Rule of Law and the Resource Curse: Abundance versus Intensity*

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Abstract

This paper examines the phenomenon of the resource curse using new data and improved methodology. It distinguishes between resource abundance (a stock) and extractive intensity (a flow), and focuses on the relationship between resources and rule of law. A simple model of endogenous rule of law is presented to motivate an empirical investigation which finds that economically large natural resource stocks are associated with lower levels of rule of law. The sample of countries examined is maximized through the use of an EMis (expectation maximization with importance sampling) algorithm to replace missing data with estimates of their distribution, thus minimizing the bias and inefficiency associated with listwise deletion.

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1. Introduction: The More You Have, The Less You Get

There is a growing concern that natural resources are associated with poor growth and development outcomes. This paper presents two improvements in the empirical literature on this 'resource curse.' First, new data on resource stocks in 1970 are constructed, enabling consideration of the differences between resource abundance, defined as large resource stocks, and resource intensity, defined as high rates of resource extraction. Most work to date has focused on measures of resource flows, particularly export intensity, rather than on resource abundance. Second, the cross-country growth regressions used in this literature are hampered by the often patchy data available for many conditioning variables, and large amounts of the available data are discarded when one or more variables are missing for an observation. Here, potential selection problems are avoided and sample size is maximized by taking advantage of improvements in imputation algorithms to impute distributions for missing information such that all observed countries are included in the empirical analysis.

Cross-country analysis and case studies suggest that countries rich in natural resources, particularly in fuels and minerals, have grown more slowly than other countries. The intuition that starting out with more wealth of this or indeed any form must be advantageous or at least neutral appears to be wrong. Resource bounty is said to be linked strongly enough to ongoing growth and development failures that it is often referred to as a 'curse'.

There are several theories of how the curse might operate through indirect effects on the pattern of economic activity within a state. Of these, some are explicitly about how resource extraction and exports affect a country's economy. These theories suggest that the extractive sector crowds out economic activities (technology spillovers, manufacturing exports, etc) that are good for growth, or that the volatility of or declines in revenues from extraction tend to slow growth (Sachs and Warner 2001). In these cases, once flows are controlled for, resource stocks would not be expected to have deleterious impacts on growth.

Another explanation focuses on links between resource extraction and institutional quality. Institutions, especially the rule of law, establish the framework within which economic activity takes place and so affect growth. Therefore, any association between institutional quality and natural resources will have indirect effects on growth. While part of an institutional explanation may be about flows, and in particular natural resource extraction rents, it also makes sense to think of institutions as potentially shaped by natural resource abundance. Thus, the relationship between abundance and the institutions that establish or fail to establish rule of law is the focus of this paper. The chief finding is that mineral wealth, in particular, is associated with lower scores on a rule of law measure common to several papers in this area, even after controlling for resource flows.

Though it proves difficult to make precise estimates of the size of the indirect effect resource abundance has on growth operating through rule of law, results are provided. This allows comparison with the previous literature. Similarly, results using listwise deletion—eliminating a country from the sample if it is missing any or the conditioning variables—are estimated. We argue that results using multiple imputation for missing information are preferable, and they differ meaningfully from results with listwise deletion. In the preferred specification, the negative effect of resource stocks on rule of law is both larger and more precisely estimated in the full sample than in the partial sample that remains after listwise deletion.

2. Literature Review

In an influential series of papers, Sachs and Warner (1995a, 1995b, 1999) investigate the relationship between resource trade intensity and growth rates using cross sectional analysis of income growth between 1970 and 1990. After controlling for political and trade characteristics, they find that an increase of one standard deviation in the resource intensity variable is associated with about a one percentage point lower growth rate.

Leite and Weidmann (1999), Gylfason et al (1999), and Isham et al (2003) investigate relationships between resource flows and indicators related to institutions, investment, and education, finding that point-source resource flows matter for characteristics that affect growth. Similarly, Sala-i-Martin & Subramanian (2003) find that once the effect of resource flows on institutions (with an emphasis on rule of law) is accounted for, resources have no effect or a small positive effect on growth rates of per capita GDP.

These authors examine the resource curse using flow measures of resource intensity or dependence, based on trade in commodities, production of minerals, or the size of the workforce employed in resource extraction. This is problematic because flows are choice variables: high levels of natural resource export intensity are plausibly endogenous to numerous political, economic and institutional variables as well as to the presence of resource stocks. Using the initial period flow variable as a proxy for resource abundance precludes distinguishing between effects on growth associated with abundance and effects associated with the economic intensity of extraction activity.

Stijns (2001) provides the only empirical investigation of a curse in resource stocks. He examines physical reserves of oil, gas, coal, minerals and land, measured near the end of his sample period, in tandem with export-based measures of flows. He is not able to use beginning-period stocks, however. Also, his use of principal component analysis to condense many mineral resources into one variable does not allow for the varying economic importance of different commodities or for straightforward interpretation of coefficients. He finds that reserves are not a key determinant of resource export flows except in the case of land, and that end-period fuel and mineral reserves are not very important in the growth regression once exports are controlled for. His investigation of correlations between several institutional measures and current oil, gas and mineral reserves yields mixed results. Measures used in the following analysis are of beginning-period stocks rather than end-period stocks, which do not account for resources extracted during the period observed, extracted resources that may in turn have affected growth. All commodities are converted to values, allowing for straightforward interpretation of coefficients and comparison across commodities.

Two thoughtful survey articles on the resource curse literature are Ross (1999) and Stevens (2003), both of which set forth the major theories regarding the mechanism by which the curse operates. Of these theories, the one that will be the focus of attention here specifies a relationship between resource abundance and governmental institutions, particularly rule of law. Numerous possibilities for the nature of this relationship have been advanced, but, as noted by both Ross and Stevens, there is a need for more rigorous research on the connection.

There is an extensive literature on the ways in which institutions matter for growth and development and on institutional change. Rosenberg and Birdzell (1986), using a primarily historical approach, emphasize the importance of institutions that allow and reward innovation for growth, particularly with regards to property rights and rule of law. Hubbard (1997) provides a more recent discussion of the transactions-cost approach to understanding the role and form of institutions emphasized by North (e.g. North 1990). Rodrik et al (2002) conclude that 'institutions rule' over other potential determinants of growth and, in particular, that geographic variables have a strong impact on institutions but little or no effect on growth beyond the institutional linkage.

The literature on links between resources and institutions is less extensive. In addition to the empirical evidence that resource exports are associated with poor institutional characteristics discussed above, there is a perception that resource booms, in particular, are consumed and not invested (Sachs and Warner 1999), and that this represents a failure of policy. Broadly speaking, Ross (1999) and Stevens (2003) sort explanations into a few main categories.

The first is that leaders of resource-rich countries systemically make poor choices about important growth-related policies, whether through excessive borrowing, irrational optimism, bad investment choices ('prestige' projects), or other failures. As Ross notes, however, it is difficult to assess rigorously the notion that resources somehow inhibit rational decision making and optimization. Another set of possible links between resources and institutions operates through political mechanisms and institutional forms. Early work on the 'staple trap' noted that dependence on one or a few extractive sectors, or 'staples', can lead to the development of institutions suitable for that sector but not for sustained growth (Watkins 1988).

A third explanation is that leaders and bureaucrats in resource-rich countries are not as responsible to the population at large as they might be in a resource-poor country. Thus, rents from the extractive sector are more easily captured than revenues from taxation and the public purse is less closely watched. This situation lends itself to corruption and rent seeking. The government faces less pressure to reform because taxes remain low and the government can afford sufficiently generous welfare to limit opposition. This seems somewhat at odds with the results of Bulte et al (2004) and Ross (2001) that aggregate welfare indicators are lower in resource-rich countries even after controlling for income levels. A more intuitively appealing version of this argues that wealth (from rents) is concentrated in the politically dominant group that extracts rents and determines policy (Stevens 2003).

Other theories of the resource curse are not set in an explicitly institutional framework. The Prebisch hypothesis, that the terms of trade for primary commodities experience a steady, secular decline, is not supported by the data (Cuddington 1992, Kellard and Wohar 2003). Another theory is that countries dependent on commodity exports for revenues are subject to many large shocks as those markets undergo fluctuations, confounding planning and investment and thus growth (e.g., Rosenberg and Birdzell 1986). These shocks might contribute to a deterioration of institutional quality or subject institutions to unusual pressures. Deacon and Mueller (2004) and Sala-i-Martin and Subramanian (2003) note that these theories are weakened by empirical studies showing that the resource curse identified thus far has different effects for different kinds of commodities (e.g., point-source versus dispersed natural resources). The effects suggested by these theories would not be expected to vary with resource endowments so much as with respect to high levels of extraction and export activity.

Another theory is that slow-developing resource-rich countries suffer from "Dutch Disease," wherein the extractive industry draws productive inputs away from the non-resource sector, reducing its competitiveness and reducing positive growth externalities that flow from the non-extractive sector but not the extractive one. Leite and Weidmann (1999) observe that any tendency towards Dutch Disease should be temporary at worst and that governments ought to be able to mitigate this effect of a resource boom. This suggests that Dutch Disease, if it is related to disappointing long-term growth rates in resource-rich countries, reflects an institutional failure rather than a direct causal effect of resource flows. Accordingly, it can usefully be addressed through the lens of institutional characteristics and effectiveness.

Economists and other researchers have not yet conclusively pinpointed the mechanism or mechanisms by which the resource curse operates or the determinants of which countries escape the curse and which succumb to it. There is evidence from studies using measures of resource flows that there is an association between resource extraction and growth. Further evidence suggests that linkages between export intensity and institutions are important and complex and that these drive at least part of the resource curse through an indirect effect on growth. Thus far no study has carefully examined resource stocks from the same period as the more commonly seen flow measures; there is also no study considering stock resource abundance that focuses on rule of law.

3. A Model of Endogenous Rule of Law

The focus here is on modeling a simple relationship between rule of law and resource abundance, accepting that theory and previous empirical work show that rule of law is an important determinant of growth. The model below is meant to be indicative rather than descriptive; it does not include many factors that certainly affect rule of law. Rather, a relationship between resource stocks and rule of law that does not depend on outgoing flows is presented in a simple motivating framework.

This model is based on that presented by Grossman and Mendoza (2003).[1] The authors show that if future income is expected to be large relative to current income, appropriative competition in the current (scarce) circumstances can be increased, possibly to the extent that net welfare over both periods is decreased by an increase in future income. They refer to this as the "paradox of anticipated abundance."

The economy consists of a large (n+1) number of identical actors who value consumption and leisure, and who receive in the initial period a common pool endowment of size (n+1)E units, where

[1] Their model is focused on appropriative competition in an environment of severe scarcity, such that starvation is a possibility between the first and second periods and competition is focused on survival.

E, the average endowment, is greater than or equal to one. Each individual appropriates e units of the endowment according to

$$e = \frac{r}{r + nR}(n+1)E, \tag{1}$$

where r is the fraction of time devoted to appropriative activity and R is the fraction of time devoted to appropriative activity on average by other actors. Thus, appropriation depends on how much time is spent by the individual on appropriative competition relative to the total amount of time spent on the activity in the economy as a whole. Abstracting from production, e units of the endowment may be freely converted to c units of consumption.[2]

Actors value current and expected future utility:

$$u = \alpha \ln(c) + \gamma h + sv + (1-s)x \tag{2}$$

Time not devoted to appropriative conflict is leisure: h=1-r. Successful appropriation increases s, the probability of attaining elite status in the future. If an actor is a member of the elite, she will enjoy future utility v, and otherwise will have lower non-elite utility valued at x. The expected future utility of elite and non-elite status are taken as given by each individual, who chooses r and h to maximize total utility subject to the time constraint and to the appropriation function, (1). We assume $\gamma > \alpha$, both positive parameters, to ensure the possibility of positive leisure.

The generality of the expression denoting expected future utility allows for varying explanations of what it means to be part of the 'elite'; a few of these will be discussed below. Larger resource stocks, which represent future income, may increase the expected value of future elite status. This is consistent with much of the discussion regarding problems associated with resource flows: they generate rents which are relatively easy to divert and are associated with increased levels of corruption. If anticipation of high future resource flows leads to higher expected value of future elite status, we will observe more conflict where there are larger resource endowments.

[2] Grossman and Mendoza include an extension treating production with more complexity; using this extension in the context of the resource curse would allow different kinds of resources to be converted to consumption with more or less ease, capturing an empirical observation of several resource curse papers, including this one, that the negative links between resources, growth and institutions are different for different kinds of resources.

The probability of attaining elite status is an increasing, concave function of consumption $s(c)$, where $s(0) = 0$ and $\lim_{c\to\infty} s(c) < 1$. Each person maximizes utility by setting $\partial u/\partial r = 0$ for $r\leq 1$ or $\partial u/\partial r > 0$ for $r=1$. If leisure is positive,

$$\frac{du}{dr} = \frac{\alpha}{c}\frac{dc}{dr} - \gamma + s'(c)\frac{dc}{dr}(v-x) = 0 \qquad (3)$$

and since $e=c$,

$$\frac{dc}{dr} = \frac{nR}{(r+nR)^2}(n+1)E.$$

If all $n+1$ actors are identical, optimal $r=R$ and $c=e=E$, and (3) simplifies to

$$\frac{du}{dr} = \frac{n}{n+1}\frac{\alpha}{R} - \gamma + \frac{n}{(n+1)R}s'(E)E(v-x) = 0. \qquad (4)$$

Setting this expression equal to zero for non-corner solutions yields the equilibrium fraction of time each member of the economy devotes to appropriative conflict,

$$R^* = \min\left\{1, \frac{n}{n+1}\frac{\alpha + s'(E)E(v-x)}{\gamma}\right\} \qquad (5)$$

and a key result: for a given level of current income E, an increase in the gap between expected elite and non-elite future utility leads to increased appropriative conflict. $R=1$ if

$$s'(E)E(v-x) \geq \gamma - \alpha \qquad (6)$$

and for any initial endowment a large enough gain to future elite status will lead to all time being allocated to conflict.

Conflict also depends on the current endowment through $s'(E)E$; if s is sufficiently concave at E, fighting for status increases with current poverty. Note that the concavity of s implies that marginal consumption raises the probability of achieving elite status more when average initial endowments are small and that the elite will be smaller in such circumstances. If the initial endowment is small enough, so that the slope of the s function is large, an increase in the unexploited resource stock and thus the expected utility of future elite status can lead to a decline in the sum of current and expected future welfare, a resource curse when current income is small and resource stocks are large.

This model facilitates thinking about the key distinction between resource flows, which measure activity in the economy now, and resource stocks, which represent potential future economic activity. It also allows linking of resource abundance, defined as resource wealth relative to current wealth, to institutions. Firstly, an economy with high levels of appropriative conflict is likely to find it relatively difficult and costly to establish rule of law, and thus will tend to establish less under very general conditions, and second, the possibility that appropriative conflict leads to the establishment of an elite, who may not value establishing or maintaining the rule of law or other institutional outcomes highly. While research on the resource curse has focused on the developing world, there is no reason to think that it only applies where starvation is a probable event, and so the survival or starvation function used in Grossman and Mendoza is not used. Instead, success in appropriation in the first period is linked to membership in an elite group in the second period.

Now, consider an explicit relationship between appropriative conflict over a common-pool resource and rule of law. Rule of law, L, reflects the scope and reliability of property rights and personal security; appropriative conflict may make rule of law more difficult and costly for a benevolent planner to provide. If $L=L(R,M)$, where M is a policy variable such as expenditures on establishing rule of law, $\partial L / \partial R < 0$ and $\partial L / \partial M > 0$, for a given level of M, more conflict (higher R) implies less rule of law (lower L). Assume additionally that the marginal cost of rule of law is increasing, $\partial^2 L / \partial M^2 < 0$ and that appropriative conflict decreases the marginal gains to rule of law associated with expenditure directed towards establishing rule of law, $\partial^2 L / \partial M \partial R < 0$. If the marginal social value of rule of law is not increasing, the increased conflict associated with larger unexploited resource stocks will unambiguously lead to a lower equilibrium provision of rule of law.

The presumption of a benevolent planner in the presence of an elite may seem implausible. If the elite are a political as well as economic elite, they may not consider the benefits of rule of law for non-elite members of the economy when deciding what level of rule of law to provide. Thus, equilibrium rule of law would be determined by the marginal benefit to the $s(n+1)$ members of the elite. Under similar assumptions as in the case of a benevolent social planner, the smaller the elite, the less provision of rule of law will be made in equilibrium. Both of these cases could hold at different parts of the process; in the initial period of conflict, a benevolent planner may find rule of law costly and difficult to establish, while in the longer term the emergent political elite may not care to work to establish rule of law.

4. Empirical Issues and Strategy

Most empirical work on the resource curse has used measures of resource flows, in particular measures of flows of raw resource exports, as indicators of resource wealth. This choice seems to be largely a matter of data availability. While stocks and flows are obviously related (a country with no natural resource stocks cannot be a country with high raw resource export intensity), flow intensity is clearly a choice variable. The strongest evidence thus far is of an export intensity curse rather than a curse related to natural resource abundance.

Resource deposits as such are not a choice variable, though measured reserves, as distinct from geologic reserves, are partially endogenous. The stock measure used will minimize but not eliminate this endogeneity, as discussed below. Evidence for a curse in stocks suggests little obvious remedy except the possibility of leaving resources unexploited and ideally unknown, unless and until mechanisms through which the relationship between abundance and poor outcomes operates can be determined and addressed. In contrast, a curse in flows simply suggests that poor resource management is the problem.

This paper investigates the relationship between resource stocks and rule of law to see if this relationship is similar to the relationship between resource export flows and rule of law, and if there is a direct stock effect on growth after controlling for any institutional relationship. Cross-country data on average per capita GDP growth rates over the period 1970-2000 are examined. A measure of the rule of law is observed at the end of the period, and resource abundance and flows are measured at the beginning of the period. Other conditioning variables are from the beginning of the sample period or earlier.

The analysis requires measures of resource stocks in 1970. Measured reserves depend on exploration activities undertaken, which in turn depend on local technology, prices, and expectations about the conditions under which extraction will take place. They should not, therefore, be taken as an indicator of geological quantities. To minimize this imprecision as much as possible, starting-period reserves are estimated by adding past production data to current reserves, so that any reserves not mapped or included in reserves in the earlier period but nonetheless present and mapped or included later as technology or other variables changed will be included. Thus, the measure of resource abundance used to assess growth after 1970 consists of the broadest available measure of current reserves (2001 in most cases) plus the total quantity extracted between 1970 and the date the reserves are measured.

Reserve values rather than physical quantities are used for point-source resources. This is superior to quantity measures for several reasons. First, it enhances comparability across resources. Physical measures of abundance per person may be suitable for considering the impact of abundance of that commodity in isolation, but such measures provide little insight into the relative importance of different commodities. They are also unsuitable for indices of resource abundance comprised of multiple commodities. Given the large number of commodities potentially of interest, using values enables the construction of an economically meaningful index of abundance, one that recognizes the differential economic impact of, for example, a ton of gold and a ton of barite.

Using stock values also enables consideration of the importance of a sector to a particular economy. Intuitively, the resource curse is formulated as a problem of developing economies in which resources are economically 'important' in some sense, so evidence of a resource curse in stocks should be scaled by the value of the stock as a fraction of some measure of the size of the economy as a whole. This paper uses the beginning-period ratio of the value of commodity stocks to GDP, so the measure of aggregate abundance in oil, coal, gas and mined minerals, *fuelminratio*, is the total value of the estimated 1970 commodity stocks divided by total GDP in 1970, and *coalratio, oilratio, gasratio* and *minratio* are analogous for disaggregated measures. Values are determined using prices from the beginning of the period observed.

Measuring rule of law is also not straightforward. While there is no single accepted practice for measuring institutional quality (of which rule of law is one dimension), this analysis follows Rodrik et al (2002) in treating current institutions as a stock which has been created by a past flow of good or bad policies, that is, by the operation of past institutions. Results thus rely upon current measures of rule of law.

Rule of law is instrumented in the growth regression using 2SLS. The focus is on the effect of abundance on rule of law, but the two stage process potentially enables estimation of the size of the indirect effect of resource abundance on growth, as it operates through rule of law. We are also interested in any direct effect of resource stocks on growth after controlling for rule of law, as this suggests that the rule of law model is insufficient to explain negative associations between resource abundance and growth.

5. Data Description

Past physical reserve estimates for coal, oil, gas and minerals are constructed by adding production figures for years prior to the current reserves figures. Full details of the data sources and of the minerals in the composite variable are in the Appendices.

Mined nonfuel minerals are represented by a composite variable. The 1970 value of the 1970 reserve of 35 different minerals in 162 countries is calculated by using 1970 prices and an estimate of 1970 reserves based on the 2002 "reserve base" added to extraction flows from 1970 to 2001. The reserve base includes deposits considered 'economic', i.e. worth extracting at current prices and extraction costs, marginally economic reserves, and sub-economic reserves "that have a reasonable potential for becoming economically available within planning horizons beyond those that assume proven technology and current economics" (U.S. Department of the Interior 2003).

The procedure of adding past production to current reserves mitigates but does not eliminate the partial endogeneity of known reserves. These data should, however, cover most mineral resources that 1970 economic actors were aware of or might reasonably have suspected. This is a clear improvement over reserves data from 1970, which would underestimate resources that could plausibly have mattered to growth in the period under consideration (and which, as Sachs and Warner (1995b) note, are not generally regarded as of high quality), as discovery was ongoing. It is also an improvement over the approach of using present-day reserves, because it accounts for depletion during the intervening period. Also, it allows for greater coverage of minerals and countries than is consistently available using historical reserves data.

To see how the abundance measures are constructed and where the endogeneity arises, consider the following identity:

$$R_0 + \sum_{t=1}^{t} D_t - \sum_{t=1}^{t} Y_t = R_t$$

Where R_0 is known reserves at the start of the observation period, R_t is current reserves, D_t is discoveries in year t, and Y_t is extraction in year t. The stock estimate,

$$\sum_{t=1}^{t} Y_t + R_t$$

is equal to

$$R_0 + \sum_{t=1}^{t} D_t$$

or measured historic reserves plus discoveries during the sample period, which may be endogenous. In the absence of reliable data on R_0 or on discoveries over time, the measure is the best available indicator of endowed natural resource wealth at the beginning of the sample period. The endogeneity is also moderated if we believe that actors had some knowledge about reserves suspected but not yet enumerated in 1970. Additionally, if the concern is that richer and more stable countries will discover more natural resources than poorer and less stable countries, this would work against any finding of a relationship between resource abundance and growth or rule of law. For a finding of a resource curse in stocks to be spurious due to this endogeneity, it would have to be the case that there is more exploration and discovery of natural resources in poor, unstable countries rather than less.

Most of these commodities come in a variety of differentially priced grades. This procedure does not distinguish grades, though measures of mineral content in mined ore for stocks and production flows have been used wherever available. Also, the same grade may be of higher value in the ground in some locations than in others, due to geological variations affecting extraction costs. Regional pricing might be of particular importance for coal and natural gas, which are not traded in a global market to the same extent that oil, metals and ores are. These data do not allow for such differences. There is no reason to think that the physical difficulty of extraction or the distribution of various grades of many different kinds of minerals varies systematically with relation to other variables influencing growth. Hence, the benefits of value-based aggregation outweigh the costs, and in any case there is no obvious alternative way to aggregate across commodities. However, note that using ‘world’ commodity prices to construct values means that there will be measurement error in these variables with attendant attenuation bias in estimated coefficients.

Measures of land abundance are also included; FAO data on arable land and land in permanent crops (e.g. grapevines, coffee, and cocoa), are considered separately, to allow for differential impacts of capital-intensive plantation agriculture and temporary crops. Arable land is defined as land under temporary crops (including land presently or recently farmed), temporary grasslands mown or used as pastureland, land in market and kitchen gardens, and land that has been fallow for less than five years. Arable land is measured in per capita terms and is included to capture any effect on rule of law or growth of relatively diffuse natural resource abundance.

In the context of institutional change and rule of law, cross-sectional regression results will reflect that data are not used for countries which came into or went out of existence in the study period. Clearly, country dissolution or formation reflects major institutional change at the same time that it makes growth and other statistics difficult to compile.

Data on economic growth are from the United Nations Statistical Division. This allows for a considerably larger sample than the Penn World Tables, which feature in much of the previous literature. To investigate the possibility that systematic differences in these data might drive different results, raw correlations between the two measures of growth and key independent variables in a common sample are examined.[3] For growth between 1970 and 1990 in 93 countries covered by the UN data and the PWT, the correlations between growth and *sxp*, the Sachs and Warner measure of resource export intensity, are -0.37 and -0.39, respectively, and the correlation between the two measures of growth is 0.88. Relationships between the various measures of resource stock abundance in this dataset and the two measures of per capita real GDP growth are similar in sign and significance as well. The UN data appear to reflect the same patterns of economic activity as the PWT with greater coverage, hence the UN data are used throughout.

6. Analysis and Empirical Results

Simple Correlations

Partial correlations are analyzed for the ratio of natural resource values to GDP for the three fuel resources, the mined minerals composite and both measures of land. The measures of mineral abundance show some of the basic patterns that might be expected from the literature assessing flows of natural resources. A few countries were found to be outliers in natural resource abundance and are omitted from this simple descriptive analysis, namely Botswana, Guinea, and Qatar, as were countries that did not have stable borders over the observation period[4].

The relationship between natural resource export intensity and resource abundance is also examined. For the 110 countries with data on export intensity in 1970, the correlation between *sxp* and the aggregate measure of point-source abundance, *fuelminratio*, is 0.49. The rank-order correlation is 0.31. Countries such as India and China had low export intensity in 1970, but had

[3] The UN data use price adjusted rates of exchange in cases where market exchange rate fluctuations do not fully capture the effects of inflation on the price level in an economy.

[4] This eliminates all of the former Soviet and Yugoslav republics, Ethiopia and Eritrea, the Czech and Slovak states, Yemen, and the UAE.

values in the top quartile for *fuelminratio* in that sample, while countries such as Uganda and the Gambia had high export intensity and low levels of abundance. This suggests that the distinction is empirically as well as theoretically important.

Considering the 167 observations remaining after removing resource outliers reveals a weakly negative relationship between resource abundance and growth, with the exception of coal, which is weakly positively related to per capita real GDP growth rates. The negative relationship is highly significant for oil and arable (non-plantation) land abundance.

Pairwise Correlations with Average Growth Rates and Rule of Law

	Per Capita Growth, 1970-2000	**Rule of Law, 2002**
minratio	**-0.073**	**-0.055**
gasratio	**-0.094**	**0.004**
oilratio	**-0.243***	**-0.025**
coalratio	**0.069**	**0.050**
arable land (temp)	**-0.216***	**-0.139**
plantation cropland	**-0.033**	**-0.148**

*** indicates *p*-value less than .05**

Measures of oil and mineral abundance as well as arable and plantation land per capita are also negatively correlated with rule of law, as measured by Kauffman et al (2003). Natural gas and coal exhibit weak positive correlations. Given that these commodities are less likely to be traded than oil and mineral ores, their profitable exploitation may depend on rule of law in the domestic economy to a greater extent than oil and minerals. The relatively large negative correlation between rule of law and arable land per capita, however, is less supportive of this hypothesis.

Conditioning Variables

The robustness of the simple relationships observed between growth, rule of law and resource abundance are now investigated more formally. The goal is to establish whether there is a relationship between resource abundance and growth, the magnitude of that relationship, and to what degree any relationship might be explained by a relationship between resource abundance and rule of law after controlling for other factors that affect economic growth.

The initial analysis is performed under listwise deletion of observations missing data on at least one variable. This analysis gives results for the sample of countries for which all conditioning data are available. Then, multiple imputation techniques are applied in an effort to use all of the data available and reduce problems associated with sample restriction. We examine both sets of results in order to compare them to the existing literature and to one another.

The Hall and Jones (1999) language variables instrument for endogenous rule of law in a two stage least squares growth regression. The equations estimated are a first stage regression with rule of law as a dependent variable,

$$RL_i = \lambda + \delta\, lgdp70_i + \tau\, NR_i + \rho\, CV_i + \sigma\, Z_i + \mu_i$$

And a second stage regression with the growth rate as a dependent variable,

$$G7000_i = \alpha + \beta lgdp70_i + \gamma NR_i + \eta\, CV_i + \kappa\, RL_i + \varepsilon_i$$

Where *RL* is a current measure of rule of law in country *i*, lgdp70 is log per capita GDP in 1970 for country *i*, *NR* is a set of measures of natural resource stock abundance in a particular country in 1970[5], *CV* is a set of conditioning variables for each country, *Z* is an instrument or instruments explaining some of the variation in institutional quality, *G7000* is the rate of growth in a country between 1970 and 2000, and μ_i and ε_i are mean-zero error terms. Variables will be described in more detail below.

[5] For natural gas, coal and oil, stocks are measured in 1971 as 1970 flows were not available.

Durlauf (2001) and others point out that this two-stage approach is vulnerable to criticism because the instruments may be correlated with variables omitted from the main growth regression, leading to correlation between the error term and the instrumented variable. If the instruments are correlated with anything that should be in the growth regression but is not, problems can arise even if the instruments pass standard statistical tests.

Due to the open-endedness of growth theories, it is reasonable to suspect that variables that might influence growth are not included in the regressions. The analysis presented here uses new data to produce a measure of the stock of natural resources available to a country at the beginning of the period analyzed. This should be uncorrelated with determinants of growth not included in cross-country growth regressions. However, concern about missing variables cannot be eliminated, especially given the sometimes marginal performance of the instruments used, so greater emphasis is placed on the first stage results. These relate resource abundance to rule of law and do not rely upon instrumental variables estimation. To the extent that the instrumented growth regressions are reliable, the indirect effect of resources on growth can be quantified. If the only relationship that can be determined with some precision is the effect of resources on rule of law, this remains informative about indirect effects on growth to the extent that we believe rule of law affects economic outcomes.

Other criticisms of cross country growth regressions suggest that it is important to consider what countries are of interest to the question and how robust results are to small changes in the sample (e.g., Knabb, forthcoming). If inclusion in the sample is driven by the availability of conditioning variables rather than any analytical reason, choice of variables amounts to choice of sample, and different results for different variables may confuse the different effects of the controlling variables and of the changing sample.

The imputation stage of analysis will limit this problem of listwise deletion – eliminating an observation if it is missing information about any variable used in the analysis – by allowing all countries in the sample to be included in the growth regression even if data on one or more conditioning variables are missing. There is evidence that the discarding of information associated with countries that are missing data for any variable used in the analysis has serious consequences for econometric results beyond the obvious efficiency loss. Results vary somewhat when excluded data are included using imputation methods; in particular, evidence of a relationship between abundance and institutions is stronger in the larger sample.

Simple OLS- Listwise Deletion

First, we consider whether our measure of resource abundance is related to growth rates in the largest sample available. This allows us to consider as a preliminary question whether there is a curse in abundance that requires explanation. The sample will be a good deal smaller once additional conditioning variables are considered without missing variables procedures, and results of this analysis for the smaller sample are presented as well.

The first equation estimated is:

$$G7000_i = \alpha + \beta\ lgdp70_i + \gamma\ fuelminratio_i + \delta\ landea_i + \varepsilon_i$$

OLS regression of growth rates from 1970 to 2000 on the log of initial income (allowing for convergence in incomes, the tendency of poor countries to grow at a faster rate), the aggregate stock variable *fuelminratio* (the value of the stock of coal, oil, gas and minerals at the beginning of the sample period to GDP), and the amount of arable land and land under plantation crops per capita is performed for all countries that did not form or dissolve in the sample period.

Examination of the *dfbeta* statistics verifies that evident outliers in resource abundance, Botswana, Guinea, and Qatar, are also acting as regression outliers for point-source resources. For land resources, Australia appears to be an outlier as well as an influential observation in the regression.[6] Botswana is a clear outlier in coal abundance, Guinea in minerals (chiefly aluminum),

[6] The statistic used is abs(dfbeta); abs(dfbeta) > 2n^(-.5) indicates that the observation should be evaluated for inclusion, where *n* is the number of observations in the regression (STATA 8 manual). The *dfbeta* statistic is a regression diagnostic which combines the regression residual with the leverage an observation exerts on the

and Qatar in natural gas and oil. Of these countries, Botswana is a fast growing country and Guinea and Qatar are growing very slowly and shrinking, respectively, over the period observed.

When observations are dropped partly due to their undue influence on the regression results, it is important to consider why they may be influencing results and to consider the implications for interpretation of the results. Results without these outliers reflect the patterns in the data that most of the countries we observe exhibit. This is certainly useful information to have. However, since most of the countries that exert strong influence on coefficient estimates are also countries that have tremendously large resource stocks relative to their GDP[7], these findings might suggest nonlinearities in the effect of resource abundance.

Dropping Australia, Botswana, Guinea and Qatar leaves 166 observations of growth and abundance. Results are reported in full in Table 1. The coefficient on *fuelminratio* is negative and significant. The standard deviation of *fuelminratio* is equal to 55.5 with the outlying observations dropped, suggesting that a one standard deviation increase in extractive resource abundance is associated with a decline of 0.39 in the growth rate, somewhat smaller than estimates based on Sachs and Warner's *sxp* (share of natural resources to GDP) variable. The land variable is also negative and significant. The standard deviation of the land variable in this sample is 0.50, suggesting that land abundance is associated with a larger decline in growth rates, of about 0.48 percentage points. The aggregate stock and land variables require different kinds of abundance to have similar

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estimated coefficient. It is scaled such that a *dfbeta* statistic equal to 1 for a particular country reveals that the omission of that country from the analysis would change the estimated coefficient by one standard deviation from the estimate with that country included. For land, a few additional countries are just over the cutoff for evaluation but upon examination are left in the sample. The Central African Republic and Niger appear to be outliers in land but are not leverage points in the regression and so are left in the sample.

[7] Guinea's mineral stocks in 1970 were worth 1,892 times the size of their economy; ten countries have oil and natural gas or mineral stocks that were worth more than 100 times their start-period GDP, and Botswana had coal stocks valued at 262 times GDP.

Table 1. Growth 1970-2000 and Natural Resource Stocks: OLS

	Full Sample		Restricted Sample	
	(1)	(2)	(3)	(4)
	Coefficient Estimate	Coefficient Estimate	Coefficient Estimate	Coefficient Estimate
Log Income Per Capita 1970	0.2343	0.2689 *	0.4815 ***	0.4739 ***
	0.1453	0.1396	0.1524	0.1537
Fuel & Mineral Stocks / GDP	-0.0070 **	-	-0.0128 ***	-
	0.0037		0.0032	
Arable and Plantation Land Per Capita	-0.9586 ***	-	-0.4762 **	-
	0.2608		0.2086	
Oil Stocks / GDP	-	-0.0299 ***	-	-0.0247
		0.0084		0.0504
Natural Gas Stocks / GDP	-	0.0756	-	-0.0027
		0.0807		0.1321
Coal Stocks / GDP	-	0.0380	-	-0.0101
		0.0310		0.0494
Mineral Stocks / GDP	-	-0.0035	-	-0.0118 ***
		0.0022		0.0029
Arable land Per Capita	-	-0.9722 ***	-	-0.4690 **
		0.2624		0.2044
Plantation Land Per Capita	-	-1.1525	-	-5.6889
		1.3210		3.6888
Constant	2.1322 ***	2.1816 ***	2.1464 ***	2.4064 ***
	0.2156	0.2214	0.2430	0.2973
Observations	166	166	74	74
R-squared	0.1122	0.1687	0.1911	0.2230

Robust Standard Errors Under Coeeficient Estimates
* P<.1, **P<.05, ***P<.01

effects on growth, which may be unreasonable. In particular, economists have long been inclined to treat oil-rich countries as fundamentally different from other economies, and others (e.g. DeLong and Williamson 1994, cited in Stijns 2001) have noted that abundance in natural resource inputs that are expensive to transport may be helpful in industrialization under some circumstances. Coal or natural gas abundance might be playing this role in our data. Additionally, Isham et al (2003) and Stijns (2001) both treat land used in capital-intensive plantation crops separately from other arable land. In the data, mineral and oil abundance tend to dominate the *fuelminratio* variable, and arable land dominates *landea.* The different abundance variables are not highly correlated; the most closely related, oil and natural gas, have a correlation coefficient of 0.51.Thus, the effects of different kinds of natural resource abundance will be emphasized here.

In an OLS regression of growth on a convergence term and oil, gas, mineral and coal abundance as well as arable land per capita and land in plantation crops, only oil and arable land have a significant relationship with growth rates. Results are reported in column 2 of Table 1. Both of them are negative; a one standard deviation increase in these variables is associated in regression (2) with declines in the growth rate of 0.70 and 0.48, respectively. A few countries that are not outliers in aggregate stock abundance are outliers in one of the narrower classifications (i.e., plantation cropland, which tends to be small relative to the arable land measure), but the sign, approximate magnitude and significance of the results are robust whether they are included or not. Because both theory and the empirical results suggest that different kinds of abundance have different effects, the preferred specifications will use disaggregated resource stocks rather than aggregated ones.

Conditioning Variables with Listwise Deletion and Instrumented Rule of Law

Next conditioning variables other than a convergence term (log initial per capita income) are added to the growth regression. There are literally dozens of variables which could plausibly be included in growth analysis, as growth theory is open-ended on the relevance of many potentially important factors. Given the limited number of countries in the world, they cannot all be simultaneously considered in an econometric analysis. Main results are examined for robustness to the inclusion of a number of additional potentially important conditioning variables as determined using Bayesian averaging of classical estimates in Sala-i-Martin et al (2004). Table 1 (columns 3 and 4) reports estimates using the same models estimated in columns one and two of Table 1 for the sample of countries for which all the main conditioning variables are available. Restricting the sample has noticeable effects on the size and significance of the coefficients, suggesting that concerns about data loss and selection in the restricted sample are not misplaced. In column 3, in contrast to column 1, aggregate farmed land is only marginally significant, whereas in the full sample the coefficient estimate was twice as large and highly significant. In column 4, in contrast to column 2, oil is no longer significant and land is smaller and less significant, while minerals abundance has become significant and the coefficient has tripled in absolute magnitude.

An important question when estimating growth regressions is exchangeability. Briefly, this is the question of whether any one country in the sample is as likely as any other to have the same kind of error term in the regression. If, for instance, a country in sub-Saharan Africa is more likely to have a negative error term than an Asian country, exchangeability is a concern (Durlauf 2001). This is related to the question of how missing data are dealt with. If any observation with no data for a particular conditioning variable is dropped, then by choosing that conditioning variable particular countries drop out of the analysis. Under listwise deletion, economists who examine the impact of different conditioning variables are likely to look at different samples of countries, or, if only countries for which data is available for all conceivably important variables are considered, will evaluate a very restricted sample.

With that in mind, results for a sample of countries for which all conditioning variables are available are presented, as is customary in the resource curse literature. Subsequent sections address the missing and dropped data. Following Sala-i-Martin and Subramanian (2003), we add primary education in 1970, the relative price of investment goods during 1960-64, a measure of how favorable the ecology of a country is to malaria transmission (this is used in preference to the MALFAL variable used in Sala-i-Martin and Subramanian because it is designed to be exogenous to economic and policy conditions), a measure of the volatility of the terms of trade for each country between 1970-2000, a measure of rule of law (Kauffman et al 2003), and a measure of coastal population density in 1965. A key hypothesis of interest is whether resource abundance has a negative effect on rule of law, which is endogenous to and interrelated with growth. To that end, rule of law is instrumented for, first using measures of the fraction of the population speaking English or other

European languages (as per Hall and Jones 1998),[8] and then testing for robustness using the colonial mortality instruments developed for a smaller set of countries by Acemoglu et al (2001). OLS results are also reported for purposes of comparison.

For the 2SLS specifications detailed above, we will refer to the indirect and the direct relationship between resource abundance and growth. The indirect relationship is the impact of resource abundance on growth that operates through the rule of law. Algebraically, it is estimated by $\Delta NR(\hat{\tau})(\hat{\kappa})$. The direct relationship is the relationship between growth and resource abundance after instrumented rule of law is controlled for, estimated by $\Delta \mathrm{NR}(\hat{\gamma})$.

Results for aggregate measures of abundance are shown in Table 2, with OLS results for GDP growth without instrumenting for rule of law provided as well. Using aggregate measures of stock abundance,[9] the direct relationship between resource abundance and growth is both larger and more significant than the indirect one. The standard deviation of *fuelminratio* in this sample is 32.8, so the estimated direct effect of a one-standard-deviation increase in point-source resource abundance is a decline of 0.34 percentage points in the average growth rate over the sample period, and the indirect effect is a decline of 0.17 percentage points. The signs of the other conditioning variables are as expected. If there is a resource curse in stocks operating through rule of law in this sample, it is not operating through rule of law alone, as the indicator of concentrated abundance has a strong direct effect on growth that persists despite controlling for any impact of resource abundance on rule of law.

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[8] This is not intended as a suggestion that European or British influence and/or contact implies good or bad institutional quality relative to one another or to other influences; it merely reflects empirical findings that these variables are associated with some of the variation in institutions, while having no theoretical or intuitive effect on growth itself. Hall and Jones suggest that this is because 'modern' capitalism developed in Europe and the nature of other countries first exposure to this system had lasting effects on the forms of institutions put in place that relate to capitalist economic activity.

[9] Only Botswana is dropped as an outlier; Guinea and Qatar do not have all the conditioning variables, and Australia is an outlier in land, which is insignificant in both stages regardless of Australia's inclusion.

Table 2. Growth 1970-2000, Rule of Law, and Aggregate Natural Resource Stocks

	OLS	2SLS		2SLS	
		Dependent Variable		Dependent Variable	
	Growth	Rule of Law	Growth	Rule of Law	Growth
Fuel & Mineral Stocks / GDP 1970	**-0.0095** **	**-0.0046** **	**-0.0104** ***	**-0.0037** *	**-0.0081** ***
	0.0041	0.0019	0.0030	0.0020	0.0023
Arable and Plantation Land p.c.	0.0422	0.0786	0.0681	0.0207	-0.0871
	0.2201	0.1066	0.2165	0.0944	0.1736
Share of NRX/GDP (sxp), 1970	-	-	-	-0.9289	**-5.5296** ***
				0.8790	1.7788
Rule of Law	1.4276 ***	-	1.1374 **	-	0.9740 *
	0.2235		0.4815		0.5405
Log Income Per Capita 1970	-1.0176 ***	0.5848 ***	-0.8372 ***	0.6321 ***	-0.7521 *
	0.1987	0.0806	0.3123	0.0844	0.3809
Primary Education Level 1970	1.8097 **	0.3114	1.7928 **	0.0795	1.7562 **
	0.8194	0.4927	0.7297	0.5141	0.7096
Price of Investment	-0.0068 **	-0.0026 ***	-0.0074 **	-0.0024 **	-0.0090 ***
	0.0028	0.0010	0.0035	0.0009	0.0031
Malarial Ecology	-0.0896 ***	-0.0004	-0.0888 **	0.0086	-0.0621 **
	0.0281	0.0158	0.0357	0.0137	0.0280
Coastal Population Density	0.0008 ***	0.0002 **	0.0009 ***	0.0002 **	0.0008 ***
	0.0003	0.0002	0.0003	0.0001	0.0002
Terms of Trade Volatility	0.0042	-0.0155 **	-0.0010	-0.0144 **	0.0027
	0.0130	0.0073	0.0115	0.0068	0.0115
Fraction English Language Users	-	0.8561 ***	-	0.7777 **	-
		0.3171		0.3240	
Fraction European Language Users	-	-0.5940 ***	-	-0.5221 **	-
		0.2093		0.2266	
Constant	0.5113	0.9595 ***	0.7963	1.1422 ***	1.6203 **
	0.6263237	0.2913	0.8083	0.2987	0.8041
Observations	74	74	74	72	72
R-squared	0.6591	0.7540	0.6933	0.7662	0.7489

Robust Standard Errors Under Coefficient Estimates
* P<.1, **P<.05, ***P<.01

The results are fairly robust to including the Sachs and Warner and Sala-i-Martin and Subramanian measures of export intensity.[10] There is evidence from the literature that export intensity can be important for growth. Since the stock variable is intended to capture a different measure, resource abundance, it may invite a specification error to exclude flows, particularly given the interest

[10] Using *sxp* with listwise deletion does drop the sample size by two. Running the regression in Table 1 on this sample yields similar signs and size of the coefficients of interest. With the sample restricted to countries for which the Sala-i-Martin and Subramanian aggregate variable is available, the coefficients and significance of the variables of interest are similar whether or not the flow variable is included for the first stage, but in the second stage the size and significance of the *fuelminratio* term increases in the second stage if the flow measure is excluded.

in relationships between resources generally, rule of law and growth. Including flows allows for institutional linkages with resource stocks, as modeled, as well as the crowding out effects of resource flows postulated in the literature. Adding the *sxp* variable, the share of raw natural resource exports to GDP, changes a few of the results modestly. The coefficient for fuels and minerals declines in absolute value by a little under 20% in both stages of the regression and decreases in significance in the rule of law regression. The coefficients on *sxp* and land are negative and insignificant (*fuelminratio* is marginally significant and negative) in the rule of law regression; *sxp* and *fuelminratio* are both negative and highly significant in the growth stage. The coefficient on *sxp* is -5.53, comparable with Sachs and Warner's results.

However, Bound et al (1995) note that even where instruments are statistically significant in the first stage, if they explain relatively little of the variation in the endogenous variable (rule of law, in this analysis) second-stage results can be biased in the same way OLS is, in addition to the relative inefficiency of 2SLS. For the first stage regressions in Table 2, joint *F*-tests of the instruments yield statistics of 5.5 and 4.3, respectively. An *F*-statistic of 4 with two instruments has an approximate bias equal to 2% of the OLS bias with a 'perfect' instrument, and higher values of the statistic are associated with decreasing bias relative to OLS with endogeneity. *F*-statistics below 10 are considered suggestive of weak instruments bias.

Results for disaggregated measures of abundance are summarized in Table 3. Mined non-fuel minerals exhibit strong negative associations with rule of law and with the growth rate. The direct effect of a one standard deviation increase in aggregate mineral wealth is a 0.34 decline in the growth rate. The effect of the same change in the first stage is a 0.14 decline in rule of law, which is itself associated with a 0.15 additional decline in the growth rate if the (not significant, p=0.219) point estimate for rule of law is used.

An *F*-test indicates that there is no significant difference between the coefficients on oil and natural gas, non-fuel minerals and coal in either stage of the column 2 estimation. Adding *sxp* has an insignificant effect on rule of law and a negative and highly significant (p= .007) direct effect on growth when stocks are controlled for, with a coefficient comparable to that found by Sachs and Warner. Mineral abundance remains negative and significant in both stages, again with a larger direct effect and a smaller indirect effect operating via an non-significant link between current rule of law and past growth. Land in plantation crops is not significant in OLS but has a negative effect on rule of law in both two-stage specifications. A one standard deviation increase in these crops is associated with a 0.18 decline in rule of law.

The potential weakness of the Hall and Jones instruments for rule of law is more apparent in these regressions. *F*-statistics for the instruments in Table 3 regressions are 2.3 and 1.8. *F*-statistics this low are associated with less effective elimination of the endogeneity bias 2SLS attempts to address. To the extent that, as economists, we are convinced that institutions surrounding property rights and rule of law must affect economic growth, the first stage estimates of associations between natural resource abundance and rule of law remain of interest, even if a precise estimate of the indirect effect of resource abundance on growth is not possible. The impact on rule of law from mineral and fuel resources estimated here is equivalent to the difference between Tanzania and Nicaragua: a move of 12 ranks in the sample of 162 countries. Even given the difficulty in measuring rule of law with precision, this is some evidence for a resource curse in abundance operating through rule of law.

Table 4 replicates the analysis of Table 3 in the sample for which data from the WDI on disaggregated shares of export categories to GDP are reported, and then repeated with those variables and the abundance variables. Results are reported in column 3 of Table 4 for four categories of export flow intensity and in column 4 condensed into two broader categories meant to capture differences between point-source and more broadly based resource flows. Results for the smaller sample without adding flows, reported in columns 1 and 2, are roughly comparable to those reported in Table 3, although the effect of resource stocks is now more significant in the first stage than in the second.

Table 3. Growth 1970-2000, Rule of Law, and Disaggregated Natural Resource Stocks

	1	2		3	
	OLS	Dependent Variable		Dependent Variable	
	Growth	Rule of Law	Growth	Rule of Law	Growth
Oil stocks / GDP 1971	**0.0614** *	-0.0036	0.0509	-0.0206	0.0478
	0.0322	0.0172	0.0411	0.0242	0.0415
Natural Gas Stocks / GDP 1971	-0.0367	0.0837	0.0187	0.0800	-0.0344
	0.0811	0.0597	0.1184	0.0592	0.1228
Mineral stocks / GDP 1970	**-0.0086** ***	**-0.0044** **	**-0.0103** **	**-0.0038** **	**-0.0073** **
	0.0026	0.0021	0.0044	0.0018	0.0035
Coal stocks / GDP 1971	-0.0092	-0.0106	-0.0131	-0.0093	-0.0106
	0.0215	0.0161	0.0208	0.0161	0.0203
Arable Land Per Capita 1970	0.0394	0.1270	0.1033	0.0762	-0.0721
	0.0394	0.1014	0.2896	0.0958	0.2128
Plantation Land Per Capita 1970	0.5059	**-2.8486** **	-1.0229	**-2.6934** *	-0.5294
	2.0674	1.3342	3.9640	1.3591	3.6900
Share of NRX/GDP (sxp), 1970	-	-	-	-0.6678	**-5.3122** ***
				0.8109	1.8915
Rule of Law	1.4775 ***	-	1.0270	-	0.9983
	0.2491		0.8267		0.9008
Log Income Per Capita 1970	-1.1261 ***	0.5735 ***	-0.8619 *	0.6198 ***	-0.8408
	0.2344	0.0859	0.4878	0.0944	0.5810
Primary Education Level 1970	1.8339 **	0.4215	1.9398 **	0.2104	1.8435 **
	0.8254	0.5321	0.9080	0.5720	0.7994
Price of Investment	-0.0061	-0.0020 **	-0.0069 *	-0.0018 **	-0.0084 **
	0.0037	0.0008	0.0040	0.0009	0.0036
Malarial Ecology	-0.0899 **	-0.0009	-0.0892 **	0.0063	-0.0646 **
	0.0354	0.0175	0.0398	0.0164	0.0309
Coastal Population Density	0.0008 ***	0.0002 *	0.0009 ***	0.0002 *	0.0007 **
	0.0002	0.0001	0.0003	0.0001	0.0003
Terms of Trade Volatility	-0.0223	-0.0210	-0.0334	-0.0183	-0.0184
	0.0244	0.0127	0.0303	0.0133	0.0280
Fraction English Language Users	-	0.5353 *	-	0.4908	-
		0.2989		0.3079	
Fraction European Language Users	-	-0.4087 *	-	-0.3622 *	-
		0.2094		0.2183	
Constant	0.5604	1.0077 ***	1.0187	1.1406 ***	1.6498
	0.7492	0.3021	0.9954	0.3278	1.3157
Observations	74	74	74	72	72
R-squared	0.7154	0.7879	0.7004	0.7958	0.7591

Robust Standard Errors Under Coefficient Estimates

* P<.1, **P<.05, ***P<.01

Table 4. Growth 1970-2000, Rule of Law, and Disaggregated Natural Resource Stocks and Flows

	1	2		3		4	
	OLS	Dependent Variable		Dependent Variable		Dependent Variable	
	Growth	Rule Law	Growth	Rule Law	Growth	Rule Law	Growth
Oil stocks / GDP 1971	**0.0786** *	-0.0081	**0.0749** *	0.0094	0.0525	-0.0087	0.0640 *
	0.0398	0.0203	0.0416	0.0153	0.0479	0.0204	0.0380
Natural Gas Stocks / GDP 1971	-0.0014	0.0569	0.0344	**0.1543** **	-0.0052	0.0681	0.1072
	0.0775	0.0443	0.1152	0.0671	0.1637	0.0416	0.1056
Mineral stocks / GDP 1970	**-0.0058** ***	**-0.0041** **	**-0.0073** *	**-0.0051** **	-0.0019	**-0.0038** **	-0.0036
	0.0019	0.0018	0.0043	0.0019	0.0039	0.0018	0.0033
Coal stocks / GDP 1971	-0.0247	-0.0040	-0.0257	0.0065	-0.0414	-0.0042	-0.0339
	0.0250	0.0146	0.0246	0.0162	0.0265	0.0152	0.0233
Arable Land Per Capita 1970	-0.0394	0.1370	0.0272	0.1327	-0.1918	0.1319	-0.1798
	0.1510	0.1298	0.2522	0.1448	0.2091	0.1358	0.1964
Plantation Land Per Capita 1970	**2.6265** **	**-2.5497** *	1.4284	-2.3990	2.7610	-2.5869	2.0609
	1.2626	1.4978	2.9981	1.7647	2.6728	1.5596	2.6755
exag/GDP	-	-	-	0.0001	-0.1192	-	-
				0.0301	0.0977		
exfood/GDP	-	-	-	0.0025	**-0.0347** *	-	-
				0.0126	0.0189		
ex ag+food/ GDP	-	-	-	-	-	-0.0003	**-0.0393** *
						0.0107	0.0204
exfuels/GDP	-	-	-	**-0.0387** *	-0.0260	-	-
				0.0219	0.0344		
exore-minerals/GDP	-	-	-	0.0020	**-0.0568** ***	-	-
				0.0058	0.0083		
ex fuels, ores & minerals/GDP	-	-	-	-	-	-0.0041	**-0.0501** ***
						0.0060	0.0082
Rule of Law	1.3864 ***	-	0.9753	-	1.7662 *	-	1.3323
	0.2650		1.0671		0.9911		0.9374
Log Income Per Capita 1970	-1.0089 ***	0.5415 ***	-0.7809	0.5248 ***	-1.2186 **	0.5464 ***	-0.9582 *
	0.2494	0.0891	0.6092	0.0089	0.9911	0.0895	0.5363
Primary Education Level 1970	0.5311	0.4836	0.6490	0.6166	0.2231	0.4891	0.4756
	0.7491	0.4823	0.7936	0.5714	0.7656	0.5066	0.7041
Price of Investment	-0.0086 ***	-0.0019 ***	-0.0093 ***	-0.0017 *	-0.0093 ***	-0.0019 **	-0.0098 ***
	0.0024	0.0007	0.0030	0.0009	0.0028	0.0008	0.0027
Malarial Ecology	-0.0809 **	0.0078	-0.0759 **	0.0103	-0.0702 ***	0.0084	-0.0571 **
	0.0305	0.0189	0.0340	0.0233	0.0250	0.0204	0.0258
Coastal Population Density	0.0021	0.0010	0.0027	0.0014 *	0.0000	0.0009	0.0011
	0.0018	0.0007	0.0026	0.0007	0.0022	0.0007	0.0021
Terms of Trade Volatility	-0.0421	-0.0378 ***	-0.0598	-0.0410 ***	-0.0017	-0.0364 ***	-0.0247
	0.0292	0.0101	0.0544	0.0113	0.0448	0.0012	0.0393
Fraction English Language	-	0.5353	-	0.5467 *	-	0.4178	-
		0.2989		0.3239		0.3057	
Fraction European Language	-	-0.4087 *	-	-0.3355	-	-0.3736 *	-
		0.2094		0.2234		0.2128	
Constant	1.4103 **	1.0077 ***	1.8294	0.8962 **	1.8577	1.0541 ***	2.0703 *
	0.5941	0.3021	1.2350	0.4243	1.1136	0.3642	1.0938
Observations	57	57	57	57	57	57	57
R-squared	0.7145	0.8617	0.7049	0.8714	0.7654	0.8625	0.7657
Robust Standard Errors Under Coefficient Estimates							

* P<.1, **P<.05, ***P<.01

However, when flow measures are included the results change. Again the stock that matters consistently is mined mineral abundance, but the nature of the relationship is different. When flows are controlled for, mineral stocks exhibit coefficient estimates consistent with a resource curse in abundance operating only through rule of law, while results for flow measures are consistent with a crowding-out process. No stock measure is significant in the second stage, while some or all of the flow measures are significant and negatively associated with growth in each specification. Plantation land is no longer significant even in the first stage, perhaps because it is more closely linked to production than mineral stocks are. The results for resource flows contrast with the Sala-i-Martin and Subramanian results, which found that second stage results were generally non-significant while first stage effects were negative and significant, though it should be noted that weak instruments and non-significant or nearly non-insignificant coefficients on instrumented rule of law remain problematic. This does not establish that rule of law does not matter for growth; the prior on the importance of institutions that regulate the ownership and disposition of property for economic growth is strong. Tests for statistical significance protect against Type I errors, rejecting the null hypothesis when it is true. In this case, we do not think that the null hypothesis of 'rule of law has no importance for growth' is true and hence we should be more concerned with the possibility of making a Type II error, accepting the null hypothesis of no effect when it is false.

The 2SLS listwise deletion regressions are repeated using an alternate instrument, developed in Acemoglu et al (2001) and based on western death rates in colonized countries during the colonial period. Table 5 shows the results. The sample size drops to 43; two stage estimation with disaggregation of stocks and flows would reduce it further and is impractical. Initial results using aggregated stocks again present a negative and significant direct effect on growth and no effect on rule of law, but the coefficient on the instrumental variable is positive rather than negative, as expected.

Table 5. Growth 1970-2000, Rule of Law, and Aggregate Natural Resource Stocks- Alternate instruments

	2SLS Dependent Variable Rule of Law		2SLS Dependent Variable Growth	
Fuel & Mineral Stocks / GDP 1970	-0.0009		**-0.0077**	**
	0.0017		0.0031	
Arable and Plantation Land Per Capita	0.0937		-0.1051	
	0.1251		0.2807	
Rule of Law	-		**2.3147**	**
			0.9203	
Log Income Per Capita 1970	0.6757	***	-1.4312	**
	0.1406		0.5442	
Primary Education Level 1970	-0.7513		2.3483	**
	0.6281		1.1177	
Price of Investment	-0.0010		-0.0071	**
	0.0008		0.0029	
Malarial Ecology	-0.0064		-0.0705	**
	0.0156		0.0330	
Coastal Population Density	0.0003	**	0.0005	
	0.0001		0.0003	
Terms of Trade Volatility	-0.0289	*	0.0387	
	0.0143		0.0400	
Settler Mortality Rates	0.0004	**	-	
	0.0002			
Constant	1.0913	***		
	0.3790			
Observations	43		43	
R-squared	0.7365		0.576	

Robust Standard Errors Under Coefficient Estimates
* P<.1, **P<.05, ***P<.01

Table 4 considers *only about a third of the countries in the dataset*. The pattern of a significant negative effect of some kinds of abundance on rule of law combined with no direct effect on growth beyond that associated with a decline in rule of law, and of a negative effect of resource flows on growth that does not operate through rule of law, is only seen with disaggregated results. This could be because disaggregation is important for either or both of resource stocks and flows, or because the analysis considers particular countries and has discarded others. It should also be noted that in neither of these cases does instrumented rule of law perform very strongly in the second-stage regressions, so we cannot draw precise conclusions about the size of the ultimate effect on growth even in this sample. In an effort to reach firmer conclusions about the complex relationships between resource abundance, flows, rule of law and growth a key constraint to our analysis needs to be addressed: missing data. This would be worthwhile even if results under listwise deletion were more precise and robust; those results would still only reflect relationships between resources, rule of law and growth in fewer than half of the observed countries.

Missing Data and Multiple Imputation

For the results reported above and in other papers in this literature, more than half of the available observations were thrown away due to missing conditioning variables. Leaving out countries with significant border changes, there are data on growth rates and resource abundance for 169 countries, 74 of which have 'complete' data for the main set of conditioning variables. Considering just the variables used thus far, a relatively small (about 12%) fraction of the data are missing, but all the available information about more than half of the countries potentially in the sample is discarded.

This can lead to statistical problems above and beyond the obvious efficiency loss, as has been known for some time by statisticians and econometricians.[11] Unless missing data are MCAR (missing completely at random - there is no possible data, missing or available, that provides information about whether an observation is more or less likely to be missing), listwise deletion is biased, sometimes severely (King et al 2001).

Methods other than listwise deletion have historically been quite demanding in terms of complexity and computational capacity and have not been in widespread use in empirical environmental or growth economics[12]. In recent years, King et al (2001) and Honaker et al (2001) have developed a generally applicable EMis (Expectation Maximization with Importance re-Sampling) algorithm for imputing missing values and provided software to implement it. They show that listwise deletion is preferable to filling in missing values using this algorithm only under very

[11] See Rubin (1996) for a discussion of the theoretical properties of analyses performed with missing data and under various methods for filling in missing data, as well as an extensive bibliography of earlier work.

[12] Some exceptions include DeCanio and Watkins (1998), Imai (2000) and Bar-Hen (2002). Kofman and Sharpe (2003) examine a sample of published papers and note that listwise deletion remains the most common way of dealing with missing data.

strong conditions and assumptions about the observed data. These assumptions are not supported for the data or models used in growth regressions.[13] EMis imputation is efficient and unbiased if data are MCAR or MAR (Missing At Random; some observations are more likely than others to be missing data, but within that group or groups data are missing at random) and ignorable. If missing values are not ignorable, listwise deletion will not eliminate any bias and remains relatively inefficient. King et al's experiments found that EMis imputed data produced regression results with root mean square errors only slightly larger than those using the complete data set, even with 50% of observations incomplete, and far smaller than those using listwise deletion in cases where data was not MCAR (pp.61-62). Kofman and Sharpe (2003) includes additional tests and descriptions of various imputation approaches and finds that EMis outperforms listwise deletion for a variety of variable types and estimation strategies.

The imputation stage, where missing values are filled in, generates a series of five datasets in which all the known (observed) values are the same but the missing observations are filled in with draws from their estimated distribution. The analytical stage is performed on each of these datasets, and the multiple imputation estimate of the coefficients is the average of the estimates from this procedure, while the standard error of the multiple imputation estimate is a combination of the standard errors in each individual estimation and the variance in the point estimates across all the datasets.

Another advantage of EMis is that the imputation stage can include variables that are not used in the analytical model, perhaps for reasons of endogeneity or when several measures of the same thing with different coverage are available, up to the computational limits of the software. Anything that might contain information that sheds light on what the missing values might be, whether it is a determinant of growth or rule of law or not, can theoretically be used. This means that missingness

[13] The conditions are: 1) that the functional form of the analysis model is completely and correctly specified, 2) that the missing data is nonignorable (missing values are ignorable if an observation for which the datum is missing is indistinguishable from an observation for which it is not missing that has the same value; there is no statistical test for ignorability), 3) that there is no data excluded from the analysis model that can be included in the imputation model to correct any nonignorability, and 4) that the number of observations lost to missingness is small.

that might be nonignorable in the analytical framework may be ignorable and MAR if additional variables not wanted for the analytical framework are controlled for in imputation. Here, the imputation and analysis stages are performed using only the variables used in the analytical models presented above, so that the only information added to the estimation is data which was discarded under listwise deletion.

Table 6 replicates the results in Table 2 using EMis and only information on the variables in the regression. The four outliers, Botswana, Australia, Guinea, and Qatar, are excluded from the analysis. Fifty-six percent of the observations have at least one missing value imputed; eighteen percent of the data used in Table 6 are imputed. Forty six percent of the information in the dataset are discarded under listwise deletion. The decline in rule of law associated with a one standard deviation increase in *fuelminratio* is significant and equal to 0.125 (the difference between Ghana and South Africa in our data), but a coefficient for instrumented rule of law cannot be estimated precisely in the growth stage. When *sxp* is added, it exhibits no detectable effect on rule of law. In contrast to table 2, the addition of resource flows makes aggregate abundance non-significant in both stages. The average of the F-tests on the instrumental variables in the first stage is 4.6 without *sxp* and 4.5 with it, ranging from 2.0 to 8.5 across the 5 imputed datasets, so performance of the instruments remains insufficient to enable precise estimation of the indirect effect of resources on growth or to eliminate concerns about weak instruments bias.

Table 6. Growth 1970-2000, Rule of Law, and Aggregate Natural Resource Stocks with EMis

	OLS	2SLS		2SLS	
		Dependent Variable		Dependent Variable	
	Growth	Rule of Law	Growth	Rule of Law	Growth
Fuel & Mineral Stocks / GDP 1970	**-0.0051** **	**-0.0020** **	-0.0052	-0.0019	-0.0007
	0.0021	0.0010	0.0034	0.0012	0.0030
Arable and Plantation Land p.c.	-0.1756	-0.0691	-0.1614	-0.0721	-0.2777
	0.2749	0.1119	0.3079	0.1131	0.3089
Share of NRX/GDP (sxp), 1970	-	-	-	-0.1697	**-3.7975** ***
				0.5207	1.2932
Rule of Law	1.1466 ***	-	1.2236	-	1.0068
	0.2115		1.3397		1.4618
Log Income Per Capita 1970	-0.9697 ***	0.5439 ***	-1.0215	0.5489 ***	-0.8252
	0.1828	0.0538	0.7067	0.0541	0.7911
Primary Education Level 1970	3.3157 ***	0.3312	3.2837 ***	0.3241	2.8362 ***
	0.8804	0.3455	0.9626	0.3471	0.8222
Price of Investment	-0.0084 ***	-0.0010	-0.0080 ***	-0.0011	-0.0078 ***
	0.0030	0.0016	0.0034	0.0016	0.0032
Malarial Ecology	-0.0274	-0.0087	-0.0278	-0.0083	-0.0216
	0.0267	0.0104	0.0304	0.0109	0.0297
Coastal Population Density	0.0010 ***	0.0003 *	0.0010 *	0.0003 *	0.0008
	0.0003	0.0001	0.0006	0.0002	0.0006
Terms of Trade Volatility	0.0100	-0.0178 ***	0.0115	-0.0177 ***	0.0133
	0.0124	0.0050	0.0307	0.0053	0.0330
Fraction English Language Users	-	0.5616 **	-	0.5487 **	-
		0.2487		0.2455	
Fraction European Language Users	-	-0.2783	-	-0.2881	-
		0.2049		0.2036	
Constant	-0.0323	0.8269 ***	-0.1336	0.8504 ***	0.6952
	0.7102	0.2388	1.2698	0.2373	1.3772
Observations	167	167	167	167	167
Mean R-squared	0.5686	0.6649	0.5194	0.6671	0.5561

Standard Errors Under Coefficient Estimates
* P<.1, **P<.05, ***P<.01

Table 7 replicates the results in Table 3 with EMis using only information in the variables in the regression, again without resource outliers. Fifty-seven percent of the observations have at least one missing value imputed; only 14% of the total values are imputed by EMis. Forty nine percent of the data were discarded under listwise deletion. There is a significant and negative effect on rule of law for minerals only; its size and significance are robust to the inclusion of *sxp*. Results differ from those in Table 3 in three key ways. The effect of mineral abundance on rule of law is slightly larger and more precisely estimated, there is no estimated direct effect of abundance on growth in any regression, including OLS, and neither oil abundance nor plantation cropland is statistically significant. The effect on rule of law amounts to a decline of 0.144 or 0.151 (in columns two and three, respectively) for an increase of one standard deviation in mineral abundance, roughly the difference between Tanzania and Nicaragua in our sample.

In each of the five imputed datasets, the instrument's performance in the analytical stage is superior to the best statistics observed with listwise deletion, though still showing signs of weakness. *F*-statistics for the instruments range from 2.4 to 5.9 and are above the cutoff of 4.0 described above in four of the five datasets; the average is 5.0, with or without the inclusion of *sxp*.

Table 4 cannot be replicated using only the variables in the analytical framework; the export share of GDP data are missing for too many of the observations. Results using additional information to improve the imputation stage are under development.

Table 8 replicates the results in Table 5 after EMis imputation, using only the variables from the regressions. Seventy-four percent of the observations have at least one missing value imputed, though only 20 percent of the data are missing before imputation. Fifty-nine percent of the available data were discarded under listwise deletion. The instrument, settler mortality, has improved performance (though still an unexpectedly positive coefficient) in this larger sample; joint *F*-statistics range from 4.1 to 13.5 with a mean of 8.1. There is a small and marginally significant effect of *fuelminratio* on rule of law only; a one standard deviation increase in abundance is associated with a 0.084 decline in rule of law. Results using the full sample are a reversal of those seen in Table 5, highlighting the importance of the imputation procedure.

Table 7. Growth 1970-2000, Rule of Law, and Disaggregated Natural Resource Stocks with EMis

	1	2		3	
	OLS	Dependent Variable		Dependent Variable	
	Growth	Rule of Law	Growth	Rule of Law	Growth
Oil stocks / GDP 1971	-0.0079	-0.0017	-0.0074	-0.0022	0.0054
	0.0084	0.0031	0.0106	0.0037	0.0095
Natural Gas Stocks / GDP 1971	0.0909	0.0383	0.0996	0.0359	0.1511
	0.0740	0.0283	0.0984	0.0332	0.0965
Mineral stocks / GDP 1970	-0.0032	**-0.0026** ***	-0.0035	**-0.0028** **	-0.0003
	0.0024	0.0010	0.0033	0.0011	0.0028
Coal stocks / GDP 1971	-0.0016	-0.0006	-0.0026	-0.0004	-0.0065
	0.0353	0.0139	0.0375	0.0159	0.0404
Arable Land Per Capita 1970	-0.2269	-0.0308	-0.1951	-0.0258	-0.3598
	0.2914	0.1148	0.3169	0.1271	0.2693
Plantation Land Per Capita 1970	-0.1617	-0.7905	-0.3215	-0.8576	1.3549
	1.2589	0.5319	1.8648	0.5876	1.5268
Share of NRX/GDP (sxp), 1970	-	-	-	0.1907	**-4.9299** ***
				0.4766	1.3322
Rule of Law	1.2119 ***	-	1.1623	-	0.9086
	0.2065		1.3104		0.8428
Log Income Per Capita 1970	-0.9997 ***	0.5401 ***	-0.9975	0.5385 ***	-0.8036
	0.1968	0.0619	0.7931	0.0679	0.6063
Primary Education Level 1970	3.2360 ***	0.4248	3.5101 ***	0.4305	3.1475 **
	1.1945	0.5691	1.3248	0.5868	1.3497
Price of Investment	-0.0083 ***	-0.0005	-0.0077 **	-0.0004	-0.0089 ***
	0.0029	0.0014	0.0033	0.0015	0.0027
Malarial Ecology	-0.0220	-0.0081	-0.0229	-0.0086	-0.0069
	0.0264	0.0107	0.0325	0.0117	0.0283
Coastal Population Density	0.0010 **	0.0002	0.0010 *	0.0002	0.0009 *
	0.0004	0.0001	0.0006	0.0001	0.0005
Terms of Trade Volatility	-0.0050	-0.0137 **	-0.0051	-0.0135 **	-0.0091
	0.0164	0.0056	0.0280	0.0061	0.0212
Fraction English Language	-	0.6807 ***	-	0.6927 ***	-
		0.2480		0.2586	
Fraction European Language	-	-0.2795	-	-0.2759	-
		0.2333		0.2422	
Constant	0.1759	0.6792 **	0.0054	0.6494 *	1.0003
	0.6702	0.3384	1.4172	0.3523	0.8117
Observations	167	167	167	167	167
Mean R-squared	0.5744	0.6583	0.5206	0.6590	0.6300

Standard Errors Under Coefficient Estimates

* P<.1, **P<.05, ***P<.01

Table 8. Growth 1970-2000, Rule of Law, and Aggregate Natural Resource Stocks- Alternate instruments & EMis

	2SLS Dependent Variable	
	Rule of Law	Growth
Fuel & Mineral Stocks / GDP 1970	**-0.0015** *	-0.0035
	0.0009	0.0027
Arable and Plantation Land Per Capita	-0.1237	-0.1706
	0.1124	0.2989
Rule of Law	-	1.2025
		0.9209
Log Income Per Capita 1970	0.6085 ***	-1.0552 *
	0.0549	0.5513
Primary Education Level 1970	-0.0074	2.8846 ***
	0.4699	0.7678
Price of Investment	-0.0002	-0.0093 ***
	0.0011	0.0024
Malarial Ecology	-0.0150	-0.0357
	0.0119	0.0232
Coastal Population Density	0.0002 *	0.0010 **
	0.0001	0.0004
Terms of Trade Volatility	-0.0255 ***	-0.0010
	0.0047	0.0254
Settler Mortality Rates	0.0004 **	-
	0.0002	
Constant	0.9895 ***	0.3406
	0.2795	1.0011
Observations	167	167
mean R-squared	0.6876	0.57086

Standard Errors Under Coefficient Estimates
* P<.1, **P<.05, ***P<.01

Interestingly, repeating the main analysis reported in Table 7 using growth rates from 1970 to 1990 (as in Sachs and Warner) leads to changes even in the first stage regressions[14]. Natural gas is positively and significantly related to growth in the OLS regression and to rule of law in first stage regressions with or without *sxp*. A one standard deviation increase in natural gas abundance is associated with an *increase* of 0.15 in rule of law. A similar increase in land in plantation crops is associated with a decline of 0.13 in the rule of law measure, again regardless of the inclusion of *sxp*. The effect previously observed for mineral abundance is stronger and more significant in this analysis than in the regressions reported in Table 7. A one standard deviation increase in mineral abundance is

[14] Results are not reported here but are available upon request.

associated with a 0.17 decline in rule of law. These results are consistent with an effect of resource abundance on growth rates that diminishes over time.

7. Conclusion and Implications

Resource abundance, as distinct from a resource extraction intensive economy, matters for rule of law, an important requirement for growth. Different kinds of resource abundance have different effects; mineral and ore wealth has the strongest association with deterioration in rule of law in the results. Additionally, the practice of discarding as much as half of the available information, as is common in the resource curse literature, is worth discontinuing, as alternatives are available and listwise deletion leads to inefficient estimation as well as bias in the results under all but the most stringent conditions. The EMis algorithm allows us to examine the resource curse in a much broader range of countries than have previously been available and produces unbiased results under plausible assumptions, and less biased results than listwise deletion under even more general conditions.

To the extent that the 'curse' is less severe when resource stocks as well as flows are examined, there is room for increased optimism about the prospects of countries which, by stock measures, are "rich" in natural resources. Controlling resource flows so that they do not blight growth becomes the goal, and research can usefully focus on questions of how that control can be facilitated and exercised, as well as why flows might hamper growth. There is also evidence that taking care to support rule of law in resource-rich developing countries may be of particular importance.

Future work will focus on determining policies that promote rule of law and on investigating development indicators other than growth, with a particular focus on less developed countries. Development indicators addressing nutrition, life expectancy and such capture the welfare implications of resource abundance more directly than average GDP growth. Another measure that could be considered is growth in 'green' or sustainable GDP, which attempts to incorporate the value of natural capital. Additionally, I will consider measures of institutional type and quality other than rule of law (democracy, stability, bureaucratic efficiency). My goal in this is to distinguish what development outcomes are relatively responsive to changes in what institutions or institutional characteristics, and what kinds of institutions are relatively responsive to changes in the economic environment (here, this will be captured by changes in the values of resource stocks, which change with reserves, exploitation, and world commodity prices).

The data on extraction over the period 1970-2000 gathered to construct stocks will enable construction of a panel of changes in resource abundance over time, so that the speed and responsiveness with which rule of law, and other measures of institutional characteristics and quality, respond to changes in abundance can be established. This could provide additional valuable guidance into the most productive avenues for development efforts. Results should provide indicators of specific areas where development efforts will have the greatest welfare impact.

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Appendix 1 – Data Sources

Mineral Stocks - In cases where countries are listed in the 2003 **Mineral Commodities Summaries (MCS)** from the USGS as having a reserve of a mineral with its size, those reserve base figures are used as current reserves. In several cases, the background material for a mineral in the MCS will name countries having substantial resources of a mineral but not provide an estimate of the size of those reserves (e.g. mercury). Where the MCS does not report figures for deposits of a given mineral in a particular country, as only 'major' reserves are detailed in the commodity reports, data from the 2001 **Minerals Yearbook (Volume III. -- Area Reports: International)** published by the US Geological Survey is used if available. The area reports are not used as the general source because only some countries in this publication series include reserve data. Small countries reserves may be undercounted, as they may have resources which are economically significant in their economy but are not significant in the global market for that particular commodity and thus are less likely to be included in the MCS. Production data is from the commodity specific **Minerals Yearbooks** (Volume I, Metals and Minerals or, for 1976 and earlier, Volume I, Metals, Minerals and Fuels)**.** A few commodities for which the Minerals Yearbooks do not report global production data were dropped, leaving 35 mineral commodities represented in the composite variable. This variable will not account for all mined mineral resources because reserve and production data are not available for all traded resources, but it should correlate with overall mineral abundance; the major traded commodities and high-value commodities are more likely to have precise data. Historical mineral prices are taken from **Metal Prices in the United States through 1998,** published by the USGS. Some minerals are not included in this source and in those cases prices are from the USGS Open File Report 01-006 (version 8.1), available online only at minerals.usgs.gov.

Coal Stocks - data on reserves comes from the 2002 IEA 'World Estimated Recoverable Coal'. Figures are for hard (bituminous and anthracite) coal and thus do not include lower grade coals. Production after 1980 is also from the IEA. Production data for 1971-1977 is from April editions of International Coal Trade (US Department of the Interior, Bureau of Mines) for the years 1975 to 1978. 1978 and 1979 data for hard coal alone are not available; they were constructed from the 1981 IEA information on world coal production in all grades under the assumption that the proportion of hard coal in total coal output for each country was equal to the average of the 1977 and 1980 proportions. 1971 price to convert stocks to values is the F.O.B. pithead price from the 1982 Annual Energy Review (Table 63).

Gas and Oil Stocks - data on reserves as of January 1, 2003 is from the Oil and Gas Journal figures reported in the 2002 International Energy Annual (IEA) published by the US Energy Information Agency (EIA). Crude oil and gas production data is compiled from a variety of sources; data from 1980 to 2002 is from the EIA tables available online, data for 1977-1979 is from the 1981 IEA, and data from 1971 to 1976 is from the 1976 and 1973 US Geological Survey (USGS) Minerals Yearbooks (Volume 1, Metals, Minerals and Fuels). The prices used to convert the 1971 quantities to values are the EIA Annual Energy Review composite crude oil refiner acquisition cost and the natural gas wellhead price.

Arable Land and Land in Permanent Crops – 1976 FAO Production Yearbook, values reported for 1970. For countries forming subsequent to 1970, data are from the 1995 FAO Production Yearbook.

Institutional Quality Variables – Kaufmann, Kraay and Mastruzzi update of Kaufmann, Kraay and Zoido-Lobaton indicators. Available at
http://www.worldbank.org/wbi/governance/govdata2002/index.html

Income Data – United Nations Statistical Division, National Accounts Main Aggregates Database. Growth rate calculated as (100/years)* (logGend-logGstart). Available at http://unstats.un.org/unsd/snaama/

Population Data – US Bureau of the Census International Data Base. Available at http://www.census.gov/ipc/www/idbnew.html

Primary Education – Barro and Lee, April 2000 update. Available at http://www.cid.harvard.edu/ciddata/ciddata.html

Relative Price of Investment Goods - SS

Malarial Ecology – Earth Institute, Columbia University; October 2003 update. Available at http://www.earthinstitute.columbia.edu/about/director/malaria/

Coastal Population Density - SS

Terms of Trade Volatility – Standard Deviation of annual changes in the terms of trade reported in the WDI

Language Instruments: Fraction English-Speaking, Fraction Non-English European Language-Speaking – Taken from Hall and Jones (1999). Available at http://elsa.berkeley.edu/~chad/HallJones400.asc

Colonial Mortality Instrument – Acemoglu et al (2001) Appendix Table A2

East Asian Dummy – From Sala-i-Martin et al (2004), with the addition of Bhutan, Brunei,Cambodia, Cook Islands, French Polynesia, Kiribati, Laos, Mongolia, Nauru, New Caledonia, North Korea, Macau, and Vietnam, which are not in the original dataset.

Latin American Dummy - From Sala-i-Martin et al (2004), with the addition of Belize and French Guiana, which are not in the original dataset.

African Dummy – From Sala-i-Martin et al (2004) – excludes N. Africa - with the addition of Djibouti, Equatorial Guinea, and Reunion, which are not in the original dataset.

Spanish or Portuguese Colonial Dummy - From Sala-i-Martin et al (2004), who got it from Barro (1999), with the addition of Cuba, Equatorial Guinea, Macau, and Sao Tome and Principe, which are not in the original dataset.

Flow Measures of Resource Intensity: Share of Natural Resources in Total Exports, Share of Natural Resource Exports to GDP

Appendix 2: Minerals included in the composite measure of mineral abundance

Antimony
Barite
Aluminum
Bismuth
Boron
Chromium
Cobalt
Columbium
Copper
Industrial Diamond
Fluorspar
Gold
Graphite
Iodine
Iron
Lead
Lithium
Manganese
Mercury
Molybdenum
Nickel
Perlite
Phosphate Rock
Platinum Group Metals
Potash
Silver
Talc/Pyrophyllite
Tantalum
Tin
Titanium concentrate, Ilmanite
Titanium concentrate, Rutile
Tungsten
Vanadium
Zinc
Zirconium