Candidate Number: 55480

EC599 / MRes Research Paper

Primary field: Macroeconomics

Title of Paper: Accounting for the Resource Curse

Word Count: 5,000 words

Supervisor: Professor Caselli

Accounting for the Resource Curse

May 29, 2008

Abstract: A substantial literature has found a robust negative correlation between economic growth and the share of income coming from resource exports, generally interpreted as a 'curse of natural resources'. I decompose aggregate growth into growth rates in the resource and non-resource sectors, and investigate how far the original correlation can be explained by other economic phenomena: (i) lower growth in the resource sector, (ii) reversion to the mean in resource extraction, and (iii) resource-funded capital accumulation. I conclude that only a small share of the resource curse is accounted for through these channels.

1 Introduction

Income from resource extraction - meaning here oil, gas, coal and minerals - is particularly interesting in the theory of growth because it can be thought to be in some weak way exogenous. Most wealth is grown through gradual accumulation of capital and productivity, but for some countries wealth has suddenly arrived due to discovering a mineral deposit, or an increase in resource prices. These episodes can be looked at to give an insight into the mechanics of growth. The most famous result in this literature is reported in Sachs and Warner (1995). Consider a country's per worker income as divided between resource (R) and non-resource (N) income:[1]

$$Y = R + N$$

Sachs and Warner found that higher resource dependence (R/Y) in 1970 was strongly associated with lower growth over the next 20 years, as shown in figure 1.[2]

The relationship survives, statistically significant and with similar magnitude, when controls are introduced for many other variables, when outliers are removed, and when alternative measures are used for resource dependence and

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[1] All variables will be per-worker, and measured in Penn World Tables 6.2 chain-weighted dollars, to match Sachs and Warner's methodology, unless otherwise mentioned.

[2] Sachs and Warner used resource exports, and include agricultural and food as resources, however the graph uses net rent income from non-renewable resources. A discussion of data sources appears in an appendix.

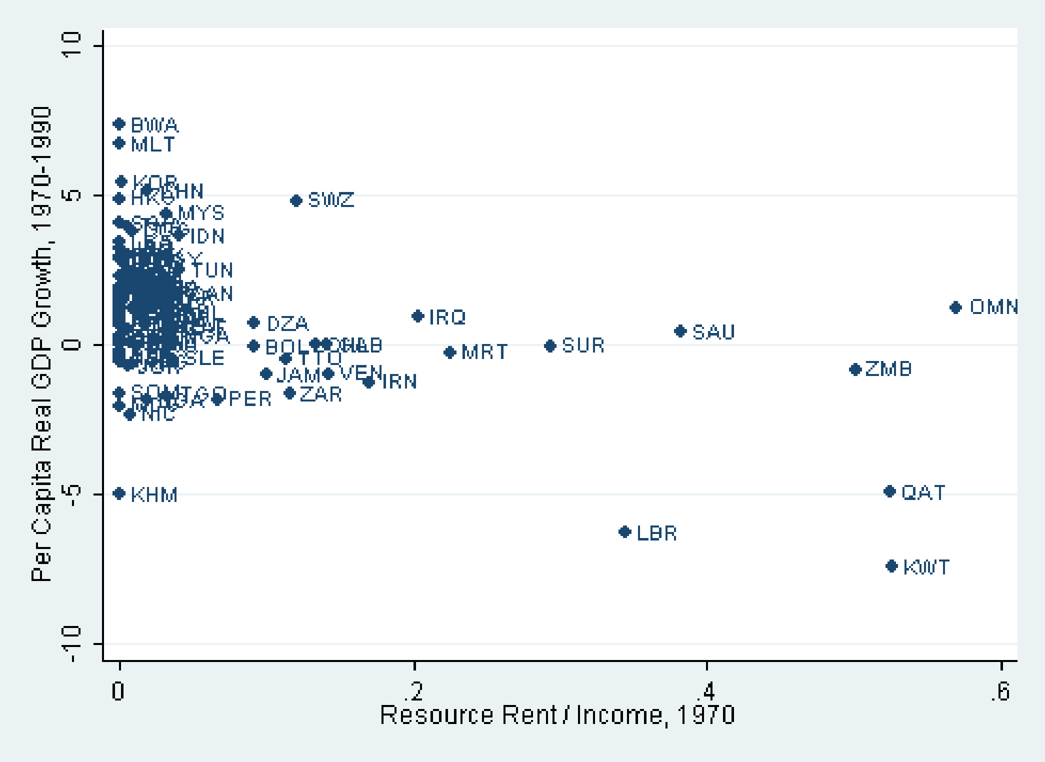

Figure 1: Resource Dependence and Growth

for growth. The relationship also holds outside the 1970-1990 time period, but not as strongly (as reported in Sachs (1995), Sachs (1997), and Sachs (2001)).

Given the evidence above, the standard interpretation has been that resource revenues have been somehow interrupting the process of growth, either through economic channels (e.g. currency over-valuation, volatility) or political channels (e.g. by funding autarky, or tying up entrepreneurial talent in rent-seeking).[3]

The estimated coefficient is typically around -10, meaning a country with 100% resource dependence would have an annual growth rate lowered by 10 percentage points. The magnitude of this effect is very large, too much to be explained by competitive crowding out through bidding up input prices. In fact, taken at face value, it implies that all but one of the countries in Sachs and Warner's sample would have been better off in 1990 had they entirely shut down their resource export sectors in 1970.[4]

Since the original paper of Sachs and Warner a number of other analyses

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[3] Some representative papers are: Krugman (1987) for currency over-valuation, and Hausmann and Rigobon (2003) for volatility. Ross (1999) and Caselli and Cunningham (2007) survey political economy explanations.

[4] To see this, first consider the equation for growth from 1970 to 1990 (Y and R without a subscript refer to 1970 values):

have appeared, claiming to solve or dissolve the puzzle. In this paper I separate out growth in the resource and non-resource sectors, to help discriminate between existing theories, and I calculate how much of the existing result can be explained by the dynamics of resource discovery.

The new explanation is composed of two propositions, with both theoretical and empirical justifications. First, that volumes of resource extracted exhibit reversion to the mean, due to the dynamics of resource discovery, so that high resource output is associated with low resource growth. Second, that resource production has a *positive* effect on the *level* of non-resource output through funding a larger capital stock (standard curse models predict a *negative* effect on the *growth* of non-resource output). Taken together these propositions predict that high resource dependence will be associated with low growth in both the resource and non-resource sectors.

Intuitively it means this: those countries which had high levels of rent per worker in 1970 (e.g. Kuwait, Libya, Zambia) were mostly countries which had recent fortuitous discoveries. Those discoveries also raised output in the non-resource sectors by funding investment. But because these countries did not make enough new discoveries to maintain significant growth in resource income, both rent and non-rent income have stagnated. Thus the correlation can be explained without any curse involved: in this model resource revenues have only beneficial effects.

Several papers have attempted to find the causal channels of the resource curse. Sachs and Warner (1997) try to account for different channels and say their variables can only account for around 1/3 of the effect, mainly through a negative effect on institutions. Murshed (2004) makes a stronger case for institutions, Papyrakis and Gerlagh (2004) argue for debt accumulation, Poelhekke (2007) argues for volatility as a transmission channel, and Gylfason (1999) argues against volatility as a transmission channel.

Another set of papers have tried to establish the conditions under which the resource curse occurs, by interacting resource dependence with other variables.

$$\begin{aligned} Y_{90} &= (1+g)^{20}Y \\ lnY_{90} &\simeq 20g + lnY \end{aligned}$$

Now construct GDP in 1990 (Y^*) under the assumption that the resource sector was entirely removed, which lowers initial GDP, but raises the growth rate ($\beta$is the effect that resource share has on growth):

$$\begin{aligned} Y^*_{90} &= (1+g-\beta\frac{R}{Y})^{20}(Y-R) \\ lnY^*_{90} &\simeq 20g - 20\beta\frac{R}{Y} + lnY + ln(1-\frac{R}{Y}) \end{aligned}$$

Comparing $Y_{90}$and Y^*_{90}, using $\beta = -0.1$, the wealth and growth effects are equal at a level of $\frac{R}{Y}$ around 80%. Only Oman had, at 89%, a resource share above this threshold. Finally, note that I have ignored any direct effect that GDP may have on growth (sometimes called the convergence coefficient), if I had included that then the growth effect of cutting off resource exports would be even stronger.

Murshed (2004), Boschini and Roine (2003) and Isham (2005) find that the effect is stronger for point-source resources than for diffuse resources. Arezki and van der Ploeg (2007), Boschini and Roine (2003), and Kolstad (2007) find the effect is stronger in countries with lower institutional quality.

An important weakness in Sachs and Warner's regression is that it uses a cross-section, so may be picking up unobserved effects correlated with resource dependence. A variety of fixed-effect panel studies have been performed, with some disagreement about how they should be specified. Manzano and Rigobon (2001) and Lederman and Maloney (2002) both find that the Sachs and Warner effect does not appear in first differences, using period sizes of 5 or 10 years. Collier and Goderis (2007) use an error-correction specification, to try to distinguish between short-run and long-run effects of resource income, and find a positive short-run effect but a negative long-run effect.

Finally, many papers have tried different right-hand side variables. The results have generally been that the association remains for different measures of resource *share* (Sachs and Warner (1997), Gylfason, Herbertsson & Zoega (1999), Stijns (2001)), but the effect does not appear either for measures of resource *reserves* or resource *production* (Stijns (2001), Brunnschweiller (2006), Brunnschweiller and Bulte (2006), Cerny and Filer (2007), but an exception is Norman (2005)). These results show that the resource curse relationship should be stated as "resource *dependent* countries have low growth," not as "resource *rich* countries have low growth."

An interpretation of these findings, advanced by Burnschweiller and Bulte (2006) and Cerny and Filer (2007), is that the original correlation occurs because some unobserved factor, e.g. institutional quality, causes long-term low growth in non-resource sectors. If resource income is distributed independently of this factor then these countries will have both low growth and a high resource share (just because the non-resource sector is smaller), without there being any real curse. Against this interpretation a few points could be made: it presupposes a negative relationship between wealth and growth, contrary to the convergence hypothesis; also, no proxy for institutional quality has been found to control for this connection, and it seems odd that resource dependence should be the best proxy that can be found for institutional weakness in the non-resource sector.

This paper's two main propositions are argued for, empirically and theoretically, in Sections 2 and 3 respectively. Section 4 combines the evidence and assesses how much of the initial correlation can be explained. The final section concludes.

2 Growth in Resource Extraction

Income growth can be decomposed into contributions from two sectors:

$$\begin{aligned} Y &= N + R \\ g_Y &= g_N(N/Y) + g_R(R/Y) \end{aligned}$$

$$= \quad g_N + (g_R - g_N)(R/Y)$$

The last line shows a mechanical accounting relationship between resource dependence (R/Y) and growth: even if the growth in the resource and non-resource sectors were unrelated to resource dependence, we may still expect a significant coefficient on resource dependence (R/Y) if the two sectors themselves have different average growth rates. Concretely, if resource output were stagnant, and non-resource output grew due to population and TFP growth, then resource-dependent countries would have lower overall growth rates just because the resource sector's low growth is dragging down average growth rates.

However the puzzle does remain once this bias is accounted for. In fact over the period under study (1970-1990) the countries for which data is available had per worker growth rates of 1.3% on average overall, but 1.7% in the resource sector, meaning that Sachs and Warner's regression result is if anything biased away from finding a curse. Therefore the cause of the curse relationship is not differences in sectoral growth rates between sectors, but within sectors; either g_N or g_R or both must be negatively correlated with resource share.

A better specification, if we are looking for the existence of a resource curse, is to use just growth in the non-resource sector as a left hand side variable. This was done in one section of Sachs and Warner's original paper, and in Manzano and Rigobon (2001); both find that the coefficient becomes smaller but remains significant.

Before proceeding to growth in the non-resource sector, which I do in the next section, it is worth looking at the relationship with growth in the resource sector. Growth in this sector has an even stronger negative relationship to resource dependence than aggregate growth has, with a coefficient around -12 (more details below). This fact is surprising as almost all theories of the curse treat resource income as exogenous.[5] Nevertheless a standard theory could be extended to incorporate this: the volatility or corruption which resources induce, and which causes slow non-resource growth, could also cause slow growth in resource output by making extraction less efficient.

However there is an alternative explanation: that the volume of resource extraction displays reversion to the mean, so that those with a higher stock tend to have a lower growth rate. A simple model of resource discovery generates this prediction, let S be the stock of resources, δ the rate of extraction, and D new discoveries, then:

$$\begin{aligned} S_{t+1} &= (1-\delta)S_t + D_t \\ E\frac{\triangle S_{t+1}}{S_t} &= -\delta + E\frac{D_t}{S_t} \end{aligned}$$

Here, if discoveries are independent of the existing stock (so that $E[D_t|S_t^{-1}] = E[D_t]$), then the growth rate of the stock is decreasing in the level of the stock,

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[5] An exception is Robinson et al. (2006), which models extraction path choices, but it is not clear what prediction it would have for this relationship.

which I call “reversion to the mean”. Note that the same holds for the flow (R) which has been assumed to be proportional to the stock. The question then turns on how the rate of discovery is related to the stock of resources: on the one hand it is implausible that discovery is entirely unrelated to stocks: Kuwait is more likely to discover a billion barrels of oil than is Switzerland; but it is also implausible that discovery is proportional to stocks, because the UK, Norway, and Australia all began producing significant quantities of oil in this period, but had near-zero production in 1970.

Reliable data on stocks and discoveries are not readily available, and the difficulty here is compounded because discovery should be interpreted as including a change in technology or resource price, which causes a known deposit to suddenly become viable to extract.[6]

However, looking at the dynamics of resource volume, there is strong evidence of reversion to the mean. Results are displayed in table 1, using a variety of techniques. All columns show the β coefficient and its t-statistic found when regressing the difference of a variable (1970-90) on its 1970 level, using this specification:

$$X_{90,i} - X_{70,i} = \alpha + \beta X_{70,i} + \epsilon_i$$

The first column uses logarithm of national output volume (different commodities may use different units, e.g. kilograms or tonnes). The second and third columns use log production per worker, and per square kilometre, respectively. The strongest effects appear for production per square kilometer, consistent with a model of random resource discovery.

These first three regressions are all sensitive to outliers with extreme growth rates, appearing when a country suddenly starts or stops extracting a resource. This can result in large standard errors and a few very influential observations. To deal with this problem I show, in the fifth column, results from regressing the change in production share on the level of production share, where share is defined as $R_i / \sum_j R_j$; again I find consistently negative coefficients, showing that countries with high production shares in 1970 tended to lose share over the next 20 years, and vice versa.[7]

A problem with the results discussed so far is that the mean-reversion could in fact itself be caused by a curse relationship: high output could cause high dependence, which causes low growth through some ’cursed’ channel. To rule out this interpretation I performed a regression with data across all resource types using country fixed effects, therefore exploiting only variation within countries,

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[6] Tsui (2005) does have data on oil discoveries.

[7] A negative bias could exist in these coefficients if missing data is more common in 1970 than in 1990; to avoid this in the resource production data I have dropped all countries which had zero or missing production estimates in 1970. A different way of dealing with the problem of influential observations is by using FGLS, regressing the variance of the growth on the level, and then using the results to weight the observations. Preliminary results using this method show only small changes in estimates.

and abstracting from the typical curse channels which operate at a national level (e.g., corruption, volatility, etc.). The specification is:

$$X_{90,i,j} - X_{70,i,j} \quad = \quad \alpha + \beta X_{70,i,j} + D_i + \epsilon_{i,j}$$

Results are shown in the last row of Table 1, they remain economically and statistically significant.

As an illustration of mean-reversion Figure 2 shows the evolution of market shares in the oil industry. Of the six large producers in 1970, all but one lost market share or, in other words, their production grew at a rate lower than that of global output.

In this section I have argued for the existence of mean-reversion in resource output, implications for the resource curse are taken up in Section 4.

Table 1: Reversion to the mean in resource production volumes, 1970-1990

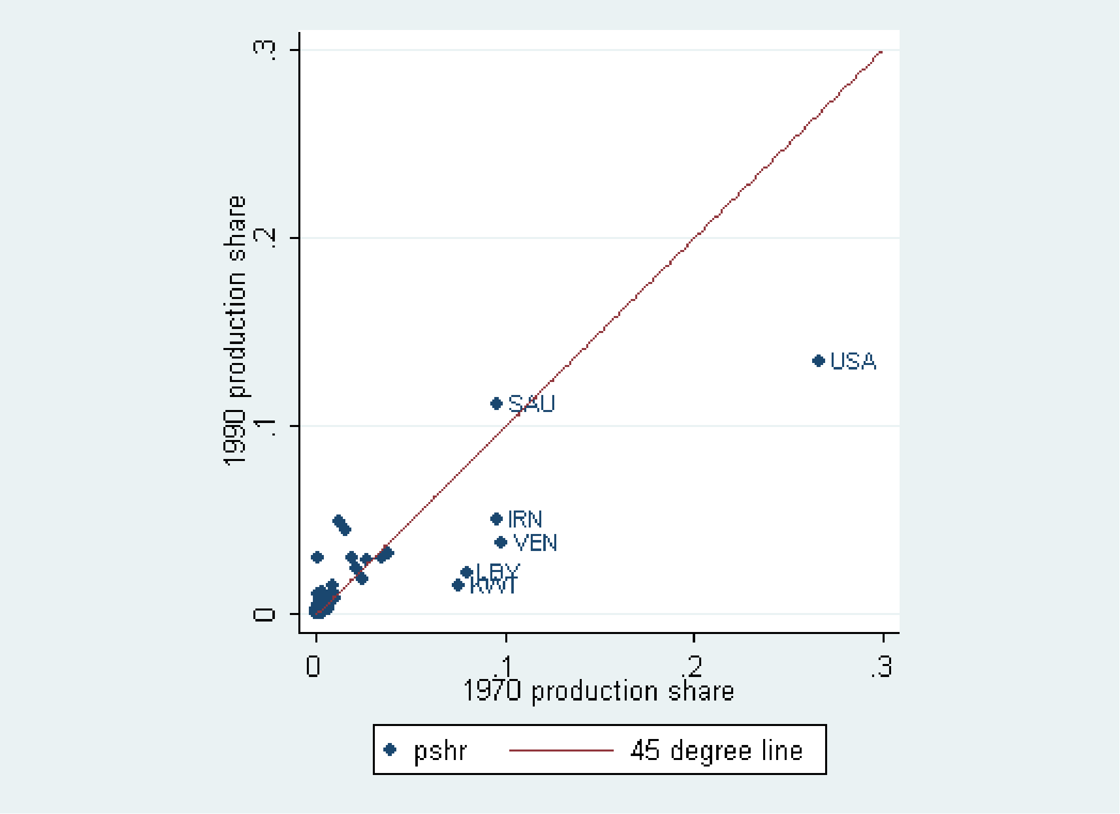
variable:	ln(production)	ln(production/worker)	ln(production/sq km)	production share	observations	1970 value (Bn$US)
bauxite	-0.17 (-1.40)	-0.15 (-1.56)	-0.21 (-1.98)*	-0.05 (-0.23)	30	1.4
copper	-0.18 (-1.61)	-0.20 (-1.78)	-0.28 (-2.14)*	-0.17 (-3.25)*	52	8.9
gas	-0.31 (-3.27)*	-0.30 (-3.45)*	-0.32 (-3.42)*	-0.39 (-22.59)*	60	17.2
gold	-0.20 (-2.11)*	-0.25 (-2.59)*	-0.31 (-3.35)*	-0.55 (-12.37)*	46	1.7
iron	-0.27 (-1.78)	-0.28 (-2.04)*	-0.59 (-4.28)*	0.01 (0.12)	58	4.3
nickel	-0.09 (-0.51)	0.07 (0.27)	0.07 (0.27)	-0.34 (-3.40)*	19	1.9
lead	-0.27 (-2.57)*	-0.27 (-2.86)*	-0.25 (-2.11)*	-0.01 (-0.08)	50	1.1
oil	-0.36 (-4.29)*	-0.38 (-5.19)*	-0.39 (-4.61)*	-0.37 (-7.04)*	57	18.0
phosphate	-0.14 (-1.00)	-0.13 (-1.79)	-0.10 (-1.42)	-0.25 (-4.26)*	24	0.9
silver	-0.30 (-2.51)*	-0.32 (-2.92)*	-0.47 (-4.20) *	-0.16 (-3.24)*	51	0.5
tin	-0.28 (-1.74)	-0.31 (-1.99)*	-0.28 (-2.01)*	-0.46 (-3.57)*	31	0.8
zinc	-0.19 (-1.62)	-0.21 (-2.07)*	-0.31 (-2.88)*	-0.19 (-2.65)*	47	1.7
hard coal	0.11 (1.24)	0.24 (1.69)	-0.09 (-0.75)	0.15 (1.34)	24	11.9
all rent	-0.13 (-1.22)	-0.29 (-2.77)*	-0.32 (-2.98)*	-0.64 (-13.81)*	69	70.9
fixed effects	-0.11 (-5.25)*	-0.11 (-5.23)*	-0.11 (-5.23)*	-0.36 (-8.54)*	432-550	

Each cell represents the coefficient from regressing the change in a variable on its lagged value. Each column represents a different variable.

Note: t statistics in parentheses, * significant at 5% level

Source: World Bank Adjusted Net Saving project, http://go.worldbank.org/3AWKN2ZOY0

Figure 2: Evolution of Oil Market Shares



3 Spillovers from resource extraction

So far we have treated the resource and non-resource sectors as independent. If there is some interdependence then mean-reversion in resource output can affect the evolution of non-resource output. In particular I will argue for a relationship of this form:

$$N = N_0 + \theta R$$

where N_0 can be considered autonomous non-resource output. If this relationship holds then growth in non-resource output will be related to growth in resource output, which could explain why high resource dependence (R/Y) is associated with low growth in the non-resource sector. I call the effect represented by θ a "spillover" for lack of a better word, but I do not restrict the effect to externalities, a better word might be "multiplier".

There are a number of reasons why θ might be expected to be positive. The most natural connection is through capital accumulation, treated below, but a resource sector could also have multiplier effects through other channels.

A force working in the opposite direction is through factor prices: a resource boom may bid up the price of labour and land, thereby lowering non-resource output (this is the basis of the Dutch disease explanation of the curse).

Determining empirically which effect dominates, and how large are the spillovers, is very difficult. A simple linear regression of non-rent income on rent income seems to support the hypothesis of a positive relationship, the coefficients are +0.77* for 1970, +0.63 for 1990, and +0.69* for differences between those two years.[8] These coefficients should be interpreted with care, because the causation may go in the opposite direction if developed economies are more likely to extract their resources, or if both resource and non-resource income are associated with geographical characteristics. Also it is difficult to account properly for the price level in resource-rich countries: resource exporters may have a high price level,[9] implying that non-resource output is overstated for these countries, so exaggerating the positive connection between resource income and non-resource income.

The Solow model can be used to find a simple estimate of the degree of spillovers through capital accumulation in steady state. Adding resource income (r) to the standard formulation, the equilibrium condition is:

$$s(r + k^{\alpha}) = (\delta + g + n)k$$

Where k is capital per effective unit of labour. The impact of a resource windfall is shown in Figure 3.

Differentiating the equilibrium condition gives an estimate for spillovers:

$$\begin{aligned} dy/dr &= 1 + \frac{dy}{dk}\frac{dk}{dr} \\ &= 1 - \frac{\alpha s k^{\alpha-1}}{\alpha s k^{\alpha-1} - \delta - g - n} \end{aligned}$$

Evaluating this expression with α=1/3, δ=0.05, n=0.03, g=0.02, s=1/5, and calculating steady-state k at r=0, the spillover coefficient is exactly 1/2. [10]

Finally, the time horizon considered is important. The argument above, for a level effect, assumes a Solow steady-state, and ignores convergence dynamics.

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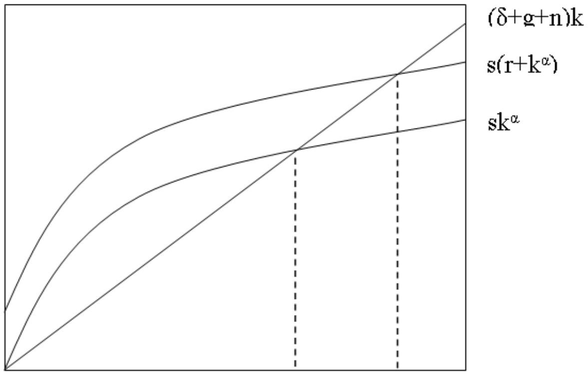
[8] I use * to signify significance at the 5% level. Using investment as a dependent variable in the same regressions finds coefficients of 0.32*, 0.23, and 0.32*, respectively.

[9] Note that the empirical relationship between resource dependence and price level does not seems strong. Sachs and Warner (2001) find a positive relationship, but they control for non-resource income, instead of total income, so that the positive effect could be purely from the fact that resource income is income, not that it is from resources. When controlling for total income I find an insignificant and negative relationship. Migration may be an important force keeping the price level down: there is a positive relationship between migration and resource dependence for every 5-year period between 1970 and 1995 (the World Bank only provides migration data for 5-year periods).

[10] This analysis assumes that resource income per effective unit of labour is constant; equivalently, that resource prices grow at about the rate of population plus productivity growth..

Figure 3: Resource windfall in Solow model



At a convergence rate of 4% only half the distance between initial capital and steady-state capital will be covered in 20 years.

In sum, it is difficult to establish an uncontroversial estimate for the magnitude of a spillover effect in this data. I proceed treating θ as an unknown variable.

4 Accounting for the Resource Curse

Finally I now consider whether the two assumptions – reversion to the mean and resource spillovers – could generate a curse-like relationship with a magnitude comparable to those found in the data; and whether a regression specified according to this theory fits the data better than the standard resource curse regressions. The results are all summarised in Table 2.

Column (1) shows the results of a standard resource curse regression, controlling just for GDP per worker. The coefficient, of -9, is similar to those found in Sachs and Warner's regressions. Columns (2) and (3) show the regression run separately for growth in resource and non-resource income, showing that resource dependence has a stronger negative relationship to growth in the resource sector (-13 versus -5).

First I confirm that the magnitude of mean-reversion is large enough to explain the curse relationship in resource growth. I have a few estimates for the magnitude of mean-reversion (expressed as a relationship between g_R and lnR): the safest is probably the fixed-effects regression reported above, at -0.6;[11] the median value across commodities is -1.3; and the value from a regression using total resource revenue (in column (4) below) finds a coefficient of -1.1.

The relationship between R/Y and lnR, holding N constant, is:

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[11] To express the 20-year difference in log-levels (reported in Table 1) as a growth rate, I divide by 20.

$$
\begin{aligned}
\frac{d\frac{R}{N+R}}{dlnR} &= (\frac{1}{N+R} - \frac{R}{(N+R)^2})R \\
&\simeq \frac{R}{N+R} = \frac{R}{Y}
\end{aligned}
$$

Where the second term in the first line is small if N > > R. The average 1970 value of R/Y in our dataset is 0.05, so I expect a relationship between between the two variables to be of that order. Regressing 1970 values of R/Y on lnR also finds a coefficient of 0.05. Putting these two relationships together, we can generate a predicted relationship between $g_R$and R/Y:

$$
\begin{aligned}
\frac{dg_R}{dR/Y} &= \frac{dg_R}{dlnR}\frac{dlnR}{dR/Y} \\
&\simeq -0.6\frac{1}{0.05} \\
&\simeq -12
\end{aligned}
$$

This calculation shows that mean-reversion predicts a resource curse relationship on the order of magnitude of -12. The actual coefficient, reported in column (2) below, is -13.

To confirm the causal link I regress g_R on both lnR and R/Y, the results are reported in column (4) below: neither variable is statistically significant, however the coefficient on lnR is of the expected magnitude, whereas the coefficent on R/Y shrinks to -1, and the t-statistic becomes very small. I interpret these results as supporting the hypothesis that the 'curse' relationship in resource growth is largely explained by reversion to the mean in resource volumes.

Next we move on to growth in the non-resource sector. Expressions for growth in this sector are more complicated, and I have not yet been able to find an entirely satisfactory way of testing the theory. Making the assumption about spillovers as above ($N = N_0 + \theta R$), non-resource growth can be expressed as:

$$
\begin{aligned}
g_N &= g_{N_0}(1 - \frac{\theta R}{N}) + g_R\frac{\theta R}{N} \\
&= g_{N_0} - \theta g_{N_0}\frac{R}{N} + \theta g_R\frac{R}{N}
\end{aligned}
$$

In this equation the initial level of resources, R, affects the non-resource growth rate in two different ways: first, by changing the weighting in the averaging between g_{N_0} and g_R; second, by lowering g_R through the reversion-to-mean effect. There is no obvious way to re-arrange this equation to make it linear in any expression composed only of known variables. The expression can be written as:

$$
g_N = g_{N_0} + \theta\frac{R}{N}(g_R - g_{N_0})
$$

Table 2: Growth Regressions, 1970-1990

	(1) g_Y	(2) g_R	(3) g_N	(4) g_R	(5) g_N
ln(Y)	0.06 (0.30)	-2.08 (1.65)	0.01 (0.03)	-1.22 (0.82)	-0.35 (1.39)
R/Y	-9.18 (5.25)**	-12.86 (1.41)	-5.46 (2.97)**	-1.09 (0.08)	-3.51 (1.35)
ln(R)				-1.11 (1.09)	
$\frac{R}{N}(g_R - 1)$					0.09 (0.57)
constant	1.01 (0.60)	21.37 (1.92)	1.21 (0.70)	18.26 (1.59)	4.32 (1.94)
observations	111	69	110	69	69
R^2	0.21	0.10	0.08	0.11	0.17

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%
All variables are per economically active person.

Assuming that $g_{N_0} = 1$ (the average value of g_N in this time period), and using the realised values of g_R, a linear regression can be performed, and is reported in column (5). The spillover coefficient (θ) is estimated at 9%, but the coefficient on resource dependence (R/Y) remains negative and economically, if not statistically, significant. I tentatively conclude from this that spillovers from reversion to the mean in resource extraction can not account for much of the association between resource dependence and growth, but I think that a more satisfactory means of testing the predictions should be possible.

5 Conclusion

This paper examined three hypotheses which could help explain the negative correlation between R/Y and g_Y: differential growth rates across sectors; reversion to the mean in resource production; and spillovers from resource growth to non-resource growth.

Average growth in resource and non-resource sectors was similar in the period under study, so between-sector differences in growth rates cannot explain the curse relationship.

Reversion to the mean in resource production seems to be an important and reliable characteristic of resource dynamics, and it appears that the relationship between resource growth and resource share is explained by this reversion

However the curse relationship also holds between R/Y and g_N, and mean-reversion by itself cannot itself explain this connection.

Adding spillovers from the resource to non-resource sector could theoretically explain this relationship; however when attempting to control for these spillovers, the strong connection between resource dependence and non-resource growth remained.

There are a number of natural extensions to this work.

Most importantly, the final step, properly testing the implications of mean-reversion for non-resource and aggregate growth, has not been satisfactorily addressed. Perhaps a nonlinear specification should be used for estimation of the unknown parameters.

Reversion to the mean in resource output could be more thoroughly investigated. A model of the aggregation of mean-reverting processes would help to check whether it is reasonable to infer mean-reversion in total resource income from average mean-reversion among volumes of resource output. Properly accounting for resource composition, price changes, and cost changes, should shed light on this. A more careful handling of price deflators would be desirable, as discussed earlier.

Finally, the regression results should be tested for robustness to the use of alternative datasets (e.g., resource exports, or gross revenue), and to the use of panel data with country fixed effects.

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Appendix: Data Sources

The dataset for Sachs and Warner's 1997 article contains a cross-section of countries, mainly put together from World Bank and Penn World Tables data, but supplemented with other data sources and some specific adjustments. In order to run some variant regressions I have constructed a new dataset, again using WDI and PWT data. I am not able to reproduce exactly their cross-section, but the regression results are very similar.

As a measure of "resource intensity," Sachs and Warner use the primary resource exports as a fraction of GNP. I prefer an alternative measure: resource rents as a fraction of GNP, as calculated in the World Bank's "Adjusted Net Savings" project (sometimes called "Genuine Savings"). The rent is calculated by multiplying the volume of resource extracted with the difference between the world price and the country's average extraction cost. Separate rent estimates are calculated for each of a variety of energy and mineral resources,[12] and summed to calculate the total rent.

I prefer rent-share over export-share for a number of reasons: first, in the standard Sachs & Warner growth regression, rent-share and export-share both get similar coefficients, but rent-share has a higher t-statistic (5.2 versus 5.0), and when both are included in a regression only rent-share remains statistically significant; second, rent-share has broader coverage (5700 versus 3500 observations for 1970-2006); third, rent-share picks out the variable of interest for most resource curse theories, whereas export-share is an imperfect measure of rents because it does not account for extraction costs, re-exporting, and domestic consumption.[13] One important difference is that rent-share has many more zero observations, in some cases because of the narrower scope, but also in some cases because of rounding error (the data is recorded as a percentage of GDP, to only two significant digits).

Variable definitions:

R: resource rent per working-age person, in PWT PPP dollars, using (i) resource rent as a share of GNP in US dollars, from the WDI; (ii) chained real GDP from PWT; (iii) population from the PWT; (iv) proportion of population that is between 15 and 64, from the WDI

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[12] Oil, gas, hard coal, soft coal, bauxite, copper, iron, lead, nickel, phosphate, tin, zinc, gold, and silver.

[13] Rent-share has a correlation of 71% with export-share over the whole sample, and it has a correlation of 87% with export share calculated with just fuel and ore exports.

N: non-resource income per working-age person, calculated as for R, but using the share of GNP not accounted for by resource rent.

Growth rates are everywhere calculated as differences in logarithms.

6 Appendix: Scatter Plots

[19, 21, 22, 20, 14, 16, 17, 9, 1, 10, 13, 12, 7, 24, 6, 2, 4, 15, 3, 23] [25, 8, 5][11, 18]

Figure 4: Some Illustrative Scatter Plots