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NATURAL RESOURCES AND ECONOMIC GROWTH: THE ROLE OF INVESTMENT

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NATURAL RESOURCES AND ECONOMIC GROWTH: THE ROLE OF INVESTMENT

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Resumen
El artículo presenta inicialmente una breve revisión de la evidencia empírica, donde se indica que la tasa de crecimiento económico desde 1965 ha tenido una relación inversa con la abundancia de recursos naturales o la intensidad en el uso de los mismos. En este sentido, el presenta trabajo propone una nueva relación entre recursos naturales y el crecimiento económico, a través del ahorro y de la inversión. Cuando la participación de los propietarios de recursos naturales en el producto nacional se eleva, la demanda por bienes de capital disminuye y ello conduce a tasas de interés mas bajas y a una desaceleración en la tasa de crecimiento. Además, el análisis muestra que la discrepancia entre las tasas social y privada de crecimiento óptimo aumenta con la participación del capital natural. La evidencia empírica para 85 países durante el periodo 1965-88 sugiere que el capital natural no sólo estaría desplazando al capital físico y humano sino que también estaría inhibiendo el crecimiento económico. Estos resultados sugieren que la fuerte dependencia de recursos naturales perjudicaría tanto al ahorro como a la inversión de manera indirecta, a través de una desaceleración del desarrollo en el sistema financiero.

Abstract
This paper begins by a brief review of empirical evidence that seems to indicate that economic growth since 1965 has varied inversely with natural resource abundance or intensity across countries. The paper then proposes a new linkage between natural resources and economic growth, through saving and investment. When the share of output that accrues to the owners of natural resources rises, the demand for capital falls and this leads to lower real interest rates and less rapid growth. Moreover, the analysis shows that the discrepancy between the privately and socially optimal rates of growth increases with the natural capital share. Empirical evidence from 85 countries from 1965 to 1998 suggests that natural capital may on average crowd out physical as well as human capital, thereby inhibiting economic growth. The results also suggest that, across countries, heavy dependence on natural resources may hurt saving and investment indirectly by slowing down the development of the financial system.

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1. Introduction

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. The world's richest countries include Hong Kong, Japan, Singapore and Switzerland which do not owe their national wealth to nature and many others, such as the United States and the United Kingdom, where natural resources nowadays play only a minor role in the generation of national income.

Among developing countries, natural resources are relatively more 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 more important. But there are also clear examples of countries that are genuinely rich in terms of natural resources but still have not been able to sustain economic growth. It thus appears that the generosity of nature may sometimes – although by no means always – turn out to be a mixed blessing. 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 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. Sierra Leone was the world's poorest country in 1998 according to the World Bank (2000). Apparently, the rich supply of diamonds has turned out to be a source of domestic strife that has both diverted precious national resources towards rent seeking of the most destructive kind and destroyed the infrastructure and social institutions that are so important for economic life. This example shows that the existence of natural resources can be both a blessing and a curse to economic growth and development.

In this paper, we consider the interaction between institutions, natural resource dependence and economic growth. In particular, we are interested in the possible mechanisms through which natural resources can stifle capital accumulation and growth and the conditions under which economic growth can take place in the presence of abundant natural resources. In this context it will be interesting to consider the experience of those countries – if any – which at some point in the past relied on nature's bounty but now enjoy the benefits of developed and diversified manufacturing and service industries.

Recent empirical research suggests that an abundance of natural resources can hurt economic growth indirectly by unleashing forces that hamper the development of the national economy, primarily through the Dutch disease, rent seeking and neglect of education. We will review this literature below, in Section 3. To some, these findings may seem counterintuitive for it should, in principle, be possible to harness natural resources without hurting national economic welfare and growth. We concur.

This paper is intended to make two main points. First, natural resource intensity may under certain conditions blunt incentives to save and invest and thereby reduce economic growth. We demonstrate this proposition by deriving the optimal saving rate in an endogenous growth model of an economy with natural resources and then subject it to empirical tests in a cross-sectional sample of 85 countries from 1965 to 1998. Second, on the premise that mature institutions contribute to an efficient use of resources, including natural resources, and that poorly developed institutions do not, we argue that natural resource abundance may also under certain conditions – to be specified – retard the development of financial institutions in particular and hence hamper saving, investment and economic growth through that channel as well.

The paper proceeds as follows. Section 2 looks briefly at the empirical evidence on natural resource dependence and economic growth. Section 3 provides a brief overview of recent literature on the subject. In Section 4, we compare the experience of Norway, the world's most successful oil exporter, with that of other oil-producing countries. In Section 5, we derive our main proposition that natural resource dependence tends to blunt incentives to save and invest. We also distinguish between the quantity and quality of investment. In Section 6, we summarize the data through simple bivariate correlations between natural resource dependence, different measures of saving and investment and economic growth. In Section 7, we then proceed to more elaborate tests of our hypothesis by multiple regression analysis in the spirit of the recent empirical growth literature. Section 8 summarizes our main results and offers a few concluding comments.

2. Preview

A rapidly expanding body of research has attempted to discern empirical growth relationships across countries. While aggregative and simple, such cross-sectional and panel data sets – often covering large numbers of countries – do provide an interesting starting point.

Figure 1 is representative of one of the empirical findings that have emerged from some recent studies, beginning with Sachs and Warner (1995). The figure covers 85 countries, and shows a scatterplot of 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). 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.[1] The latter proxies may be prone to bias due to product and labor market distortions. The growth rate has been adjusted for initial income: the variable on the vertical axis is 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. When we also purge the natural capital share of that part which is explained by the country's initial stage of development, we get very similar results as in Figure 1. The 85 countries in the sample are represented by one observation each for each variable under study, an average for the entire sample period, 1965-1998 (see Table 1 and Appendix).[2]

[1] 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, natural capital in 1994 is probably a pretty good proxy for natural resource abundance in the period under review, 1965-1998. 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 natural capital in 1994 as a proxy for natural resource abundance, and also by measuring growth in terms of GNP per worker rather than GNP per capita.

2 The reason why there are 85 countries in the sample and not 92 is that (a) for five countries for which estimates of natural capital exist, there are missing data on economic growth since 1965 (Bolivia, Germany, Tanzania, Uganda and Vietnam) and (b) for two countries, the available data are problematic (Lesotho and Saudi-Arabia). Specifically, Lesotho is omitted because of its extremely low recorded genuine saving rate (-55 percent of GDP), and Saudi-Arabia is omitted because of extreme fluctuations

The regression line through the scatterplot in Figure 1 suggests that an increase of about eight or nine percentage points in the natural capital share from one country to another is associated with a decrease in per capita growth by one percentage point per year on average.[3] The relationship is also significant in a statistical sense (Spearman's r = -0.64), and conforms to the partial correlations that have been reported in multiple regression analyses where other relevant determinants of growth (investment, education, etc., as well as initial income) are taken into account.[4] A similar relationship has been reported in a number of recent studies, including Sachs and Warner (1995, 1999), Gylfason and Herbertsson (2001), and Gylfason, Herbertsson and Zoega (1999).

We are aware that the study of bivariate cross-sectional relationships has many shortcomings. For one thing, such studies bypass the diversity of individual country experiences as well as intranational developments over time. For another, they do not distinguish cause from effect. We intend the correlations presented in this paper merely to describe the data in ways that are consistent with the results of multiple regression analysis that can help account for more potential sources of growth.

The classification of all 85 countries is presented in Table 1. The table indicates that good growth performance appears incompatible with a share of natural resources in excess of 15 percent of national wealth. More generally, in line with Figure 1, the countries in our sample appear to be concentrated on the diagonal linking the south-west and the north-east corners of the table. 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 in Figure 1 and Table 1. The first group consists of eight African countries (Central African Republic, Chad, Guinea-Bissau, Madagascar, Mali, Niger, Sierra Leone and

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in its recorded average rate of economic growth over long periods. With the exception of the latter two countries, no outliers are excluded from the analysis, so that the sample size remains the same, 85, throughout the paper.

[3] There is admittedly an element of statistical bias in Figure 1 in that increased investment increases physical capital, thereby reducing the share of natural capital in national wealth *and* increasing economic growth. (The same point can be made about education and human capital.) This bias, however, is probably not serious because Figure 1 can be reproduced by using different measures of natural resource abundance, such as the share of the primary sector in the labor force (as in Gylfason, Herbertsson and Zoega, 1999) and the share of primary exports in total exports or GDP (as in Sachs and Warner, 1999).

[4] The correlation weakens a bit if we confine the regression to the 77 countries where the natural capital share is below 0.25, thus leaving out the cluster of eight observations in the southeastern corner of

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 countries that are relatively resource-poor by our measure, but whose economies have grown very rapidly since 1965 (Botswana[5], China, Indonesia, Japan, Korea, Malaysia, Mauritius and Thailand). The remaining 69 countries in our sample fall between the two extremes. The fact that erstwhile resource-rich countries such as Botswana, China, Indonesia, Malaysia, Mauritius and Thailand are classified as resource-poor in our sample attests to the successful diversification of their economies away from natural resources over the years.[6]

The question is bound to arise what makes the eight high-performance economies in the second group different from the eight African laggards in the first. A key factor that distinguishes the two groups is saving and investment. Specifically, the group of natural-resource-rich, slow-growth countries shown in the south-west corner of Table 1 has an average gross saving rate of only 5 percent, ranging from -2 percent in Guinea-Bissau to 19 percent in Zambia, whereas the natural-resource-poor, high-growth group shown in the north-east corner has an 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-rich, 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-poor, 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 on saving and investment in this paper.

Figure 1, but even so it remains statistically significant (Spearman's $r = -0.52$).

[5] Botswana's natural capital share is small as shown in Table 1 because the World Bank does not provide an estimate the country's diamond rent. The inclusion of Botswana in our sample does not materially influence any of the empirical results presented in the paper.

[6] In Botswana, agriculture accounted for only 4 percent of GDP in 1998 compared with 11 percent in 1980. The corresponding figures for sub-Saharan Africa as a whole are 17 percent and 18 percent (World Bank, 2000). The decline in the share of agriculture in Botswana's GDP since 1980 is a sign of diversification as well as drought. But see footnote 5.

Table 1. Natural resource dependence and economic growth

Share of natural capital in national wealth (%)	Growth of GNP per capita per year 1965-1998, adjusted for initial income (%) ≤ -3%	-3%< ≤-2%	-2%< ≤ -1%	-1%< ≤ 0%	0%< ≤ 1%	1%< ≤ 2%	3%<
≤ 5%	Jordan	El Salvador South Africa	Guatemala Morocco	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 Columbia Dominican Rep. Mexico Pakistan Sri Lanka Sweden Trinidad and Tobago Tunisia	Finland Ireland Norway	Malaysia Thailand	Botswana China
10% < ≤ 15%	Nicaragua Malawi Mozambique	Congo The Gambia	Bangladesh Namibia Uruguay	Australia Paraguay	Canada	Indonesia	
15% < ≤ 20%	Côte dÏvoire 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						

An important limitation of our data is a lack of observations on the share of natural resources in national wealth at the beginning of thesample period. While economic growth is measured as an average from 1965 to 1998, our measure of the importance of natural resources – their share of total wealth – applies to the year 1994. This may explain, in part, why some formerly resource-dependent countries such as Botswana, China, Malaysia, Mauritius and Thailand are counted as relatively resource-poor. The pattern in the table can thus conceivably arise through self selection as the good performers move towards the upper right-hand corner – having high growth and a low share of natural resources in national wealth – while the poor performers move into the bottom left-hand corner – with low or negative growth and heavily dependent on natural resources. However, when alternative measures of natural-resource dependence – their share of exports, national output, or the labor force – are used at the beginning of the period or as period averages, we also find an inverse relationship between natural resource intensity and economic growth (see Gylfason, Herbertsson and Zoega, 1999, and Gylfason and Herbertsson, 2001).

3. Literature

Four key linkages between abundant natural resources and economic growth have been described in recent literature.

First, natural resource abundance can lead to the Dutch disease, which can appear 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 service exports (Corden, 1984). Recurrent booms and busts tend to increase exchange rate volatility (Gylfason, Herbertsson and Zoega, 1999; Herbertsson, Skuladottir and Zoega, 1999), thus reducing investment in the tradable sector as well as exports and imports of goods and services (see Dixit and Pindyck, 1994). 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.[7] 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 service exports that may contribute more to economic growth.

This idea accords with the view that technological discoveries and innovation take

[7] Herbertsson, Skuladottir and Zoega (1999) provide empirical support for this thesis by showing how domestic supply shocks in Iceland – which take the form of changes in the fish catch – affect real wages, not only in the fisheries but in all other sectors as well.

place in manufacturing rather than agriculture (see 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 service exports, which are probably good for growth (Frankel and Romer, 1999)[8] – not only their quantity but their kind and quality as well.[9]

In second place, huge natural resource rents, especially in conjunction with ill-defined property rights, imperfect or missing markets and lax legal structures in many developing countries and emerging market economies, 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, 2001a, 2001b; 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 that result in current account deficits, disproportionate fiscal redistribution and reduced growth. The combination of abundant natural resources, missing markets and lax legal structures may have quite destructive consequences. 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. Moreover, an abundance of natural resources may tempt foreign governments to invade with destructive consequences and the possibility of such an event may prompt the domestic authorities to spend vast resources on national defense. Military expenditures tend to inhibit growth through their adverse effects on capital formation and resource allocation (Knight, Loayza and Villaneuva, 1996).

Rent seeking can also take more subtle forms. For example, governments may be tempted to thwart markets by granting favored enterprises or individuals privileged access to common-property natural resources, as, for example, in Russia, or they may offer tariff protection or other favors to producers at public expense, creating competition for such favors among the rent seekers (Krueger, 1974). Extensive rent

[8] A dissenting view is expressed in Rodriguez and Rodrik (2000).
[9] 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).

seeking – i.e., seeking to make money from market distortions – can breed corruption in business and government, thus distorting the allocation of resources and reducing both economic efficiency and social equity (Shleifer and Vishny, 1993). Empirical evidence and economic theory suggest that import protection, cronyism and corruption all tend to impede economic efficiency and growth (Bardhan, 1997; Mauro, 1995; Murphy, Shleifer, and Vishny, 1993).

The question of causality remains. Clearly, the presence of natural resources is a necessary condition for such rent seeking to take place. However, it is by no means enough. In principle, natural resources can, of course, coexist with well-defined property rights, well-functioning markets and the rule of law in an efficient and dynamic market economy. The interesting question from our point of view is whether, in practice, natural resource abundance tends to thwart attempts towards establishing such a growth-friendly institutional framework.

Third, natural resource abundance may reduce private and public incentives to accumulate human capital due to a high level of non-wage income – e.g., dividends, social spending, low taxes.[10] Empirical evidence shows that, across countries, school enrolment at all levels is inversely related to natural resource abundance, as measured by the share of the labor force engaged in primary production (Gylfason, Herbertsson and Zoega, 1999). There is also evidence that, across countries, public expenditures on education relative to national income, expected years of schooling and secondary-school enrolment are all inversely related to natural capital as measured here (Gylfason, 2001).[11] This matters because more and better education stimulates 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.

Again, the question of causality remains. It is likely that economic underdevelopment – poverty – causes natural resources to be relatively important *and*

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[10] However, the rent stream from abundant natural resources may enable nations to give a high priority to education – as in Botswana, for instance.

[11] As far as economic growth is concerned, however, the supply of education may matter less than demand (see Birdsall, 1996). This is relevant here because public expenditure on education tends to be supply-determined and of mediocre quality, and may thus fail to foster efficiency, equality and growth, in contrast to private expenditure on education, which is generally demand-led and thus, perhaps, likely to be of a higher quality and more conducive to growth. For this reason, we prefer to use secondary-school enrolment rates rather than public expenditures on education as our measure of education in the empirical analysis presented in Sections 6 and 7.

makes it difficult to fund and operate educational establishments. On the other hand, and more interestingly from our point of view, it is also possible that abundant natural resources reduce the demand for training and education.

Fourth, 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 good and growth-friendly economic management, including free trade, bureaucratic efficiency, 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). From this perspective, one reason why high inflation tends to hurt economic growth (Bruno and Easterly, 1998; Gylfason and Herbertsson, 2001) may be that high inflation reflects flawed policies or weak institutions which impede growth. Incentives to create wealth through good policies and institutions may wane because of the relatively effortless ability to extract wealth from the soil or the sea. Manna from heaven can be a mixed blessing. Unconditional foreign aid may be a case in point (see Burnside and Dollar, 2000).

4. Norway

It is by no means inevitable that existing natural resources prevent the emergence of a dynamic economy or that the discovery of such resources acts to dampen an already developed economy. Natural resources can be a blessing as well as a curse.
Norway is a case in point. The world's second largest oil exporter (after Saudi-Arabia), Norway shows as yet no clear symptoms of the Dutch disease – other, perhaps, than a stagnant ratio of exports to GDP, albeit at a rather high level, or about 40 percent of GDP, since before the oil discoveries, indicating that Norway's oil exports have crowded out non-oil exports krone for krone relative to income; moreover, Norway has attracted a relatively limited, yet gradually increasing inflow of gross foreign direct investment, equivalent to 8 percent of GDP in 1998 (adjusted for purchasing power parity; see World Bank, 2000), far below the figures for Sweden and Finland next door (23 percent and 36 percent). Nor does Norway show any signs yet of socially damaging rent-seeking behavior even if increasingly loud calls are being voiced – and heard! – for using more of the oil revenue to address domestic social needs rather than continue to build up the government-owned oil fund, which is

invested in foreign securities. There are as yet no clear signs either of a false sense of security or of an inadequate commitment to education, on the contrary: for example, college enrolment rose from 26 percent of each cohort to 62 percent between 1980 and 1997. Growth has thus far remained stubbornly high. Even so, some observers of the Norwegian scene have recently expressed concerns that some deep-seated structural problems in the country's education and health care sectors (government monopoly, insufficient competition, low efficiency, etc.) may be misdiagnosed as financial problems because the money available from the oil fund may blunt the willingness of politicians to undertake difficult structural reforms.

Most other oil-producing countries, including virtually the entire membership of OPEC, carry these symptoms to varying degrees. From 1965 to 1998, GNP per capita in the OPEC countries *decreased* on average by 1.3 percent per year. Negative economic growth over this 33-year period was accompanied by an average ratio of gross domestic fixed investment to GDP of 23 percent for the 11 OPEC countries on average, a respectable ratio by world standards (compared with 27 percent in Norway). Why did all this investment in the OPEC countries go hand in hand with negative growth for so long? – a phenomenon familiar also from the former Soviet block which, under socialism, saved and invested more of its national economic output year after year than most OECD countries and yet failed to grow (Easterly and Fischer, 1995). The answer must involve the efficiency of investment. For it is not enough to invest; to sustain economic growth, the investments must be of high quality. A false sense of security may lull countries with oil in abundance or other natural resources into reducing, if not the quantity of investment, then its quality, or both. The same argument applies to human capital and perhaps to social capital as well.

One of the factors that separates the different experiences of Norway and the OPEC countries, we suggest, is timing. Norway was already a developed country at the time of the oil discoveries in the 1970s. Most importantly, Norway's political and social institutions were mature and the economic and financial system was relatively developed, although by no means fully liberalized. All of this facilitated judicious and far-sighted management of Norway's oil wealth, at least compared with most other oil producers (Hannesson, 2001). In contrast, full-fledged capitalist development did not take place in most OPEC countries prior to the discovery of their oil resources, or since for that matter (Karl, 1997). While Norway has built up substantial assets abroad, Saudi-Arabia has accumulated debts.

It appears from our informal discussion that saving and the quantity and quality of investment may be among the key factors that separate those resource-rich countries, like Norway, that have grown rapidly from those that have had less success. We now turn to the interplay between natural capital and the quantity and quality of investment in a theoretical context.

5. Theory

Our aim in this section is to show how optimal saving, and also the rate of growth of output and capital, depends on the intensity of natural resources and the quality of the capital stock.

We take output to be produced by labor L, natural resources N and capital K and the production function to be of the Cobb-Douglas variety:

(1) $$Y = AL^a N^b K^{1-a-b}$$

where A represents overall efficiency, including technology and quality (more on this in Section 5.3). We can rewrite equation (1) in per capita terms: $y = An^b k^{1-a-b}$ where $y = Y/L$, $n = N/L$ and $k = K/L$.

Equation (1) encapsulates a technology where natural resources can be bundled together with either labor or capital in the production process (Bruno, 1984). Imagine the production of oil or fish fit for consumption. One way to generate value added Y would be to use a lot of raw materials – fish or crude oil – and to sell these unprocessed with a minimum input of labor and capital. However, the same value of output can be attained with fewer raw materials and more labor or capital to produce a more refined good. We need a production function that generates smooth and differentiable isoquants in the L-N-K space such as the one given by equation (1).

We distinguish between the structure of the economy and its abundance of natural resources. By structure we mean the importance of natural resources to the national economy while abundance refers to the supply (per capita) of the natural resources. Within the Cobb-Douglas framework, the exponents in the aggregate production function (1) denote factor shares – hence the structure of the economy – 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. The distinction between structure and abundance allows us to distinguish between the effect of a change in the factor share b on growth, on one hand, and a change in the abundance of the natural resource N, on the other. In Figure 2, we describe changes in abundance by horizontal movements, holding the structure of the economy unchanged, and structural changes by vertical movements, holding resource abundance unchanged.

5.1 *Optimal saving in the Solow model*

To set the stage, we start with the Solow model and derive the optimal saving rate in an economy with natural resources. Consumption per capita, $c = C/Y$, is proportional to output:

(2) $$c = (1 - s)y$$

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

(3) $$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - g = \frac{sY - dK}{K} - g = s\frac{y}{k} - d - g$$

where g is the growth of the labor force and d is the depreciation rate. We abstract from technological progress. In the steady state where $\dot{k}/k = 0$, 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:

(4) $$\frac{k}{y} = \frac{s}{g + d}$$

Solving the normalized version of equation (1) and equation (4) together for y and substituting the result into the consumption function (2) gives

(5) $$c = (1 - s)A^{\frac{1}{a+b}} n^{\frac{b}{a+b}} \left(\frac{1}{g + d}\right)^{\frac{1-a-b}{a+b}} s^{\frac{1-a-b}{a+b}}$$

Maximizing consumption per capita in equation (5) with respect to s gives the following simple solution for the optimal saving rate:

(6) $$s = 1 - a - b$$

Hence, the greater the role of natural resources in the generation of national output – i.e., the greater b in equation (1) – 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 (6) obviously becomes $1 - a$, the golden-rule formula.

Equations (1), (4) and (6) imply that

- The larger the share of natural resources in national income b, the lower is the elasticity of output with respect to the saving rate.[12] When b increases, the production function becomes more concave when plotted against capital and a given proportional increase in the saving rate raises future output, and hence also consumption, less.
- Because the elasticity of output with respect to saving is decreasing in b, the optimal saving rate – which maximizes steady-state consumption – is also a decreasing function of b. The larger the share of natural resources in national income, the lower is the optimal saving rate.
- Heavy dependence on natural resources as measured by their share in national income b causes the capital-output ratio to be lower due to a lower optimal saving rate. In effect, natural capital crowds out physical capital to a degree.
- In the long run, the level of output per capita is inversely related to the share of natural resources in national output, given the level of natural resources N, due to less saving. However, notice that an increase in their level – holding their share of national income constant – makes output as well as the stock of capital rise.
- In contrast, the speed of adjustment towards steady state is an increasing function of the share of natural capital in national income b. The larger the natural capital share, the smaller is the share of physical capital in national income and hence the more rapid is the adjustment to steady state.[13]

In sum, an economy where the owners of natural resources receive a high fraction of national income converges quickly to a steady state with a low saving rate and a

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[12] By equation (5), the elasticity is $(1 - a - b)/(a + b)$ which is decreasing in b.

[13] The speed of adjustment is given by $(1 - (1 - a - b))(g + d)$ which is increasing in b. This is the rate of decrease of the difference between the current and the steady-state level of capital and is

correspondingly low capital-output ratio and where, most importantly, output per capita is also low.

5.2 *Optimal saving in the Ramsey model*

Because our derivation of the optimal saving rate in the Solow model does not constitute microeconomic optimization from first principles, we now proceed to derive the optimal saving rate in the Ramsey model which is more firmly grounded in the optimization behavior of firms and consumers.

Assume the same production function as in the Solow model above. As before, output can be either saved – that is, added to the capital stock – or consumed. Now enters the central planner who maximizes the welfare of the representative consumer by solving the following optimization problem:

$$(7) \qquad \max_{c} \int_{0}^{\infty} u(c_t) e^{-rt} dt$$

where c is consumption per capita as before and r is the pure rate of time preference, subject to the constraints

$$(8) \qquad k_0 = \bar{k}_0$$

$$(9) \qquad \dot{k} = An^b k^{1-a-b} - c - (d + g) k$$

where $\bar{k}_0$ is a constant. The necessary conditions that have to be satisfied along an optimal path are

$$(10) \qquad (1-a-b) An^b k^{-a-b} - d = r - \frac{\dot{u}_c}{u_c}$$

$$(11) \qquad \dot{k} = An^b k^{1-a-b} - c - (d + g) k$$

Equation (10) is the well-known Keynes-Ramsey rule. The left-hand side shows the marginal benefit of saving – that is, postponing consumption – which is the net marginal product of capital and the right-hand side shows the marginal cost which is the sum of the pure rate of time preference and the (absolute) rate of growth of marginal utility. The higher the net marginal product of capital, the greater is the benefit from saving more and the more impatient the representative consumer, the

independent of the saving rate. See Romer (1996), page 22.

greater is the cost. Finally, if consumption is expected to grow in the future ($\dot{u}_c < 0$), this constitutes an extra cost of increasing saving: it is costly to postpone consumption to a later time when it will be valued less.

The Keynes-Ramsey rule tells us that changes in factor intensity that increase the share of national income going to the owners of natural resources reduce the marginal benefit of saving and hence also capital accumulation for all plausible parameter values.[14] It follows that an economy whose industries rely heavily on the use of natural resources tends to have a relatively low steady-state stock of capital, other things being equal. A structural change that makes oil more important relative to capital will reduce the optimal saving rate. In contrast, an increase in the natural resource base (an oil discovery, for instance) – holding the share of the resource in national income constant – causes the marginal benefit of saving to go up and hence also its optimal level.

In steady state we have $\dot{u}_c/u_c = \dot{k} = 0$ which implies, after some manipulation of equations (10) and (11), that

(12) $$s = \frac{y-c}{y} = (1-a-b)\left(\frac{d+g}{d+r}\right)$$

This result simplifies to $s = 1-a-b$ as in equation (6) in the Solow model if $g = r$. In any case, the optimal rate of saving varies inversely with the share of natural resources in national income, b.

We also find that the speed at which the economy travels along a saddle path towards steady state is increasing in the share of the natural resource in national income. An increase in the parameter b makes the production function be more concave in capital. As a result, a fall in the stock of capital below its steady-state value has a greater effect on its marginal product and hence also on the incentive to save and invest. Therefore, saving will increase more and we will move faster back to steady state.

To see how expectations about how permanent a natural resource boom is enter the calculations we need to solve the model with the use of a phase diagram (not shown)

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[14] An increase in b reduces the marginal product of capital as long as $\log(n/k) < 1/(1-a-b)$. Assuming that $a + b = 0.5$ as a minimum makes the critical value of the natural capital/physical capital ratio equal to $e^2 \approx 7.39$ which ensures that the above inequality is satisfied for all countries in our data

and pay close attention to whether it is the structure of the economy – represented by the parameter b in the production function – that is changing or the supply of the resource N, holding the factor share constant. To make a long story short, the Keynes-Ramsey rule (10) can be rewritten as the following Euler equation:

$$\frac{\dot{c}}{c} = \frac{1}{q}\left[(1-a-b)n^{b}k^{-(a+b)} - (d+g)\right] \tag{13}$$

where q is the coefficient of relative risk aversion – assuming that the utility function in equation (7) is of the CRRA form, $u(c_t) = \frac{1}{1-q}c^{1-q}$. Equations (11) and (13) can now be used to solve the model and derive the following results:

- *A permanent increase in b* – the share of natural capital in national income – makes consumption jump immediately and then gradually decline to a lower level than before as the capital stock is gradually depleted. While both investment and output are lower in the new steady state, the saving rate – which is the ratio of the two – is lower because of the diminishing marginal product of capital.
- *A transitory increase in b* makes consumption jump initially – albeit not by as much as in the case of a permanent change – and subsequently both consumption and capital decline until b comes down again. At exactly that moment we hit the old saddle path. Thereafter, consumption and capital gradually increase along the old saddle path until we hit the original steady state.
- *A permanent increase in N* (holding b constant) – i.e., holding technology constant – makes consumption jump immediately so that we hit a new saddle path after which we move upwards along the new path towards a new steady state where both the level of consumption and the stock of capital are higher than before. Note the interesting twist to this saga: A permanent resource boom – holding the share of natural resources in national income constant – raises consumption by more than the increased supply of the natural resource would imply. There is a secondary effect through capital accumulation. When N goes up, output increases and so do permanent income and consumption, but because the marginal product of capital goes up, the incentive to save is enhanced and the capital stock is gradually increased. As a result, steady-state consumption rises by more than the rise in income caused by more abundant natural resources.

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set where Niger has the highest value of n/k, 5.66.

- *A temporary increase in N* also causes consumption to jump and then to grow gradually alongside the capital stock. However, when the natural resource boom comes to an end we hit the old saddle path and both consumption and capital fall as we move down the old saddle path (as in Rodriguez and Sachs, 1999). There occurs a transitory consumption boom. Importantly, consumption is maintained at a higher level than its original steady state for a period which is longer than the duration of the natural resource boom.

5.3 *Endogenous growth*

Rather than focus on medium-term growth, we would now like to write down a model that shows how economic growth depends on the abundance of natural resources and the quality of the capital stock, even in the long run. In particular, we will show how natural resources can affect the rate of growth of output and capital both directly through the quantity of investment as well as indirectly through the quality of investment. Our model of choice is only one of several possible ones; accordingly, its implications need scrutiny and testing.

We adopt the pioneer endogenous growth model of Romer (1986) where sustainable growth arises from constant returns to capital at the social level. At the firm level, however, we have constant returns to all factors of production and diminishing returns to capital. The root of constant social returns to capital lies in learning-by-investing and instantaneous knowledge spillovers across firms.

We expand the model to include natural resources. We assume that both the productivity of labor as well as that of the natural resource is augmented through learning and that the level of labor- and natural-resources-augmenting technology can be proxied by the aggregate stock of capital, which is a function of past investment; hence the generation of knowledge. We assume that the number of workers is fixed. This gives us the following production function for the representative firm:

(14) $$Y_i = \left(qK_i\right)^{1-a-b}\left(KN_i\right)^b\left(KL_i\right)^a$$

where Y_i denotes the output of the representative firm i and q is the exogenous productivity of capital, and takes a value between zero and one. Equation (14) gives equation (1) when $A = q^{1-a-b}K^{a+b}$, $K = \sum_i K_i$, $L = \sum_i L_i$, $N = \sum_i N_i$ and all firms are of equal size.

Like Scott (1989), we distinguish between quantity and quality (see also Lal and Myint, 1996, Ch. 2). If some investment projects miss the mark and fail to add commensurately to the capital stock, we have $q < 1$. One way to interpret q is to view it as an indicator of distortions in the allocation of installed capital due, perhaps, to a poorly developed financial system, but perhaps also due to trade restrictions or government subsidies that attract capital to unproductive uses in protected industries or in state-owned enterprises where capital may be less productive than in the private sector (Gylfason, Herbertsson and Zoega, 2001). Another way is to view the quality index q as the ratio of the economic cost (i.e., minimum achievable cost) of creating new capital to the actual cost of investment (Pritchett, 2000) – that is, K is then measured on the basis of actual costs which may overstate its productivity. Yet another way is to view q below 1 as a consequence of aging: the larger the share of old capital in the capital stock currently in operation, that is, the higher the average age of capital in use, the lower is its overall quality (Gylfason and Zoega, 2001). For our purposes, the three interpretations are analytically equivalent. However, we assume that the quality of capital has remained constant in the past which means that all units of capital are of the same quality. In other words, we are not interested here in the implications of having different vintages of capital.

The other important new element here is the presence of natural resources. Whereas capital is owned by a class of capitalists, the natural resources are owned by individuals – the *naturalists*. 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 the capital sell their services to firms. As in the other two factor markets, we have an equilibrium under perfect competition where marginal product equals the sum of the real interest rate r and the rate of depreciation d

$$(15) \qquad \frac{dY_i}{dK_i} = (1-a-b)q^{1-a-b}K_i^{-a-b}(KN_i)^b(KL_i)^a = r + d$$

The depreciation rate d is the rate at which installed capital loses its usefulness over time, as a result of economic obsolescence as well as physical wear and tear (Scott, 1989). The parameters q and d could both be modeled as endogenous choice parameters (as in Gylfason and Zoega, 2001), but here we treat them as exogenous magnitudes for simplicity, even if we acknowledge that depreciation may depend on quality, through obsolescence.[15]

Households with an infinite planning horizon maximize discounted future utility with respect to consumption per capita and subject to an asset-accumulation constraint. This gives the standard Euler equation for the growth of consumption per worker:

(16) $$g = s\left(r - r\right)$$

where s is the elasticity of intertemporal substitution (assuming constant relative risk aversion) and r is the rate of time preference. Using equation (16) and assuming symmetric equilibrium, we get the following expression for the optimal rate of growth of consumption and output:

(17) $$g = s\left((1 - a - b)q^{1-a-b}N^{b}L^{a} - d - r\right)$$

Thus, economic growth depends on several factors:

- The rate of growth varies directly with the quality of the capital stock q. The higher quality, the higher is the price of capital – for a given level of capital – and hence the real rate of interest. A higher interest rate induces consumers to postpone consumption – i.e., to save and accumulate capital.
- The rate of growth depends on the size of the labor force L. This is the scale effect that is common in the growth literature. A larger aggregate labor force raises the private marginal product of capital and hence also the price of capital – the real rate of interest. This leads to increased saving and a more rapid rise of consumption.

[15] We thus view quality and durability as two different things. The pyramids of Egypt were high-quality investments in their day – good at preserving mummies! – and they have lasted a long time (high q, low d); they remain among Egypt's major sources of foreign exchange. High-quality computers, by contrast, do not last long because they are quickly rendered obsolete by better machines (high q, high d). Soviet housing, which sometimes began to crumble even before construction was completed, is an example of low-quality, low-durability investment (low q, high d). But some low-quality investments last a long time, like Mr. Hoxha's concrete bunkers, hundreds of thousands of them, scattered all across Albania: they were built to last as long as the pyramids, but they remain utterly useless, or worse because it would be so costly to demolish them (low q, low d).

- The rate of growth is inversely related to the pure rate of time preference r. The higher the rate of time preference – i.e., the more impatient are workers – the greater is current consumption and the slower is the growth of consumption in the future due to less saving.
- The rate of growth is inversely related to the rate of depreciation d. A "good" investment combines high quality and low depreciation. Equation (17) shows that "bad" investments retard the build-up of useful capital over time in two ways: (a) by adding capital of low quality, with q below 1, hence lowering the price of capital and blunting the incentive to save and invest, and (b) by increasing the depreciation rate d, thus decelerating output from the supply side.

Most importantly from our perspective, the intensity of natural resources affects the rate of growth. Given our assumptions of constant returns to scale and competitive markets, the exponents a and b in the production function show the share of output going to labor and the naturalists, respectively, so the remainder goes to the capitalists. Equation (17) shows that both the share of the naturalists in output b as well as the term N^b in the production function affect the growth rate.

A rise in the supply of natural resources N causes their price to fall while keeping the factor share constant at b. However, an increase in the share of output going to the owners of the natural resource, b, causes the price to rise while leaving N unchanged due to its fixed supply. These changes affect the rate of growth of consumption and output:

- A rise in the supply of the natural resource N – with an unchanged state of technology and hence unchanged factor shares – leads to a fall in its price and an increase in the quantity used in production. The increased use of the natural resources raises the marginal product of capital, hence also the demand for capital and its price – the real rate of interest. A higher real interest rate lowers the price of future consumption and makes workers substitute future for current consumption. Saving and investment increase and hence also the pace of learning and knowledge spillovers. The rate of economic growth has increased. But notice that this is a scale effect similar to the one involving the size of the labor force.
- A rise in the share of output going to the owners of the natural resource, b, reduces the marginal productivity of capital. This lowers the real rate of interest and raises the price of future consumption. Facing a higher price of future consumption,

workers increase current consumption at the expense of future consumption. Saving is reduced and so are investment, learning and growth in this closed economy. Given competitive markets, the share going to the naturalists can only increase due to changes in the production function.[16]

The socially optimal rate of growth of consumption – which comes from the solution to the central planner's problem – depends on the social marginal product of capital, not the private marginal product. The rate of growth of consumption and output is now given by

$$g = s\left(q^{1-a-b}N^{b}L^{a} - d - r\right) \tag{18}$$

Notice that the privately optimal growth rate in equation (17) is smaller than the socially optimal one in equation (18). The difference lies in the term $1 - a - b$ in the marginal product expression in the former equation. As a result, the discrepancy between the actual and the optimal rate of growth is increasing in the share of output going to the naturalists b. In other words, the extent of the market failure inherent in the Romer model varies directly with the share of output going to the owners of the natural resources.

5.4 *Natural capital, financial intermediation and growth*

We have identified a direct link between natural resources and economic growth, through saving and investment. There may also be an indirect effect through the productivity of capital q. An abundance of natural resources may hamper the emergence of a well-developed financial system. If so, this outcome is likely to result in an inefficient allocation of savings across sectors and firms – that is, reduce the value of q in the equations above – and to reduce the average productivity of capital and so to further blunt incentives to save and invest by reducing the marginal productivity of capital at a given level of the capital stock.

When a large part of national wealth is stored in a natural resource, renewable or not, there is less need for financial intermediation to conduct day-to-day transactions. Dissaving can take the form of more rapid depletion of the resource and saving can take the form of less rapid depletion or of more rapid renewal in the case of renewable

[16] Alternatively, we could have derived the same result assuming imperfect competition and monopoly rents in the market for the services of natural resources. Changes in these rents would then affect growth.

natural resources. In some countries, such as the oil-rich OPEC states, saving also takes the form of deposits in foreign banks. In this case, domestic financial intermediation becomes even less important. In contrast, when saving is piled up at home in the form of physical capital, domestic banks and stock markets assume paramount importance. By linking up domestic savers and investors, the domestic financial system contributes to a more efficient allocation of capital across sectors and firms.

Further, a well-developed financial system helps drive a wedge between the effect of foreign and domestic saving on economic growth. In other words, as the financial system matures and becomes more efficient at allocating capital at home, foreign savings – i.e., deficits on the current account of the balance of payments – become relatively less useful when not channeled through the domestic banking system. In a mature financial system, investment financed through domestic saving can be more effective at stimulating economic growth than investment financed by foreign saving.

Not only is it thus possible for an abundance of natural resources to hamper the development of the financial system and hence to distort the allocation of capital but economic growth may slow down due to a detrimental effect of financial backwardness on the quantity and quality of saving and investment. King and Levine (1993) find that indicators of financial development and their predetermined components predict subsequent growth, physical capital accumulation and improvements in the efficiency of capital allocation.[17] Hence, our hypothesis that natural resource dependence tends to go along with an underdeveloped financial system means, if King and Levine are right, that resource dependence also tends to hinder future gains in efficient capital deepening and economic growth.

6. Correlations

To recapitulate, we posit that heavy dependence on natural resources may reduce saving and investment and hence inhibit economic growth. Resource dependence may also slow down the development of the financial system, thereby reducing the quality of investment decisions and hence also the productivity of capital and also, perhaps, raising the ensuing rate of depreciation. If so, a given investment rate is likely to generate a lower rate of growth of output, other things being equal.

[17] Benhabib and Spiegel (2000) report similar findings.

In empirical research on economic growth thus far, the effects of investment on growth have not generally been found to be very strong or highly significant. Many researchers, including Doppelhofer, Miller and Sala-i-Martin (2000), do not even consider investment as a potential determinant of long-run growth, presumably because they view investment, like growth, as an endogenous variable. Moreover, Sachs and Warner (1997, 2001) report that they have found little evidence of a link between natural resource abundance and investment. Almost invariably, the volume of gross investment has been used as the sole measure of investment in such studies, with mixed results (Levine and Renelt, 1992; Barro and Sala-i-Martin, 1995). This practice means that net investment and replacement investment have been assumed to have identical effects on growth. We have pointed out that the higher the fraction of gross investment needed to replace old capital, the lower will be the rate of growth of output. We now want to take a further step and, as a prelude to the regression analysis that follows, study the cross-country correlations among (a) natural resource intensity, gross investment and genuine (i.e., quality-adjusted) saving which takes into account the depreciation of physical, human and natural capital as well as the stock of foreign assets, and (b) investment, saving, and economic growth.

6.1 *Gross investment and growth*

Before embarking on the regression analysis in Section 7, let us inspect the data. The upper panel of Figure 3 shows a scatterplot of the average ratio of gross domestic investment to GDP in 1965-1998 and natural resource intensity measured as before. When we purge the natural capital share of that part which is explained by the country's initial income per head, we get very similar results as in Figure 3a.[18] The group of eight low-growth, natural-resource-rich African countries identified in Figure 1 is visible in the lower right-hand corner of Figure 3a. The high-growth, natural-resource-poor countries are also easy to spot in the upper left-hand corner of the figure. Apart from these two groups, the relationship between the two variables is not very clear, even if it remains statistically significant. A clearer relationship emerges when we plot economic growth against the investment ratio over the same period, 1965-1998. The figure in the lower panel of Figure 3 shows the cross-country relationship between the rate of growth, on the one hand, and the sum of domestic and

[18] The same applies to Figures 4a, 5a and 6a.

foreign saving (the latter measured by the current account deficit) without any attempt to adjust investment for quality, q. The regression line through the 85 observations suggests that an increase in the investment ratio by about four percentage points is associated with an increase in annual economic growth by 1 percentage point. The relationship is significant (Spearman's $r = 0.65$).[19]

6.2 *Genuine saving and growth*

As we saw in Section 5, however, high saving and investment rates do not necessarily stimulate growth if they are accompanied by rapid depreciation of physical capital.[20] Depreciation calls for investment to replace the depleted capital, thus rendering a smaller share of domestic (and foreign) saving available for fresh capital formation. A similar argument applies to natural capital. This is where the World Bank's new estimates of genuine saving rates enter the picture (see Appendix for a description of the data). Countries that run down their stocks of physical and natural capital will have low, perhaps even negative, genuine saving rates which, therefore, may be taken as a rough indication of the physical and economic durability of their capital and the sustainability of their natural resource management, at least in a physical sense. For example, the average genuine domestic saving rate of the 11 OPEC countries in 1970-1998 was -7 percent, ranging from -25 percent in Kuwait to 10 percent in Indonesia, compared with 17 percent for Norway.

Genuine domestic saving differs from net domestic saving (i.e., gross domestic saving minus depreciation) by the rundown and depreciation of natural capital, adjusted by current expenditure on education, which increases or improves human capital[21] even if it is classified as current expenditure in national income accounts. Genuine saving is intended to indicate the difference between sustainable net national product and consumption, where sustainable net national product means the maximum amount that could be consumed without reducing the present value of

[19] The slope of the regression line through the scatterplot is consistent with the coefficients on investment in cross-country growth regressions reported in recent literature (Levine and Renelt, 1992).
[20] Scott (1989) is of a different opinion. He claims that depreciation reflects mainly the economic obsolescence of capital, and does not necessarily reduce its usefulness. To him, therefore, gross investment is the correct measure of capital accumulation in growth research. In his own words, "workers … benefit from rising wages which result in appreciation which is omitted from the conventional accounts. Were it included, it would offset depreciation on capital assets. It would then be clear that net investment for society as a whole is (approximately) equal to gross investment as conventionally measured, and not to gross investment minus depreciation." (p. 92).
[21] But recall the reservations expressed in footnote 11.

national welfare along the optimum path (Hamilton, 2001).[22] Genuine saving rates are higher than net saving rates in those countries where improvements in human capital outweigh the deterioration of natural capital, and conversely. In view of these adjustments, one might expect genuine saving rates to be more closely correlated with natural capital and economic growth than gross investment rates.

The data seem to confirm this conjecture. The upper panel of Figure 4 shows a scatterplot of genuine domestic saving in 1970-1998 (the World Bank figures do not reach further back) and natural capital as measured before. The regression line through the 85 observations suggests that an increase of about two and a half percentage points in the natural capital share from one country to the next is associated with a decrease in genuine saving by one percent of GDP. The relationship is statistically significant (Spearman's r = -0.53).[23] The correlation between genuine saving and natural capital in Figure 4a is closer than that between gross investment and natural capital in Figure 3a. On the other hand, the inverse relationship between net investment and natural capital (not shown) is weaker than the ones shown in Figures 3a and 4a, but still significant. This seems to suggest that it is not enough to adjust gross investment for depreciation of physical capital; we need to adjust it for depreciation of other types of capital as well.

The lower panel of Figure 4 shows a scatterplot of economic growth and genuine domestic saving in 1970-1998 in the same 85 countries. The regression line suggests that an increase in the genuine saving rate by about seven percentage points is associated with an increase in annual economic growth by 1 percentage point. The relationship is highly significant (Spearman's r = 0.72). Again, the correlation between genuine saving and growth in Figure 4b is closer than that between gross investment and growth in Figure 3b. Further, the direct relationship between economic growth and net investment (not shown) is weaker than the ones shown in

[22] More specifically, genuine domestic saving is defined as net domestic saving plus education expenditure minus energy depletion, mineral depletion, net forest depletion and carbon dioxide damage (World Bank, 2000, p. 171). Estimates that are missing include the depletion and degradation of soils and net depletion of fish stocks. The most important pollutants affecting human health and economic assets are also excluded (particulate emissions, ground-level ozone, acid rain). In some cases, the resource depletion estimates of the World Bank are quite high because the entire mineral-resource rent is counted as depletion whereas the alternative user cost approach allocates only a fraction of the rent to depletion. The median genuine saving rate in our sample is 9 percent, and ranges from -21 percent to 23 percent. The corresponding figures for the gross investment rate are 20 percent, 7 percent and 32 percent.

[23] The correlation weakens a bit if we limit the regression to the 77 countries where the natural capital share is below 0.25, but it remains statistically significant (Spearman's r = -0.43).

Figures 3b and 4b, but still highly significant. This suggests once more that it is not enough to adjust gross investment for physical depreciation. It seems that, in a broad sense, quality counts.

6.3 *Gross saving and growth*

The difference between gross investment and genuine saving comprises four terms: (a) depreciation of physical capital, (b) depreciation of natural capital, (c) depreciation of human capital and (d) rundown of foreign capital – the current account deficit. How much of the difference between the results reported in Figures 3 and 4 can be traced to the current account? To find out, we subtract the current account deficit/GDP ratio from the gross investment rate in order to obtain the gross domestic saving rate and then redraw the scatterplots.

The upper panel of Figure 5 shows the scatterplot of gross domestic saving in 1970-1998 and natural capital. The results are essentially the same as in Figure 4a, even if the correlation now is a bit weaker (Spearman's r = -0.40). The lower panel of Figure 5 shows the scatterplot of economic growth and gross domestic saving in the same 85 countries. Again, the results are essentially the same as in Figure 4b (Spearman's r = 0.73). The correlations between natural capital, gross saving and growth in Figure 5 are a bit stronger than the ones between natural capital, gross investment and growth in Figure 3, but the differences are small.

To summarize, the data show that, across countries,

(a) economic growth varies directly with gross investment, genuine saving and gross saving (Figures 3b, 4b, and 5b),

(b) gross investment, genuine saving and gross saving are all inversely related to resource dependence (Figures 3a, 4a, and 5a), and

(c) growth varies inversely with natural resource dependence (Figure 1).

Through any one of the three possible channels under review here (gross investment, genuine saving or gross saving), an increase in the share of natural capital in national wealth by 10 percentage points from one country to another is associated with a decrease in per capita economic growth by 0.5-0.6 percentage points. Natural resource dependence thus appears to inhibit economic growth significantly by weakening public and private incentives to save and invest as well as to build up human capital (Barro, 1997; Temple, 1999; Gylfason, 2001), in addition to the linkages through the Dutch disease, rent seeking, policy failures and institutional weaknesses stemming from a false sense of security, reviewed in Section 3. If so, the adverse effects of natural resource dependence on economic growth since the 1960s that have been reported in the literature may, in part, reflect the effect of investment and genuine saving on growth.

At last, we look at the data on financial development. The upper panel of Figure 6 below shows a cross-sectional scatterplot of financial development, for which we use the average ratio of M_2 and GDP in 1965-1998 as a proxy, like King and Levine (1993), and natural resource dependence as measured before. The figure covers the same 85 countries as before. The lower panel of the figure relates our measure of financial development to average economic growth per capita over the same period. Figure 6a shows a clear negative correlation between natural resource dependence and financial depth (Spearman's r = -0.68).[24] Similarly, Figure 6b shows a positive relationship between our measure of financial depth and average economic growth (Spearman's r = 0.66). However, the question of causality remains. It is possible that heavy dependence on natural resources actually hinders the development of the financial sector and hence also growth, as we are inclined to think, but other possibilities also exist; in particular, some unspecified third factor may inhibit both financial development and economic growth.

7. Regressions

It remains to see if the statistical patterns reported in the preceding section hold up under closer scrutiny. The first three rows in Table 2 report seemingly unrelated regression (SUR) estimates of a system of three equations for the 85 countries in our sample where

(a) economic growth per capita depends on the share of gross domestic investment in GDP 1965-1998, the gross secondary-school enrolment rate, the natural capital share 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 and initial income; and

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[24] The exponential regression curve becomes steeper if we limit the regression to the 77 countries where the natural capital share is below 0.25, but even so the correlation remains highly significant (Spearman's r = -0.61).

(c) investment depends on the natural capital share.

It is not our contention that earlier writers, including ourselves, have been misguided by their use of imperfect proxies for natural resource intensity. Even so, knowing that we could recount essentially the same story as we are about to tell here using the earlier proxies, we prefer here to use the World Bank's natural capital estimates for the reason stated in Section 2. The recursive nature of the system shown in Table 2 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.[25]

Table 2. Regression results: Growth and gross investment

Dependent variable	*Constant*	*Natural capital*	*Initial income*	*Enrolment rate*	*Investment*	R^2
	10.1 (6.0)					
Enrolment rate	-103.7 (7.5)	-0.75 (4.2)	19.9 (12.4)			0.72
	22.5 (29.3)					
Economic growth	7.29 (4.8)	-0.12 (6.7)	-0.58 (3.2)			0.35

Note: 85 observations. t-statistics are shown within parentheses.

All the parameter estimates in Table 2 are economically and statistically significant. The coefficient on initial income in the growth equation indicates a convergence speed of 1.5 percent per year, which is not far below the 2-3 percent range typically reported in statistical growth research. The direct effect of natural capital on growth is -0.06. The indirect effect of natural capital on growth through education is $-0.75\times0.05 \approx -0.04$ and the additional indirect effect through investment is $-0.20\times0.10 = -0.02$. The novelty here is the part of the story involving investment; as far as we know, this linkage – from heavy dependence on natural resources to slow growth via investment

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

– has not been documented in econometric work before. The total effect of natural capital on growth is thus about -0.12 (for given initial income), which is very close to the value of the slope of the regression line in Figure 1. This means that the implicit constraint on the coefficient of initial income as well as the omission of education and investment in Figure 1 do not bias the quasi-reduced-form estimate of the slope of the regression line in the figure. The bottom row in Table 2 shows the OLS estimate of the reduced-from equation for growth implied by the equation system above. Like Figure 1, Table 2 indicates that an increase in the natural capital share by eight or nine percentage points is associated with a decrease in growth by about one percentage point. Of the total effect of natural capital on growth, about a third can thus be attributed to education according to this interpretation, and about one-sixth to investment. This still leaves about a half of the total effect to be explained by other factors, perhaps the Dutch disease, rent seeking and policy failures.

Notice that the positive coefficient of initial income in the enrolment equation shows that the significance of the enrolment variable in the growth equation is not just an indirect effect of low initial income. Higher income raises the enrolment rate which then raises the rate of growth, contrary to the convergence hypothesis. It thus appears that there is a relationship between growth and enrolment that is independent of the effect of initial income on enrolment. The results shown in Table 2 imply absolute as well as conditional convergence because the total effect of an increase in initial income on growth is $-1.54 + 19.9\times0.05 \approx -0.54$ which is significantly negative in a Wald test ($p = 0.00$). Further, 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 against a constant as well as the logarithm of initial income. The effect of initial income on the natural capital share is significantly negative, with a coefficient of -4.56 (with $t = 4.6$), but in other respects the estimation results are virtually identical to the ones shown in Table 2. In this case, the total effect of an increase in initial income on growth is $-1.54 + 20.0\times0.05 + 0.06\times4.56 \approx -0.27$ which is barely significantly negative in a Wald test ($p = 0.045$). Hence, when we take the statistical relationship between natural capital and initial income into account, the evidence for absolute convergence weakens considerably. When, on the other hand, we added initial income as a potential determinant of investment, in order to allow for the possibility that investment is lower at low levels of income than at higher levels (Chenery and Syrquin, 1975), the effect of initial income on investment turned out to be economically and statistically insignificant.

The use of net investment instead of gross investment yields similar results that are significant throughout, but slightly less so than the ones shown in Table 2, especially the investment equation. When net investment and depreciation enter separately into the equation system, the coefficient on depreciation (0.24, with t = 3.9) in the growth equation is significantly larger than the coefficient on net investment (0.08, with t = 2.9). Other parameter estimates remain virtually unchanged. Natural capital has a similar effect on depreciation as on net investment.[26] The depreciation of natural resources (energy, minerals, forest, carbon dioxide damage) is not significantly related to growth nor is the dependence on natural resources more likely to cause such depreciation.

7.1 *From gross investment to genuine saving*

Table 3 shows the results we get when we replace gross investment by genuine saving in our model, and can be interpreted in the same way. The results are essentially the same as the ones shown in Table 2 except there is a closer correlation between genuine saving and natural capital in Table 3 than there is between gross investment and natural capital in Table 2 (compare Figures 4a and 3a). The direct effect of natural capital on growth is again -0.06. The indirect effect through education is $-0.82\times0.05 \approx -0.04$. The further indirect effect through genuine saving is $-0.41\times0.08 \approx -0.03$, which is smaller than indicated by Figure 4 where education is absent. The total effect of natural capital on growth is thus about -0.13 (for given initial income). In this case, education explains a bit less than a third of the total effect and genuine saving a bit less than a fourth, which leaves almost a half to be explained by other factors.

Genuine saving seems to contribute a bit more than gross investment to the total effect of natural capital on growth, even if the difference is not large. This was to be expected because, as noted before, genuine saving includes a correction for the depreciation of physical and natural capital as well as for improvement in human capital. Therefore, unlike the indirect effect of natural capital on growth through the volume of gross investment in Table 2, the indirect effect of natural capital on growth

[26] Very similar results obtain when the eight countries with natural capital shares above 0.25 are

through genuine saving in Table 3 reflects the quality as well as quantity of physical, natural and human capital. For example, if increased natural resource dependence from one place to another reduces the quantity and quality of investment or if it reduces the quality of natural or human capital, then the ultimate effect of natural capital on growth will be larger, other things being the same. Even so, the refinement achieved by replacing gross investment by genuine saving in our empirical analysis, while statistically significant, is rather small. Gross investment even without adjustment for depreciation appears to be a significant and robust determinant of economic growth, as claimed by Scott (1989).

Table 3. Regression results: Growth and genuine saving

Dependent variable	*Constant*	*Natural capital*	*Initial income*	*Enrolment rate*	*Genuine saving*	*R^2*
Economic growth	12.7 (10.0)	-0.06 (4.4)	-1.69 (9.1)	0.05 (6.0)	0.08 (5.0)	0.71
Enrolment rate	-90.4 (6.3)	-0.82 (4.6)	18.4 (10.8)			0.72
Genuine saving	12.0 (9.7)	-0.41 (5.3)				0.25
Economic growth	7.29 (4.8)	-0.12 (6.7)	-0.58 (3.2)			0.35

Note: 85 observations. t-statistics are shown within parentheses.

Table 4 shows the results we get when we try gross saving in our model rather than gross investment. We do this in order to assess the contribution of foreign saving to domestic growth. The direct effect of natural capital on growth is once again -0.06. The indirect effect through education is now $-0.82\times0.04 \approx -0.03$. The further indirect effect through gross saving is $-0.42\times0.09 \approx -0.04$, which, once again, is smaller than indicated by Figure 5 where education is absent. Thus, the total effect of natural capital on economic growth is still about -0.13 (for given initial income). In this case, education explains a bit less than a fourth of the total effect and gross saving a bit less than a third, which still leaves almost a half to be explained by other factors as before.

The results shown in Table 4 suggest that gross domestic saving has slightly more explanatory power (i.e., higher R^2) in our growth equation than gross domestic

excluded from the analysis.

investment on its own (Table 2). This means that, in our sample at least, persistent current account deficits do not seem to be good for growth. Also, when the current account deficit is added as a separate variable to the equation system presented in Table 4, this addition is not statistically significant in the growth equation; gross saving seems to suffice. These results seem to suggest that domestic investment matters for economic growth only insofar as it is financed by domestic saving. This finding is perhaps not as surprising as it might seem, however, in view of the prevalence of foreign borrowing by the government in many of the developing countries in our sample. Like foreign aid, foreign lending to many developing countries tends not to be repaid but rolled over.

Table 4. Regression results: Growth and gross saving

Dependent variable	*Constant*	*Natural capital*	*Initial income*	*Enrolment rate*	*Gross saving*	R^2
	11.3 (9.1)	-0.06 (4.9)	-1.60 (9.1)	0.04 (5.4)	0.09 (6.4)	0.74
Enrolment rate	-89.4 (6.3)	-0.82 (4.6)	18.2 (11.0)			0.72
	21.7 (15.9)	-0.42 (4.9)				0.22
Economic growth	7.29 (4.8)	-0.12 (6.7)	-0.58 (3.2)			0.35

Note: 85 observations. t-statistics are shown within parentheses.

7.2 *Economic growth and financial maturity*

This brings us to our last consideration in this paper: the role of the financial system. We showed in our model how growth depends on the productivity of capital. We also suggested that this might be affected by the state of the domestic financial system: A more advanced system would be likely to raise the productivity of capital – for a given amount of capital – and hence also the rate of interest, saving and growth. This provides an indirect route between natural resources and economic growth if these thwart the development of the financial system.[27]

[27] Referring back to Table 1, we might add that the M_2/GDP ratio is higher in the group of resource-poor, high-growth countries in the north-east corner of the table than it is in the resource-rich, low-

Table 5. Regression results: Growth and financial depth

Dependent variable	*Constant*	*Natural capital*	*Initial income*	*Enrolment rate*	*Gross saving*	*Financial depth*	R^2
Economic growth	11.7 (9.4)	-0.06 (5.2)	-1.64 (9.2)	0.04 (5.4)	0.09 (6.4)		0.74
Enrolment rate	-70.7 (5.3)	-0.90 (5.2)	16.0 (10.1)				0.70
Gross saving	2.97 (0.4)	-0.26 (2.5)				4.95 (3.0)	0.28
Financial depth	3.78 (54.8)	-0.03 (7.4)					0.39
Economic growth	7.29 (4.8)	-0.12 (6.7)	-0.58 (3.2)				0.36

Note: 85 observations. t-statistics are shown within parentheses.

Rather than extend all the regression results from Tables 2-4 to accommodate the financial depth variable, we focus on the case with gross saving, for the other two cases are quite similar. Table 5 shows the results we get when gross saving depends on natural capital as well as on the logarithm of the M_2/GDP ratio, which in turn depends on natural capital.[28] Apart from the addition of the financial depth variable to the system of equations, the results are quite similar as in Table 4. What is new is this: natural capital now influences growth through four distinct channels: directly (-0.06), through education ($-0.90\times0.04 \approx -0.04$), through gross saving ($-0.26\times0.09 \approx -0.02$), and through financial depth via gross saving ($-0.03\times4.95\times0.09 \approx -0.01$). In sum, the total effect of natural capital on growth is -0.13 as before.

When the gross saving rate and the logarithm of the M_2/GDP ratio enter the growth equation as a multiple, the estimated coefficient remains highly significant, indicating that the effect of gross saving on economic growth varies directly with the maturity of the financial system. However, we find no clear evidence of our earlier conjecture that the contribution of foreign saving to economic growth varies systematically with financial maturity as measured here.

growth group in the south-west corner, or 47 percent compared with 16 percent.

[28] In our sample, the M_2/GDP ratio varies inversely with inflation, measured as the inflation distortion $\pi/(1+\pi)$ where π is the average inflation rate from 1965 to 1998. When we purge the M_2/GDP ratio of its inflation-related component and re-estimate the system, we obtain similar results as in Table 5.

8. Conclusion

In this paper, we have proposed a linkage between natural resources and economic growth, through saving and investment. When the share of output that accrues to the owners of natural resources rises, the demand for capital falls – and this leads to lower real interest rates, less saving and less rapid growth. However, economic and institutional reforms paving the way to a more efficient allocation of capital may enhance the quantity as well as the quality of new investment and sustain growth.

We have extended a well-known endogenous growth model to include natural resources as an input into the production of final goods. The model implies that the larger the share of natural capital in national income, the lower is the rate of growth of consumption and the greater is the need for measures to spur investment. Finally, the more productive the capital stock, the higher is the rate of growth.

Using a data set recently released by the World Bank (2000) we calculated correlations between growth (adjusted for initial income), the share of natural capital in total wealth and saving and investment. The results can be summarized as follows:

- Investment in physical capital is inversely related to the share of natural capital in national wealth and directly related to the development of the financial system.
- The development of the financial system – measured by the ratio of M_2 to GDP – is also inversely related to the share of natural capital in national wealth.
- The secondary-school enrolment rate – which is our measure of education – is inversely related to the natural capital share.
- Economic growth is inversely related to natural resource abundance as well as to initial income and directly related to the level of education and investment.

In addition, we found that foreign saving – in the form of current account deficits – was inversely correlated with growth. Even if investment financed by domestic saving is good for growth this does not seem to apply to investment financed by foreign saving.

We conclude that economic and structural reforms leading to more efficient capital markets, increased investment and a better allocation of capital across sectors may help start growth in countries that are well endowed in terms of natural resources. An excessive dependence on natural resources may, *ceteris paribus*, stifle the development of efficient capital markets. Even so, active measures to construct an institutional environment that contributes to saving and high-quality investment may ensure growth and enhance welfare in the presence of abundant natural resources.

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Appendix: Data and definitions

	Natural capital share 1994	Investment ratio 1965-98	Enrolment rate 1965-98	Genuine saving rate 1970-98	Gross saving rate 1970-98	Money and quasi-money 1965-98	Per capita growth 1965-98	Per capita income 1998	Per capita growth, adjusted, 1965-98
Argentina	6.7	23	56	11	22	16	0.4	11728	-1.6
Australia	11.9	24	86	9	23	46	1.7	21795	-0.2
Austria	2.6	24	92	18	26	*71*	2.6	23145	0.6
Bangladesh	14.1	20	18	2	10	20	1.4	1407	-2.0
Belgium	0.0	20	97	15	20	*64*	2.3	23622	0.4
Benin	7.7	15	12	0	4	19	0.1	857	-3.3
Botswana	6.3	27	26	23	35	20	7.7	5796	4.0
Brazil	7.9	21	33	14	21	17	2.2	6460	-0.4
Burkina Faso	16.9	21	3	-2	3	15	0.9	866	-2.7
Burundi	19.9	12	3	-5	1	14	0.9	561	-2.9
Cameroon	21.1	21	17	9	20	17	1.3	1395	-2.1
Canada	11.1	22	87	12	23	45	1.8	22814	0.0
Central African Rep.	30.2	10	10	-1	2	17	-1.2	1098	-4.2
Chad	37.1	7	5	-5	-1	11	-0.6	843	-3.9
Chile	9.8	19	55	3	20	25	1.9	8507	-0.5
China	7.2	31	45	16	35	65	6.8	3051	2.9
Colombia	7.2	19	40	9	20	16	2	5861	-0.7
Congo	14.5	32	50	1	23	17	1.4	846	-2.3
Costa Rica	8.2	21	40	16	21	32	1.2	5812	-1.3
Côte DIvoire	18.0	17	16	19	21	27	-0.8	1484	-3.7
Denmark	3.8	23	101	15	23	49	1.9	23855	0.1
Dominican Rep.	12.4	21	35	9	15	21	2.3	4337	-0.6
Ecuador	17.0	19	43	4	22	20	1.8	3003	-1.2
Egypt	4.5	21	52	0	14	60	3.5	3146	0.2
El Salvador	2.8	16	24	3	9	29	-0.4	4008	-2.8
Finland	6.6	24	102	16	26	*46*	2.4	20641	0.4
France	2.7	22	86	15	23	*55*	2.1	21214	0.2
Gambia, The	11.8	20	13	-6	5	22	0.4	1428	-2.8
Ghana	7.2	12	31	1	8	17	-0.8	1735	-3.6
Greece	3.7	25	80	11	17	42	2.4	13994	0.2
Guatemala	3.3	14	16	3	11	21	0.7	3474	-2.0
Guinea-Bissau	44.2	29	6	-5	-2	14	-0.1	573	-3.7
Haiti	6.7	11	13	-6	3	24	-0.8	1379	-3.8
Honduras	9.9	20	22	13	17	24	0.6	2338	-2.3
India	19.8	19	34	8	20	32	2.7	2060	-0.7
Indonesia	12.4	26	31	10	29	22	4.7	2407	1.0
Ireland	8.1	21	90	16	21	*52*	3	17991	0.8
Italy	1.3	22	72	15	23	*64*	2.5	20365	0.5
Jamaica	6.8	25	58	7	20	36	-0.4	3344	-2.9
Japan	0.8	31	92	22	33	91	3.5	23592	1.4
Jordan	1.6	29	48	-7	-4	79	-0.4	2615	-3.1
Kenya	9.4	17	17	9	17	29	1.3	964	-2.3
Korea	1.7	29	72	21	29	31	6.6	13286	3.6
Madagascar	41.9	11	15	0	4	17	-1.8	741	-4.9
Malawi	11.8	17	6	5	11	19	0.5	551	-3.2
Malaysia	8.6	28	48	19	34	53	4.1	7699	1.2
Mali	41.0	18	7	0	3	18	-0.1	673	-3.6
Mauritania	21.6	20	9	-21	4	16	-0.1	1500	-3.2
Mauritius	1.2	22	45	16	21	46	3.8	8236	1.0
Mexico	5.9	20	43	7	23	20	1.5	7450	-0.9
Morocco	4.1	20	26	8	14	42	1.8	3188	-1.2
Mozambique	12.7	13	5	-12	-9	26	0.5	740	-3.1
Namibia	10.1	19	52	-5	12	33	0.7	5280	-1.8
Nepal	17.7	18	22	0	10	22	1.1	1181	-2.3
Netherlands	1.5	22	99	18	25	*69*	1.9	22325	0.0
New Zealand	18.5	22	87	18	22	41	0.7	16084	-1.1
Nicaragua	13.9	20	34	0	6	25	-3.3	1896	-5.6
Niger	54.2	11	4	0	6	12	-2.5	729	-5.5
Norway	10.0	27	94	17	31	51	3	26196	1.0
Pakistan	5.6	16	16	0	9	40	2.7	1652	-0.8
Panama	6.5	20	55	21	23	37	0.7	4925	-1.8
Papua New Guinea	19.3	23	11	-1	18	31	0.5	2205	-2.4
Paraguay	11.5	21	26	12	19	19	2.3	4312	-0.6
Peru	7.8	21	53	8	20	17	-0.3	4180	-2.7
Philippines	6.2	22	62	10	21	28	0.9	3725	-1.8
Portugal	2.3	27	59	15	19	*85*	3.2	14569	0.8
Rwanda	21.7	13	5	-6	2	14	0	650	-3.6
Senegal	16.8	12	12	1	6	22	-0.4	1297	-3.5
Sierra Leone	28.0	7	13	-3	8	14	-1.6	445	-5.1
South Africa	5.0	22	62	4	21	53	0.1	8296	-2.0
Spain	2.9	23	84	13	22	*72*	2.3	15960	0.2
Sri Lanka	7.4	22	57	9	14	26	3	2945	-0.3
Sweden	5.6	20	91	15	21	*52*	1.4	19848	-0.5
Switzerland	0.9	25	85	20	27	108	1.2	26876	-0.4
Thailand	6.5	29	29	20	28	47	5	5524	1.7

Togo	15.2	17	20	10	16	27	-0.6	1352	-3.6
Trinidad and Tobago	9.5	21	62	-2	28	35	2.6	7208	-0.1
Tunisia	7.9	26	34	11	23	40	2.7	5169	-0.2
Turkey	5.0	19	37	11	16	21	2.1	6594	-0.5
United Kingdom	1.9	18	88	9	17	*72*	1.9	20314	0.0
United States	4.1	18	91	8	18	63	1.6	29240	-0.1
Uruguay	11.6	14	67	9	16	32	1.2	8541	-1.1
Venezuela	18.9	22	33	-2	30	25	-0.8	5706	-3.0
Zambia	37.8	18	17	-2	19	23	-2	678	-5.2
Zimbabwe	8.5	17	26	12	17	21	0.5	2489	-2.4

Source: World Bank (2000). The ratio of money and quasi-money to GDP for eight of the industrial countries in the sample is taken from International Monetary Fund, *International Financial Statistics*.

Note: All figures are expressed as percentages except income per capita in 1998 which is expressed in U.S. dollars.

Gross domestic saving is calculated as the difference between GDP and public and private consumption.

Net domestic saving is equal to gross domestic saving less the value of consumption of fixed capital.

Physical depreciation (consumption of fixed capital) represents the replacement value of capital used up in the process of production.

Depreciation of human capital is measured by education expenditure which refers to the current operating expenditures on education, including wages and salaries and excluding capital investments in buildings and equipment.

Energy depletion is equal to the product of unit resource rents and the physical quantities of energy extracted. It covers crude oil, natural gas and coal.

Mineral depletion is equal to the product of unit resource rents and the physical quantities of minerals extracted. It refers to bauxite, copper, iron, lead, nickel, phosphate, tin, gold and silver.

Net forest depletion is calculated as the product of unit resource rents and the excess of roundwood harvest over natural growth.

Carbon dioxide damage is estimated to be \$20 per tonne of carbon times the number of tons of carbon emitted.

Genuine domestic saving is equal to net domestic saving, plus education expenditure and minus energy depletion, mineral depletion, net forest depletion and carbon dioxide damage.

Source: World Bank (2000), page 171.

Figure 1. Economic growth and natural capital

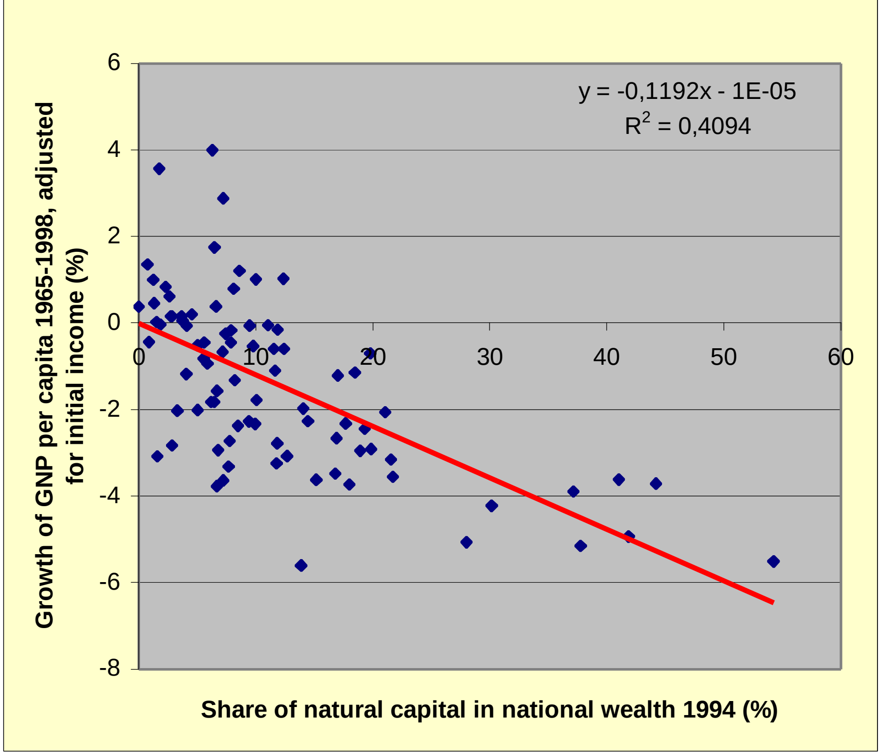
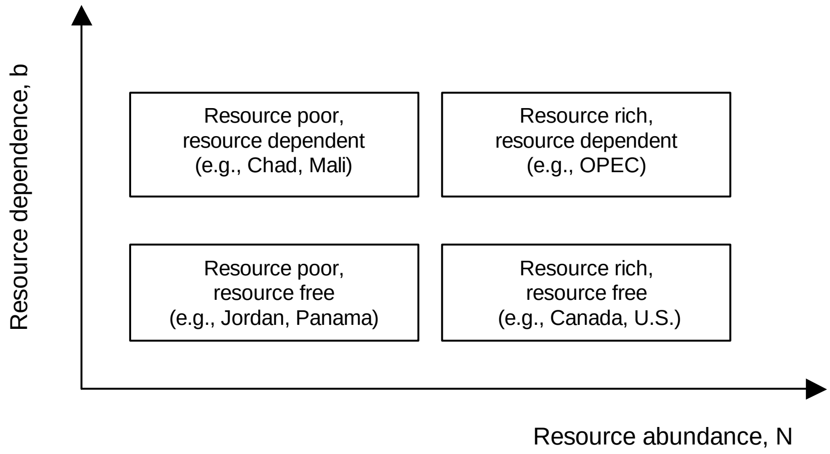


Figure 2. Natural resource abundance and economic structure



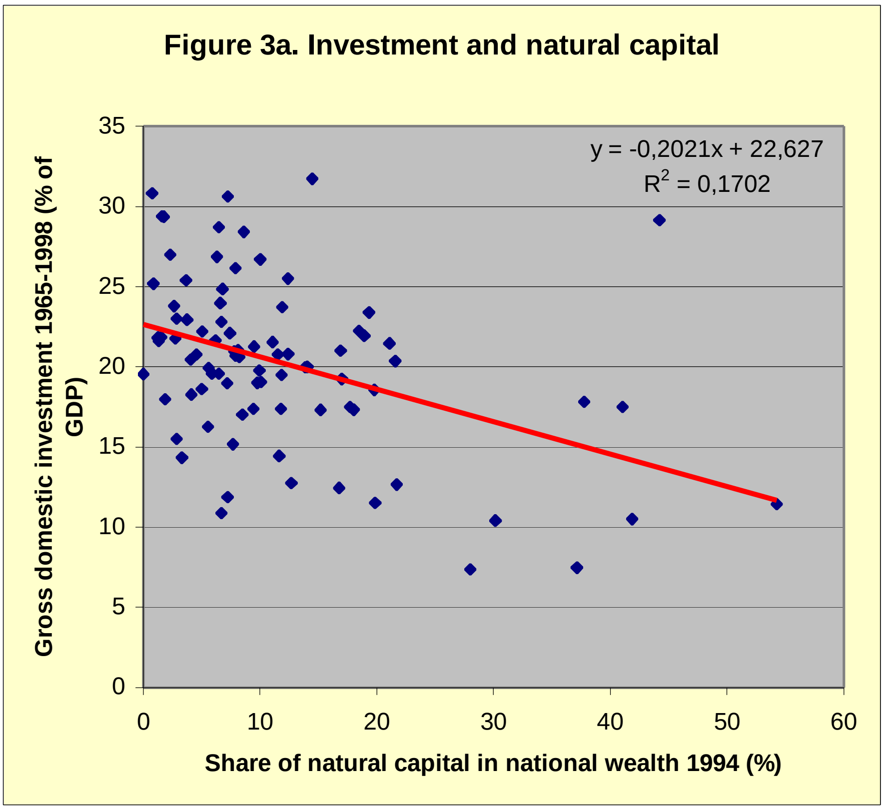


Figure 3a. Investment and natural capital
y = -0,2021x + 22,627
R2 = 0,1702
Gross domestic investment 1965-1998 (% of GDP)
Share of natural capital in national wealth 1994 (%)
35
30
25
20
15
10
5
0
0
10
20
30
40
50
60

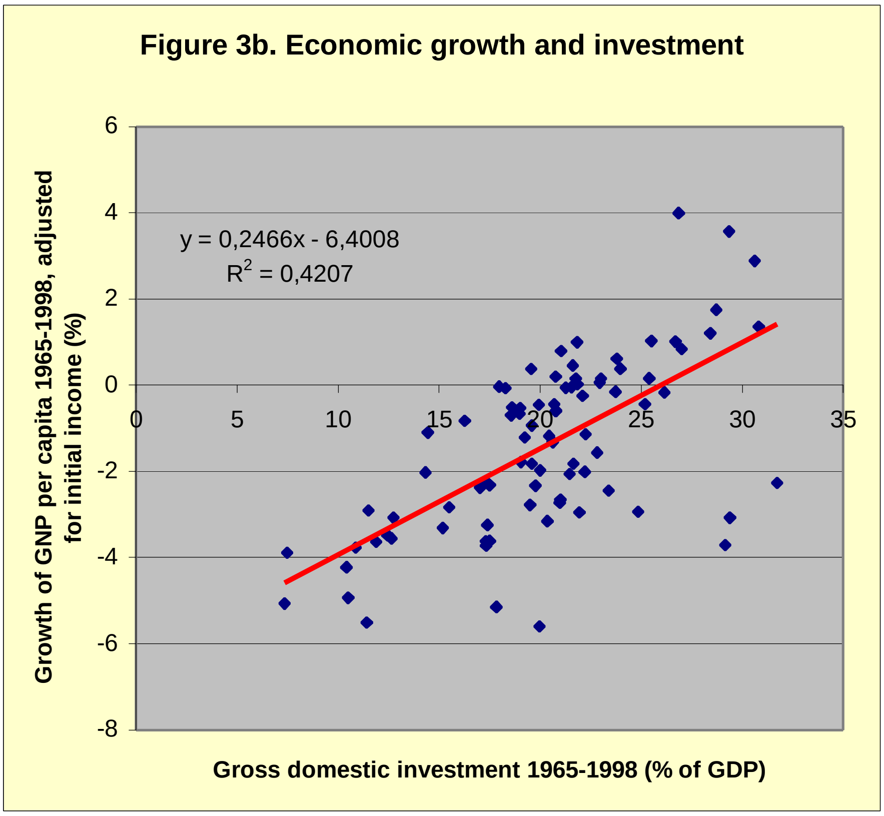


Figure 3b. Economic growth and investment
y = 0,2466x - 6,4008
R2 = 0,4207
Growth of GNP per capita 1965-1998, adjusted for initial income (%)
Gross domestic investment 1965-1998 (% of GDP)
6
4
2
0
-2
-4
-6
-8
0
5
10
15
20
25
30
35

Figure 4a. Genuine saving and natural capital

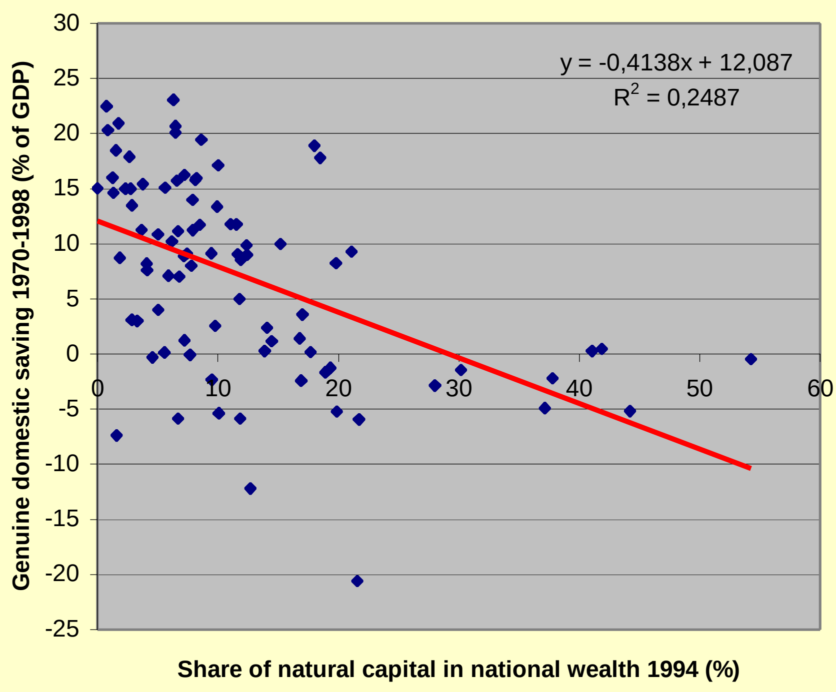
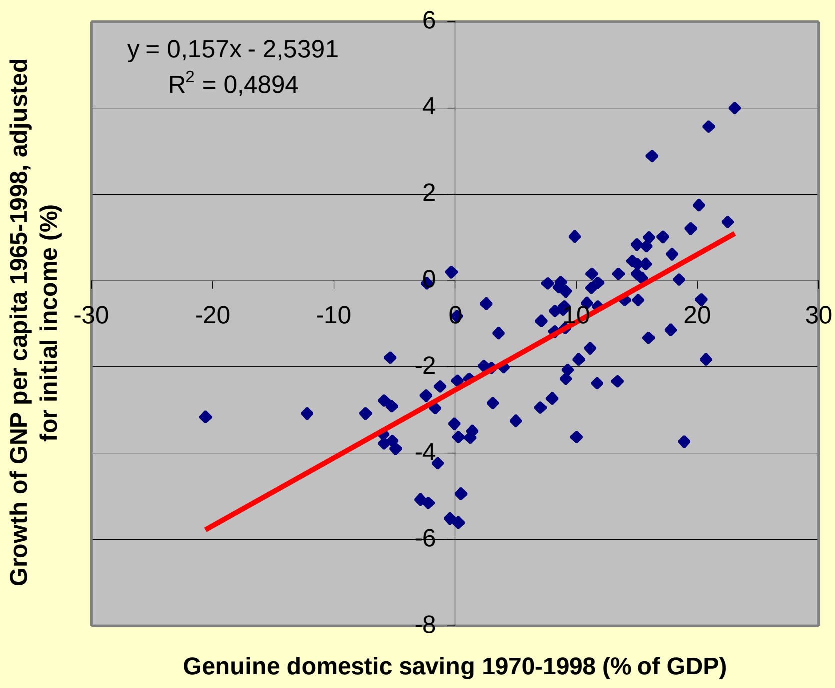


Figure 4b. Economic growth and genuine saving



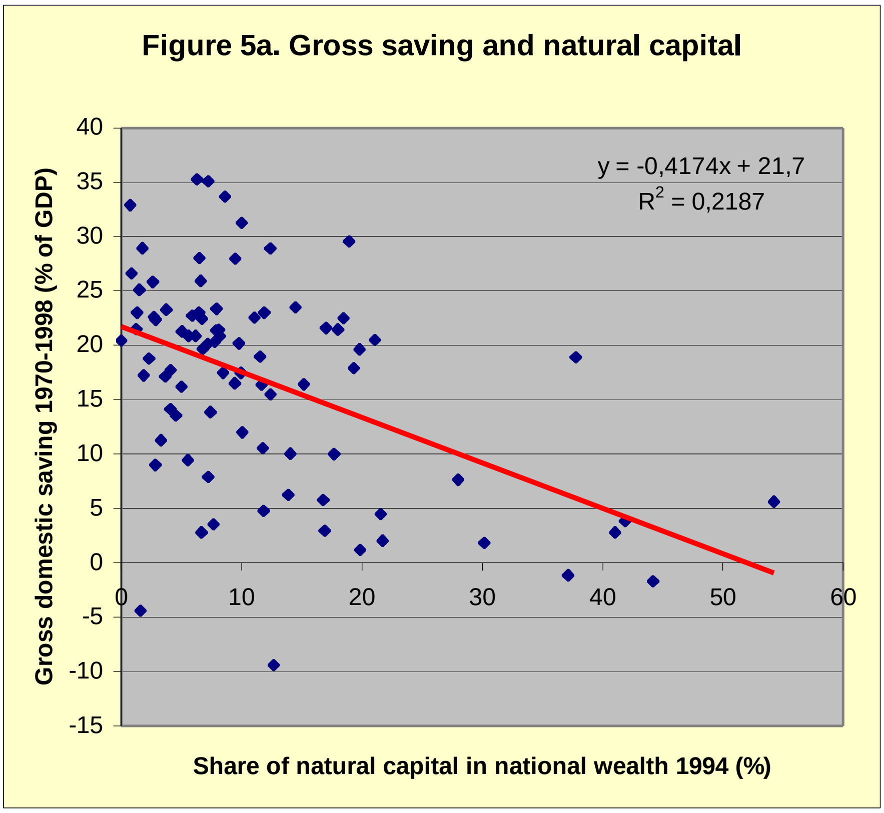


Figure 5a. Gross saving and natural capital
y = -0,4174x + 21,7
R^2 = 0,2187
Gross domestic saving 1970-1998 (% of GDP)
Share of natural capital in national wealth 1994 (%)
40
35
30
25
20
15
10
5
0
-5
-10
-15
0
10
20
30
40
50
60

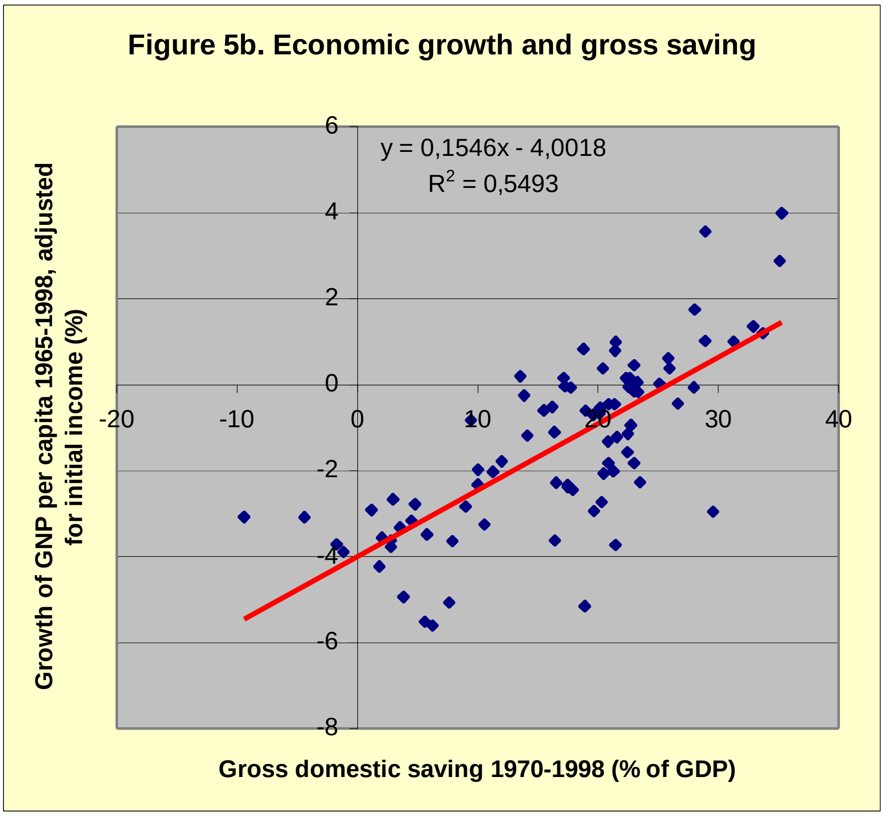


Figure 5b. Economic growth and gross saving
y = 0,1546x - 4,0018
R^2 = 0,5493
Growth of GNP per capita 1965-1998, adjusted for initial income (%)
Gross domestic saving 1970-1998 (% of GDP)
6
4
2
0
-2
-4
-6
-8
-20
-10
0
10
20
30
40

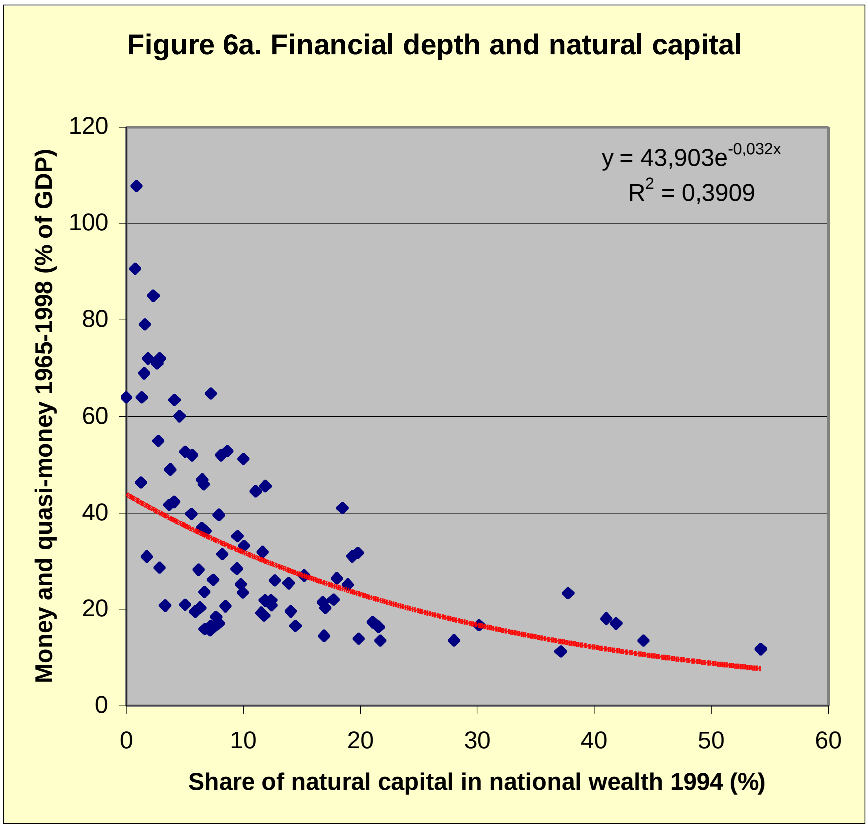


Figure 6a. Financial depth and natural capital
y = 43,903e-0,032x
R2 = 0,3909
Money and quasi-money 1965-1998 (% of GDP)
Share of natural capital in national wealth 1994 (%)
0
20
40
60
80
100
120
0
10
20
30
40
50
60

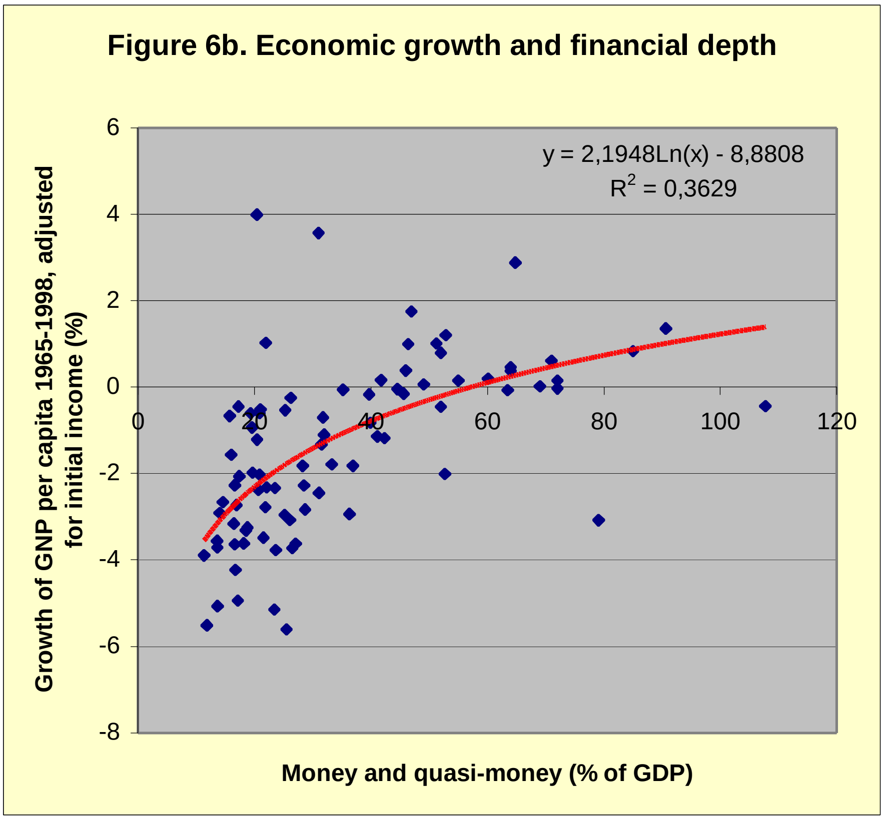


Figure 6b. Economic growth and financial depth
y = 2,1948Ln(x) - 8,8808
R2 = 0,3629
Growth of GNP per capita 1965-1998, adjusted for initial income (%)
Money and quasi-money (% of GDP)
6
4
2
0
-2
-4
-6
-8
0
20
40
60
80
100
120

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