THE PUNGENT SMELL OF RED HERRINGS:
Subsoil assets, rents, volatility and the resource curse
THE PUNGENT SMELL OF “RED HERRINGS”: Subsoil assets, rents, volatility and the resource curse

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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.
Abstract
Brunnschweiler and Bulte (2008) provide cross-country evidence that the resource curse is a “red herring” once one corrects for the endogeneity of natural resource exports and allows resource abundance to have an effect on growth. Their results show that resource exports are no longer significant while the value of subsoil assets has a significant positive effect on growth. But the measure of subsoil assets that has been used is based on World Bank estimates of natural capital, which are valued as proportional to current rents, and thus also endogenous. Furthermore, their results may suffer from omitted variables bias, weakness of the instruments, violation of exclusion restrictions and misspecification error. Correcting for these issues and instrumenting resource exports with values of proven reserves at the beginning of the sample period; there is no evidence for the resource curse either and subsoil assets are no longer significant. However, we provide evidence that resource dependence leads to more volatility and thus indirectly to worse growth prospects.

Keywords: resource curse, resource exports, resource rents, natural capital, subsoil assets, reserves, instrumental variables, volatility

JEL code: C12, C21, C82, F43, O11, O41, Q32

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1. Introduction

Brunnschweiler and Bulte (2008ab) argue that the well-documented resource curse originating from the pioneering cross-country study of Sachs and Warner (1997) is a “red herring”. This is quite a bold claim given the huge empirical literature in economics and political science on the potential adverse effects of natural resources on growth performance. Interestingly, they base their critique on the endogeneity of resource dependency, conventionally measured by natural resource exports. It is, after all, reasonable to conjecture that resource exports themselves may be affected by the growth rate of the economy. To overcome the problem, trade openness and a presidential system dummy are put forward as instruments for natural resource exports. Natural capital as estimated by World Bank (2006a) is used as a measure of the value of subsoil assets. Re-estimation then shows that resource dependence has no significant effect on growth whereas resource abundance, measured by the value of subsoil assets, has a significant positive effect on the growth rate of the economy. Hence, Brunnschweiler and Bulte (2008ab) conjecture in their influential study that the curse is a “red herring”.

However, examining in detail the data for the value of subsoil assets that they and various others have used to shed doubt on the resource curse, it becomes apparent that these data are proportional to current natural resource rents. Although the factor of proportionality varies with the ratio of reserves to current production, this is not the case for those resources for which reserves data are missing. World Bank (2006a) made the heroic assumption for their 1994 data that natural resources for which reserves data are missing, regardless of where they are, what type they are and what date it is, will last a further 20 years. For their 2000 data the World Bank even assumed all reserves last 20 years. This may make sense if one attempts to get a rough one-off cross-country estimate of natural capital and net adjusted saving, but using the resulting data as a cross-country or panel dataset of subsoil wealth seems hazardous. When one finds that the effect of resource exports on growth is insignificant and that of natural capital (i.e., the so-called value of subsoil assets) is positive and significant, one could also conclude that there is no curse as subsoil assets or possibly resource rents appears to boost growth.

To tackle the intricate issue of endogeneity of natural resource exports and the quality of institutions, Brunnschweiler and Bulte (2008a), from now on referred to as BB, instrument natural resource exports with average openness and a presidential system dummy and instrument the quality of institutions with latitude. Although BB include all exogenous variables in both stages of IV regressions for economic

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4 See also Mehlum et al. (2006), Boschini et al. (2007) and van der Ploeg and Poelhekke (2009ab) for empirical evidence on the natural resource curse.
5 A “red herring”, often used in mystery novels, diverts attention from the truth about, say, the identity of the guilty party. The “red herring” is a preserved fish with brownish color and pungent smell. One etymology is that it was used in the training of scent hounds and also to deflect attention from the smell of a fox or badger. Another (unlikely) reading is that escaped convicts would throw “red herrings” to confuse the dogs chasing them. (http://en.wikipedia.org/)
6 Brunnschweiler and Bulte (2009) also argue that the detrimental effect of natural resources on war and conflict established and further evaluated by Collier and Hoeffler (1998, 2004, 2005), Reynal-Querol (2002), Ross (2004), Ron(2005) and Fearon (2005) among others, is also a “red herring”.
7 Ding and Field (2005) and Alexeev and Conrad (2005) also find that, if natural resource abundance is used rather than natural resource dependence, a positive effect on growth is found. These studies also seem to appear to confuse natural resource abundance with natural resource rents.
growth in preliminary regressions instrumenting one endogenous variable at a time (presented in their Table 4), they omit several exogenous variables in the first stages of their more important robustness exercises when all endogenous variables are instrumented at once (presented in their Table 5). The latter generally yields inconsistent estimates. Openness and a presidential system dummy as (weak) instruments for natural resource exports give noisy estimates of resource exports and an insignificant coefficient on the predicted value of resource exports in the second stage. BB also use institutional quality in both the first- and the second-stage IV regressions, which leads to misspecification of the IV regressions if institutional quality is endogenous. Furthermore, weakness of the instruments leads to biased estimates (i.e., a bias towards the OLS estimates). Apart from these issues with appropriate use of instrumental variables, the second-stage regressions may suffer from omitted variables bias as average saving or investment rates, schooling, openness, and population growth do not feature in the second stage. The standard errors which they report for the second stage may be too small, so that natural resource exports may be more significant than is suggested. Furthermore, the value of subsoil assets is closely related to natural resource rents and is thus just as endogenous as natural resource exports. This begs the question why subsoil assets themselves are not instrumented and why resource rents are not used as a potential determinant of growth performance.

The objective of this comment is twofold. First, we inform the profession in detail about the World Bank (2006a) measures of natural capital and heed some warnings in which contexts they can be used and when not. To do this, we highlight the clever albeit heroic assumptions that have been made to calculate these path-breaking measures of natural capital. Second, we examine whether the resource curse really is a “red herring” and whether the value of subsoil assets is a blessing for growth as suggested by BB. We therefore re-estimate their IV regressions making sure to use the full range of exogenous variables, obey the exclusion restriction, avoid omitted variables bias in the second stage, and calculate the correct standard errors. We believe openness and a presidential system dummy are weak instruments for natural resource exports (or rents), hence we use not yet extracted reserves per capita measured in barrels, m3s or tons as an alternative instrument that should not have a direct effect on growth performance. Openness can then also be a potential determinant of economic growth in the second stage.

We argue on the basis of a careful examination of the dataset used by BB that the conventional resource curse is indeed a “red herring”. In line with BB, there seems to be no negative significant effect of resource exports on growth. Although there may be some evidence that resource rents have a positive effect on growth, we find that it is not robust. We also re-examine the evidence for the resource curse using actual subsoil reserves obtained from Norman (2009). Although these data are much more exogenous than data for natural capital, they relate to economically recoverable reserves and thus depend on the price of natural resources and the state of technology. Although they are not perfectly exogenous, it is still essentially random whether a country has resources in the ground and in the ground reserves should not affect growth directly. When we use this direct measure of reserves, we find no evidence for either a resource curse or blessing. However, if we use reserves to instrument for the

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8 Although BB claim that the results are robust to including some of these additional regressors it may still be the case that the results are inconsistent if these are also left out of the first stages.
endogeneity of resource exports, we are able to find a significant negative effect of volatility on growth and a significant positive effect of resource exports on volatility. Hence, under the proviso that even the reserves data are somewhat endogenous, we argue in line with van der Ploeg and Poelhekke (2009ab) that the evidence does not seem to contradict the hypothesis that the quintessence of the resource curse is the notorious volatility of commodity prices.

The outline of the remainder is as follows. Section 2 described in detail how the World Bank calculates its estimates of natural capital and the value of subsoil assets and demonstrates that these data are closely related to natural resource rents. Section 3 criticizes the use of the value of subsoil assets as an explanatory variable. Section 4 re-estimates the effect of resources on growth playing careful attention to the detailed econometric specification, using reserves as an instrument for resource exports and the value of subsoil assets, and also using data from the more recent Penn World Tables. The results are disappointing, since there is no evidence for a curse or a blessing of resource exports. However, the value of subsoil assets has no significant effect on growth either. Section 5 uses the same data and instrumental variables to explain growth of GDP per capita and volatility of unanticipated growth. We then find support that resource exports are associated with higher volatility and consequently lower growth. Section 5 concludes with some lessons from this tale of “red herrings”.

2. How is the World Bank measure of natural capital constructed?

As noted by World Bank (2006a, Appendix 1), there are three reasons why it is difficult to estimate the value of energy and mineral resources. First, the importance of the value of natural resources in national accounting has only recognized in the last decades, and most efforts to estimate these values are undertaken by international organizations (such as the UN or the World Bank) rather than by countries themselves. Second, there are no private markets for subsoil resource deposits which might convey information on the value of these reserves. Third, reserves are only those that are economically viable to extract or produce at the time of determination and therefore depend on the prevalent price of resources and cost of extraction. Nevertheless, World Bank (2006a) assigns dollar values to the stocks of hydrocarbon energy (oil, gas and coal) using the reserves data from the BP Statistical Review of World Energy and to the stocks of ten minerals and metals (bauxite, copper, gold, iron, ore, lead, nickel, phosphate rock, silver, tin and zinc) for those countries that have production figures.

For a particular country and resource, the value of assets is defined as the present value of rents:

\[
V_i \equiv \sum_{i=1}^{T_i-1} \pi_i q_i (1 + r^*)^{-t}.
\]

where \(\pi q_i\) denotes economic profit or rent at time \(i\) (with \(\pi\) denoting rent per unit of natural resource production and \(q_i\) production), \(r^*\) is the growth-corrected social discount rate, and \(T_i\) is the remaining lifetime of the resource measured from time \(t\) onwards. Since future rents are not known, World Bank (2006a) assumes that unit natural resource rents grow at the rate \(g \equiv \dot{\pi} / \pi = r / \left[ 1 + (\epsilon - 1)(1 + r)^T \right].\)
where $\varepsilon = 1.15$ is the elasticity of the cost function, as suggested by the ingenious study of Vincent (1997), and $r$ indicates the social rate of discount. Appendix 1 explains what assumptions are needed to arrive at this expression and how this relates to the issue of sustainability of natural resources. With a growth-corrected social discount rate equal to $r^* = (r-g)/(1+g)$, the value of resource wealth at any point of time is proportional to natural resource rents:

$$V_t = \pi_t q_t \left( \frac{1+r}{r-g} \right) \left[ 1 - \left( 1 + r^* \right)^{-T} \right].$$

The factor of proportionality is smaller if the remaining lifetime of the resource is less, the growth rate of natural resource rents is smaller and the social discount rate is bigger.

Lifetime years of a resource in a particular country can be calculated as the ratio of reserves to current production. World Bank (2006a, Appendix 1) reports median lifetime years for oil, gas, hard coal and soft coal of 17, 36, 122 and 192 years, respectively, and for bauxite, copper, gold, iron ore, lead, nickel, phosphate, tin, silver and zinc of 178, 38, 16, 133, 18, 27, 28, 22 and 17 years, respectively. With the exception of coal, bauxite and iron which are very abundant, the median reserves-to-production ratios are around 20 to 30 years. To overcome the practical problem of missing data for many resources, World Bank (2006a) takes a pragmatic approach and chooses for all those resources a smaller value of $T = 20$ for all resources and all countries despite lifetime years differing by resource, country and date. For example, no account is necessarily taken of the fact that a gold mine may have only 15 years left in 2000 and thus only 10 years left in 2005. And no allowance is made for the very large lifetimes of coal, bauxite and iron and for the specific circumstances of some countries and some resources. In defense, World Bank (2006a) argues that extending the lifetime beyond 20 years should not matter that much as future rents carry less weight being more heavily discounted. Furthermore, uncertainty increases with longer lifetimes and it may then be prudent not to weigh distant rents too much.

With a lifetime of 20 years and a social discount rate of $r = 0.04$, we have:

$$T = 20, \quad g = 0.03, \quad \frac{1+r}{r-g} = 104, \quad 1 + r^* = \frac{1+r}{1+g} = 1.0097, \quad V_t = 18.3 \pi_t q_t.$$  

The value of sub-soil assets for 2000 calculated by World Bank (2006a) is thus simply 18.3 times current natural resource rents.\(^9\) Fig. 1(a) indicates that this ratio is relatively constant as the time horizon of the resource is changed. It increases from 14 times natural resource rents for a lifetime of 15 years to 32.3 for a lifetime of 58 years, and thereafter the ratio of sub-soil asset value to current rents gradually declines to 26 (i.e., $(1+r)/r$). With a lifetime more relevant for coal or bauxite, say 175 years, we have a ratio of 26.2 (which seems unrealistically low). Doubling the life to 40 years increases the ratio of the value of subsoil assets to 31.9, which is less than double. With a longer lifespan of the resource, the costs of extraction rise substantially and therefore the growth rate of resource rents falls (and tapers off

\(^9\)World Bank (1997) calculates the value of subsoil assets for 1994 in a similar way using average resource rents for the period 1990-94 with again the assumption of a social discount rate of 4 percent per annum and a common lifetime of 20 years for all natural resources for which reserves and production data is missing.
to zero for extremely long lifetimes). Consequently, the growth-corrected social discount rate is higher which tends to reduce the value of sub-soil assets. The other effect is due to the truncation term \[ 1 - (1 + r^*)^{-T_t} \], which rises as the lifetime \( T_t \) increases. If the escalation-of-cost effect dominates the truncation effect, higher lifetimes lower the ratio of the value of subsoil assets to current rents. This occurs for \( T_t > 58 \).

We also see from Fig. 1(a) that the ratio of sub-soil asset value to current rents is quite sensitive to the choice of social discount rate; the ratio being higher for higher real rates of interest. Of course, the assumption of a common social discount rate of 4 percent for all countries is not realistic. The celebrated Keynes-Ramsey rule suggests to use a social discount rate given by \( r = \rho + \eta g_C \), where \( g_C \) denotes the growth rate of private consumption, \( \rho \) the pure rate of time preference, and \( \eta \) indicates the elasticity of the marginal utility of income (i.e., the coefficient of relative risk aversion or the inverse of the elasticity of intertemporal substitution). For example, with a pure rate of time preference of 2 percent, a coefficient of relative risk aversion of 2/3 and a growth rate of private consumption of 3 percent, the social discount rate is 4 percent per annum. More realistic might thus have been to give fast-growing developing economies a higher social discount rate and declining economies a lower social rate of discount, but that has not been done. For example, Vincent (1997) uses for fast-growing Malaysia a social discount rate of 10 percent per annum. Resource exporters typically experience disappointingly low long-run growth rates, which suggests that the line with long dashes is more realistic.

**Figure 1: Ratio of value of subsoil assets to current rents**

(a) Varying \( T_t \) and \( r \)  
(b) Varying \( T_t \) and \( \varepsilon \)

Fig. 1(b) illustrates that a smaller curvature of the cost function (lower \( \varepsilon \)) leads to a higher ratio of the value of subsoil assets to current rents across the whole range of lifetimes, but especially in the range 50-90 years.

The World Bank also provides detailed estimates of natural capital for timber resources, non-timber forest resources, cropland, pastureland and protected areas. Since most of the literature on the
resource curse is particularly interested in the potential harmful effect of appropriable or easily lootable (point-based) natural resources (e.g., Boschini, et al., 2007), we will focus here on the subcategory subsoil wealth of natural capital.

3. Can natural capital and subsoil assets really be viewed as truly exogenous variables?

We learn from section 2 and Appendix 1 that the measures of natural capital constructed by the World Bank are innovative in that they give novel insights into the magnitude of natural capital relative to human capital, physical capital, etc., but it is a large leap to use these measures as a cross-country or panel data set for the value of subsoil assets. These measures of natural capital assume the same social discount rate of 4 percent per annum regardless of whether a country is a fast- or a slow-growing economy. One may expect resource-rich fragile states with very low or even negative rates of growth to have a much lower discount rate and thus a higher ratio of subsoil wealth to resource rents. For fast-growing countries like China the ratio would be much lower. Furthermore, the 2000 measures of natural capital and the 1994 measures only for those cases where reserve data are missing assume the same remaining lifetime of the resource of 20 years and the same elasticity of the cost of extraction, regardless of the type of resource, the country concerned and the calendar date. Appendix 1 points out that the calculations of current rents in World Bank (2006a) are based on the possibly dated estimate of the cost function for Malaysian oil fields given in World Bank (1992) and used by Vincent (1997). In fact, these calculations are only an approximation and lead to an over-estimate of current marginal costs of extraction and thus to an under-estimate of current resource rents and reserves. The same curvature of the cost function and erroneous calculation is applied to all energy and mineral resources regardless of where the production takes place. It follows that, for those resources for which data are missing, the World Bank measures of natural capital are 18.3 times current resource rents, regardless of the type of the resource, the country concerned and the calendar date. Another assumption underlying the calculations of natural capital is that the price of natural resources is exogenous, so no allowance is made for market power. Due to these strong assumptions, measures of subsoil wealth are to all intents and purposes proportional or closely related to measures of current resource rents. Resource rents are just as endogenous as resource exports, and therefore these measures of subsoil wealth are just as endogenous. These measures of natural capital and subsoil assets can thus not be viewed as truly exogenous variables and should therefore also be instrumented.

We therefore re-examine the evidence for the resource curse using actual reserves data from Norman (2009). The index of reserves measures the 1970 value of 35 commodities using reserves data from a combination of reports by the US Geological Survey and the US Energy Information Agency.

10 Reserves

These are: 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 and zirconium.
are measured as the latest (2002) observed level of reserves\textsuperscript{11} plus total production during the years preceding the estimate of reserves to capture as closely as possible actual subsoil stocks, even if they are partly discovered in later years or only deemed profitably extractable in later years. This yields the broadest available measure of reserves. Taking only 1970 reserves would have underestimated actual and reasonably expected reserves and limited country coverage. Even though fast-growing countries may have relatively more reserves due to better discovery and extraction technology, it is still essentially random whether a country has resources in the ground. Furthermore, in the ground reserves should not affect growth directly. Although this measure is somewhat endogenous, we suspect it is much less so than resource rents or the World Bank measures of the value of subsoil assets.

4. Re-examining the natural resource curse with genuine data on subsoil assets

The data used by BB are described in Appendix 2. One problem with this influential study, as pointed out in detail in sections 2 and 3, is that their proposed measure of resource abundance, log subsoil 2000 taken from World Bank (2006a), is not exogenous. In any case, they do not use it as an exogenous instrument but as an additional exogenous regressor in the growth regression. They use average openness for the period 1950-60 and a presidential system dummy for 1970 as instruments for mineral exports and use latitude as an instrument for institutional quality (i.e., rule of law or government effectiveness). They also use the log of hydrocarbon reserves per capita for 1993 taken from Sala-i-Martin and Subramanian (2003)\textsuperscript{12} and also the log fuel and non-mineral fuel per-capita stocks taken from Norman (2009). If the latter data are the best reserves variable in the sense of suffering least from the problem of endogeneity, then their regressions 5 (reproduced as regression 1 in Table 2 below) and 6 of Table 5 are their best estimates. On the basis of these 3SLS estimates, it seems at first blush that it is possible to make the case that the resource curse is a “red herring” and that, if anything, non-mineral fuel per capita stocks have a positive effect on growth.

However, one can also make some econometric comments on these 3SLS estimates. First, the second-stage growth regressions appear to suffer from omitted variables bias because usual determinants of growth (average saving or investment rates, schooling, openness, or population growth) do not feature in these regressions. Openness could not be used as a determinant of growth, since it was already used as an instrument for mineral exports. This issue may be particularly troublesome for 3SLS estimation because 3SLS is very sensitive to the assumed exclusion restrictions in each equation. If only one is invalid (i.e. if initial income does affects rule of law) then all other parameters in each equation are generally inconsistent. We believe that the robustness of 2SLS estimation is more important for achieving consistent results than the possible efficiency gains of 3SLS in a cross-country growth setting. Second, the variable lgdp70, which is assumed to be exogenous in the second-stage growth regressions, is not included in the first-stage regressions. This omission will generally lead to inconsistent results due to correlation between the first stage error and the omitted variable. Third, their first-stage excluded F-

\textsuperscript{11} Including deposits considered worth extracting at current prices and extraction costs, and reserves that have potential to become economically available within planning horizons.

\textsuperscript{12} These are the log of total BTUs per person of proven crude oil and natural gas reserves in 1993 in WRI (1996).
test suggests that the instruments underidentify the instrumented variables, which leads to biased estimates (i.e., a bias towards the OLS estimates). Actual proven reserves rather than the value of subsoil wealth based on rents ought to be a good instrument for resource exports whereas it should not have a direct effect on growth performance. Fourth, the Shea’s partial R² is reported to be 0.43 which implies noisy first-stage estimates, leading to inflation of the second-stage standard errors by $0.43^{0.5} = 1.5$ (Shea, 1997). This may mean that the mineral exports variable \( \text{minxp7080s} \) is much more significant than is suggested. Fifth, institutions are a regressor in the second stage but are also included in the first-stage regressions for resource dependence. However, if institutions are endogenous and some assumed exclusion restrictions are violated, than the first-stage regressions for resource dependence are misspecified.

We therefore re-estimate the IV regressions with the following changes:

- To avoid misspecification, institutional quality and openness are not used as instruments in the first stage of the IV regressions as they are potential determinants of growth performance in the second stage. This also helps to avoid the pitfall of omitted variables bias in the second-stage IV regressions. We focus on 2SLS results, rather than 3SLS regressions. The latter are much less robust to misspecification of the first stages which we believe to be more important than any potential efficiency gains from 3SLS regression.

- To further avoid the problem of omitted variables bias, population growth, average saving or investment rates and schooling levels are added to institutional quality and initial GDP per capita as potential determinants of economic growth in the second-stage IV regressions.

- Resource exports (minxp) are instrumented with reserves, and a presidential system dummy. Institutional quality is still instrumented with latitude. To avoid inconsistent estimates, we also include all the other exogenous variables in the second stage (i.e., openness, \( \text{lgdp70} \), population growth, average investment rates and schooling levels. We thus project each of the potentially endogenous regressors on the full set of exogenous variables and use this as the regressor for the second stage. Additionally, we update the data with recent version (6.2) of the Penn World Tables.

As discussed at the end of section 3, reserves are measured at the beginning of the sample period in 1970 to avoid the problem of endogeneity of reserves. Table 2 reports the results of our IV regressions. Regressions 1 reproduce the 3SLS specification of BB, their Table 5, column 5, which has non-robust standard errors. This specification suggests an insignificant but positive effect of mineral exports on the growth rate of the economy, so that resources appear to be a blessing rather than a curse. 2SLS regressions 2 incorporate several of our suggested improvements to the specification. First of all, average natural resource exports between 1970 and 1989 (minxp) is replaced with resource exports in

13 For reasons of space and clarity, we only use rule of law as a proxy of institutions and not also government effectiveness.
1970 (natpoint70), and mineral abundance (lallminpc) as captured by the 1970 stock of reserves per capita is now used as an excluded instrument along with the presidential dummy (pres70s) and latitude. Moreover, we include several previously omitted variables such as the average investment intensity between 1970 and 2000 (invgdp7000), initial schooling (human70) and average population growth between 1970 and 2000 (gpop7000) and we let openness (open5060s) affect growth directly. Also rule of law in 1996 (rule) no longer enters the first stage for resource exports because it is endogenous. Even though the instruments are exogenous as may be gleaned from the high p-value of the Hansen J test statistic (which is robust to heteroskedasticity), we still see that the first stages are underidentified. The Cragg-Donald (1993) F-statistic is far below 10, which means that the IV estimates have a bias of over 30% towards the corresponding OLS coefficient (Stock and Yogo, 2005). Even the F-test by first stage on the excluded instruments are very small (unlike the Cragg-Donald statistic they are not robust to heteroskedasticity and do not take into account the correlation among instruments across the first stages) and suggest that especially latitude as an instrument for rule of law performs poorly. We therefore gain little from instrumenting, yielding the inconsistent result that resource exports have a weakly significant positive effect on growth.

### Table 2: IV estimates for the effect of natural resources on growth

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<td>(0.008)</td>
<td>(0.030)</td>
</tr>
<tr>
<td><strong>lallminpc</strong></td>
<td>0.016***</td>
<td>-0.026</td>
<td>-0.190</td>
<td>-0.015</td>
</tr>
<tr>
<td></td>
<td>(0.024)</td>
<td>(0.015)</td>
<td>(0.008)</td>
<td>(0.030)</td>
</tr>
<tr>
<td>('mineral abundance')</td>
<td>0.055</td>
<td>0.020***</td>
<td>-0.015</td>
<td>0.014***</td>
</tr>
<tr>
<td></td>
<td>(0.074)</td>
<td>(0.004)</td>
<td>(0.008)</td>
<td>(0.030)</td>
</tr>
<tr>
<td><strong>latitude</strong></td>
<td>2.071***</td>
<td>-0.006</td>
<td>-0.029</td>
<td>-0.009</td>
</tr>
<tr>
<td></td>
<td>(0.588)</td>
<td>(0.004)</td>
<td>(0.008)</td>
<td>(0.030)</td>
</tr>
<tr>
<td><strong>Constant</strong></td>
<td>0.791</td>
<td>0.090</td>
<td>-3.076**</td>
<td>24.575***</td>
</tr>
<tr>
<td></td>
<td>(15.786)</td>
<td>(0.135)</td>
<td>(24.872)</td>
<td>(0.135)</td>
</tr>
<tr>
<td><strong>Observations/Countries</strong></td>
<td>84</td>
<td>84</td>
<td>84</td>
<td>84</td>
</tr>
<tr>
<td><strong>R-squared</strong></td>
<td>0.582</td>
<td>0.51</td>
<td>0.87</td>
<td>0.952</td>
</tr>
<tr>
<td><strong>Hansen J overidentification</strong></td>
<td>0.526</td>
<td>0.596</td>
<td>0.607</td>
<td>0.607</td>
</tr>
</tbody>
</table>
In regressions 3 we additionally update the data to a more recent version of the Penn World Tables (6.2, from Heston et al., 2006) and replace initial resource exports with the average over 30 years (natpoint7000). For lack of a good instrument for rule of law, we replace rule of law in 1996 with rule of law in 1984 to limit reverse causality as much as possible. Latitude is consequently no longer included in the first stage for resource exports. The diagnostic statistics are now much more favorable. The instruments are exogenous according to the Hansen test and strongly predict resource exports as suggested by the Cragg-Donald statistics. Population growth is now also significant. However, resource exports do not significantly affect growth. The sign is negative, pointing in the direction of a curse, but the standard error is large.

Regressions 4 also look at subsoil assets (based on rents, from BB) as a measure of a country’s endowment of natural resources. This time we do not assume that it is endogenous for reasons explained before and instrument it with actual reserves. The model works rather well judging from the very good Cragg-Donald F statistic and the overidentification test. We can therefore safely conclude that subsoil assets have no effect on growth.

5. Volatility seems to be quintessence of the resource curse

Instrumenting mineral exports with reserves and correcting for omitted variable bias, we thus concur with BB that there is no evidence for a traditional version of the resource curse. However, we depart from BB in that we believe that there is no evidence for a direct positive and significant effect of the value of subsoil assets on the rate of economic growth either. Of course, the reserves data taken from Norman (2009) are also not immune to worries of endogeneity, but hopefully less so than if the value of subsoil assets would have been used as instruments. So the literature on the resource curse does appear to be full of “red herrings”. However, in van der Ploeg and Poelhekke (2009ab) we argue that there is support for an indirect effect of natural resources on growth via the volatility channel. To put this thesis to the test whilst allowing for the endogeneity of mineral resource exports, we estimate IV regressions for the average growth in GDP per capita over the sample period and the volatility of unanticipated output growth over the sample period. Using a dataset with $N$ countries and a sample period of $T$ years, we estimate the following three-equation econometric model for growth in GDP per capita:

$\begin{align*}
\text{GDP per capita} &= \beta_0 + \beta_1 \text{Volatility} + \beta_2 \text{Subsoil Assets} + \epsilon \\
\text{Volatility} &= \gamma_0 + \gamma_1 \text{Volatility} + \gamma_2 \text{Subsoil Assets} + \delta \\
\text{Subsoil Assets} &= \delta_0 + \delta_1 \text{Subsoil Assets} + \delta_2 \text{Volatility} + \zeta
\end{align*}$

14 The critical value above which the bias towards the OLS equivalent is less than 10% is for this case 19.93, and 11.59 for 15% bias (Stock and Yogo, 2005).

15 The critical value above which the bias is less than 10% is 19.93 for this case.
\[
\Delta \log(y_{it}) = \lambda \sigma_i + X_{i1970} \theta + Z_{i1970} \beta + \mu \hat{r}_{i1970} + \epsilon_{it}, \quad \epsilon_{it} \sim N(0, \sigma_i^2), \quad i = 1, \ldots, N, \quad t = 1, \ldots, T.
\]

\[
\sigma_i^2 = \exp(Z_{i1970} \gamma + \nu \hat{r}_{i1970} + c) \quad \text{and}
\]

\[
r_{i1970} = \xi a_{i1970} + \omega X_{i1970} + \chi Z_{i1970} + \theta_i, \quad \theta_i \sim N(0, \tau^2),
\]

where \(y_{it}\) is GDP per capita in country \(i\) for year \(t\), \(\sigma_i\) is the standard deviation for country \(i\) of the innovation terms \(\epsilon_{it}\), \(X_{i1970}\) is a vector of control variables for country \(i\) and year 1970, \(r_{i1970}\) is a measure of resource dependence (mineral resource exports) for country \(i\), and \(a_{i1970}\) is a measure of resource reserves (abundance). Equation (1a) explains growth output, equation (1b) explains volatility in unanticipated output growth, and equation (1c) is the first stage regression for resource dependence, where \(\hat{r}_{i1970}\) indicates the predicted instrumented values. The errors \(\epsilon_{it}\) are the deviations of growth from the predicted values based on the controls. Average volatility \(\sigma_i\) is assumed constant over time, but differs for each country depending on the initial country characteristics captured in \(Z_{i1970}\). We also allow for direct effects of these variables on growth (\(\beta\)). The error terms are assumed to be uncorrelated across countries, but we allow for correlation of the errors within countries over time. The parameters \(\lambda, \mu, \nu, c\) and the vectors \(\theta, \beta, \gamma, \omega, \chi\) are the coefficients assumed to be constant across countries. We estimate these coefficients by maximizing the corresponding log-likelihood function.

We thus extend Ramey and Ramey (1995) in two ways: explaining the volatility of unanticipated output growth with observable country characteristics; and instrumenting to allow for the endogeneity of natural resource exports. We also extend van der Ploeg and Poelhekke (2009ab) by instrumenting natural resource exports. The traditional view ignores the volatility channel and interprets a significant negative estimate of \(\mu\) as evidence for the natural resource curse. The evidence presented in section 2 based on BB suggests, in fact, that \(\mu\) is insignificantly different from zero and possibly even positive, which undermines the case for the traditional resource curse. However, the total effect of natural resource dependence on unanticipated output growth is given by the following expression

\[
d\Delta \log(y_{it}) / dr_{i1970} = \mu + \frac{1}{2} \lambda \nu \sigma_i.
\]

Hence, if resource dependence exerts a positive influence on volatility (positive \(\nu\)) and volatility exerts a negative influence on growth in unanticipated output (negative \(\lambda\)), there may be a resource curse even if \(\mu\) is positive provided that \(\lambda, \nu\) and \(\sigma_i\) are big enough. Note that our specification implies that a curse is more likely to occur in more volatile countries. The estimation results are reported in regressions 5-6 of Table 3. Interestingly, this seems to support the idea that there is a positive direct effect of the initial mineral resource exports on growth but also that there is a negative indirect of initial mineral resource exports on growth via volatility. The reason that we do not find a significant effect of mineral resource exports on growth in Table 2 may thus be due to omitting the adverse effect of volatility on growth.

Natural resource export intensity enters both the matrices \(X\) and \(Z\), but we assume that it is endogenous and therefore instrument it with actual abundance of reserves in 1970. Table 3 therefore reports a first
stage with lallminpc as the excluded instrument and a second stage according to equation (1). \textsuperscript{16} We did not use the presidential dummy as an instrument, because it had no predictive power for resource exports. Omitting it improves the first stage F-statistics even though we sacrifice the Hansen test because the model is just identified. However, from the previous regressions we feel confident that actual reserves are exogenous. We also exclude rule of law in 1984 because it was never significant and limits the sample. Instead we work with openness in 1970 (open70) and a measure of financial development (private credit as a percentage of GDP, findev70). We also control for one lag of per capita GDP growth (ld_gdppc) and a measure of barriers to trade as captured by remoteness (distance to the nearest coast or navigable river, distcr) and initial investment intensity (invgdp70). \textsuperscript{17} We let resource export intensity in point-source resources (such as metals, natpoint70) affect both GDP per capita growth and volatility. Diffuse resources (such as agriculture, natnonpoint70) may additionally affect output volatility. Also openness and financial development may have direct and indirect effects. See also van der Ploeg and Poelhekke (2009ab) for details and an extensive discussion of the specification. \textsuperscript{18} Descriptive statistics of the variables used in the regressions reported in Table 3 are presented in Appendix 3.

The results are surprising. First of all, resource exports have a direct positive effect on growth as shown by the 'mean equation' (1a) in regressions 5. However, we also find that volatility affects growth negatively, which itself is heavily increased by dependence on natural resource exports (as in equation 1b). The net effect of resource dependence actually predicts a negative effect of resource on growth! The idea is that volatile swings of world resource prices translate into severe shocks to GDP in countries that depend on natural resource exports. In van der Ploeg and Poelhekke (2009b) we show that the detrimental effect through volatility can be mitigated with better financial institutions and less limits to trade diversification. The diagnostic statistics of regressions 5 are not great, but even with a noisy first stage we still find significant instrumented effects on growth. In regressions 6 we use averages over time for resource and investment intensity instead of initial levels. In this case the Cragg-Donald F-statistic is more favorable. The direct positive effect of resources disappears. However, we still find that resources increase macroeconomic volatility which in turn has a detrimental effect on growth. These estimates allow us to fill in equation (2): \[
\frac{\partial \Delta \log (y_{it})}{\partial r_{70}} = 0.055 + 0.5 \times -0.388 \times 11.767 \times \sigma.
\] This implies that the net effect of resource dependence on growth is a curse for countries with growth volatility above 2.41%. This is the case for say Bolivia, but not for Norway with its strong institutions and financial

\textsuperscript{16} A complicating factor is that the predicted resource export intensity is a generated regressor (Pagan, 1984), which causes standard errors to be too small (although coefficients are consistently estimated). A common solution is to block bootstrap the standard errors, which re-samples every replication from within each cluster (each country) to allow errors to be correlated within countries, but independent between countries. Since it is very difficult to achieve convergence of the log-likelihood function for every replication, we use the fact that block bootstrapping is asymptotically equivalent to panel robust sandwich standard errors (Cameron and Trivedi, 2005). The latter correction of the standard errors is what we use. We can therefore directly interpret the results. 

\textsuperscript{17} Averages are taken between 1970 and 2003, since we have GDP per capita growth data up to and including 2003.

\textsuperscript{18} In van der Ploeg and Poelhekke (2009b) we also instrumented the investment share. This yielded smaller effects of investment intensity on growth but did not affect the other results.
development. Both average about 15% point-source resource dependence between 1970 and 2003. We therefore believe that a curse exists, be it indirectly, through volatility.

Table 3: IV estimates for the effect of natural resources on volatility and growth

<table>
<thead>
<tr>
<th>dependent variable: d_gdppc</th>
<th>(S)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st stage for:</td>
<td>2nd stage</td>
<td>1st stage for:</td>
</tr>
<tr>
<td>Mean equation:</td>
<td></td>
<td>\text{natpoint70}</td>
</tr>
<tr>
<td>\text{Resource dependence (point-source)}</td>
<td>0.122***</td>
<td>(0.036)</td>
</tr>
<tr>
<td>\text{ld_gdppc}</td>
<td>-0.019</td>
<td>0.224***</td>
</tr>
<tr>
<td>\text{invgdp70}</td>
<td>0.392**</td>
<td>-0.032**</td>
</tr>
<tr>
<td>\text{gpop7003}</td>
<td>-3.069</td>
<td>-0.518***</td>
</tr>
<tr>
<td>\text{ldgppc70}</td>
<td>0.025</td>
<td>-0.020***</td>
</tr>
<tr>
<td>\text{human70}</td>
<td>-0.014*</td>
<td>0.003***</td>
</tr>
<tr>
<td>\text{Volatility ((\sigma))}</td>
<td>0.769</td>
<td>-1.205**</td>
</tr>
<tr>
<td>\text{findev70}</td>
<td>-0.059</td>
<td>-0.014**</td>
</tr>
<tr>
<td>\text{open70}</td>
<td>-0.058*</td>
<td>-0.004</td>
</tr>
<tr>
<td>\text{Constant}</td>
<td>-0.048</td>
<td>0.239***</td>
</tr>
<tr>
<td>Instrument:</td>
<td></td>
<td>\text{lallminpc ('mineral abundance')}</td>
</tr>
<tr>
<td>\text{Variance equation:}</td>
<td></td>
<td></td>
</tr>
<tr>
<td>\text{Resource dependence (point-source)}</td>
<td>2.644***</td>
<td>(1.059)</td>
</tr>
<tr>
<td>\text{Resource dependence (diffuse)}</td>
<td>0.139</td>
<td>1.085*</td>
</tr>
<tr>
<td>\text{findev70}</td>
<td>-1.646***</td>
<td>(0.123)</td>
</tr>
<tr>
<td>\text{open70}</td>
<td>-0.717***</td>
<td>(0.101)</td>
</tr>
<tr>
<td>\text{distcr}</td>
<td>0.000</td>
<td>0.001***</td>
</tr>
<tr>
<td>\text{Constant}</td>
<td>-6.125***</td>
<td>(0.039)</td>
</tr>
<tr>
<td>Observations</td>
<td>2016</td>
<td>2016</td>
</tr>
<tr>
<td>Countries</td>
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<td>60</td>
</tr>
<tr>
<td>year dummies in mean eq.</td>
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<td>yes</td>
</tr>
<tr>
<td>R-squared</td>
<td>0.51</td>
<td></td>
</tr>
<tr>
<td>Log likelihood</td>
<td>2594</td>
<td>3759</td>
</tr>
</tbody>
</table>

\(^{19}\) Out of 68 countries in the sample of regression (6), only 19 (mostly OECD countries) have growth volatility below 2.41%.
6. Conclusion

The natural resource curse as first established by Sachs and Warner (1997) has rarely been questioned. Brunnschweiler and Bulte (2008ab) therefore deserve the credit for questioning the exogeneity of natural resource dependence and therefore questioning the validity of the curse itself. They find that, once resource dependence is instrumented with natural resource abundance, the curse as popularized by Sachs and Warner (1997) turns out to be a “red herring”; resource dependence has no significant effect on growth. Our comments on BB are directed at a better understanding of the data used to measure subsoil assets, the econometric methodology, and the specification of the resource curse.

The World Bank (1997, 2006a) estimates of natural capital need to be properly understood. They are a big leap forward, since for the first time they provide the profession with an estimate of the value of exhaustible and renewable resources to be used in conjunction with estimates of human capital and physical capital. These figures can be used to assess crucial sustainability issues, but care is necessary when they are used as regression variables in cross-country and panel studies. The reason is that the World Bank had to make many heroic assumptions to arrive at these figures. First, the same social discount rate of 4 percent per annum is used regardless of whether a country is a fast- or a slow-growing economy. But for a fast-growing country like China a higher interest rate may be more appropriate and thus the ratio of natural capital to rents would be lower. Second, for those resources for which data are missing, the same remaining lifetime of the resource of 20 years and the same elasticity of the cost of extraction, regardless of the type of resource, the country concerned and the calendar date, is used. The calculations of current rents are based on dated estimates of the cost function for Malaysian oil fields. Third, these calculations over-estimate current marginal costs of extraction and thus under-estimate current resource rents and reserves. Fourth, the price of natural resources is exogenous, so no allowance is made for market power.

Due to these strong assumptions, measures of subsoil wealth are closely related to current resource rents. Since resource rents are endogenous, these measures of subsoil wealth are endogenous. This means that the econometric tests using the World Bank estimates of natural capital data reported in Brunnschweiler and Bulte (2009ab) can be criticized as the used measures of subsoil assets are not truly exogenous and cannot be used as an instrument for resource exports. This is why we focus in our econometric tests on the specifications that use fuel and non-mineral fuel per-capita stocks from Norman (2009) as a more exogenous measure of resource abundance. They are not perfect, but may be the best and least exogenous we have at our disposal.
We improve on the econometric methodology of Brunnschweiler and Bulte (2009ab) by introducing important omitted variables such as schooling, investment and population growth in the growth equation, excluding institutional quality and openness as instruments as they are potential determinants of growth performance, including all the other exogenous variables in the set of instruments, and also using the latest version of the Penn World Tables. We concur with Brunnschweiler and Bulte (2009ab) that there is no evidence for a traditional resource curse and there may be even a small positive direct effect of resource dependence on growth. However, once we allow for the possibility that resource dependence boosts volatility and volatility harms growth while still instrumenting resource dependence with resource abundance, we find strong empirical evidence for an indirect curse operating through the volatility channel. The total effect of resource dependence on growth may thus be negative, especially in very volatile countries. Volatility thus appears to be the quintessence of the natural resource curse. Although the pungent smell of “red herrings” also affects the reserves data of Norman (2009), the endogeneity problem is less. We therefore conjecture that the traditional resource curse may be a “red herring”, but we cannot rule out the possibility that natural resources are an important driver of the volatility curse.

References


Appendix 1: Extraction costs and sustainability of natural resources

Here we sketch the ingenious arguments underlying the cost function approach adopted by Vincent (1997). The Hartwick rule ensures that a country can sustain a constant level of consumption by maintaining a constant total stock of capital, broadly defined to include physical capital, human capital, natural resource capital and environmental quality. Hartwick (1977, 1990) shows that this requires that a country needs to deplete a non-renewable resource at a rate equal to the so-called Hotelling rents \( \pi(t)q(t) \), where \( q(t) \) denotes the level of natural resource production, unit rents are defined by \( \pi(t) = \rho(t) - c'(q(t)) \) and \( c(q(t)) \) denotes the cost function for producing natural resources, all at time \( t \). Unit rents are thus equivalent to the exogenous price of natural resources minus marginal extraction cost. The required rate of depletion is thus less than total resource rents \( \rho(t)q(t) - c(q(t)) \). When resource extraction begins, marginal rent is low and Hotelling rents are relatively low compared to total rents. As
extraction continues, the logic of the Hotelling rule demands that marginal rents rise and thus that Hotelling rents grow more in line with total rents. Just before the resource becomes exhausted, Hotelling rents have reached total rents. Hartwick and Hagemann (1993) suggest a sinking-fund interpretation: investing the Hotelling rents in an interest-bearing account each year implies that, by the time the well or mine reaches exhaustion, there are sufficient funds to buy an equally valuable well or mine and sustain business. Over time, a growing proportion of resource rents need to be invested in the sinking fund as the time that is available to earn interest before exhaustion shrinks. If each period actual rents rather than Hotelling rents are consumed, the economy is no longer sustainable and will not be able to sustain a constant level of consumption.

Since data on marginal extraction costs and Hotelling rents are not available, Vincent (1997) converts total resource rents into Hotelling rents by using estimates of the elasticity of the marginal cost curve and the number of years before the well or mine is exhausted. He adopts an aggregate approach for a wide range of minerals in Malaysia produced at hundreds of sites with varying resource quality and extraction costs. Suppose extraction costs for producing \( q(t) \) barrels, m³s or tons of the resource are given by \( c(q(t)) = \Xi q(t)^\varepsilon \) with \( \varepsilon > 1 \) to ensure \( c''(q(t)) > 0 \). Since at the time of exhaustion \( T \) marginal cost \( \varepsilon \Xi q(T)^{\varepsilon-1} \) must equal average cost of extraction \( \Xi q(T)^{\varepsilon-1} \) in an optimal program, we must have \( q(T) = 0 \) and marginal rents at time \( T \) simply equal \( p \). Vincent (1997) applies Hotelling’s (1931) rule, namely that the rate of growth of marginal rents should equal the social rate of discount, to obtain the marginal rent at terminal date \( T \) as \( p = [p - c'(q(t))] (1+r)^{T-t} \) and thus marginal extraction cost at time \( t \) equals:

\[
\text{(A1)} \quad c'(q(t)) = p [1 - (1+r)^{(T-t)}] \quad \text{and} \quad c(q(t)) = c'(q(t))q(t)/\varepsilon.
\]

This expression for marginal extraction costs is not quite correct, since it erroneously assumes that resource production levels are constant for the remaining life of the resource (i.e., assumes \( q(s) = q(t) \) for \( t \leq s < T \) and \( q(T) = 0 \) whereas the logic of the Hotelling rule suggests that resource production levels and marginal extraction costs gradually diminish over the remaining life of the resource until they become zero at the date of exhaustion. The correct application of Hotelling’s rule gives the permanent value of marginal extraction costs at time \( t \) as:

\[
\text{(A1)'} \quad p(1-(1+r)^{(T-t)}) = c'(q(t)) \equiv (1+r)^{T-t} \sum_{s=t}^{T} c'(q(s))(1+r)^{-(s-t)} < c'(q(t)).
\]

The erroneous assumption used in Vincent (1997) and World Bank (2006a) thus leads, unfortunately, to an over-estimate of current marginal costs of extraction and thus to an under-estimate of current resource rents. Working with the approximation of Vincent (2007) and making use of the expressions in (A1), we see that the ratio of Hotelling rents to total rents can be written as:
where $S(t)$ denotes the stock of reserves in the ground at time $t$ and $S(t)/q(t)−1$ is a proxy for the remaining years of the resource. Note that $\Theta(T) = 1$. The value of $\varepsilon$ chosen by Vincent (1997) is 1.15, which comes from the development cost function for Malaysian oil fields reported in World Bank (1992).

Total development costs corresponding to an oil field of size $Z$ equals $c_0(Z) = 40Z^{0.85}$, so that the development costs of a marginal field are $c'_0(Z) = 34Z^{-0.15}$ and decline with the size of an oil field. If largest fields are put into production first, increases in production are associated with declining marginal field size and thus rising marginal development costs. Since operating costs do not vary with field size, the overall marginal cost elasticity equals the marginal development cost elasticity:

$$
(A4) \quad \varepsilon - 1 = \frac{dc'_0(Z)/dZ}{[q/c'_0(Z)]} = -0.15 \frac{dZ}{dq} \quad \frac{q}{Z} = 0.15 \quad \text{and} \quad \varepsilon = 1.15,
$$

where it has been assumed that $Z$ is inversely proportional to $q$ to capture the notion that the number of large fields is smaller than the number of smaller fields. It follows from expression (A2), Hotelling’s rule (marginal unit rents, $\pi(t) = p - c'(q(t))$) must grow at a rate equal to the social rate of discount), and the approximation $\ln(1+r) \equiv r$ that unit rents $\pi(t) = p - c'(q(t))/q(t) = \Theta(t) [p - c'(q(t))]$ must grow at the rate that is used in the calculations of natural capital in World Bank (2006a):

$$
(A4) \quad g(t) \equiv \pi(t)/\pi(t) = r - \Theta(t)/\Theta(t) = r / \left[1 + (\varepsilon - 1)(1 + r)^{(T-t)}\right].
$$

---

Appendix 2: Description of data

<table>
<thead>
<tr>
<th>Mnemonic</th>
<th>Description</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>minxp7080s</td>
<td>GDP share of total yearly mineral exports, defined as the sum of mineral fuels, ores and metal exports, averaged over 1970–1989. Fuels comprise SITC section 3 (mineral fuels); ores and metals comprise the commodities in SITC sections 27 (crude fertilizer, minerals not elsewhere specified (n.e.s.)), 28 (metalliferous ores, scrap), and 68 (non-ferrous metals). Data taken from Brunnschweiler and Bulte (2008)</td>
<td>World Development Indicators and PWT 6.1</td>
</tr>
<tr>
<td>lsubsoil_1994</td>
<td>Ln of subsoil assets, estimated in US$ per capita. The measures include energy resources (oil, natural gas, hard</td>
<td>World Bank (1997)</td>
</tr>
</tbody>
</table>
coal, lignite) and other mineral resources (bauxite, copper, iron, lead, nickel, phosphate, tin, zinc). Based on rents averaged between 1990 and 1994. T=20 only for those resources where reserves data was not available. Does not include gold and silver.

- **lsubsoil_2000**: as in lsubsoil_1994, but also includes gold and silver and refers to the year 2000 only. T=20 only for all resources and countries.

- **g7000**: Ln of growth of real GDP per capita between 1970 and 2000.


- **Latitude**: Absolute value of latitude of a country on a scale of 0–1.

- **lgdp70**: Ln of real GDP per capita in 1970.

- **open5060s**: Measure of trade openness (in nominal terms), defined as the sum of imports and exports over GDP. Average between 1950 and 1969.

- **pres70s**: Binary indicator for form of government, coded 1 if the chief executive is directly presidential or a strong president elected by an assembly. Coded 0 if parliamentary. Value for early 1970s.

- **rule 1996**: Measures the quality of contract enforcement, the police and the courts, as well as the likelihood of crime and violence in 1996. Recalibrated to assume values between 0 (worst) and 5 (best).

**Additional data:**

- **d_gdppc**: Annual Ln difference in real GDP per capita, Laspeyres

- **distcr**: Minimum distance in km to nearest navigable river or coast

- **findev**: Domestic credit to private sector (% of GDP)

- **gpop**: Ln difference in total population. Averages are taken by country across the given period

- **human**: Average schooling years in the population (age 25+)

- **invgdp**: Gross fixed capital formation as % of GDP. Averages are taken by country across the given period

- **ld_gdppc**: One year lag of annual Ln difference in real GDP per capita, Laspeyres

- **lgdppc**: Ln real GDP per capita in 1970.

- **natpoint**: F.o.b. value of exported fuels+ores&metals as a percentage of GDP. Averages are taken by country across the given period

- **natnonpoint**: idem, but foods and agricultural raw materials. Averages are taken by country across the given period

- **open**: dummy: open to trade = 1
<table>
<thead>
<tr>
<th>rule 1984</th>
<th>A country’s score on the law and order index in 1984 (first year available)</th>
</tr>
</thead>
</table>

Welch (2008)
### Appendix 3: Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>regression 5</th>
<th></th>
<th>regression 6</th>
<th></th>
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<tr>
<td></td>
<td>mean</td>
<td>sd</td>
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Countries (with * included in regression 6, but not in regression 5 due to data availability constraints): Algeria, Argentina, Australia, Austria, Belgium, Benin, Bolivia, Brazil, Cameroon, Canada, Central African Republic, Chile, Colombia, Congo, Rep., Costa Rica, Denmark, Dominican Republic*, Ecuador, Egypt, Arab Rep., El Salvador, Finland, France, Ghana, Greece, Guatemala, Honduras, Iceland*, India, Ireland, Israel, Italy, Jamaica*, Japan, Jordan, Kenya*, Korea, Rep., Malaysia, Mali, Mexico, Netherlands, New Zealand, Nicaragua, Niger, Norway, Pakistan, Panama, Paraguay*, Peru, Philippines, Portugal, Senegal, South Africa*, Spain, Sri Lanka, Sweden, Switzerland, Syrian Arab Republic*, Thailand, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda*, United Kingdom, United States, Uruguay, Venezuela, Zambia.
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