Natural Resources and Economic Growth: The Role of Investment

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Abstract

Is it possible that excessive reliance on natural resources affects saving and investment in a way that retards economic growth? – and thus, in the long run, the level of output per capita. This paper reviews the literature, explores the data and compares and contrasts the explanatory power and interplay of natural resources and civil liberties, our proxy for institutional variables currently under scrutiny in the literature. We propose that natural resource dependence may be viewed as an exogenous factor that impedes economic growth and investment as well as institutions, even if we stress that natural resource abundance may be good for growth.

Natural resources are an important source of national wealth around the world. Yet, experience shows that natural riches are neither necessary nor sufficient for economic prosperity and progress. Among the world's richest countries are Hong Kong, Japan, Luxembourg, Singapore and Switzerland, and they clearly do not owe their national wealth to nature. In this paper we maintain that relying too heavily on natural resources may reduce saving, investment and growth, thereby lowering the level of consumption and output per capita in the long run.

Among developing countries, natural resources are in many cases prevalent. This may to some extent reflect their underdevelopment: the modest size of the modern sector of the economy makes agriculture and other natural-resource-based economic activity relatively important. But there are also examples of countries that are genuinely rich in terms of natural resources but still have not been able to sustain economic growth while other countries, similarly endowed, have succeeded. Take Botswana and Sierra Leone, both of which produce diamonds for export. By and large, Botswana has managed the revenue and rent stream from its main natural

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resource in ways that have contributed to impressive economic growth since independence in 1966 – in fact, the world's highest recorded rate of growth of gross national product (GNP) per capita from 1965 to 1998, even if it slowed down after 1990. Meanwhile, Sierra Leone has remained mired in poverty, ravaged by crippling internal warfare as local warlords have continued to fight for control over the diamond trade (Olsson, 2006). Sierra Leone was the world's poorest country in 1998 according to the World Bank (2000).

In our thesis, natural resources are an essentially exogenous factor that can hamper economic growth through macroeconomic channels as well as through institutions. This hypothesis differs from that of, among others, Acemoglu, Johnson and Robinson (2001) who proposed that living conditions in colonial times dictated whether Europeans decided to settle down in the colonies and bring in European institutions. According to this alternative hypothesis, economic performance depends on current institutions, which depend on past institutions, which in turn depend on living conditions – e.g., settler mortality – in colonial times. Acemoglu, Johnson and Robinson (2001) claim that once institutions are accounted for there is no room left for other explanations of economic growth having to do with economic policy or geography (Sachs, 2003). In contrast, we argue that dependence on natural resources today affects current institutions as well as macroeconomic outcomes.

1. Preview

Table 1 is representative of the empirical findings on natural resources and growth that have emerged from some recent studies, beginning with Sachs and Warner (1995). The table covers 85 countries, and shows economic growth per capita from 1965 to 1998 and natural resource dependence as measured by the share of natural capital in national wealth in 1994 – i.e., the share of natural capital in total capital, which comprises physical, human and natural capital (but not social capital; see World Bank, 1997).[1] The growth rate has been adjusted for initial income.[2] The table

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[1] The natural capital variable used here is close to the source: it is intended to come closer to a direct measurement of the intensity of natural resources across countries than the various proxies that have been used in earlier studies, mainly the share of primary (i.e., nonmanufacturing) exports in total exports or in gross domestic product (GDP) and the share of the primary sector in employment or the labor force. Alas, 1994 is the only year for which the World Bank has as yet produced data on natural capital, for 92 countries. In most cases, however, the share of natural capital in national wealth in 1994 is probably a pretty good proxy for natural resource dependence in the period under review, 1965-1998.

indicates that good growth performance appears incompatible with a share of natural resources in excess of 15 percent of national wealth.[3] More generally, the countries in our sample appear to be concentrated on the diagonal linking the southwest and northeast corners of the table (the correlation between the two variables is -0.62). There are also quite a few countries above the diagonal, with slow economic growth and a small endowment of natural resources, including several countries in Central and South America and the Caribbean. Perhaps more interestingly, we detect two distinct groups of countries. The first group consists of eight African countries (Central African Republic, Chad, Guinea-Bissau, Madagascar, Mali, Niger, Sierra Leone and Zambia), all of which depend on natural resources, with natural capital constituting more than a quarter of their national wealth, and have experienced negative per capita growth since 1965. The other group also has eight mostly Asian countries that are relatively independent of their natural resources by our measure, but whose economies have grown rapidly since 1965 (Botswana[4], China, Indonesia, Japan, Korea, Malaysia, Mauritius and Thailand). The remaining 69 countries in our sample fall between the two extremes. All our data are presented in Appendix B.

A question now arises: What makes the eight high-performance economies in the second group different from the eight African laggards in the first? As an empirical matter, a key factor that distinguishes the two groups is saving and investment. Specifically, the group of natural-resource-dependent, slow-growth countries shown in the southwest corner of Table 1 has an average gross saving rate of only 5 percent of GDP, ranging from -2 percent in Guinea-Bissau to 19 percent in Zambia, whereas the natural-resource-free, high-growth group shown in the northeast corner has an

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There are exceptions, true, such as Malaysia, Mauritius and Mexico, where the share of primary exports in merchandise exports decreased dramatically from 1965 to 1998 as a result of economic diversification away from primary production. Even so, all the empirical results reported in this paper can be reproduced without significant deviations by using the average primary export share during 1965-1998 rather than the natural capital share in 1994 as a proxy for natural resource dependence, and also by measuring growth in terms of GNP per worker rather than GNP per capita.

[2] By growth adjusted for initial income is meant that part of economic growth that is not explained by the country's initial stage of development, obtained from a regression of growth during 1965-1998 on initial GNP per capita (i.e., in 1965) as well as natural capital.

[3] The reason why there are 85 countries in the sample and not 92 is that (a) for six countries for which estimates of natural capital exist, there are missing data on either economic growth since 1965 (Bolivia, Germany, Tanzania, Uganda and Vietnam) or civil liberties (Namibia) and (b) Saudi-Arabia is omitted because of extreme fluctuations in its recorded average rate of economic growth over the period under review. With the exception of Saudi-Arabia, no outliers are excluded from the analysis, so that the sample size remains the same, 85, throughout the paper.

[4] Botswana's natural capital share is small as shown in Table 1 because the World Bank does not provide an estimate of the country's diamond rent.

average gross saving rate of 32 percent, with individual observations clustered in the range between 28 and 35 percent. A similar pattern emerges when we replace gross domestic saving with gross domestic investment. In this case, the group of natural-resource-dependent, slow-growth countries has an average gross investment rate of 14 percent, ranging from 7 percent in Chad to 29 percent in Guinea-Bissau, whereas the natural-resource-free, high-growth group has an average gross investment rate of 28 percent, with individual observations clustered in the range between 26 and 31 percent. Hence our focus is on saving and investment plus institutions in this paper.

Table 1. Natural resource dependence and economic growth

	Growth of GNP per capita per year 1965-1998, adjusted for initial income (%)						
Share of natural capital in national wealth (%)	≤ -3%	-3%< ≤-2%	-2%< ≤ -1%	-1%< ≤ 0%	0%< ≤ 1%	1%< ≤ 2%	3%<
≤ 5%	Jordan	El Salvador South Africa	Guatemala Morocco	Lesotho Netherlands Switzerland Turkey U.K. U.S.	Austria Belgium Denmark Egypt France Greece Italy Portugal Spain	Japan Mauritius	Korea
5% < ≤10%	Benin Ghana Haiti	Honduras Jamaica Kenya Peru Zimbabwe	Argentina Costa Rica Panama Philippines	Brazil Chile Colombia Dominican Rep. Mexico Pakistan Sri Lanka Sweden Trinidad, Tobago Tunisia	Finland Ireland Norway	Malaysia Thailand	Botswana China
10% < ≤ 15%	Nicaragua Malawi Mozambique	Congo The Gambia	Bangladesh Uruguay	Australia Paraguay	Canada	Indonesia	
15% < ≤ 20%	Côte d'Ivoire Senegal Togo Venezuela	Burkina Faso Burundi Nepal Papua New Guinea	Ecuador New Zealand	India			
20%< ≤ 25%	Mauritania Rwanda	Cameroon					
25%< ≤ 30%	Sierra Leone						
30%<	Central African Rep. Chad Guinea Bissau Madagascar Mali Niger Zambia						

Table 2 shows per capita growth in the same 85 countries as before and their natural resource abundance as measured by the amount of natural capital per person in 1994; natural capital is defined as in Table 1. Table 2 suggests a tendency for resource-poor countries to grow slowly and thus to cluster in the northwest corner of the table. Even so, there is no clear sign here of a direct relationship between resource abundance and growth (the correlation between the two variables is 0.14). Together, Tables 1 and 2 seem to suggest that natural resource dependence may be inversely related to economic growth, for various reasons that will be discussed below, even if natural resource abundance *per se* may be good for growth. There is no inconsistency involved if, for example, the abundant natural resources are managed so as to encourage diversification away from excessive dependence on them. This paper aims to look at this possibility as well as the role of investment and institutions in the cross-country relationship between natural resources and economic growth.

Table 2. Natural resource abundance and economic growth

Growth of GNP per capita per year 1965-1998, adjusted for initial income (%)

Natural capital per person ($ thousands)	≤ -3%	-3%< ≤-2%	-2%< ≤ -1%	-1%< ≤ 0%	0%< ≤ 1%	1%< ≤ 2%	3%<
≤ 5	Benin Côte D'Ivoire Ghana Haiti Jordan Malawi Mali Mozambique Nicaragua Rwanda Sierra Leone Togo	Bangladesh Burkina Faso Burundi Congo El Salvador Gambia, The Guatemala Honduras Jamaica Kenya Nepal Peru South Africa Zimbabwe	Argentina Morocco Philippines	Belgium India Lesotho Netherlands Pakistan Sri Lanka Switzerland Turkey United Kingdom	Egypt Italy Mauritius Portugal	China Japan	Korea
5 < ≤10	Cen. Afr. Rep. Chad Guinea-Bissau Madagascar Mauritania Senegal Zambia	Cameroon Pap. New Guin.	Costa Rica Indonesia Panama	Brazil Colombia Dominican Rep. Mexico Paraguay Tunisia	Austria France Greece Spain	Thailand	Botswana
10 < ≤ 15	Niger		Uruguay	Chile Ecuador Sweden Trin. and Tobago	Denmark	Malaysia	
15 < ≤ 20				United States	Finland Ireland		
20< ≤ 25	Venezuela						
25< ≤ 30					Norway		
30<			New Zealand	Australia Canada			

2. Literature

Natural resources are a fixed factor of production and hence, almost by definition, impose a restriction on economic growth potential. This restriction may – depending on the nature of the production technology – cause a growing labor force and a growing stock of capital to run into diminishing returns. This is the first reason for an adverse effect of natural resources on growth found in the literature. Nordhaus (1992) has shown that the steady-state rate of growth of output per capita in an economy with natural resources is proportional to the rate of technological progress adjusted for a "population growth drag" due to diminishing returns as well as a "natural resource depletion drag" due to declining levels of exhaustible natural resources.

Second, huge natural resource rents may create opportunities for rent-seeking behavior on a large scale on the part of producers, thus diverting resources away from more socially fruitful economic activity (Auty, 2001; Gelb, 1988). For example, Tornell and Lane (1998) show that terms-of-trade windfalls and natural resource booms may trigger political interaction, or games, among powerful interest groups – games that result in current account deficits, disproportionate fiscal redistribution and reduced growth. In extreme cases, civil wars break out – such as Africa's diamond wars – which not only divert factors of production from socially productive uses but also destroy societal institutions and the rule of law. Collier and Hoeffler (1998) show empirically how natural resources increase the probability of civil war. Another extreme case involves foreign governments invading with destructive consequences and the accompanying defense expenditures. Military expenditures tend to inhibit growth through their adverse effects on capital formation and resource allocation (Knight *et al*., 1996). Huge natural resource rents are especially risky when they can be extracted from a narrow geographic or economic base (e.g., oil and minerals) and are easy to grab (Isham *et al*., 2006; Mehlum *et al.*, 2006).

Third, natural resource abundance can lead to the Dutch disease, in several guises. A natural resource boom and the associated surge in raw-material exports can drive up the real exchange rate of the currency, thus possibly reducing manufacturing and services exports (Corden, 1984). Recurrent booms and busts tend to increase real exchange rate volatility (Gylfason *et al*., 1999), thus reducing investment in the tradable sector as well as exports and imports of goods and services. The Dutch disease can also strike in countries that do not have their own currency (e.g.,

Greenland, which uses the Danish krone; see Paldam, 1997). A boom in the primary sector then increases wages in that sector, thereby attracting labor from other industries or imposing higher wage costs on them, especially in countries with centralized wage bargaining. Through some or all of these channels the Dutch disease can reduce total exports relative to GNP (Gylfason, 1999) or at least skew the composition of exports away from manufacturing and services exports that may contribute more to economic growth. This idea accords with the view that technological discoveries and innovation take place in manufacturing rather than agriculture (Kaldor, 1966). To the extent that the great productivity improvements that have taken place in agriculture in recent decades reflect technological spillovers from other sectors, the Dutch disease may slow down economic growth by impeding manufacturing and services exports, which are probably good for growth (Frankel and Romer, 1999)[5] – not only their quantity but their kind and quality as well.[6]

Fourth, natural resource abundance may weaken private and public incentives to accumulate human capital due to a high level of non-wage income – e.g., dividends, social spending and low taxes. Empirical evidence suggests that, across countries, school enrolment at all levels is inversely related to natural resource dependence, as measured by the share of the labor force engaged in primary production (Gylfason *et al*., 1999). There is also evidence that, across countries, public expenditures on education relative to national income, expected years of schooling and secondary-school enrolment rates are all inversely related to the share of natural capital in national wealth (Gylfason, 2001). This matters because more and better education seems good for growth. For example, Temple (1999) shows that economic growth varies directly with educational attainment across countries once a few outliers have been removed from the sample of Benhabib and Spiegel (1994), who had found limited support in their data for the hypothesis that education is good for growth.

Finally, and this point is closely related to the preceding one, abundant natural resources may imbue people with a false sense of security and lead governments to lose sight of the need for human capital accumulation as well as good and growth-friendly economic management, including free trade, bureaucratic efficiency,

[5] A dissenting view is expressed in Rodriguez and Rodrik (2000).

[6] In our sample of 85 countries, there is a significant negative correlation between the ratio of exports to GDP, adjusted for country size based on population, and the share of natural capital in national wealth (not shown). There is also a significant positive correlation between the export ratio adjusted for country size and per capita growth adjusted for initial income (not shown).

institutional quality and sustainable development (Sachs and Warner, 1999; Rodriguez and Sachs, 1999). Put differently, abundant natural capital may crowd out social capital in a similar manner as human capital (Woolcock, 1998; Paldam and Svendsen, 2000). Unconditional foreign aid, or aid that is not supported by good policies and institutions, may be a case in point (Burnside and Dollar, 2000). And if natural capital tends to crowd out social as well as human capital, then why should it not crowd out real capital as well? It is to this question that we now turn.

3. Resource dependence or path dependence?

Above we made the empirical observation that differences in saving and investment distinguish the resource-rich, slow-growth countries in our sample from the resource-poor, rapid-growth countries. We focus on two possible explanations for this pattern.

First, the mechanisms surveyed in Section 2 – population growth and resource depletion drag, rent seeking, Dutch disease, neglect of education – can all be expected to reduce saving and investment. When resources are devoted to rent seeking as well as internal strife and corruption, productive investment is likely to suffer. Similarly, when investment in human and social capital is adversely affected by natural resources, investment in physical capital may also suffer due to the complementarity between different forms of produced capital: education, good institutions, and investment tend to go hand in hand. And the Dutch disease – through wages or the real exchange rate – will shrink the manufacturing and other export sectors and hamper investment.

Another view is that poor institutions are mainly to blame for low growth. The problem of endogeneity can be resolved either by arguing that natural resources may affect the institutional environment or that the current poor state of affairs is a result of institutional heritage: adverse living conditions in colonial times reduced the inflow of Europeans to the colonies and prevented Western institutions from taking hold. Following this thesis, the former colonies still suffer poor institutions that deter saving, investment and growth. In this case the problem is not excessive reliance on natural resources at present but institutional path dependence. Our empirical strategy in Section 4 is intended to enable us to distinguish between those two hypotheses.

In Gylfason *et al*. (1999) we derive the effect of the Dutch disease on economic growth in a two-sector model with tradable and non-tradable goods. An appreciation

of the domestic currency in real terms lowers the price of tradable output and reduces investment, learning and growth. Increased volatility of the real exchange rate has the same effect. In Gylfason and Zoega (2003) we develop a model of rent-seeking behavior that also produces an adverse effect of natural resources on growth. We assume that learning mainly occurs in manufacturing and not in the primary sector. It follows that if the riches of nature tempt workers away from manufacturing and into the primary sector, there will be fewer hands left to work in manufacturing, hence less learning and lower rates of growth. The growth of output per capita will then be an increasing function of the scale and scope of the manufacturing sector and a decreasing function of the natural resource rent.

Here, however, we tell a different story: one in which natural capital may crowd out real capital by reducing national saving and investment, thereby impeding economic growth. A model of this mechanism is presented in Appendix A. In the model, we distinguish between the intensity and abundance of natural resources. By intensity, or dependence, we mean the importance of natural resources to the national economy while abundance refers to the supply (per capita) of the natural resources. The distinction between dependence and abundance allows us to distinguish between the effect of a change in the share of natural resources in output on growth, which we expect to be negative through the mechanisms outlined in Section 2, and a change in the abundance of the natural resource on growth, which may nevertheless be positive.

4. Natural resources and institutions

We now want to test our hypothesis that natural resource dependence hurts investment and growth in addition to the mechanisms surveyed in Section 2 within a framework that also allows for the possibility that poor institutions impede growth. We do this by estimating the following equations:

(1) $$g = f_1(y_0, h, i, b, n, c, p)$$

(2) $$h = f_2(y_0, b, n, c)$$

(3) $$i = f_3(y_0, b, n, c)$$

(4) $$c = f_4(y_0, b, n)$$

The rate of per capita economic growth is a decreasing function of initial output per capita y_0 as well as of the dependence on natural resources b and population growth p, and an increasing function of education h, the investment rate i, the abundance of natural resources n and the set of relevant institutions c, which we proxy by an index of civil liberties. Further, we postulate that both education and investment vary inversely with natural resource dependence and directly with natural resource abundance as well as the extent of civil liberties. We also allow education and investment to depend on initial income. At last, we view civil liberties as a function of the three exogenous variables in the model, i.e., initial income and the two natural resource variables. Notice the recursive nature of the four equations of the model. Civil liberties depend solely on exogenous variables by equation (4), so that education and investment also do so by equations (2) and (3), and hence growth also depends solely on exogenous variables by equation (1).

Before embarking on the regression analysis below, let us inspect the data. Figure 1 shows a scatterplot of economic growth per capita from 1965 to 1998 and natural resource dependence measured as before.[7] The group of eight low-growth, natural-resource-dependent African countries identified in Table 1 is visible in the southeast corner of Figure 1. The high-growth, natural-resource-free countries are also easy to spot in the northwest corner of the figure. In Figure 2 we plot the investment ratio against natural resource dependence over the same period, 1965-1998. Apart from the two clusters in the corners, the relationship between the two variables is not very clear to the naked eye, even if it remains statistically significant when the two clusters are removed. Figures 3 and 4 show growth, investment and natural resource abundance as measured by natural capital per person in 1994 (in thousands of US dollars).

We want to assess the effects of natural resource dependence as measured by the share of natural resources in national wealth and of natural resource abundance as measured by natural capital per person on investment and growth. Moreover, we want to test whether the inclusion of civil liberties, our proxy for institutions, in our model renders the natural resource variables or other determinants of growth insignificant. The first four rows in Table 3 report seemingly unrelated regression (SUR) estimates of a system of four equations for the 85 countries in our sample where

(a) Economic growth per capita depends on the share of gross domestic

[7] When we purge the natural capital share of that part which is explained by the country's initial

investment in GDP 1965-1998, the gross secondary-school enrolment rate, the natural capital share, natural capital per person, civil liberties,[8] population growth, and the logarithm of initial per capita income (i.e., in 1965), defined as purchasing-power-parity adjusted GNP per capita in 1998 divided by an appropriate growth factor;

(b) The enrolment rate in turn depends on the natural capital share, natural capital per person, civil liberties and initial income;

(c) Investment also depends on the natural capital share, natural capital per person, civil liberties and initial income; and

(d) Civil liberties depend on the natural capital share, natural capital per person and initial income.

The recursive nature of the system shown in Table 3 and the conceivable correlation of the error terms in the three equations make SUR an appropriate estimation procedure (Lahiri and Schmidt, 1978). In particular, this method produces unbiased, efficient and consistent parameter estimates without any need to correct for simultaneity bias, provided that equations (11)-(14) are correctly specified.[9]

All the parameter estimates in Table 3 are economically and statistically significant, with one exception (the effect of civil liberties on investment). The coefficient on initial income in the growth equation indicates a convergence speed of almost 2 percent per year, which is close to the 2-3 percent range typically reported in statistical growth research. These results are consistent with earlier work that assumes constant returns to scale and ascribes roughly three-fourths of output to capital in a broad sense (Mankiw *et al*., 1992). Nordhaus (1992) ascribes one-fifth of output to natural resources (energy and land) and the rest to capital and labor, arguing that the historical growth record is consistent with constant returns to scale.

There is both a direct effect of the natural capital share on growth in Table 3 as well as an indirect effect through education and investment. As far as we know, this linkage – from heavy dependence on natural resources to slow growth via investment – has not been documented in econometric work before. Moreover, the table shows an

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income per head, we get very similar results as in Figure 1.

[8] The civil liberties index is an average for the years 1972-1990 and is taken from Przeworski et al. (2000). The index ranges from 1 (full civil liberties) to 7 (negligible civil liberties). All other data are taken from the World Bank (2000, 1997).

[9] However, the fact that ordinary least squares (OLS) estimates of the system (not shown) are almost the same as the SUR estimates shown in Table 3 indicates that the correlation of error terms across equations is of minor consequence.

additional indirect effect of the natural capital share on growth through civil liberties. Notice also that an increase in civil liberties stimulates growth directly as well as indirectly by encouraging education and perhaps also investment as well, even if the latter effect is statistically insignificant. These effects appear to be fairly strong. For example, an increase in civil liberties from the level of Turkey or Uruguay in the middle of the range to that of, say, Switzerland and the U.K. at the top goes along with an increase in per capita growth by one percentage point.

Table 3. Regression results: Growth and investment

Dependent variable	Natural capital share	Natural capital per person	Initial income	Population growth rate	Civil liberties index	Enrolment rate	Gross investment rate	R^2
Economic growth	-0.08 (5.8)	0.05 (2.7)	-1.89 (9.2)	-0.56 (3.0)	-0.27 (2.5)	0.02 (2.5)	0.08 (3.7)	0.75
Enrolment rate	-0.77 (4.1)	0.54 (2.2)	13.00 (5.2)		-3.82 (2.5)			0.77
Gross investment	-0.26 (4.0)	0.16 (1.8)	-1.92 (2.2)		-0.73 (1.4)			0.24
Civil liberties	0.04 (3.1)	-0.05 (2.9)	-0.95 (6.5)					0.65
Economic growth	-0.13 (8.8)	0.09 (4.5)	-1.57 (8.1)	-1.01 (5.5)				0.62

Note: 85 observations. t-statistics are shown within parentheses. Constant terms are not shown. An increase in civil liberties makes the civil liberties index go down.

Notice, furthermore, that an increase in natural capital per person has a positive effect on growth, education and investment. Because natural capital per person equals, by definition, the multiple of the share of natural capital in national wealth and wealth per person, we can infer from Table 3 that the total effect of an increase in the natural capital share on economic growth is -0.13 [= -0.08 + (-0.77×0.02) + (-0.26×0.08) + (0.04×(-0.27)] plus 0.087 [= 0.05 + (0.54×0.02) + (0.16×0.08) + (-0.05×(-0.27)] times wealth per person (in hundreds of thousands of US dollars). Therefore, the total effect of an increase in the natural capital share on growth declines with wealth per person but remains negative as long as national wealth per capita is below USD 150,000 (= $0.13/0.087\times 10^5$), which is roughly the cut-off point between the 20 industrial countries and 65 developing countries in the sample.[10] The bottom line in

[10] To be on guard against the possibility that the natural capital share may in fact be a proxy for the level of development, we added to our system an auxiliary regression of the natural capital share

the table shows the reduced-form regression of growth on the three exogenous variables in our model. The population growth drag is quite strong.

5. Conclusion

In this paper, we have proposed a linkage between natural resources and economic growth, through saving and investment. Our results can be summarized as follows:

- Accumulation of physical capital through investment, human capital through secondary education and social capital through civil liberties is inversely related to the share of natural capital in national wealth.
- Economic growth is inversely related to natural resource dependence as well as to initial income and directly related to the level of education, investment and civil liberties.
- Even if the dependence on natural resources adversely influences investment, education, civil liberties and growth, the abundance of natural resources measured by resources per head of population varies directly with investment, education, civil liberties and growth.
- The effect of natural resources on investment, education and growth documented in earlier research survives the introduction of a variable measuring civil liberties. Natural resources appear to have an additional indirect effect on investment, education and growth through the nature and quality of social institutions.

Hence, we have seen that the natural resource variable survived the introduction of the institutional variables. Likewise, the institutional variables survived the presence of the natural resource variable. It thus appears that, on its own, neither story can explain growth retardation in full. This does not surprise us: economic growth is a complicated process that is driven forward by several different, interrelated factors. However, the onus rests with the natural resource story because international differences in the dependence on natural resources can also explain the diversity of institutions across countries. It seems that natural resources may affect growth both directly through macroeconomic variables, as well as indirectly through institutions.

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against a constant as well as the logarithm of initial income and natural capital per person. The effect of initial income on the natural capital share is significantly negative, with a coefficient of -6.33 (with t = 6.1), and the effect of natural capital per person on the natural capital share is significantly positive, with a coefficient of 0.52 (with t = 4.0), but in other respects the estimation results are virtually identical to the ones shown in Table 3. Hence, when we take the statistical relationship between natural capital and initial income into account, the evidence for absolute convergence weakens a bit.

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Appendix A: The golden rule with natural resources

Here we explore the effect of natural resources on growth through investment in a neoclassical growth model. Following Nordhaus (1992) we assume that output is produced by labor L, natural resources N and capital K and the production function to be of the Cobb-Douglas variety with constant returns to scale:

$$Y = AL^{a}N^{b}K^{1-a-b} \tag{A1}$$

where A represents overall efficiency, including technology and quality. This gives a production function that generates smooth and differentiable isoquants in L-N-K space. We can rewrite equation (A1) in per capita terms: $y = An^{b}k^{1-a-b}$ where $y = Y/L$, $n = N/L$ and $k = K/L$. Equation (A1) encapsulates a technology where natural resources can be bundled together with either labor or capital in the production process (Bruno, 1984).[11]

Within the Cobb-Douglas framework, the exponents in the aggregate production function (A1) denote factor shares while the factor inputs are absolute quantities. An increase in the parameter b thus means that the economy now relies more heavily on natural resources in producing output – independently of its supply – while an increase in N implies that the supply has increased. Thus we distinguish the effect of a change in the factor share b on growth from the effect of a change in the abundance of the natural resource N on growth.

A class of capitalists owns the stock of capital and individuals also own the natural resources. The total stock of natural resources is given and hence also the supply of their services. We take these services to be fixed and exogenous so that no opportunities for intertemporal allocation of these resources arise. We assume a perfectly competitive market for the services of natural resources. In equilibrium, supply of and demand for natural resources are equalized and the marginal product is equal to their real price. Similarly, there is perfect competition in the market for labor and the marginal product of labor is equal to the real wage. Finally, we have a market for capital where the owners of capital sell its services to firms.

[11] Like Nordhaus (1992) we can justify the constant returns to scale assumption by appealing to the standard replication argument: An economy that has twice as many workers, twice as extensive natural resources and twice as much capital is also going to produce twice as much output. We test this assumption empirically in Section 4.

Assuming a constant capital/output ratio K/Y – a reasonable assumption in steady state – we can rewrite equation (A1) in terms of logarithms and then derive the following expression for the rate of growth of output per capita g:

$$(A2) \qquad g = \left(\frac{1}{a+b}\right) g_A - \left(\frac{b}{a+b}\right)(g_L - g_N)$$

where g_A, g_L and g_N are the rates of growth of technology, the labor force and the natural resource. If the resource is renewable and constant, g_N disappears from the equation. If the resource is non-renewable and a fraction u of the remaining stock of the resource is used up every year, then the term $g_L - g_N$ can be replaced by g_L + u in equation (A2).[12] This sum represents the two drags discussed by Nordhaus (1992).

Notice the conflict between the advance of technology that increases output per capita over time and the diminishing returns due to the fixed or declining supply of the natural resource. The drag on growth is greater, the higher is the value of b – that is, the greater is the dependence on natural resources – and the higher are the rates of population growth g_L and resource depletion u. This effect is uncontroversial: The inability to augment one factor of production is bound to introduce diminishing returns to the remaining factors. Clearly, if production is heavily dependent on the natural resource – that is, if the value of the parameter b is high – the drag becomes more severe. Even so, a natural resource boom – increased abundance – would increase g_N and hence also g by equation (A2).

We will now show that the effect of natural resources on growth is not confined to the steady-state growth drag described above. The level of saving and investment may also be affected. This affects the level of steady-state income per capita as well as its rate of growth in the transition to a steady state.

Consumption per worker, $c = C/L$, is proportional to output per worker:

$$(A3) \qquad c = (1-s)y$$

where $s = S/Y$ is the saving rate. In the transition towards a Solovian steady state the capital/labor ratio evolves according to

$$(A4) \qquad g_k = g_K - g_L = \frac{sY - \delta K}{K} - g_L = s\frac{y}{k} - \delta - g_L$$

[12] If the resource is managed such that it grows at the same rate as output, equation (A2) simplifies to the neoclassical steady-state solution: $g = g_A$.

where g_k is the growth of the capital/labor ratio and δ is the depreciation rate. We now assume away technical progress for simplicity and without loss of generality. In the steady state where $g_k = 0$, the capital/output ratio is an increasing function of the saving rate and a decreasing function of the depreciation rate and the rate of population growth:

$$\text{(A5)} \qquad \frac{k}{y} = \frac{s}{g_L + \delta}$$

Solving the normalized version of equation (A1) and equation (A5) together for y and substituting the result into the consumption function (A3) gives

$$\text{(A6)} \qquad c = (1-s) A^{\frac{1}{a+b}} n^{\frac{b}{a+b}} \left(\frac{s}{g_L + \delta} \right)^{\frac{1-a-b}{a+b}}$$

Maximizing consumption per capita in equation (A6) with respect to s gives the following simple solution for the optimal saving rate:[13]

$$\text{(A7)} \qquad s = 1 - a - b$$

Hence, the greater the role of natural resources in the generation of national output – i.e., the greater b in equation (A1) – the smaller is the optimal saving rate. Put differently, the presence of natural resources – that is, a positive share of natural resources in national income – reduces the marginal productivity of capital and thereby also the propensity to save. This way, natural capital crowds out physical capital. In an economy without natural resources ($b = 0$), the optimal saving rate in equation (A6) becomes $1 - a$, the traditional form of the golden-rule formula.

The differential equation (A4) has the Bernoulli form and can be solved so as to describe the evolution of capital over time:

$$\text{(A8)} \qquad k_t^{a+b} = \left[k_0^{a+b} - \frac{sAn^b}{g_L + \delta} \right] e^{-(a+b)(g_L+\delta)t} + \frac{sAn^b}{g_L + \delta}$$

where the subscript t denotes time and k_0 denotes the initial stock of capital per worker. Equation (A8) implies that the speed of adjustment towards steady state

[13] This derivation does not constitute microeconomic optimization from first principles, as we assume the saving rate to be fixed. However, it is possible to bypass this assumption and derive the optimal saving rate in the Ramsey model instead; this yields $s = (1 - a - b)[(\delta + g_L)/(\delta + \rho)]$ where ρ is the pure rate of time preference. This result simplifies to $s = 1 - a - b$ as in the Solow model if $g_L = \rho$. In either

$(a+b)(g_L+\delta)$ is increasing in the dependence on natural resources *b*. The economy will converge to the last term in the equation, either from above as in Rodriguez and Sachs (1999) or from below:

$$\text{(A9)} \qquad \lim_{t\to\infty} k_t = \left(\frac{sAn^b}{g_L+\delta}\right)^{\frac{1}{a+b}}$$

The corresponding steady-state solution for output per capita is found by substituting equation (A9) into the normalized version of equation (A1) or, equivalently, by combining equations (A3) and (A6):

$$\text{(A10)} \qquad y = A^{\frac{1}{a+b}} n^{\frac{b}{a+b}} \left(\frac{s}{g_L+\delta}\right)^{\frac{1-a-b}{a+b}}$$

Increased dependence on natural resources reduces the saving rate by equation (A7) and thereby also the steady-state levels of capital and output per worker by equations (A9) and (A10). Given the current stock of capital, however, the rate of economic growth is reduced during the transition to the steady state. We acknowledge but do not pursue here the possibility, stressed in Section 2, that natural resource dependence may also adversely affect the efficiency parameter *A*, which reflects education and the quality of institutions among other things and exerts a strong influence on steady-state output per capita and transitional growth. Notice also that the abundance of natural resources has a positive effect on the level of output and consumption per capita in long-run equilibrium even if the dependence on natural resources has a negative effect on both variables through the optimal saving rate. However, the abundance of natural resources has no effect on the capital/output ratio, which nonetheless varies inversely with the dependence on natural resources by equations (A5) and (A7).

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case, the optimal rate of saving varies inversely with the share of natural resources in national income.

Appendix B: The data

	Natural capital share 1994	Natural capital per person 1994 (thousands)	National wealth per person 1994 (thousands)	Investment ratio 1965-98	Enrol-ment rate 1965-98	Civil liberties 1972-90	Per capita growth 1965-98	Per capita income 1998	Per capita growth, adjusted, 1965-98
Argentina	6.7	9,8	147	23	56	3,26	0.4	11728	-1.6
Australia	11.9	35,3	297	24	86	1,00	1.7	21795	-0.2
Austria	2.6	7,6	286	24	92	1,00	2.6	23145	0.6
Bangladesh	14.1	3,1	22	20	18	4,37	1.4	1407	-2.0
Belgium	0.0	0,0	287	20	97	1,00	2.3	23622	0.4
Benin	7.7	1,9	25	15	12	6,32	0.1	857	-3.3
Botswana	6.3	5,6	89	27	26	3,06	7.7	5796	4.0
Brazil	7.9	7,1	89	21	33	3,42	2.2	6460	-0.4
Burkina Faso	16.9	2,4	14	21	3	4,79	0.9	866	-2.7
Burundi	19.9	1,9	10	12	3	6,21	0.9	561	-2.9
Cameroon	21.1	6,8	32	21	17	5,47	1.3	1395	-2.1
Canada	11.1	36,6	331	22	87	1,00	1.8	22814	0.0
Central Afr. Rep.	30.2	6,5	21	10	10	6,16	-1.2	1098	-4.2
Chad	37.1	5,5	15	7	5	6,53	-0.6	843	-3.9
Chile	9.8	14,4	148	19	55	4,37	1.9	8507	-0.5
China	7.2	2,7	37	31	45	6,42	6.8	3051	2.9
Colombia	7.2	6,1	85	19	40	2,89	2	5861	-0.7
Congo	14.5	4,4	31	32	50	6,00	1.4	846	-2.3
Costa Rica	8.2	7,9	96	21	40	1,00	1.2	5812	-1.3
Côte D'Ivoire	18.0	3,8	21	17	16	5,21	-0.8	1484	-3.7
Denmark	3.8	11,1	295	23	101	1,00	1.9	23855	0.1
Dominican Rep.	12.4	8,4	68	21	35	2,58	2.3	4337	-0.6
Ecuador	17.0	11,3	67	19	43	2,95	1.8	3003	-1.2
Egypt	4.5	2,4	52	21	52	4,58	3.5	3146	0.2
El Salvador	2.8	1,1	40	16	24	3,84	-0.4	4008	-2.8
Finland	6.6	15,9	241	24	102	1,89	2.4	20641	0.4
France	2.7	8,1	297	22	86	1,89	2.1	21214	0.2
Gambia, The	11.8	2,1	18	20	13	2,68	0.4	1428	-2.8
Ghana	7.2	1,9	27	12	31	5,05	-0.8	1735	-3.6
Greece	3.7	5,2	142	25	80	2,42	2.4	13994	0.2
Guatemala	3.3	1,7	52	14	16	4,00	0.7	3474	-2.0
Guinea-Bissau	44.2	8,0	18	29	6	6,12	-0.1	573	-3.7
Haiti	6.7	0,8	13	11	13	5,72	-0.8	1379	-3.8
Honduras	9.9	3,4	34	20	22	3,00	0.6	2338	-2.3
India	19.8	3,9	20	19	34	3,11	2.7	2060	-0.7
Indonesia	12.4	7,5	60	26	31	5,21	4.7	2407	1.0
Ireland	8.1	17,8	219	21	90	1,21	3	17991	0.8
Italy	1.3	3,4	257	22	72	1,53	2.5	20365	0.5
Jamaica	6.8	3,1	45	25	58	2,58	-0.4	3344	-2.9
Japan	0.8	2,3	304	31	92	1,00	3.5	23592	1.4
Jordan	1.6	1,0	64	29	48	5,63	-0.4	2615	-3.1
Kenya	9.4	1,7	18	17	17	4,89	1.3	964	-2.3
Korea	1.7	2,9	168	29	72	5,16	6.6	13286	3.6
Lesotho	3.3	0.9	28	43	18	4,68	3.1	2194	-0.3
Madagascar	41.9	6,5	16	11	15	4,84	-1.8	741	-4.9
Malawi	11.8	0,9	7	17	6	6,47	0.5	551	-3.2
Malaysia	8.6	11,8	137	28	48	3,95	4.1	7699	1.2
Mali	41.0	4,8	12	18	7	6,16	-0.1	673	-3.6
Mauritania	21.6	5,1	24	20	9	6,00	-0.1	1500	-3.2
Mauritius	1.2	1,2	99	22	45	2,53	3.8	8236	1.0
Mexico	5.9	6,6	113	20	43	3,74	1.5	7450	-0.9
Morocco	4.1	2,2	54	20	26	4,63	1.8	3188	-1.2
Mozambique	12.7	1,1	9	13	5	6,81	0.5	740	-3.1
Nepal	17.7	2,9	16	18	22	4,53	1.1	1181	-2.3
Netherlands	1.5	4,1	272	22	99	1,00	1.9	22325	0.0
New Zealand	18.5	51,1	277	22	87	1,00	0.7	16084	-1.1
Nicaragua	13.9	3,7	27	20	34	4,58	-3.3	1896	-5.6
Niger	54.2	12,3	23	11	4	6,00	-2.5	729	-5.5
Norway	10.0	30,2	302	27	94	1,00	3	26196	1.0
Pakistan	5.6	1,9	34	16	16	4,74	2.7	1652	-0.8
Panama	6.5	6,3	97	20	55	4,74	0.7	4925	-1.8
Pap. New Guinea	19.3	7,5	39	23	11	2,13	0.5	2205	-2.4
Paraguay	11.5	7,0	61	21	26	5,16	2.3	4312	-0.6
Peru	7.8	4,6	59	21	53	3,84	-0.3	4180	-2.7
Philippines	6.2	2,7	44	22	62	4,26	0.9	3725	-1.8
Portugal	2.3	4,0	175	27	59	2,53	3.2	14569	0.8
Rwanda	21.7	1,1	5	13	5	5,68	0	650	-3.6
Senegal	16.8	5,3	32	12	12	4,11	-0.4	1297	-3.5
Sierra Leone	28.0	3,0	11	7	13	5,00	-1.6	445	-5.1
South Africa	5.0	4,2	83	22	62	5,56	0.1	8296	-2.0
Spain	2.9	5,7	201	23	84	2,95	2.3	15960	0.2
Sri Lanka	7.4	3,5	47	22	57	3,53	3	2945	-0.3
Sweden	5.6	14,6	260	20	91	1,00	1.4	19848	-0.5
Switzerland	0.9	3,1	352	25	85	1,00	1.2	26876	-0.4
Thailand	6.5	7,6	117	29	29	3,95	5	5524	1.7
Togo	15.2	2,7	18	17	20	5,89	-0.6	1352	-3.6
Trin. and Tobago	9.5	12,1	128	21	62	1,89	2.6	7208	-0.1
Tunisia	7.9	6,4	81	26	34	4,84	2.7	5169	-0.2
Turkey	5.0	3,9	79	19	37	3,95	2.1	6594	-0.5
United Kingdom	1.9	4,9	266	18	88	1,05	1.9	20314	0.0
United States	4.1	16,5	401	18	91	1,00	1.6	29240	-0.1
Uruguay	11.6	14,8	127	14	67	4,00	1.2	8541	-1.1
Venezuela	18.9	20,8	110	22	33	2,11	-0.8	5706	-3.0
Zambia	37.8	5,5	15	18	17	5,11	-2	678	-5.2
Zimbabwe	8.5	2,5	30	17	26	5,00	0.5	2489	-2.4

Source: World Bank (1997, 2000).

Note: All figures are expressed as percentages except natural capital per person, national wealth per person income and per capita income, which are expressed in U.S. dollars.

Figure 1. Natural resource dependence and growth

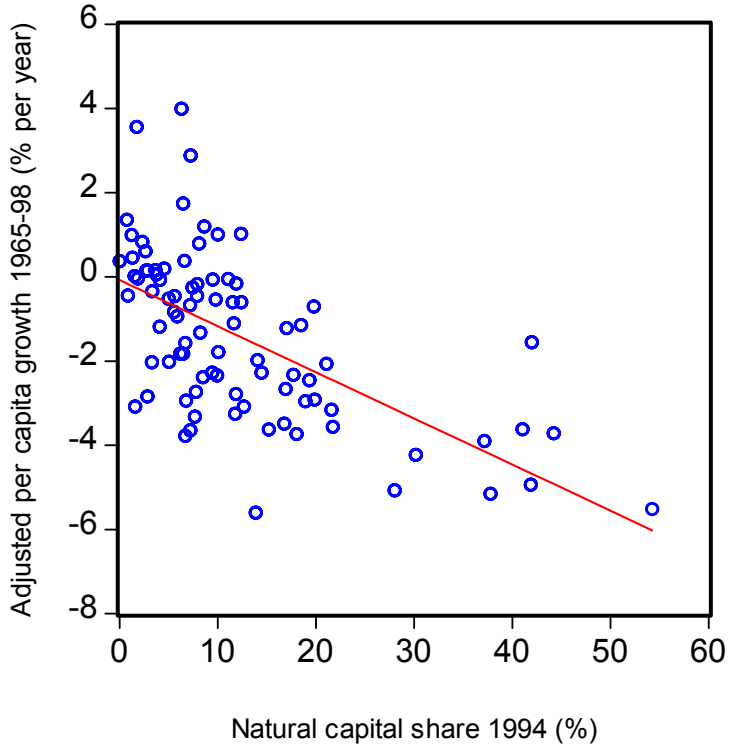

Figure 2. Natural resource dependence and investment

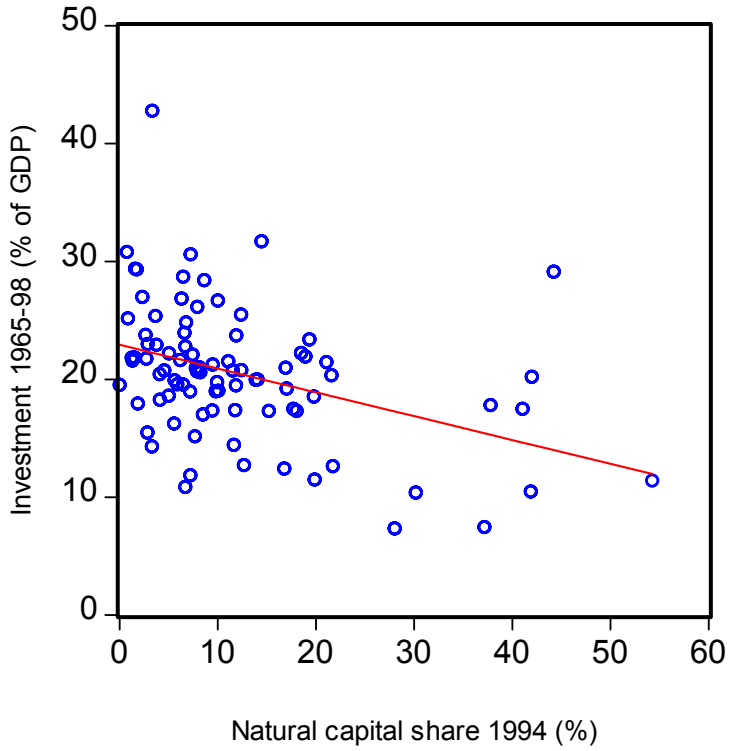

Figure 3. Natural resource abundance and growth

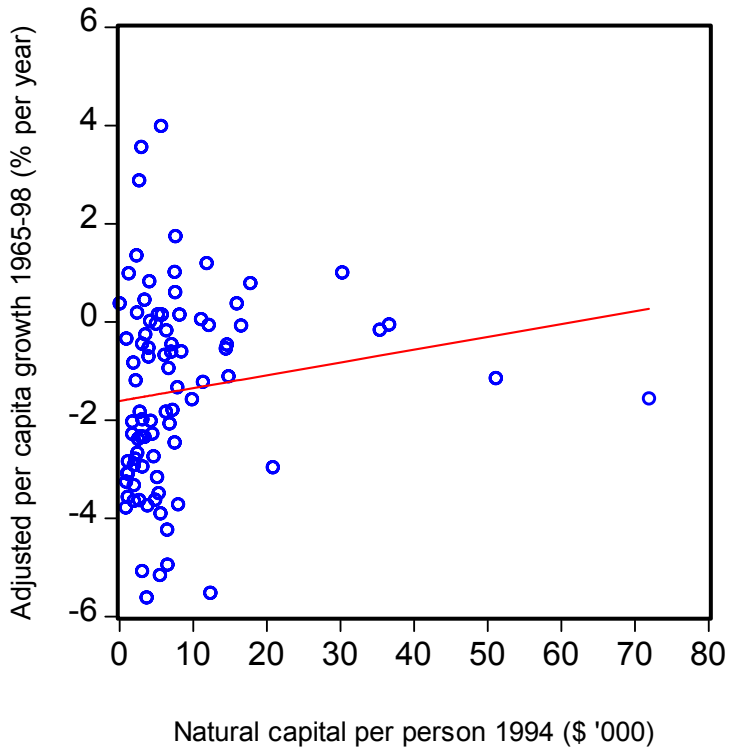

Figure 4. Natural resource abundance and investment