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The resource curse hypothesis and its transmission channels

Elissaios Papyrakis * and Reyer Gerlagh

IVM, Institute for Environmental Studies, Vrije Universiteit, Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands

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We examine empirically the direct and indirect effects of natural resource abundance on economic growth. Natural resources have a negative impact on growth if considered in isolation, but a positive direct impact on growth if other explanatory variables, such as corruption, investment, openness, terms of trade, and schooling, are included. We study the transmission channels, that is, the effect of natural resources on the other explanatory variables, and calculate the indirect effect of natural resources on growth for each transmission channel. The negative indirect effects of natural resources on growth are shown to outweigh the positive direct effect by a reasonable order of magnitude. *Journal of Comparative Economics* ●●● (●●●) (●●●●) ●●●–●●●. IVM, Institute for Environmental Studies, Vrije Universiteit, Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, The Netherlands.

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1. Introduction

Despite the potentially beneficial impact of natural resource wealth on economic prosperity, natural-resource abundant economies tend to grow at a slower pace (Sachs and Warner, 1995, 1997, 1999a; Rodriguez and Sachs, 1999; Leite and Weidmann, 1999; Gylfason, 2000, 2001a). Over the last two centuries, countries rich in natural

* Corresponding author.
E-mail address: elissaios.papyrakis@ivm.vu.nl (E. Papyrakis).

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resources, e.g., Russia, Nigeria and Venezuela, experienced growth of comparatively low or mediocre magnitude. Sachs and Warner (1995) claim that this is a historically common pattern. Countries that base their economies on natural resources tend to be examples of development failures. In contrast, countries that had only limited access to natural resources, such as Japan, Hong-Kong, Korea, Singapore, and Switzerland, experienced remarkably high economic growth rates. Using growth regressions, we study the transmission channels through which natural resource abundance affects growth negatively. We investigate the effect of natural resources on corruption, investment, trade, schooling and then, indirectly, on economic growth.

Many development economists, e.g., Nurkse (1953) and Rostow (1960), accentuate the positive role of natural resources in economic development. To many economists the tendency of natural resource-rich countries to experience low economic growth is a conceptual puzzle. Economists consider natural resources to be a potential source of income, some of which is saved and converted into capital to support increases in future output levels. For example, resource rents may be used for the construction of roads, modernization of telecommunication systems, health and educational programs. Several countries did benefit from their natural wealth; the nineteenth century resource booms in Latin America stimulated economic progress. For example, Ecuador experienced a significantly higher income per-capita level after its boom (Sachs and Warner, 1999a). Similarly, the industrial revolution in Great Britain and Germany was possible only because of the vast deposits of ore and coal (Sachs and Warner, 1995). As a more recent example, Norway manages its natural-resource abundance well and converts it into economic prosperity. Although Norway did experience a recession for several years, the way in which its present and future natural wealth is exploited provides an example of carefully planned development. Almost 80% of the oil rents are collected through taxes and fees and then invested in foreign securities to protect the economy from abrupt and large income increases so that a fair division of oil rents between generations is achieved (Gylfason, 2001a).

Given the relatively few successful examples, this paper investigates the causes for under-performance by most resource-rich countries. In the literature, several negative transmission channels have been investigated. At a natural resource discovery, the resulting sudden increase in income may lead to sloth and less need for sound economic management and for institutional quality (Sachs and Warner, 1995; Gylfason, 2000, 2001a). The boom may also create a false sense of security and weaken the perceived need for investment and growth-promoting strategies. Natural resource abundant economies benefit less from the technology spillovers that are typical in manufacturing industries because the exports of these industries are harmed by an appreciation of the local currency, e.g., through the inflationary pressure resulting from increased domestic demand (Sachs and Warner, 1995, 1999a; Gillis et al., 1996; Gylfason, 2000, 2001b). Finally, as the natural resource sector expands relative to other sectors, the returns to human capital decrease and investments in education decline (Gylfason, 2001a).

Our analysis follows the methodology set in by Mo (2000, 2001), who investigates the transmission channels through which income inequality and corruption affect growth. We use cross-country regressions to show that, on average, natural resources are associated with these phenomena that impede the economic process. Taking account of the relation

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between natural resources and other indices used for growth regressions, we highlight the curse of natural resources. Specifically, we find that, if the negative indirect effects are excluded, natural resources contribute positively to economic growth. However, if the negative indirect impacts are included, these outweigh the positive direct contribution of natural resources to economic growth. We emphasize that this is an empirical finding and not an economic theory. If the government were to succeed in preventing the occurrence of these indirect phenomena, the country would benefit from its natural wealth.

The next section is devoted to the basic growth regressions. We verify that, in general, natural resource abundance impedes economic development rather than stimulates it. However, we also find that, if other indices such as corruption, investment, openness, terms of trade, and schooling are taken into account as independent variables, resource abundance has a positive direct impact on growth. Section 3 studies empirically the transmission channels and compares their relative weights in the overall negative impact of natural resources on economic growth. Section 4 concludes with a policy discussion on how to avoid the resource curse.

2. Basic cross-country regressions

To identify the dependence of growth on natural resource abundance, we estimate cross-country growth regressions following the empirical work of Kormendi and Meguire (1985), Grier and Tullock (1989), Barro (1991) and Sachs and Warner (1995, 1997). We base our equations on the conditional convergence hypothesis, i.e., different growth rates between different countries are explained by various characteristics of these countries; however, high-income countries have lower growth rates than low-income countries, all other things equal. Thus, per-capita economic growth from period 1975 (t_0) to 1996 (t_T), denoted by $G^i = (1/T)\ln(Y_T^i/Y_0^i)$, depends negatively on initial per-capita income Y_0^i. It also depends on natural resource abundance R^i, and on a vector of other explanatory variables Z^i. Hence, we have:

$$G^i = \alpha_0 + \alpha_1 \ln\left(Y_0^i\right) + \alpha_2 R^i + \alpha_3 Z^i + \varepsilon^i, \tag{1}$$

where i corresponds to each country in the sample. Our focus is on the sign of the coefficient for resource abundance, α_2, and its relation to the vector of other variables Z.

The long-term income effects of a change in a country's resource income can be described by changes in the current value of resource abundance and the other characteristics in Eq. (1). We denote these permanent changes by ΔR and ΔZ in Eq. (1). As we show in Appendix A, a permanent difference in R or Z has a long-term effect on expected income given by

$$E\left(\Delta \ln(Y_\infty)\right) = -(\alpha_2/\alpha_1)\Delta R - (\alpha_3/\alpha_1)\Delta Z, \tag{2}$$

where $\Delta \ln(Y_\infty) = \ln(Y_\infty)^j - \ln(Y_\infty)^i$.

Taking exponentials, we can rewrite Eq. (2) and calculate the relative long-term income effect as

$$E(\Delta Y_\infty / Y_\infty) = \exp\left[-(\alpha_2/\alpha_1)\Delta R - (\alpha_3/\alpha_1)\Delta Z\right] - 1. \tag{3}$$

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For small values of $(\alpha_2/\alpha_1)\Delta R$ and $(\alpha_3/\alpha_1)\Delta Z$, we can use the following approximation:

$$E(\Delta Y_\infty / Y_\infty) \approx -(\alpha_2/\alpha_1)\Delta R - (\alpha_3/\alpha_1)\Delta Z. \quad (4)$$

The ratio $-(\alpha_2/\alpha_1)$ captures the long-term income effect of changes in resource endowments. Similarly, the ratio $-(\alpha_3/\alpha_1)$ captures the long-term impact of changes in other explanatory variables. Assuming conditional convergence, i.e., $\alpha_1 < 0$, four different situations may arise. A ratio $-(\alpha_2/\alpha_1) = 1$ indicates that an immediate 1% increase in current income based on natural resource exploitation, i.e., $\Delta R = 0.01$, also raises the long-term income level by 1%, i.e., $\Delta Y_\infty / Y_\infty = 0.01$. If $-(\alpha_2/\alpha_1) > 1$, resource abundance is so beneficial to growth that a 1% increase in current resource income raises long-term income by more than 1%. On the other hand, if $-(\alpha_2/\alpha_1) < 1$, a 1% increase in resource income results in less than a 1% raise in long-term income. In the later situation, the economy benefits from resource expansion but the permanent income effect is smaller than the temporary resource income effect. Finally, if $\alpha_2 < 0$ and $\alpha_1 < 0$, resource expansion leads to only a short-lived increase in income because growth is affected negatively. Hence, in the long term, the level of permanent income is actually less than it would be without the increase in natural resources. This corresponds to a situation known as the curse of natural resources.

We estimate growth Eq. (1) using ordinary least squares (OLS)[1] and increase gradually the set of variables Z^i. Appendix B lists the variables and the data sources. As a starting point, we include only initial income per capita in year 1975 ($\ln Y_{75}$) and natural resource abundance, for which we take the share of mineral production in GDP in 1971 (*SNR*) as a proxy. The results, presented in column (1) of Table 1, indicate a highly significant and negative relationship between economic growth and natural resources. A one-percentage point increase in income from mineral resources relative to total income decreases growth by 0.075% per year. An increase in income from mineral resources of one standard deviation (0.07), decreases the growth rate by about 0.5% per year. Hence, natural resources appear to be an impediment to economic growth.

In the next regression, we include a measure of corruption for the 1980 to 1985 period from Transparency International. Higher values of the index correspond both to higher levels of corruption and to lower levels of institutional quality and the period is the earliest for which the index is available. In our regressions, we try to choose variables that refer either to the beginning of the overall period or to average values for the entire period to avoid endogeneity problems that may arise between variables. However, Mo (2001) argues that endogeneity is less likely for the corruption variable because institutions tend to evolve slowly. The second regression in column (2) shows a negative sign for the coefficient α_1, which supports the conditional convergence hypothesis. Furthermore, corruption affects

[1] Alternatively, the method of seemingly unrelated regressions (SUR) can be used to estimate simultaneously the basic cross-country regression, given by Eq. (1), and the indirect transmission channels, given by Eq. (5) in the following section, as a system of equations. The specification of our system of equations allows us to use OLS because the OLS and SUR estimates coincide in this system. Incorporating all transmission channels into the basic growth regression and allowing all indirect transmission channels to have identical explanatory variables implies that no possible correlation among individual error terms is assumed. Hence, the correction in SUR is unnecessary.

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Table 1
Growth regressions as in Eq. (1)

Dependent variable: G_{75-96}	(1)	(2)	(3)	(4)	(5)	(6)
Constant	−2.62	10.03	11.66	12.87	12.33	12.03
Ln Y_{75}	0.52**	−1.16***	−1.61***	−1.77***	−1.76***	−1.61***
(0.89)	(2.48)	(−3.00)	(−4.93)	(−5.55)	(−5.98)	(−3.91)
SNR	−7.57***	−7.39**	−4.41	−3.11	0.93	1.59
(0.07)	(−4.09)	(−2.04)	(−1.47)	(−1.07)	(0.32)	(0.59)
Corruption		−0.44***	−0.30**	−0.26**	−0.19*	−0.09
(2.68)		(−3.06)	(−2.52)	(−2.25)	(−1.76)	(−0.86)
Investments			0.16***	0.13***	0.15***	0.16***
(8.06)			(4.82)	(4.15)	(5.07)	(5.56)
Openness				1.26**	1.64***	1.26**
(0.45)				(2.31)	(3.23)	(2.39)
Terms of trade					−0.27**	−0.31***
(1.90)					(−2.52)	(−3.23)
Schooling						0.58
(0.61)						(1.23)
R^2 adjusted	0.18	0.25	0.51	0.55	0.62	0.66
N	103	47	47	47	46	39

Notes: 1. The standard deviations for the independent variables are in parentheses, based on the sample of 39 core countries used in the regression in column (6). 2. The *t*-statistics for the coefficients are in parentheses.

* 10% level of significance.
** 5% level of significance.
*** 1% level of significance.

economic growth negatively, as expected. An increase in the corruption level of one standard deviation decreases growth by 1.17%, which is 2.68 multiplied by 0.44. In the long term, this leads to a permanent income decrease of 74%,[2] indicating that corruption impedes growth considerably. The coefficient for natural resources is almost unaffected, although its significance is reduced substantially. An increase in natural resource income of 1% of total income decreases growth by 0.07% per year and reduces long-term total income by about 6.4% from Eq. (4). This regression illustrates the point that, although natural resources increase wealth in the short term, the economy loses more in long-term growth than it gains in the short run.

In the subsequent columns of the table, we include as independent variables the ratio of real gross domestic investment to real GDP averaged over the period from 1975 to 1996, an index of openness, measured by the percentage of years during the period 1970 to 1990 in which the country is considered to be an open economy by Sachs and Warner (1995), a terms of trade index measuring the average annual growth over the period from 1970 to 1990 in the ratio of the export price index divided by the import price index, and a schooling index proposed by King and Levine (1993), measuring the log of the average number of years of secondary schooling from 1970 to 1989, as a proxy for educational quality. As we include more explanatory variables, the coefficient on natural resources decreases gradually and becomes less significant in columns (3)

[2] This change is calculated as $\exp(-1.17/1.16) - 1 = -0.74$.

and (4). In columns (5) and (6), it becomes positive but has a low level of significance. Consequently, natural resources may not be harmful to growth per se. The final regression indicates the effects of natural resources, corruption, investment, trade policies, terms of trade, and schooling on economic growth. Hence, the indirect effects of all transmission channels are taken into account by the coefficients of these variables. The coefficient on natural resources measures the direct effect on growth; excluding the indirect effects, we find an almost one-to-one relation between natural resource income and long-term income, from the ratio of their coefficients. Therefore, an increase in resource income is permanent, although the low significance of the direct effect of natural resources on growth suggests a cautious interpretation. Nonetheless, since resource-abundance does not have a significantly negative direct effect on economic development, the indirect effects must be responsible for the overall harmful impact of natural resources on economic growth. We investigate the transmission channels for the indirect effects in the next section.

The coefficient for corruption also decreases as more explanatory variables are added but it remains negative, although eventually insignificant. Mo (2001) shows that corruption affects growth negatively through several indirect channels and that the corruption coefficient loses significance as these channels are included in the regression. However, corruption has no direct positive effect on income, because its coefficient remains negative. Furthermore, the coefficients for investment, openness, terms of trade, and schooling do not vary much. Their signs accord with intuition and are similar in value to those found in the literature. An economy characterized by a high investment ratio, a higher openness index, a lower initial income per capita, a decrease in terms of trade, and high educational standards is expected to experience a relatively high growth rate (Sachs and Warner, 1995, 1997, 1999b; Sala-I-Martin, 1997; Mo, 2001). Finally, we run a series of growth regressions equivalent to those in Table 1 using only the 39 countries that appear in column (6) and find that the coefficients do not change qualitatively nor do they change in an appreciable quantitative manner. Appendix C provides a list of the 47 countries included in columns (2) to (4) of Table 1 and the ones excluded to constitute the core sample of 39 countries of the last regression.

3. The transmission channels

To analyze the magnitude and relative importance of the transmission channels, we estimate the effect of natural resources on corruption, investment, openness, terms of trade, and schooling to capture their indirect effects on economic growth. First, we estimate the dependence of these variables on resource income from the following:

$$Z^i = \beta_0 + \beta_1 R^i + \mu^i, \tag{5}$$

where Z^i, β_0, β_1, and μ^i are vectors of which each element is associated with the indices of corruption, investment, openness, terms of trade, and schooling. To avoid having different sample sizes due to data availability, we confine the transmission analysis to only the 39 countries used in the last regression of Table 1. As Table 2 indicates, these coefficients are not highly significant due to small sample size. Running the same regressions for the largest possible sample available for each transmission channel yields significant coefficients at

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Table 2
Indirect transmission channels

	Corruption	*Investments*	*Openness*	*Terms of trade*	*Schooling*
Constant	5.87	20.77	0.68	−0.74	−0.70
SNR	7.21	−28.83	−1.82*	7.75*	−2.16
(0.07)	(1.13)	(−1.52)	(−1.74)	(1.75)	(−1.50)
R^2 adjusted	0.007	0.034	0.051	0.052	0.032
N	39	39	39	39	39

Note: 1. The *t*-statistics for the coefficients are in parentheses.
* 10% level of significance.

the 1% level for the terms of trade and openness indices and at the 5% level for the investment and schooling indices. The significance of the corruption channel also improves although it remains the weakest channel and its index is significant at only the 16% level. Additionally, taking the larger samples increases the R^2 for each transmission channel and the values of the coefficients are robust against the sample size.

Since natural resources explain part of the variation in investment and other variables, we compute the direct and indirect effects of natural resources on growth. Substituting Eq. (5) into Eq. (1) yields:

$$G^i = (\alpha_0 + \alpha_3\beta_0) + \alpha_1 \ln\left(Y_0^i\right) + (\alpha_2 + \alpha_3\beta_1)R^i + \alpha_3\mu^i + \varepsilon^i, \tag{6}$$

where $\alpha_2 R^i$ is the direct effect of natural resources on growth, $\alpha_3\beta_1 R^i$ is the indirect effect of natural resources on growth, and μ^i are the residuals of Eq. (5). The estimated values for the coefficients α_1, $\alpha_2 + \alpha_3\beta_1$, and α_3 of Eq. (6) are listed in Table 3. The coefficient of natural resources includes both direct and indirect effects. A 1% increase in natural resource income leads to a decrease in the growth rate of 0.096%, and a decrease in long-term income of about 6% from Eq. (4), which is consistent with column (2) of Table 1.[3] An increase in the share of mineral production in GDP of one standard deviation would directly and indirectly lead to a reduction in annual per-capita growth of 0.67%, which is equal to 0.07 times −9.60, and a long-term income decrease of 33% from Eq. (3).

In addition, we can estimate the relative importance of each transmission channel in explaining the indirect negative impact of natural resources on economic growth. The results are presented in Table 4. The effect of natural resources on corruption is depicted in the first column of Table 2.[4] Natural resources tend to increase the level of corruption, but the indirect effect on growth is relatively small compared to the other transmission channels, at 6%. This finding is consistent with recent empirical work by Sachs and Warner (1995) and Gylfason (2000). Although the contribution of the corruption channel to the indirect negative impact of natural resources seems minor, it does have a

[3] However, this regression in Table 1 is based on a larger sample.

[4] An extensive literature considers the endogeneity of social capital and institutions and concludes that institutions are not affected by other factors in the short run, but they are in the long term. We link institutional quality to natural resource abundance. Acemoglu et al. (2001), Mauro (1995) and Hall and Jones (1999) relate institutions to the mortality rate of settlers during colonization, ethnolinguistic fragmentation, and geographical characteristics, respectively.

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Table 3
Growth regression, including indirect effects

Dependent variable: $G_{75–96}$	(7)
Constant	16.53
$\ln Y_{75}$	-1.61^{***}
(0.89)	(−3.90)
SNR	-9.61^{***}
(0.07)	(−4.30)
μ^1 (*Corruption*)	−0.091
(2.63)	(−0.86)
μ^2 (*Investments*)	0.16^{***}
(7.82)	(5.56)
μ^3 (*Openness*)	1.26^{**}
(0.43)	(2.39)
μ^4 (*Terms of trade*)	-0.31^{***}
(1.82)	(−3.23)
μ^5 (*Schooling*)	0.58
(0.59)	(1.23)
R^2 adjusted	0.66
N	39

Notes: 1. The standard deviations for the independent variables are in parentheses. 2. The *t*-statistics for the coefficients are in parentheses.
** 5% level of significance.
*** 1% level of significance.

Table 4
Relative importance of transmission channels

Transmission channels	α_3 (Table 1)	β_1 (Table 2)	Contribution to $\alpha_3\beta_1$	Relative contribution
Corruption	−0.09	7.21	−0.65	6%
Investment	0.16	−28.83	−4.61	41%
Openness	1.26	−1.82	−2.29	21%
Terms of trade	−0.31	7.75	−2.40	21%
Schooling	0.58	−2.16	−1.25	11%
Total			−11.2	100%

significant consequence, since it alone cancels out about 40% of the positive direct effect of natural resources on economic growth, which is 0.65 from Table 4 divided by 1.59 from Table 1. Explanations of the effect of natural resources on institutional quality and, more specifically on corruption, are found in the literature. Krueger (1974) argues that natural resources provide rents, so that they promote rent-seeking competition rather than productive activities. Moreover, rents induce economic agents to bribe the administration in order to gain access to them (Sachs and Warner, 1995; Gray and Kaufmann, 1998; Ascher, 1999; Leite and Weidmann, 1999; Rodriguez and Sachs, 1999; Gylfason, 2001a; Torvik, 2002). Furthermore, Mauro (1998) claims that natural resource abundance is often associated with the emergence of politically powerful interest groups that attempt to influence politicians to adopt policies that may not favor the general public interest.

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The second transmission channel, investment, is the most important as it accounts for 41% of the indirect negative impact of natural resources on growth. Gylfason and Zoega (2001) argue that natural resource wealth decreases the need for savings and investment, because natural resources provide a continuous stream of future wealth that is less dependent on the transfer of man-made capital to future periods. However, world prices tend to be more volatile for primary commodities than for other goods. Therefore, an economy based on primary production will fluctuate from booms to recessions, which creates uncertainty for investors in these natural resource economies (Sachs and Warner, 1999b). Additionally, during a natural resource boom, increased rents in the primary sector cause a reallocation of factors of production from manufacturing towards the booming primary sector. Since the manufacturing sector is often characterized by increasing returns to scale and positive externalities, a decrease in scale of manufacturing decreases the productivity and profitability of investment, which accelerates further the decrease in investment (Sachs and Warner, 1995, 1999a; Gillis et al., 1996; Gylfason, 2000, 2001a). Finally, Gylfason and Zoega (2001) conclude that the rate of optimal savings and the maturity of the financial system is negatively related to the share of natural resources in national output.

The international transmission channel consists of the effects of natural resources on the degree of openness of the economy and its terms of trade. Taken together these two channels account for another 42% of the negative indirect impact of natural resources on growth. Natural resource abundance reduces openness and has negative effects on the terms of trade. Since natural resources weaken the manufacturing sector, policy makers may impose import quotas and tariffs that, in the short run, protect domestic producers (Auty, 1994; Sachs and Warner, 1995). However, in the long run, such measures reduce the openness of the economy and retard its integration into the global economy. In addition, natural resource booms increase domestic income and, consequently, the demand for goods, which generates inflation and an overvaluation of the domestic currency. Hence, the relative prices of all non-traded goods increase and the terms of trade deteriorate, so that exports become expensive relative to world market prices and decline. This phenomenon is known as the Dutch Disease (Sachs and Warner, 1995; Torvik, 2001; Gylfason, 2000, 2001a, 2001b; Rodriguez and Sachs, 1999).

Finally, the schooling transmission channel is almost twice as important as the corruption channel. Natural resource booms lead to a decline in the manufacturing sector for which human capital is an important production factor. Hence, Gylfason (2001a) argues that the need for high-quality education declines and, with it, the returns to education. Sachs and Warner (1995) claim that natural resource abundance creates a false sense of confidence and that easy riches lead to sloth. An expanding primary sector does not need a high-skilled labor force, so that spending on education need not increase. Hence, the future expansion of other sectors that require educational quality is restricted (Gylfason, 2000, 2001a, 2001b; Sachs and Warner, 1999b) and technological diffusion is retarded (Nelson and Phelps, 1966). Our result that schooling is a more important and more significant transmission channel than corruption contrasts with the empirical results in Sachs and Warner (1995, 1999a).

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4. Conclusions

During the past decades, the paradox of a negative impact of natural resource abundance on economic growth has been widely observed. Many countries rich in oil reserves, gas, or tropical forests used for timber production experienced disappointing growth levels. In contrast, many resource-poor countries experienced strong growth. However, exceptions to this phenomenon can be found. In the eighteenth and nineteenth centuries, iron and coal reserves were the stimulus for the industrial revolution and growth. In the twentieth century, resource abundant countries such as Norway and Iceland experienced remarkable and sustained growth rates. Hence, natural resource wealth may stimulate growth but only under certain conditions. A natural resource economy that suffers from corruption, low investment, protectionist measures, a deteriorating terms of trade, and low educational standards will probably not benefit from its natural wealth due to adverse indirect effects.

Our empirical analysis indicates that natural resource wealth increases growth, if negative indirect effects are excluded. However, if these transmission channels are included, the overall effect of natural resource abundance on economic growth is strongly negative. Moreover, the investment channel is shown to be the most important of these transmission channels. Extensions of this analysis can expand the sample used for the empirical analysis and identify additional transmission channels through which natural resources affect growth. In addition, the mechanisms behind the transmission channels can be investigated more thoroughly. A better understanding of these mechanisms is essential for developing policy measures to reduce the negative impact of natural resources on economic growth.

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Appendix A. Long-term income effects

In this appendix, we derive the long-term income effects of Eq. (2), using the description of economic growth in Eq. (1). Since G^i represents income growth in country i over a period of T years, we rewrite Eq. (1) as

$$\left(\ln\left(Y_T^i\right) - \ln\left(Y_0^i\right)\right)/T = \alpha_0 + \alpha_1 \ln\left(Y_0^i\right) + \alpha_2 R^i + \alpha_3 Z^i + \varepsilon^i. \tag{A.1}$$

After rearranging terms, we derive income for country i at the end of the period, i.e., in year T as

$$\ln\left(Y_T^i\right) = \alpha_0 T + (\alpha_1 T + 1)\ln\left(Y_0^i\right) + \alpha_2 T R^i + \alpha_3 T Z^i + T\varepsilon^i. \tag{A.2}$$

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We use this equation to calculate the difference in expected income from changes in R and Z. Since the level of initial income has not changed, we abstract from any convergence impacts on long-term growth ($\Delta \ln(Y_0) = \ln(Y_0^j) - \ln(Y_0^i) = 0$). This allows us to focus on income differences generated either by the resource-abundance factor or the vector of the other explanatory variables Z. Hence, we have:

$$E\big(\Delta \ln(Y_T)\big) = \alpha_2 T \Delta R + \alpha_3 T \Delta Z, \tag{A.3}$$

where $\Delta \ln(Y_t) = \ln(Y_t^j) - \ln(Y_t^i)$. To assess the long-term effects of R and Z on income, we assume that ΔR and ΔZ are constant over time and study the propagation of income differences over time. After two periods of T years, income differences are equal to

$$E\big(\Delta \ln(Y_{2T})\big) = (\alpha_1 T + 2)(\alpha_2 T \Delta R + \alpha_3 T \Delta Z). \tag{A.4}$$

After three periods, we have:

$$E\big(\Delta \ln(Y_{3T})\big) = \big(1 + (\alpha_1 T + 1) + (\alpha_1 T + 1)^2\big)(\alpha_2 T \Delta R + \alpha_3 T \Delta Z). \tag{A.5}$$

Since $0 < \alpha_1 T + 1 < 1$, as t goes to infinity, the first term on the right hand side reduces to

$$\begin{aligned}\big(1 + (\alpha_1 T + 1) + (\alpha_1 T + 1)^2 + (\alpha_1 T + 1)^3 + \cdots\big) &= 1\big/\big(1 - (\alpha_1 T + 1)\big) \\ &= -1/(\alpha_1 T).\end{aligned} \tag{A.6}$$

Hence, Eq. (2) is derived.

Appendix B. List of variables

G: Average annual growth in real GDP per person from 1975 to 1996, calculated as $G = (\ln(Y_{1996}/Y_{1975})/21) \times 100\%$. Source: Center for International Comparisons at the University of Pennsylvania (CIC), 2002.

$\mathrm{Ln}\, Y_{75}$: The log of real GDP per capita in 1975 at 1985 international prices. Source: Center for International Comparisons at the University of Pennsylvania (CIC), 2002.

SNR: The share of mineral production in GDP for 1971. Source: Center for International Development at Harvard University (CID), 2002.

Corruption: The Corruption Perception Index from 1980 to 1985 from Transparency International. The index means the degree to which corruption is perceived to exist among public officials and politicians. Source: Center for Globalization and Europeanization of the Economy (CeGE), 2002 of the Georg-August-University of Goettingen and Transparency International Organization (TI), 2002.

Investment: Average real gross domestic investment, private and public, at 1985 international prices, from 1975 to 1996. Source: Center for International Comparisons at the University of Pennsylvania (CIC), 2002.

Openness: The fraction of years from 1965 to 1990 in which the country is rated as an open economy according to the criteria imposed by Sachs and Warner. Source: Center for International Development at Harvard University (CID), 2002.

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Terms of trade: The average annual growth in the log of external terms of trade between 1970 and 1990, where the terms of trade is given by the ratio of an export price index to an import price index. Source: Center for International Development at Harvard University (CID), 2002.

Schooling: The log of average secondary schooling from 1970 to 1989, known as the King and Levine Index. Source: Center for International Development at Harvard University (CID), 2002.

Appendix C. List of countries in samples

1. Argentina*	11. China*	21. Ireland	31. Nigeria*	41. Taiwan*
2. Australia	12. Colombia	22. Israel	32. Norway	42. Thailand
3. Austria	13. Denmark	23. Italy	33. Pakistan	43. Turkey
4. Bangladesh*	14. Ecuador	24. Japan	34. Philippines	44. Uganda
5. Belgium	15. Egypt	25. Jordan*	35. Portugal	45. United Kingdom
6. Bolivia	16. Finland	26. Kenya	36. Singapore	46. United States*
7. Brazil	17. France	27. Malaysia	37. South Africa	47. Venezuela
8. Cameroon	18. Greece	28. Mexico	38. Spain	
9. Canada	19. Hong Kong	29. Netherlands	39. Sweden	
10. Chile	20. India	30. New Zealand	40. Switzerland*	

* Countries excluded in sample used for regressions (2)–(4).

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