in Jörg Mayer, Brian Chambers, and Ayisha Farooq, eds., *Development Policies in Natural Resource Economies*, Cheltenham, Edward Elgar, pp. 189-205.

Moroney, John R. (1975), Natural resource endowments and comparative labor costs: a hybrid model of comparative advantage, *Journal of Regional Science* 15 (2), 139-50.

Neary, J. Peter, and Sweder van Wijnbergen, (1986), Natural resources and the macroeconomy: a theoretical framework, in J. Peter Neary and Sweder van Wijnbergen, eds., *Natural Resources and the Macroeconomy*, Oxford, Basil Blackwell, pp. 13-45.

Nordhaus, W. (1992), Lethal model 2: the limits to growth revisited, *Brooking Papers on Economic Activity* 2, 1-59.

Ohlin, Bertil (1967), *Interregional and International Trade*, Revised edition, Cambridge, MA, Harvard UP.

Ohlin, Bertil, Per-Ove Hesselborn, and Per Magnus Wijkman, eds. (1977), *The International Allocation of Economic Activity*, New York, Holmes & Meier Publishers.

Owens, Trudy, and Adrian Wood (1997), Export-oriented industrialization through primary processing? *World Development* 25 (9), 1453-70.

Radetzki, Marian (1990), *A Guide to Primary Commodities in the World Economy*, Oxford, Basil Blackwell.

Radetzki, Marian (2008), *A Handbook of Primary Commodities in the Global Economy*, Cambridge, Cambridge UP.

Roemer, Michael (1979), Resource-based industrialization in the developing countries: a survey, *Journal of Development Economics* 6, 163-202.

Roemer, Michael (1985), Dutch disease in developing countries: swallowing bitter medicine, in Mats Lundahl, ed., *The Primary Sector and Economic Development*, London, Croom Helm, pp. 234-52.

Ross, Michael L. (2001), Does oil hinder democracy?, *World Politics* 53 (3), 325-61.

Sachs, J. and A. Warner (1995), Natural resource abundance and economic growth, NBER Working Paper Nº 5398, National Bureau of Economic Research, Cambridge MA.

Sachs, J. and A. Warner (1997), Natural resource abundance and economic growth, HIID Working Paper, Cambridge MA.

Sachs, J. and A. Warner (2001), Natural resources and economic development: the curse of natural resources, *European Economic Review* 45, 827-38.

Sala-i-Martin, Xavier (1997a), I just ran four million regressions, NBER Working Paper No 6252, Cambridge, MA, National Bureau of Economic Research.

Sala-i-Martin, Xavier (1997b), I just ran two million regressions, *American Economic Review Papers and Proceedings* 87 (2), 178-83.

Sala-i-Martin Xavier, Gernot Doppelhofer, and Ronald I. Miller (2004), Determinants of long-term growth: a Bayesian averaging of classical estimates (BACE) approach, *American Economic Review* 94 (4), 813-35.

Sarmiento, Eduardo (1988), Development of industrial versus primary exports, in Miguel Urrutia and Setsuko Yukawa, eds., *Economic Development Policies in Resource-rich Countries*, Tokyo, United Nations University, pp. 90-111.

Snape, R. (1977), Effects of mineral development on the economy, *Australian Journal of Agricultural Economics* 21, 147-56.

Stiglitz, Joseph E. (1976), Monopoly and the rate of extraction of exhaustible resources, *American Economic Review* 66 (4), 655-61.

Stiglitz, Joseph E. (2007), What is the role of the State?, in Macartan Humphreys, Jeffrey D. Sachs, and Joseph E. Stiglitz, eds., *Escaping the Resource Curse*, New York, Columbia University Press, pp. 23-52.

Stiglitz, Joseph E., and Partha Dasgupta (1982), Market structure and resource depletion: a contribution to the theory of intertemporal monopolistic competition, *Journal of Economic Theory* 28 (1), 128-64.

Tilton, John E. (1983), Comparative advantage in mining, Working Paper 83-91, International Institute for Applied Systems Analysis, Laxenburg, Austria.

Tilton, John E. (1992), Mineral endowment, public policy and competitiveness: A survey of issues, *Resources Policy*, December, 237-49.

Tilton, John E. (2003), Creating wealth and competitiveness in mining, *Mining Engineering*, September, 15-22.

Trefler, Daniel (1995), The case of missing trade and other mysteries, *American Economic Review* 85 (5), 1029-46.

United Nations Industrial Development Organization (UNIDO) (1981), *World Industry in 1980*, New York, United Nations.

United Nations Industrial Development Organization (UNIDO) (1986), *International Comparative Advantage in Manufacturing: Changing Profiles of Resources and Trade*, Vienna.

van Marrewijk, Charles (2009), Intra-industry trade, forthcoming in K. Reinert and R. Rajan, eds., *Princeton Encyclopedia of the World Economy*, Princeton, Princeton UP.

van Wijnbergen, S. (1984), The Dutch disease: a disease after all?, *Economic Journal* 94, 41-55.

Vanek, Jaroslav (1963), *The Natural Resource Content of United States Foreign Trade, 1870 – 1955*, Cambridge, MA, MIT P.

Vasquez Cordano, Arturo (2006), La organizacion economica de la industria de hidrocarburos en el Peru: El mercado del gas licuado de petroleo, *Revista de la Competencia y de la Propiedad Intelectual* 2 (3), 63-131. Available at: http://www.indecopi.gob.pe/ArchivosPortal/boletines/recompi/castellano/articulos/invierno2006/art2.pdf

Venables, Anthony (2007), Trade, location, and development: an overview of theory, in Daniel Lederman and William F. Maloney, eds., *Natural Resources: Neither Curse nor Destiny*, Palo Alto, CA, Stanford UP, and Washington, DC, The World Bank, pp. 259-87.

Verdoorn, Pieter (1960), The intra-bloc trade of BENELUX, in E. A. G. Robinson, ed., *Economic Consequences of the Size of Nations*, London, Macmillan, pp. 291–329.

Wood, Adrian (1994), Give Heckscher and Ohlin a chance!, *Weltwirtschaftliches Archiv* 130 (1), 20-49.

Wood, Adrian J. B. (1999), Natural resources, human resources and export composition: a cross-country perspective, in Jörg Mayer, Brian Chambers, and Ayisha Farooq, eds., *Development Policies in Natural Resource Economies*, Cheltenham, Edward Elgar, pp. 39-52.

Wong, Kar-yiu (1995), *International Trade in Goods and Factor Mobility*, Cambridge, MA, MIT P.

Wright, Gavin, and Jesse Czelusta (2004), Why economies slow: the myth of the resource curse, *Challenge* 47 (2), 6-38.

Wright, Gavin, and Jesse Czelusta (2007), Resource-based growth past and present, in Daniel Lederman and William F. Maloney, eds., *Natural Resources: Neither Curse nor Destiny*, Palo Alto, CA, Stanford UP, and Washington, DC, The World Bank, pp. 183-211.

Yukawa, Setsuko (1988), Constraints on the development of resource-rich countries: a comparative analysis, in Miguel Urrutia and Setsuko Yukawa, eds., *Economic Development Policies in Resource-rich Countries*, Tokyo, United Nations University, pp. 1-40.