NATURAL RESOURCE ABUNDANCE AND ECONOMIC GROWTH REVISITED

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Abstract

Data on energy and mineral reserves suggest that natural resource abundance has not been a significant structural determinant of economic growth between 1970 and 1989. The story behind the effect of natural resources on economic growth is a complex one that typical growth regressions do not capture well. Preliminary evidence suggests that natural resources may affect economic growth through both "positive" and "negative channels." Potential reverse causality running from these "channels" to fuel and mineral reserves further complicates the analysis. I conjecture that, as economic historians suggest, the ability of a country to exploit its resource base depends critically on the nature of the learning process involved.

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I. Introduction

The observation that resource-poor economies can sometimes outperform resource-rich economies is nothing new in the field of economic history [De Long and Williamson, 1994]. Typical examples include the Netherlands versus Spain in the 17th century, and Switzerland and Japan versus Russia in the 19th and 20th centuries.

Sachs and Warner [1995b] — hereafter referred to as SW — show that economies with a high ratio of natural resource exports to GDP in 1971 (their base year) tended to have low growth rates during the subsequent period 1971-89. This negative relationship holds true after controlling for variables found to be important to economic growth, such as initial per capita income, trade policy, government efficiency, and investment rates.

The consequences of the SW paper for economic development are far reaching. SW conclude that "one of the surprising features of modern economic growth is that economies abundant in natural resources have tended to grow slower than economies without substantial natural resources[1]." This way of formulating their result is misleading. SW stop short of making specific recommendations for resource exporting countries. However, they practically leave us with the impression that developing countries should leave their natural resources undiscovered and/or unexploited.

The purpose of this paper is to check whether SW's negative relationship between natural resource abundance and economic growth holds when one uses actual data about energy, mineral reserves and production. The SW result is not robust to changes in the measure of natural-resource abundance from trade-flows to reserves or production. Natural resources *per se* do not seem to have a significant influence on growth rates.

I will not contest the observation made by SW that natural resource export intensity is associated with slower rates of economic growth. It is not the objective of this paper to argue that countries rich in natural resources unambiguously have faced or face better growth prospects. However, the proposition that natural resource production comes systematically at the expense of the manufacturing sector, learning-by-doing, and thus economic growth is not supported by the data.

What are the necessary conditions for a manufacturing sector to be built around a comparative advantage in natural resources? A resource-rich country may export few natural resources *per se* at the same time that its manufacturing sector exports embody intensively its natural resources. There is no clear historical evidence that, as SW assume in their working paper, learning-by-doing is restricted to the manufacturing sector, and is nonexistent in other sectors such as resource production or agriculture. Economic historian Gavin Wright suggests that if resources are "developed" through advanced forms of knowledge development, their spillover effects may be just as powerful as anything done in manufacturing.

Natural resource are not significant determinants of economic growth in this sample because of coexistence of what I call "positive" and "negative channels" of effect running from natural resources to factors that affect economic growth. Evidence of the existence of both types of channel will be presented.

This paper is organized as follows. Section II reviews key literature regarding the role of natural resources; Section III presents the data on natural resource production and reserves and investigates the empirical relationship between primary exports, resource production and reserves, and economic growth; Section IV specifies the growth

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[1] That's the opening sentence of the abstract of Sachs and Warner (1995b)

regressions, estimation and test results are provided; Section V interprets the results and investigates evidence of channels of effect of natural resources on economic growth; Section VI concludes.

II. Literature review

Matsuyama [1992] derives a formal model of what is called the "linkages approach" to the analysis of the role of natural resources for growth. He investigates the role of agriculture in a model in which manufacturing is characterized by learning-by-doing. He concludes that forces that push the economy away from manufacturing and towards agriculture lower the growth rate of the economy, by reducing learning-induced growth of manufacturing. Since the learning effects are external to the firm, market equilibrium is not efficient.

Feenstra [1990] as well as Grossman and Helpman [1991] have worked out models where a country that is lagging technologically can be driven by trade to specialize in traditional goods and thereby experience a reduction in its long run rate of growth. Such models are formalizations of old arguments about infant industries and the need for temporary protection to catch up with more advanced countries [Rodriguez and Rodrik, 1999].

In the NBER working paper version of their article, SW generalize Matsuyama's model using the framework of the "Dutch disease" model. In the Dutch disease model, named after the disappointing economic experience of the Netherlands (and the U.K.) following the discovery of North Sea oil in the 1970s, the economy has three sectors: a tradable natural resource sector, a tradable (non-resource) sector, and a non-traded sector. The greater the natural resource endowment, the higher is the demand for non-tradable goods, and consequently, the smaller will be the allocation of labor and capital to the manufacturing sector. This "Dutch disease" is an actual problem for the economy if there is something special about the sources of growth in manufacturing, such as the learning by doing stressed by Matsuyama.

When a natural resource has high transportion costs, then its physical availability within the economy is essential for the introduction of a new industry or a new technology. De Long and Williamson [1994] remind us that coal and iron ore deposits were a prerequisite for the development of an indigenous steel industry in the late 19th century. Resource-rich economies such as Britain and Germany grew particularly rapidly at the end of the last century. In contrast, for Carlo Bardini [1997] the poor performance of the Italian economy before World War I is explained by the lack of domestic coal reserves, which resulted in a backward economic structure of production.

J.H. Habakkuk [1962] linked high productivity in the US to resource abundance, starting a long debate on nineteenth-century American development. The timing of the U.S. leadership in industrial production coincides with its leadership in the production of coal, copper, petroleum, iron ore, zinc, phosphate, molybdenum, lead and tungsten. The United States was uniquely situated with respect to the availability and cost of mineral resources; at least as importantly, the range of available minerals was far wider than in any other country.

Gavin Wright [1990] analyses the reasons behind American technological leadership in manufactured goods at the turn of the 20th century. He estimates the factor content of trade in manufactured goods. The outstanding characteristic of American manufacturing exports was their intensity in non-reproducible natural resources. Such resource intensity had been increasing over the half-century prior to the Great Depression.

David and Wright [1997] challenge the premise that resource abundance simply reflected a country's geological endowment of mineral deposits. They argue, in the century following 1850, the US exploited its natural resource potential to a far greater extent than other countries, and did so across virtually the entire range of industrial minerals. Natural resource abundance was an endogenous, "socially constructed" condition that was not geologically pre-ordained. They hint at the fact that strong "positive feedbacks" even in the exploitation of depletable resources, were responsible for the explosive growth of the US "minerals economy."

Mitchener and McLean [forthcoming and 1999] study convergence in US regional growth from 1880 to 1980. Their results suggest that in 1880 states obtained an advantage in productivity from the mining industry independent of the other influences. They find that the independent influence of mineral abundance on state productivity was strongest at the end of the 19th century. Their argument is that in frontier states, where labor and capital are often in scarce supply, a large initial endowment of resources improves opportunities for economic agents to acquire scarce factors quickly, and to grow extensively, acquiring more capital and labor so the resource base can be further exploited. Bernard and Jones [1996] suggest that the resource sector may be important for explaining productivity differences across states as late as the 1980s.

For SW one of the characteristic features of modern economic growth is that economies with abundant natural resources have recently tended to grow less rapidly than those without. In the model they present at the end of their working paper, they assume that learning-by-doing is proportional to the relative size of the manufacturing sector. If their model correctly describes an important feature of modern economic development, those countries which have been lucky enough to exploit their natural resources at a time when they were essential to the development of an industrial sector should still be experiencing higher growth rates because of the inherited size of their industrial sectors.

Gallup and Sachs [1998] regress levels of per capita income on non-conventional explanatory variables. They find that levels of per capita income across countries in 1995 are positively related to deposits of some natural resources. This implies that measures of mineral reserves included in a cross-country regression partly capture the usual disadvantage of being a technological frontrunner. In other words, natural resources are highly correlated with original GDP per worker, a variable traditionally included to capture conditional convergence effects. This tends to understate the advantageous role natural resources play for growth, even controlling for initial per capita income.

The economic disaster of resource-abundant Sub-Saharan Africa (and to a lesser extent Latin America) is used as the prime example of the detrimental effect of natural resources can have on economic growth and development. Lane and Tornell [1995] argue that a windfall coming from a terms-of-trade improvement or a discovery of natural resource deposits can lead to a “feeding frenzy” in which competing factions fight for natural resource rents, and end up inefficiently exhausting the public good.

The experience of developed countries seems to contrast with that of LDC’s in this respect. The key to this puzzle may be that in a country with a well defined and well-functioning property right system, a natural resource boom would probably not lead to a war of attrition. In a society with a shakier social infrastructure and dysfunctional economic policy, such booms may lead to wasteful rent seeking and possible rising inequality, making consensus on growth enhancing policies hard to reach.

Angus Deaton [1999] argues that the revenues commodity exports provide are a potential source of funds for investment. Even temporary price booms provide windfalls that, if invested, can enhance future growth. The importation of investment has been a preeminent feature of the American economic development in the 19th century and of the East Asian economic “miracle” [Dani Rodrik, 1994].

For Angus Deaton, in Africa, the problem has been the low quality of investment and the absence of complementary factors, particularly education. The degree of processing in Africa's exports is generally low. Ownership of minerals is often concentrated, so that increases in commodity prices lead to increases in income inequality. Nonetheless, he argues that there is a strong relationship between GDP growth and commodity price growth, with commodity price growth leading economic growth. This is reminiscent of the “Big Push” model of Murphy, Shleifer, and Vishny [1989].

Brad De Long [2000] optimistically proposes that the tropics' comparative advantage, now and in the future, is in light manufacturing. Within a generation the tropics will import food on a large scale from the temperate zone. He reasons that the key is productivity in manufacturing and services, where the tropics do not have any ecological disadvantage. In this context, provided these countries succeed in “getting economic policy right,” tropical countries with a substantial endowment in natural resources may see this comparative advantage reinforced rather than weakened, and have a chance of establishing “endogenous growth.”

III. Data

When one starts thinking about the effect of natural resources on economic growth, three options offer themselves: natural resource exports, production or reserves. The claim that being a resource export dependent country slows down its expected rate of growth, is a different claim than arguing that high mineral reserves or production of those reserves is associated with slower rates of growth.

Once out of the 2-by-2 Hecksher-Ohlin model, there is no guarantee that higher relative endowment of a specific factor (say, mineral reserves) will necessarily translate to exports being more natural-resource intensive than imports. Countries tend to export goods which embody intensively the factors that they are relatively well endowed in, but this need not hold for any specific good. Elasticities of substitution for production and consumption play a crucial role. Conversely, observing that a country's exports are more resource-intensive than its imports does not necessarily imply a higher relative endowment in those resources. See Leamer [1980] for seminal work on these issues.

It is worthwhile investigating separately the effects of natural resource endowment, production and trade on economic growth. SW's preferred measure of resource dependence is the ratio of primary-product exports to GDP in 1970. This paper considers production and reserves data gathered from three sources about land, fuels and minerals. Land, measured as the log of the ratio of total land area to population in 1971, comes (as in SW) from Table 1 of the FAO's 1971 Production Yearbook. Oil, gas and coal reserves as well as production data come from the US Department of Energy [1999]. Series for oil, gas and coal reserves per 1,000 inhabitants are labeled OILR, GASR and

COALR respectively. Similarly, series for oil, gas and coal production per 1,000 inhabitants are labeled OILP, GASP and COALP respectively.

Mineral production and reserves data from the U.S. Geological Survey, Minerals Program (U.S.G.S.) [1999] are for the availability per country of 57 different mineral resources. The limited number of degrees of freedom in a cross-section of countries makes estimating a separate coefficient for each of these minerals virtually impossible. In an attempt to summarize this rich data, I have calculated separately the first two principal components for these series. These indexes will be referred to hereafter as MINR1 and MINR2 in the case of reserves data, and MINP1 and MINP2 in the case of production data.

The method of principal components offers little hope of enabling me to give a specific interpretation to the resulting index, other than to say tautologically that MINR1 is the first principal of these series of mineral reserves, for example. However, principal components extract by construction a maximum of information from the data (given the arbitrary number of principal components which are considered), provide us with two perfectly orthogonal series, and offer the advantage of being less arbitrary than some other indexes. Other types of indexes have been used (not reported) and lead to similar conclusions.

Since the use of reserve data is essential to this paper, it is necessary to discuss how these measures are developed and what they reflect. Mineral geologists scoff at reserve numbers, and no one believes that they really represent comprehensive measures of “resource endowments.” “Working inventory” is a commonly used term. Reserves numbers are sensitive to technology, costs, financial and government structures and the product price. While these limitations are acknowledged, in order to come as close to the concept of resource endowment as possible, the broadest definition of mineral reserve, what the U.S.G.S. calls the Reserve Base, will be used. They define it as:

> "That part of identified resource that meets specified minimum physical and chemical criteria related to current mining and production practices. Including those for grade, quantity, thickness, and depth. The reserve base is the in-place demonstrated (measured plus indicated) resource from which reserves are estimated. It may encompass those parts of the resources that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics. The reserve base includes those resources that are currently economic (reserves), marginally economic (marginal reserves), and some of those that are currently subeconomic (subeconomic reserves). The term "geological reserve" has been applied by others generally to the reserve base category, but it may also include the inferred-reserve-base category; it is not part of the [U.S.G.S.] specification system." U.S.G.S. [1999], Appendix D.

One implication is that this measure of resource abundance *may* reflect the state of technological expertise that has gone into its development. Some countries have larger known reserves of some minerals, not because they are better endowed than other countries, but because they have had earlier access to geological expertise. Conversely, what about an economy where the minerals are being developed with advanced outside technology, while the rest of the economy is well within the technological frontier? This paper does not attempt to dismiss this possible bias of stock measures. Actually, this bias is part of the reason why the SW formulation can be misleading. What the natural resources do to a country's productivity and growth prospects depends on the nature of the learning process.

There is a high degree of correlation between production and reserves data for oil, coal, gas and minerals. This correlation is obvious for MINR1 *vs.* MINP1 and MINR2 *vs.* MINP2 in Figure VII and Figure VII *bis*, which plots mineral reserves against minerals production. Figure VIII, IX, and X do a similar job respectively for oil, natural gas and coal. They also reveal strong correlation between fuel reserves and production.

Table VI reports correlation coefficients for reserves and production data for oil, gas, coal, MINR1 and MINR2. Correlations between reserves and production all range between 71 and 97%.

As Figure VII, VIII, IX, and X illustrate, data for reserves and production carry different, though highly correlated, information about natural resources. In order to get as close as possible to the concept of “abundance”, I will focus in this paper on results corresponding to reserves of fuels and minerals. The regressions presented in the rest of the paper have been run with production data. However, switching to production data does not alter the main conclusions and so they are not reported. (They are available from the author upon request.)

Endogeneity is a potential problem. It is possible that rich countries have more reserves of natural resources because they have been investigating their ground longer and in more efficient ways. Fuel and mineral reserves have a correlation coefficient with the logarithm of initial income ranging from 17 to 28%. However, this kind of endogeneity biases results against the conclusions of this paper. Natural resource abundance per capita partly proxies for initial output per capita and will catch part of the disadvantage of being a technological frontrunner; this is the case even if initial per capita income is controlled for. In contrast, the correlation coefficient for land per capita is *minus* 13%. This tends to understate the absolute value of the negative coefficient that is found for land. Again, this kind of endogeneity biases results against the conclusions regarding land.

How dependent are the reserve data on economic growth from 1970 to 1989? I will assume that this type of endogeneity is limited and can be safely ignored. Ideally, reserve data for the year 1970 should be used but this data is not available for many countries. Alternatively, I would like to instrument for mineral and fuel reserves. However, satisfying instruments have not been found[2]. For example, geographical variables have been dismissed as instruments. These instruments will predict a component of natural resources which relates to belonging to one growth club versus another, say Sub-Saharan Africa versus ASEAN countries. In fact, these instruments act like a set of dummy variables for continental membership. They pick up the effect of missing variables that explains continental differences in average growth rates.

An interesting question is whether primary export intensity is associated with land, fuel and natural resources. I run regressions with SXP (the ratio of primary-product exports to GDP in 1970) as the dependent variable. Fuel and minerals reserves as well as some control variables are considered as candidates for explanatory variables. Table 5 reports the results of seven regressions of this kind.

Regressions S1 considers a constant and SOPEN, SW's index of openness. The more open an economy is the smaller the ratio of its primary-product exports to GDP in 1970. Interestingly, SOPEN is statistically significant with a p-value of .3%. S2 introduces ACCESS, a dummy variable equal to 1 if a country has access to the sea. Access to the sea is associated with a higher share of primary-product exports in GDP. In S3, LGDPEA70, the logarithm of GDP per capita in 1970, is introduced. Higher income is associated with a lower share of primary exports in GDP. However, the coefficients corresponding with income and access to the sea are not statistically different from zero and so, in S4-S7, both of these variables have been dropped.

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[2] However, the author is very much open to suggestions.

S4 uses SOPEN together with land (LAND) and oil (OILR), natural gas (GASR), coal (COALR), and minerals (MINR1&2) reserves as regressors. SOPEN is negatively associated with economic growth, but this time it is not statistically significant below a p-value of 34%. Land is positively and strongly associated with primary product export intensity at a p-value as low .4%. At alpha below 5%, the only other significant variable is COALR, coal reserves. Surprisingly, coal reserves are negatively associated with primary product intensity.

S5 tests the robustness of these results to the introduction of regional dummy variables. The dummy variables associated with Sub-Saharan Africa are significant with a p-value of .3%. A country that is part of Sub-Saharan Africa exports an additional 7% of GDP as primary products. OECD countries tend to export 6% fewer primary products as a share of GDP (with a corresponding p-value below 3%). Latin-American (Asian) countries export a larger (smaller) share of their GDP as primary products but the corresponding dummies are insignificant.

Sub-Saharan African countries that are usually associated with low scores of openness are large exporters of primary products. In the presence of dummies, openness is positively associated with primary export intensity (with a corresponding p-value of 5.5%). For natural resources, coal reserves are again negatively associated with primary export intensity at a very low p-value of .9%. MINR1 is positively associated with SXP at a p-value of 6.8%.

In S7, land, fuel and mineral endowments have been kept while the regional dummies have been dropped. The coefficient on SOPEN switches back to a negative sign. Coal is negative and significant. No other fuel or mineral index is significant below a p-value of 20%.

The bottom of Table III reports two sets of tests, one regarding the null hypothesis of non-zero coefficients on fuels and minerals, the other the null hypothesis of non-zero coefficients on dummy variables. The later null regarding regional dummies cannot be rejected below a p-value of .04%. This indicates that there is a regional pattern to primary export intensity and that there are a number of missing variables. This is an important topic for further research but the analysis stops here since a thorough analysis of the determinants of primary product trade patterns is outside the scope of this paper. I cannot reject the null-hypothesis that natural resources are statistically significant in S5 at a p-value varying between 9 - 13%.

Natural resources matter in determining the share of GDP composed of primary exports though somewhat marginally. Regional affiliation matters more for primary export intensity than reserves of fuels and minerals. Land is always a positive determinant of SXP. It is significant (at a p-value below, at most, 5.5%), except in S6 where fuel and mineral reserves have been omitted. Land, which is a key input to agriculture, is a more important determinant of primary export intensity than other natural resources. This suggests that being relatively well endowed in land translates to primary (agricultural) exports somewhat more systematically than natural resources do. It is notable that coal reserves are always negatively correlated with primary exports. I conjecture that coal is still today associated with heavy industrialization, and thus, associated with secondary (rather than primary) export intensity. See Section V for preliminary evidence.

I turn my attention to the rates of economic growth in the sample and their association with natural resources. Figures I, II and III plot GEA7090 against OILR, GASR and COALR. No clear relationship emerges from these three graphs. The same conclusion is reached in Figures V and VI with respect to mineral reserves. Neither minerals nor fuel reserves appear to be associated with economic growth in a clear way. In contrast, Figure IV shows that land is negatively correlated with growth in the sample.

SW propose a “non-parametric” test for their proposed negative relationship between primary export intensity and economic growth. Are there countries that are in the top quartile for primary export intensity and that have sustained levels of growth above 2%? They only identify three such cases: Botswana, Malaysia, and Mauritius. A similar test is conducted in this paper by counting countries that are in the top quartile for land, oil, natural gas, coal and minerals and that have sustained levels of growth above 2%.

Table VII reports the corresponding counts. In the sample, a total 29 countries had average growth rates above 2% for the period 1970-1989. Out of these, six countries scored in the top quartile in oil reserves; six countries scored in the top quartile in natural gas reserves; four scored in the top quartile of coal reserves; four scored in the top quartile of MINR1; and ten scored in the first quartile of MINR2. In contrast, there are only two countries, Canada and Cameroon, in the first quartile for land that have had an average growth rate above 2%.

The most salient observation is Canada, which scored in the first quartile in all six categories and has had an average growth rate of 2.2% over the two decades in question. China, Indonesia, Norway and Spain scored in three out of six categories and have had growth rates of 2.3, 4.6, 2.9 and 2.1% respectively. Overall, 17 countries out of 29 with average growth rate above 2% scored in the first quartile in at least one of the six categories of natural resources. SW's non-parametric test leads to different conclusions when run in terms of reserves rather than primary export intensity. This test suggests that while exporting primary products or being well endowed in land may be incompatible with fast growth in the sample, being highly endowed in fuels or minerals is not. The following section proceeds to more formal tests of this conjecture.

IV. Growth regressions

SW mostly work with cross-country growth regressions as described in Barro and Sala-I-Martin [1995]. Economic growth in economy *i* between time *t=0* and *t=T* (here and in SW, 1970 and 1989) — hereafter labeled GEA7090 — is a negative function of (the logarithm of) initial income Y_0^i — labeled LGDPEA70 — and a vector of structural characteristics of the economy $\mathbf{Z}_0^i$, *i.e.*

(1) $$\frac{\log(Y_T^i / Y_0^i)}{T} = \delta_0 + \delta_1 \log(Y_0^i) + \delta \mathbf{Z}_0^i + \varepsilon^i .$$

Their goal is to test whether measures of resource dependence are among the $\mathbf{Z}_o^i$'s. SW's sample does not include Russia or Eastern Europe, as Summers and Heston [1991] provide no data for these countries. SW identify and exclude six countries as outliers: Chad, Gabon, Guyana, Malaysia, Oman and Saudi Arabia. However, estimation results when these countries are thrown back into their sample are presented. Four other oil-intensive countries, Bahrain, Iraq, Kuwait and the United Arab Emirates, are absent from their sample where there is no GDP data available for the full 1970-1989 period. Exclusion of these observations does not seem to drive their results.

SW introduce a number of control variables to attempt to isolate the effect of primary export intensity. The same control variables are used in the regressions presented in this section. SOPEN is an openness variable measuring the fraction of years between 1965 and 1989 that the country was integrated in the global economy. A country is integrated during a particular year if it maintained reasonably low tariffs and quotas, and did not have an excessively high black market exchange rate premium [Sachs and Warner, 1995a]. INV7089 is the average investment to GDP ratio during the two decades considered in SW. RL is a Rule of Law index presented in Knack and Keefer [1995]. Finally, DTT7090, is the average annual growth rate of the log of the external terms of trade between 1970 and 1990 [Source: WD95]. Data on investment and income come from the Penn World Table (Mark 5.6) compiled by Summers and Heston [1991].

Tables I to IV report results. A star indicates a variable statistically different from zero at a 5% level of significance, two stars, at 10%. My goal is to illustrate the irrelevance of fuels and minerals reserves in growth regressions. I have chosen a generous threshold for type-I error in order to reject the null hypothesis of no effect of natural resources on economic growth at the highest conventionally accepted level for "alpha."

Table I reproduces SW's results from regressions of growth on their control variables and SXP, primary export intensity. Each specification is identified by a code, SW1-5. Results presented in Table I are identical to those of SW for SW1 and SW2. Results differ slightly for SW3, SW4 and SW5. Most of the differences are negligible except for INV7089, where the coefficient from Table I is roughly one tenth of that of SW[3].

All variables have rather stable coefficients, both in terms of sign and magnitude. LGDPEA is consistently negative, indicative of conditional convergence. All variables are significant at 10%. DTT7090 plays a positive role for growth in this sample. SW introduce this variable to rule out the possibility that adverse trends in global export prices could explain the coefficient of SXP, the share of primary exports in GDP. Their main finding is that SXP has a negative and significant coefficient. The coefficient on SOPEN is positive, open economies grow faster in this sample. INV7089 has a positive impact on growth as predicted by the neo-classical growth model. The Rule of Law is favorable to growth.

In Table II, SXP is replaced by data that has been collected on (the logarithm of the ratio of) land (to population in 1971, labeled LAND), fuel reserves per 1000 inhabitants (OILR, GASR, and COALR) and mineral reserves per 1000 inhabitants (the principal components of which are denoted as MINR1 and MINR2). In all other respects these regressions are identical to those of SW. Each specification is identified by a code, OLS1-5. SW5 in Table I is compared to OLS5 in Table II. Coefficients for variables included in both specifications are similar. However, regressions in Table II have higher positive coefficients for both SOPEN and DTT7090.

SOPEN and SXP have a correlation coefficient equal to –30% in this sample, countries that export primary products are closed according to SW's criteria. The negative coefficient associated with SXP in SW1-5 could be due to colinearity with

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[3] This problem has not been solved yet. There is probably a scale problem with the data received from SW for INV7089.

SOPEN. Once SXP is excluded from the specification, the SOPEN coefficient becomes more strongly positive. This is because, according to SW, part of the detrimental effect that being a primary product exporter has on growth is attributed to being a closed country.

It is noteworthy that the coefficient on LGDPEA70 is larger in absolute value in OLS7 (-1.4) than in OLS5 (-1.2). This indicates that natural resources, given that they are positively correlated with income, partly capture the conditional convergence effect associated with being a technological frontrunner. This type of endogeneity overstates any negative effect natural resources may have on economic growth and hence biases results *against* the conclusion drawn in this paper.

The change in the coefficient for DTT7090 is intuitive. If primary export intensive economies have been hurt substantially by decreases in world commodity prices, SXP, the share of primary export in GDP should pick up part of this effect. Removing SXP from the regressions should leave DDT7090 with more explanatory power, and a higher coefficient. Indeed in OLS5, DTT7090 becomes significant at 5% whereas it was not significantly different from zero in SW5.

LAND is negatively associated with economic growth. Across OLS1-5, its highest p-value is no more than .1%. None of the coefficients associated with fuels or minerals is statistically different from zero even with "alpha" of 10%. This suggests a different statistical, and economic, role played by land endowments versus that played by fuel and mineral reserves. OLS1-4 show that this lack of individual significance is not due to correlation between natural resource variables and other determinants of growth such as SOPEN, INV7089, RL and DTT7090.

Coefficients associated with fuels and minerals could be jointly significant even if they are not individually so. Table III conducts joint significance tests for energy reserves (OILR, GASR, and COALR) and mineral reserves (*i.e.* MINR1 and MINR2). The null hypothesis that they are jointly insignificant cannot be rejected at a significance level of 51% for the LR Test, 32% for the LM Test and 40% for the Wald Test. Adjusted R^2 is equal whether or not fuels and minerals are taken into consideration (compare in OLS5 with OLS7 in Table II.)

It is worth reemphasizing the basics of statistical inference in this context. Such high p-values for joint (and individual) significance mean that if the null hypothesis that natural resources have no effect on economic growth (in the context of the present specifications) is rejected, there is a high risk of rejecting a correct hypothesis. This is different from saying that tests lead us to accept the hypothesis that natural resources play no role for economic growth.

Apart from land, natural gas is the only reserve variable which is negatively associated with growth in all regressions, albeit insignificantly. Other coefficients either have unstable signs or are always positive (coal and MINR2). I conjecture that natural resources may have both positive and negative effects on growth, and these may tend to cancel out. Section V explores how natural resources may affect growth.

Table IV addresses the possibility that natural resources actually proxy for membership in some high or low “growth club”. Thus, in specifications labeled D1 to D6, SAFRICA, LAAM, ASEAN and OECD are introduced as dummy variables corresponding to Sub-Saharan Africa, Latin America, ASEAN and OECD countries. No sign change in coefficients other than that for natural resources is observed on control variables. LAND is negatively associated with growth, although its coefficient is not significant when DTT7090 is introduced in D5-7.

The coefficients for OILR, GASR, COALR and INDMIN are all individually insignificant. Natural gas is the only reserve variable negatively associated with growth in all specifications, albeit insignificantly. The MINR1 coefficient has an unstable sign while other coefficients are always positive (oil, coal and MINR2). In Table III, the null hypothesis of coefficients equal to zero on natural resource (land excepted) would have to be rejected with a minimum probability of type I error reaching 65%.

It is noteworthy that the coefficient on LGDPEA70 is larger in absolute value in D7 (-1.74) than in D5 (-1.62). This indicates that natural resources, given that they are positively correlated with income, partly capture the conditional convergence effect associated with being a technological frontrunner. This type of endogeneity overstates any negative effect natural resources may have on economic growth and biases results *against* my conclusion.

Table III reports the result of a test of the null hypothesis of zero coefficients for regional dummy variables in D5. This hypothesis is rejected with an alpha equal to .6%. Adjusted R^2 rises from 63% in OLS5 to 68% in D5. Dummies play an important statistical role in these regressions. When dummies are omitted, natural resource variables would partly pick up the effect of being a member of a "low growth club" such as Latin America or Sub-Saharan Africa or the effect of a set of omitted variables common to these countries. For this reason, specifications D1-5 are preferred to OLS1-5.

Table II *bis* and IV *bis* are the equivalent of Table II and IV respectively, where SXP, primary export intensity, has been reintroduced. The corresponding specifications are OLS1b-5b and D1b-D5b respectively. It is interesting to know both what happens to SXP and to natural resource variables when they are present together in regressions. Coefficients on control variables do not switch sign from Table II to Table II *bis* or from Table IV to Table IV *bis*.

In both cases, the coefficient on LGDPEA70 is larger in absolute value in OLS7b (D7b) than in OLS5b (D5b). Natural resources, given that they are positively correlated with income, partly capture the conditional convergence effect associated with being a technological frontrunner. This type of endogeneity overstates any negative effect natural resources may have on economic growth and hence biases results *against* my conclusion.

In Table II bis, SXP is negative and significant at maximum p-value of .5%. Adjusted R^2 increases in each of the specifications with the introduction of SXP, for example from 63% to 73% from OLS5 to OLS5b. SXP plays an essential role for growth irrespective of the presence of the natural resource variables.

LAND still plays a negative role for growth even in the presence of SXP, with a p-value varying between .1 and 10.1%. A high value for land corresponds to a potential comparative advantage in agriculture, and to a tendency for countries with high values for LAND to specialize in agriculture. One possible interpretation of these results is that land itself (and the likely specialization in agricultural production) may be detrimental to growth, independent of the damaging effects of primary product exports. The assessment of this coefficient is subject to important caveats that are reviewed in the next section.

OILR, COALR and MINR2 have positive and insignificant coefficients. So does MINR1, except in OLS2b. Natural Gas (GASR) is the only natural resource negatively

—albeit insignificantly— associated with growth (as in Table II). Table III reports tests for the null hypothesis of no natural resource effect (except for LAND). Rejecting this null hypothesis is associated with probabilities of type I error ranging between 87 and 91% depending on which joint test is used. The risk of rejecting a correct hypothesis is too important to be ignored.

In Table IV bis, LAND is insignificant in some specifications. Controlling for unmeasured regional characteristics and missing variables through dummy variables, the presence of SXP makes LAND redundant. This indicates that the effect of land on economic growth may not be robust. The high number of regressors (up to 17) to observations varying from 71 to 87 makes this insignificance difficult to interpret. In Table III, joint tests of significance of regional dummy variables reject the null hypothesis with p-values ranging from .6 to 1%.

In contrast, corresponding tests for joint significance of natural resources yield remarkably high p-values ranging from 84 to 90%. This implies, as SW conclude, that SXP is a "diehard" determinant of economic growth. To further verify the robustness of SXP, SW check if SXP is significant in regression specifications from four previous studies. They conclude that natural resource export intensity and openness are significant when added to regression specifications of other studies; adjusted R^2's are raised substantially and some previously insignificant variables become statistically significant. A similar test for fuel and mineral reserves variables has been conducted (not reported but available upon request.) In none of the specifications proposed by other authors are the individual coefficients on reserves significant at any acceptable p-value.

In Barro's [1991] specification, joint tests cannot reject the null hypothesis of no effect of natural resources at a p-value ranging between 33 and 46%. In De Long and Summers' [1991] specification, the p-value ranges between 37 and 49%. Using the specification proposed by Mankiw, Romer and Weil [1992], this p-value varies from 34 and 40%. Finally, using King and Levine's [1993] specification, the p-value ranges between 65 and 73%.

V. The channels of operation

This section attempts to explain the lack of individual and joint significance of the fuel and mineral reserves variable. Table VIII reports coefficients of linear correlation between LAND, OILR, GASR, COALR, MINR1, and MINR2 with a number of variables considered to be important for economic growth. Table VIII is divided into five sub-tables. Table VIII-A reports (partial) linear correlations between land, fuel and mineral reserves and school attendance variables. Table VIII-B uses variables that are regarded as "symptoms" of "Dutch disease." Table VIII-C uses saving and investment rates, as well as investment in equipment and other types of structures. Table VIII-D uses two indicators of how market oriented economic policy is. Finally, Table VIII-E uses indexes of the quality of the political infrastructure.

Causality cannot be determined in this context, even less so than in the case of growth regressions, since neither endogeneity nor the effect of other variables is controlled for. I propose this approach only as a preliminary step towards the collection of stylized facts regarding land as well as fuel and mineral reserves, with the hope that these stylized facts prove useful in more elaborate analyses. I am looking for signs of "positive" and "negative channels", through which natural resources affect economic growth in favorable and unfavorable ways. Land, oil and gas reserves, coal reserves, and mineral reserves are considered in separate sub-sections as they reveal different patterns of correlation.

Land

LAND is consistently positively correlated with variables considered to be detrimental to growth, and is negatively correlated with variables considered to be favorable to economic growth. There is overwhelming preliminary evidence that land is positively correlated with poor education, poor quality of political institutions, interventionist economic policy, less favorable investment-saving characteristics, and "Dutch disease" related effects.

In Table VIII-A, LAND is negatively correlated with the primary school enrollment rate (PRI70), the secondary school enrollment rate (SEC70) and the change in the total years of education in the population over age 15 from 1970 to 1990 (DTYR7090).

In Table VIII-E, LAND is correlated with a higher risk of government repudiation of contracts (negative correlation with GRC), a higher risk of expropriation (negative correlation with RE), lower bureaucratic quality (BQ), higher index of corruption in government (negative correlation with CORR), a lower rule of law (RL) and a higher number of revolutions and coups per year, averaged over the period 1970-1985 (REVCOUP). LAND is only correlated with a very slightly lower number of assassinations per million inhabitants per year over 1970 -1985 (ASSASSP).

In Table VIII-D, LAND is negatively correlated with the fraction of years during the period 1970-1990 in which the country is rated as an open economy according to the criteria proposed by Sachs and Warner [1995a] (SOPEN); it is also positively correlated with the ratio of real government consumption spending net of spending on the military and education to real GDP (GVXDXE).

In Table VIII-C, LAND is negatively correlated with national saving as a percent of GDP (NS7089), with the ratio of real gross domestic investment to real GDP (INV7089), with investment spending on equipment as a fraction of GDP from 1970-1985 (EQUIP), and with investment spending on structures other than equipment as a fraction of GDP from 1970-1985 (NES). Investment goods are also more expensive in countries with large values of land, LAND is positively correlated with the log of the ratio of the investment deflator to the GDP deflator in 1970 (LPIP70).

Finally, land is coupled in Table VIII-B with “Dutch disease” symptoms. LAND is negatively correlated with real growth in the non-natural resource sector of the economy (GNR7090) and with the change in the share of manufacturing exports in total exports (DMX7090). Moreover, LAND is associated with a higher ratio of value added in services to value added in manufacturing (SERVS70), a smaller share of manufacturing exports in total exports (SMX70), and a higher share of exports of primary products in 1970 (SXP).

Interpreting these results is tricky and should be done with caution. One can imagine that by locking a country into an agricultural trade export pattern, a relatively high endowment in land, can prevent a country from industrializing, and thus from reaping the benefits of learning-by-doing associated with industrial production. Lower productivity and growth can in turn be associated with a number of detrimental effects on education and political institutions, making these variables the outcome of trade specialization rather than the cause.

However, the flip side of land area *per capita*, is population concentration, which because of network and human capital externalities, is beneficial to productivity. Population concentration increases may lead to acceleration in the rate of technological innovation as in new growth theory or in empirical models like Michael Kremer [1993]. Population concentration may also capture the phase of demographic transition which a country is in. Land "champions" in this sample, besides Australia and New Zealand, are typically sub-Saharan countries like Botswana, Mauritania, Congo, Zambia, Mali, Madagascar, Somalia, and South Africa or Latin American countries like Uruguay, Paraguay, and Argentina.

<u>Oil and Gas Reserves</u>

The case of oil and gas reserves is a mixed one. Oil and gas seem to have "positive" and "negative" channels of interaction with economic growth. There is evidence that oil and gas reserves are associated with better education, more market-oriented economic policy, and more favorable investment-saving characteristics. However, they come with some "Dutch disease" symptoms. The evidence is mixed regarding the quality of political institutions.

In Table VIII-A, OILR and GASR are positively correlated with the primary (PRI70) and secondary (SEC70) school enrollment rate as well as with the change in the total years of education in the population over age 15 from 1970 to 1990 (DTYR7090).

In Table VIII-E, OILR and GASR are associated with a higher risk of government repudiation of contracts (GRC) and a higher risk of expropriation (RE). However, oil and gas reserves do not seem to be associated with corruption in government (CORR) and they even come with somewhat better bureaucratic quality (BQ), stronger rule of law (RL), a somewhat lower number of revolutions and coups per year (REVCOUP) and slightly fewer assassinations (ASSASSP).

In Table VIII-D, OILR and GASR are positively correlated with the Sachs and Warner openness variable (SOPEN), and they are negatively correlated with the ratio of real government consumption spending net of spending on the military and education to real GDP (GVXDXE).

In Table VIII-C, OILR and GNW are positively correlated with national saving (NS7089), with real gross domestic investment (INV7089), and with investment spending on structures (NES). OILR is positively correlated with investment spending on equipment (EQUIP). Investment goods are cheaper in countries with large reserves of natural gas and oil (LPIP70). The only exception is that GASR is slightly negatively correlated with investment spending on equipment (EQUIP).

In Table VIII-B, oil and gas reserves are associated with some “Dutch disease” symptoms. Larger reserves of oil and gas come with slower real growth in the non-natural resource sector of the economy (GNR7090), a smaller share of manufacturing exports in total exports (SMX70), a smaller *change* in the share of manufacturing exports in total exports (DMX7090), and a higher share of primary products in exports (SXP). Nevertheless, higher oil and gas reserves come with a lower ratio of value added in services to value added in manufacturing (SERVS70).

The preliminary nature of this evidence suggests caution in interpreting the results. One possible interpretation is that oil and gas revenues allow countries to afford better education, allow for consensus on market-oriented economic policies, higher bureaucratic quality as well as higher saving and investment rates. Oil and gas "champions" in this sample like Norway and Australia are examples. On the other hand, the endogenous character of reserve data suggest that the causality may actually run the other way: countries with higher human capital may have an easier time discovering (and exploiting) their oil and natural gas resources.

Another reading of the evidence is that oil and gas extraction draws resources away from the manufacturing sector and leads to feeding frenzy by the ruling elite through expropriation (of natural resources) and repudiation of contracts, as illustrated in the political economy literature. However, oil and gas extraction does not increase the size of the service sector at the expense of the manufacturing sector as is expected in a standard Dutch disease model. Oil or gas "champions" Venezuela, Iran, Congo Brazzaville, Trinidad & Tobago and Algeria are examples.

Coal reserves

The case of coal reserves is also mixed but it takes a different form from that of oil, gas and mineral reserves. Coal reserves are associated with more market oriented economic policies and with more favorable investment-saving market characteristics. The evidence is unclear regarding education, political institutions, and "Dutch disease" symptoms.

In Table VIII-A, COALR is negatively correlated with the primary school enrollment rate (PRI70) and the change in total years of education in the population over age 15 from 1970 to 1990 (DTYR7090). However, TRC is more strongly positively correlated with the secondary school enrollment rate (SEC70).

In Table VIII-E, TRC is associated with a higher risk of government repudiation of contracts (GRC) and a higher risk of expropriation (RE). However, coal-abundant countries see a lower number of revolutions and coups per year (REVCOUP) and fewer assassinations (ASSASSP). Furthermore, TRC is associated with lower corruption in government (CORR), better bureaucratic quality (BQ) and stronger rule of law (RL).

In Table VIII-D TRC is positively correlated with the SW criterion of openness (SOPEN) and it is negatively correlated with the ratio of real government consumption spending net of spending on the military and education to real GDP (GVXDXE).

In Table VIII-C TRC is positively correlated with national saving (NS7089), with domestic investment (INV7089), with investment spending on equipment (EQUIP) and with investment spending on structures other than equipment (NES). Investment goods are cheaper (LPIP70) in countries with large reserves of coal.

In Table VIII-B larger reserves of coal come with a slightly smaller change in the share of manufacturing exports in total exports (DMX7090) and a higher ratio of value added in services to value added in manufacturing (SERVS70). Nonetheless, coal abundance is associated with a larger share of manufacturing exports in total exports (SMX70), and a smaller share of exports of primary products in 1970 (SXP). Coal abundance is clearly associated with faster real growth in the non-natural resource sector of the economy (GNR7090).

One possible interpretation of this evidence is that coal reserves are associated with a large manufacturing sector, albeit decreasing in size, a growing service sector, and low primary export intensity. This reminds us of the production structure of many industrialized countries. Coal-abundant countries in this sample like Australia and the

U.S.A. illustrate this case well. These facts could explain higher saving and investment rates, as well as heavier investment in equipment and infrastructure. However, it is not possible to rule out reverse causality. Another possible interpretation of partial coefficients is that coal, like oil and gas, leads to some feeding frenzy by the ruling elite through expropriation and repudiation of contracts.

Mineral Reserves

The case of mineral reserves is similarly mixed: minerals seem to have both "positive" and "negative" channels of effect on economic growth. There is preliminary evidence that oil and gas reserves are associated with better education and growth enhancing economic policy. They are generally associated with more favorable investment-saving characteristics. The evidence in favor of the presence of some "Dutch disease" symptoms is, at worst, mixed. The evidence is unclear regarding the quality of political institutions.

While MINR1 is associated with a lower primary school enrollment rate (PRI70), and a smaller change in the total years of education (DTYR7090), MINR2 is actually positively correlated with both of these variables (see Table VIII-A). Both MINR1 and MINR2 are strongly associated with a higher secondary school enrollment rate (SEC70).

In Table VIII-E, both mineral reserve indexes are inversely correlated with the risk of government repudiation of contracts (GRC). MINR1 is slightly correlated a higher risk of expropriation (RE), but MINR2 is slightly inversely correlated with such risk. In contrast, both mineral indexes are correlated with a lower number of assassinations (ASSASSP), with lower corruption in government (CORR), better bureaucratic quality (BQ) and stronger rule of law (RL). Finally, while MINR1 is positively correlated with the number of revolutions and coups (REVCOUP), MINR2 is very slightly negatively correlated with the number of revolutions and coups.

In Table VIII-D, MINR1 and MINR2 are positively correlated with the Sachs and Warner openness index (SOPEN). They are also negatively correlated with the ratio of real government consumption spending, net of spending on the military and education, to real GDP (GVXDXE).

In Table VIII-C, MINR1 and MINR2 are positively correlated with national saving (NS7089), with real gross domestic investment (INV7089), with investment spending on equipment (EQUIP) and with investment spending on structures (NES). Investment goods are cheaper (LPIP70) in countries with large mineral reserves.

In Table VIII-B, larger mineral reserves are associated with a larger share of manufacturing exports in total exports (SMX70), with a lower ratio of value added in services to value added in manufacturing (SERVS70), and a somewhat lower share of exports of primary products (SXP). These three elements cast doubt on the existence of a “Dutch disease” channel associated with mineral abundance. While MINR1 is correlated with a slightly slower rate of real growth in the non-natural resource sector of the economy (GNR7090), and a slightly smaller change in the share of manufacturing exports in total exports (DMX7090), MINR2 has a slightly positive correlation with changes in these variables. MINR1 “champions” are Australia, Canada, South Africa and the U.S.A.; MINR2 “champions” are Canada, the U.S.A., Chile, Bolivia, Peru and Spain.

Summary

Table IX presents a summary of the findings presented in this section. Although conclusions are phrased in terms of causality, these are preliminary propositions and the nature of the evidence does not warrant interpretation in terms of causality.

School attendance may be hampered by a higher land endowment but fostered by oil, gas, and mineral reserves. The evidence is mixed regarding coal reserves. Another possible interpretation is that causality runs the other way and that human capital helps oil, gas, and mineral discoveries and their exploitation. These interpretations need not be mutually exclusive.

The working of the political infrastructure seems to be hampered by a high land endowment. Things are unclear regarding oil, gas, coal and mineral reserves. The pattern for resources other than land is that resource abundance leads to abuse of power by the government through expropriation and repudiation of contracts. This is in accordance with Gelb's [1988] observation that natural resource production generates high economic rents and that governments earn most of the rents from that exploitation. However, resource abundance is positively associated with other indicators of the prevalence of the rule of law and bureaucratic performance. Another possible interpretation could be that the rule of law and bureaucratic performance facilitate discovery of resources.

The aggregate saving and investment rates, and the rate of investment in equipment and other structures are lower in the case of high land endowment but higher for countries with abundant oil, gas, and mineral reserves. Even though reverse causality cannot be ruled out, this supports the idea that oil, gas, and mineral production revenues help fund investment projects as Angus Deaton [1999] suggests. Similarly, higher relative land endowments come with interventionist economic policy, whereas oil, gas, and mineral reserves are associated with more market-oriented economic policies.

"Dutch disease" symptoms seem present in the case of land, oil and gas. The evidence is mixed for coal. Larger mineral reserves actually foster trade specialization in manufacturing and a smaller relative size of the non-traded (service) sector. Minerals are associated with a somewhat lower share of primary product exports in GDP. The evidence is ambiguous regarding the effect of mineral reserves on the real growth in the non-natural resource sector of the economy and the evolution of the share of manufacturing exports in total exports.

VI. Conclusions

SW argue that one of the characteristic features of modern economic growth is that resource-rich economies have grown less rapidly than those that are resource-poor. This may be true of land, which is seen as one of the main factor endowments for agriculture. The fact that land per capita is the inverse of population concentration warrants cautious interpretation of this result. Actual data on fuel and minerals reserves show that natural resource abundance has not been a significant structural determinant of economic growth between 1970 and 1989.

Even in the presence of reserve variables, primary export intensity still significantly hampers economic growth. Combining this with the absence of a significant role played by the reserves themselves brings us to the conclusion that, in terms of economic development, what matters most is what countries do with their natural resources. I conjecture that this can be traced back to the type of learning process involved in exploiting and developing the natural resources. Looking at R&D and patent data with an eye on natural resources is a promising path for future research. I consider this question in a separate paper currently underway.

Analysis of partial correlations between land as well as fuel and mineral reserves and a number of determinants of economic growth reveals a complicated reality. While land is negatively associated with all determinants of economic growth, the same is not true of minerals, coal, oil or natural gas. Natural resources may affect economic growth through both positive and negative channels.

School attendance is positively correlated with oil, gas, and mineral reserves. The pattern for resources other than land is that resource abundance tends to lead to abuse of power through expropriation and repudiation of contracts by the government. However, resource abundance is often positively associated with other indicators of the rule of law and bureaucratic performance. The aggregate saving and investment rates, and the rate of investment in equipment and other structures are higher for countries with abundant oil, gas, and mineral reserves. In addition, oil, gas, and mineral reserves are associated with more market-oriented economic policies.

"Dutch disease" symptoms seem present in the case of land, oil and gas. The evidence is mixed for coal. Coal and mineral reserves are associated with trade specialization in manufacturing and with a somewhat lower share of primary product exports in GDP. Mineral reserves are also associated with a smaller relative size of the non-traded (service) sector.

This coexistence of both "positive" and "negative channels" through which natural resources affect economic growth would explain the lack of significance of the fuel and mineral reserve variables. Nonetheless, plausible reverse causality running from the channels to fuel and mineral reserves further complicates the analysis.

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Table I

Method of estimation = Ordinary Least Squares

Dependent variable: GEA70

Specification

Table II

Table II bis

Method of estimation = Ordinary Least Squares

Dutch disease

Dependent variable: GEA70

Variable	*Specification* OLS1b		OLS2b		OLS3b		OLS4b		OLS5b	OLS6b	OLS7b
C	3.399	*	8.174	**	9.657	**	13.310	**			

Table IV Method of estimation = Ordinary Least Squares Dependent variable: GEA70

Specification	*D1*	*D2*	*D3*	*D4*	*D5*	*D6*	*D7*
C	6.539 **	8.637 **	9.351 **	13.208 **	13.060 **	14.019 **	13.977 **
	2.428	*2.263*	*2.120*				

Table IV bis

Table VI - Correlations between Reserves and Production

Table VII - "Non-Parametric Test"

Table VIII Channels of Operation - Partial linear correlations