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RESOURCE DEPENDENCE, KNOWLEDGE CREATION, AND GROWTH: REVISITING THE NATURAL RESOURCE CURSE

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Several explanations have been put forward for the phenomenon - referred to as 'curse of natural resources' - that resource-rich countries tend to display low rates of economic growth. This paper studies an R&D-related explanation, using an endogenous growth model with natural resources and R&D-based technological change. For suitable values of preference parameters, the model predicts that knowledge creation as well as capital formation are inversely related to natural-resource intensity, thus providing an explanation for the 'curse'. Estimation results on cross-sectional data for 77 countries (1965-1998) are consistent with these predictions. Basic results of the paper remain valid when institutional aspects (corruption, democracy) are included.

Keywords: Endogenous Technological Change, Economic Growth, Natural Resource Curse, Natural Resources
JEL classification: O3, O4, Q3

1. INTRODUCTION

Starting with Sachs and Warner (1995) a growing body of research has found that countries which are rich in natural resources tend to display relatively low rates of economic growth (see, e.g., Gylfason *et al.* (1999), Gylfason (2001), Rodriguez and Sachs (1999), Sachs and Warner (2001) and the contributions in Auty (2001)). This phenomenon has come to be termed the 'curse of natural resources'.

A variety of mechanisms have been proposed in order to explain the 'natural-resource curse'. Most of these explanations have in common that they follow a crowding-out logic: An abundance of or heavy dependence on natural resources crowds out some activity 'x' which is thought to be growth-enhancing. The major channels that have been proposed are the following (for an overview and discussion see, e.g., Gylfason (2002)).

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• Dutch disease: The natural resource sector is able to pay higher wages, thus bidding up the overall wage level and reducing the competitiveness and growth of the manufacturing sector.

• Rent-seeking and social capital: Resource-rich countries are more prone to rent-seeking, corruption, and inadequate governance, thus crowding out social capital.

• Education and human capital: School enrollment rates and public spending on education tend to be low in resource-rich countries.

• Saving, investment, and physical capital: Natural resource abundance tends to blunt private and public incentives to save and invest.

These propositions on how the 'natural-resource curse' may become effective have mostly received rather good empirical support, but some of them are based mainly on heuristic arguments, lacking theoretical analysis of why and how these types of crowding out should occur.

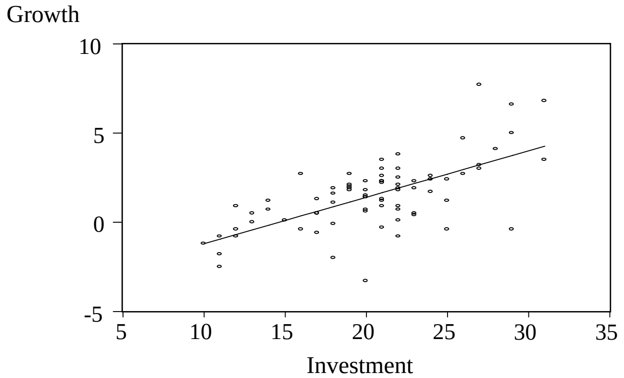
The present paper addresses an additional channel through which dependence on natural resources may affect growth prospects, and it does so within an excplicit growth-theoretic framework. Motivated by the observation (to be discussed in section 2) that resource-rich countries tend to have low levels of R&D, the paper examines how knowledge creation may be affected by natural-resource intensity. By extending the Romer (1990) model of endogenous technological change to include natural resources, the prediction is obtained that knowledge generation as well as capital formation may be inversely related to natural resource intensity. Estimation results on cross-sectional data for 77 countries over the period 1965-1998 are consistent with these predictions.

The issue of innovation and growth in resource-rich countries has previously been addressed mainly in terms of historical case studies (Maloney (2002)). Papers which address the 'natural resource curse' in an endogenous growth framework (see, e.g., Gylfason and Zoega (2002)) build upon the assumption of constant returns to capital as the origin of sustainable growth, rather than considering the purposeful creation of knowledge through R&D. They are thus unable to address possible impacts of natural-resource dependence on growth through the formation of knowledge. The contribution of the present paper is to examine the relationship between natural-resource dependence and knowledge formation by (a) considering an explicit R&D-based endogenous growth model with natural resources and (b) testing that model on cross-sectional data. As it turns out in the present model, including R&D activities implies that natural-resource dependence affects not only the formation of knowledge, but also the formation of capital.

The paper is organized as follows. Section 2 provides some empirical background to motivate the subsequent analysis. Section 3 develops the theoretical framework, and Section 4 presents the empirical approach and evidence. Section 5 concludes.

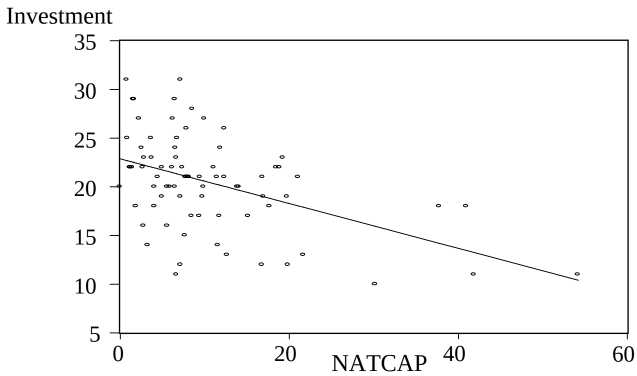
2. BACKGROUND AND MOTIVATION

An important channel through which natural-resource dependence may affect growth is through capital formation. As noted by Gylfason and Zoega (2002), countries with low growth rates tend to be characterized by low investment ratios, and investment ratios are low in countries that are rich in natural resources. Figures 1 and 2 reproduce the pertinent evidence for a sample of 77 countries (with growth rates referring to 1965-1998).[1]



Notes: 'Growth' is the average growth rate of GDP per capita 1965-1998. 'Investment' is the average investment /GDP ratio 1965-1998.

Figure 1. Growth vs. Investment



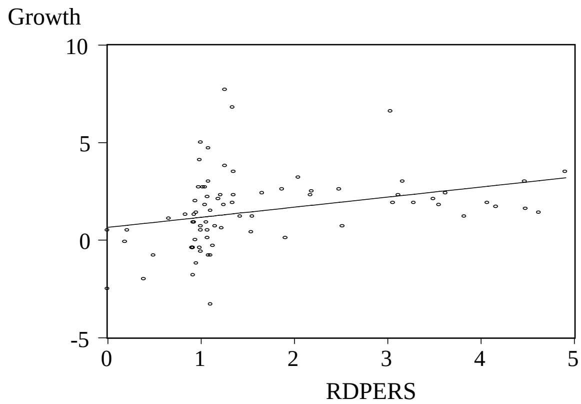
Note: 'NATCAP' is the share of natural capital in national wealth 1994.

Figure 2. Investment vs. NATCAP

[1] For the definitions and sources of the data see section 4.1; for the countries and data see Appendix B.

The intensity of natural resources is measured by the share of natural capital in national wealth in 1994 (World Bank (1997)). In choosing this measure of natural-resource dependence we follow Gylfason and Zoega (2002) who emphasize that this natural capital variable comes 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 of the labor force.[2]

An additional observation which can be made is that countries with low growth rates typically have low levels of research and development. Choosing the fraction of scientists and engineers in the total population as a proxy for R&D intensity, Figure 3 shows this relationship.[3] Moreover, as displayed in Figure 4, R&D intensity tends to be inversely related to intensity in natural resources.



Note: RDPERS is the share of R&D scientists and engineers in the population (persons per thousand; various years within 1980-1997)

Figure 3. Growth vs. RDPERS

[2] The natural capital variable is available only for 1994. Nevertheless, it is probably a pretty good proxy for natural resource intensity in the period under review, 1965-1998. Admittedly, there may be an element of bias in Figure 2 in that increased investment increases manufactured capital, thereby reducing the share of natural capital in national wealth. This bias, however, is probably not serious since Figure 2 can essentially be reproduced by using the measures of natural resource dependence mentioned above.

[3] Jones (1995) has presented evidence for the OECD which does not support the prediction that a higher scale of R&D input (e.g., the number of scientists and engineers devoted to R&D) increases the growth rate. The sample shown in Figure 3 is more encompassing than just the OECD. When our data set is restricted to the OECD subset (as of the mid-1990s) the scatter plot of growth vs. R&D intensity in fact suggests a slightly declining relationship.

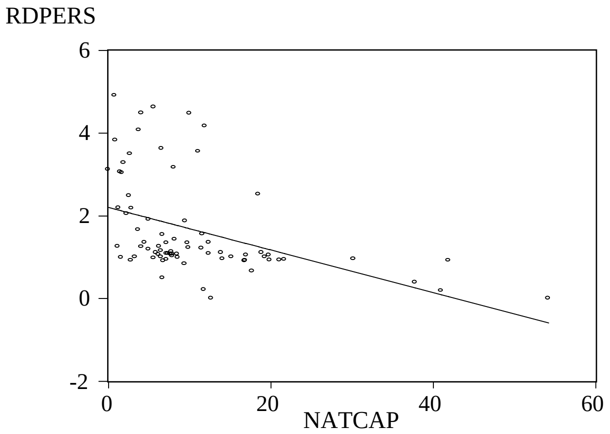


Figure 4. RDPERS vs. NATCAP

As a final observation it is worth noting that there may exist an inverse relationship between a country's growth rate and its population size. Especially, countries with negative growth rates almost invariably are small countries. In our sample there are 15 countries with negative growth, 1965-1998. These countries have an average population of 3.994 million, as of 1965, whereas the 62 countries with positive growth have an average population of 40.654 million. Growth failure thus seems to occur mainly when the population is small (see also Perälä (2003)).

Even though bivariate cross-sectional relationships have many shortcomings, the correlations discussed above capture some important features of the data which one may not wish to miss when formulating and testing a growth model with natural resources:

(a) Resource-rich countries tend to have low rates of capital formation.

(b) Resource-rich countries tend to have low rates of R&D.

(c) Slow-growing countries tend to be small countries.

The present paper aims to integrate these observations into a consistent theoretical framework. Obviously, not only (b) but also (c) suggests that a model with endogenous, R&D-based technological change might be appropriate, as these models typically involve a scale effect with respect to country size. In addition, as it turns out, the growth model with endogenous technological change considered below also accounts for (a).

It may be added that most studies of the 'natural-resource curse' explicitly or implicitly proceed within the neoclassical growth paradigm, with no account of the endogenous nature of technological change. An important property in such frameworks is convergence. While the convergence property is absent from early endogenous growth models, some recent extensions accommodate the possibility of convergence by introducing international knowledge spillovers (see Aghion and Howitt (1998), chapter 12, Barro and Sala-i-Martin (2004), chapter 8). Though not explicitly incorporating these features in our theoretical framework, we will consider the issue of convergence in several versions of our empirical specification. These versions will also address the role of institutional factors (corruption, democracy). It will be seen that these extensions leave the core implications of the model intact.

3. THEORETICAL FRAMEWORK

The framework employed in this paper is based on the endogenous technological change model of Romer (1990). Extensions of that model which account for natural resources have been proposed by Schou (1996), Aghion and Howitt (1998), Barbier (1999), Scholz and Ziemes (1999) and Welsch and Eisenack (2002). The present study follows the latter paper. The main text presents only the basic model structure and the results. Most of the derivation of results is relegated to an Appendix.

3.1. The Model

The economy consists of a sector producing conventional output (referred to as manufacturing sector), a technology sector, a resource sector and an immortal household. The technology sector carries out research and development (R&D), whose outcome, technological progress, shows up as an expansion of the number of varieties of capital goods. Each variety is identified with a separate industry acting as inventor and producer of this type of capital.

The number of capital varieties available at a certain time is treated as a continuous variable, *A*. Augmenting the formulation common in the endogenous growth literature (see, e.g., Aghion and Howitt (1998), section 1.6) by including natural resources as a production input, the production function can be written as

$$X = L_X^{\alpha} \cdot N^{\beta} \cdot \int_0^A K_i^{\gamma} di \qquad (\alpha, \beta, \gamma > 0)\,, \tag{1}$$

where $X = \text{output} = \text{GDP}$, $L_X = \text{labor employed in production}$, $N = \text{natural resource input}$,[4] $K_i = \text{input of capital of type } i \in [0, A]$ and $\alpha + \beta + \gamma = 1$ (constant returns to scale). The parameter β, which denotes the factor share of natural resources, will be our measure of natural resource intensity. The larger β, the more heavily the economy relies on natural resources in producing output.[5]

[4] The precise nature of the natural resource (renewable or non-renewable) will play no role until subsection 3.2.

[5] In contrast to Gylfason and Zoega (2002), who treat the *amount* of natural resource input, *N*, as an exogenous variable, *N* is fully endogenous in the present framework, given natural resource *intensity*, β.

Output (GDP) is a homogeneous good which can be used for consumption and capital formation. Natural resources are supplied at a price *p* (measured in units of output). Costs of resource extraction or harvesting are disregarded. The resource price *p* thus corresponds to the Hotelling rent or shadow price of the resource.[6]

The expansion of the number of capital varieties is described by the specification suggested by Romer (1990):

$$\dot{A} = \theta \cdot L_A \cdot A \qquad (\theta > 0), \tag{2}$$

where $L_A =$ labor employed in research, and $\dot{A} = dA/dt$ is the derivative of *A* with respect to time *t*.[7] $L_A = L - L_X$, where *L* is exogenous.

An assumption implicit in eqs (1) and (2) is that natural resources are required in physical production only, not in research. This should be regarded as a tractable approximation to the idea that research is substantially less intensive in natural resources relative to production.[8]

With respect to the household the standard Ramsey model is adopted. The household discounts future utility at a fixed pure rate of time preference, ρ. The instantaneous utility function exhibits a constant elasticity of marginal utility (inverse value of the elasticity of intertemporal substitution), whose magnitude is denoted by $\eta (> 0)$. The size of the population (household) is measured by *L*. The household owns the economy's assets (capital),[9] earns wage and interest income, and spends its income on consumption and capital formation.

With these assumptions, the key condition from household optimization is the familiar Ramsey rule for the growth rate of consumption:

$$\hat{C} = \frac{r - \rho}{\eta}, \tag{3}$$

[6] All factor prices are measured in units of output.

[7] This notation for time derivatives will be retained throughout the paper.

[8] It should also be noted that the process of knowledge acquisition described by Equation (2) is not necessarily restricted to new technological knowledge. It may also include the adoption and assimilation of existing knowledge, since the latter also require human resources. In this sense, international knowledge spillovers are not ruled out by the above formulation. However, the formal exposition does not differentiate between the generation and assimilation of knowledge. Possible implications that may arise when the two processes differ will be addressed in subsection 4.3.

[9] A similar set-up is chosen in Barro and Sala-i-Martin (2004, chapter 6). None of the results would change if capital were owned by the firms, and the household owned shares of stock in the firms.

where $\hat{C} = \dot{C}/C$ is the growth rate[10] of consumption, and r is interest rate.

The institutional structure of the model is as follows. In manufacturing there is a representative, perfectly competitive firm. The technology sector, by contrast, is composed of *A* different firms, each identified with one variety of capital good. The number of firms in the technology sector changes as *A* evolves in time. For convenience, each of these firms acts as inventor and producer of the capital good under consideration. Once a new variety is available, the inventor retains a perpetual monopoly right over the production of this capital good. Given a particular invention, the activity of the corresponding firm in the technology sector then consists of renting 'general capital' from the household at the rental price $R = r + \delta$ ($\delta =$ depreciation rate), merging it with specific knowledge, and lending the specific capital good to the manufacturing sector at a rental rate z_i.

The incentive for undertaking an invention effort consists of the monopoly profit to be extracted from the capital good in which this particular invention will be embodied; inventions *per se* are not marketable. The amount of labor to be channeled into the invention of a new capital good *i* at time *t* then depends on the present value of monopoly profit, $V_i(t)$, relative to the *R&D* cost that must be expended to secure $V_i(t)$. In a free-entry equilibrium in the technology sector, the monopoly profit and the *R&D* cost must be equal.

This equilibrium condition is the basis for solving the model. The derivation and precise statement of this condition are presented in Appendix A. The way how to solve the model is sketched in Appendix B.

3.2. Solution

In equilibrium we have the following relationships between the various growth rates:

$$\hat{C} = \hat{X} = \hat{N} + \hat{p} = \hat{K} + \hat{A}\,. \tag{4}$$

The growth rates of *X*, *K* and *A* are as follows:

$$\hat{X} = \frac{1}{v} \cdot \left(\left(1 + \frac{\beta}{\alpha}\right) \cdot u \cdot \theta \cdot L - \left(1 + \frac{u}{\alpha}\right) \cdot \beta \cdot \hat{p} - (\alpha + \beta) \cdot \rho \right), \tag{5}$$

$$\hat{K} = \frac{1}{v} \cdot \left(\frac{\beta}{\alpha} \cdot u \cdot \theta \cdot L - \left(\eta + \frac{u}{\alpha}\right) \cdot \beta \cdot \hat{p} - \beta \cdot \rho \right), \tag{6}$$

[10] The 'hat' notation for relative changes will be retained throughout the paper.

$$\hat{A} = \frac{1}{v} \cdot \left(u \cdot \theta \cdot L - (1-\eta) \cdot \beta \cdot \hat{p} - \alpha \cdot \rho\right), \tag{7}$$

where $u = \gamma \cdot (1-\gamma)$ and $v = u - \beta + \eta \cdot (\alpha + \beta)$.

Up to this point, the rate of change of the resource price has been taken to be exogenous. Since the costs of resource extraction are disregarded, the Hotelling rule applies: $\hat{p} = r$ (Dasgupta and Heal (1979)).[11] By observing Equations (3) and (4) we then obtain $\hat{p} = \eta \hat{X} + \rho$. Inserting this into (5) - (7), respectively, yields the following:

$$\hat{X} = \frac{u\theta L - \alpha\rho + [\frac{u}{\alpha}\theta L - (2 + \frac{u}{\alpha})\rho] \cdot \beta}{u + \alpha\eta + [(2 + \frac{u}{\alpha})\eta - 1] \cdot \beta}, \tag{8}$$

$$\hat{K} = \frac{[\frac{u}{\alpha}\theta L - (\eta + 1 + \frac{u}{\alpha})\rho] \cdot \beta}{u + \alpha\eta + [(2 + \frac{u}{\alpha})\eta - 1] \cdot \beta}, \tag{9}$$

$$\hat{A} = \frac{u\theta L - \alpha\rho + [(\eta - 1)\rho] \cdot \beta}{u + \alpha\eta + [(2 + \frac{u}{\alpha})\eta - 1] \cdot \beta}. \tag{10}$$

These results will now be discussed.

3.3. Discussion

The discussion will first address the general structure of the results and then turn to the role of natural resource intensity.

From Equation (8) it can be seen that the rate of output growth increases in population size (scale effect) and decreases in the rate of time preference and the elasticity of marginal utility. According to the numerator, growth may be negative in small economies if the rate of time preference is large. The influence of the elasticity of marginal utility shows up in the denominator; it reflects a desire - originating in decreasing marginal utility - to smooth down the consumption trajectory. The

[11] The condition $\hat{p} = r$ applies only to non-renewable resources. For renewable resources, $\hat{p}$ equals r less the own rate of return of the resource (rate of regeneration). In equilibrium, the own rate of return and r are equalized, implying $\hat{p} = 0$ If a fraction λ of the natural resource is non-renewable, the aggregate resource price evolves according to $\hat{p} = \lambda r$. The implications are stated in Appendix C.

denominator is common to Equations (8) - (10). It will be positive unless the elasticity of marginal utility is very small.

The general logic of the results is familiar from endogenous growth models. This refers especially to the scale effect. Somewhat more specifically, the model has inherited the basic structure of the Romer (1990) model: in the special case $\beta = 0$, $\alpha + \gamma = 1$ (i.e., if natural resources were not among the inputs and production displayed constant returns with respect to labor and capital) the relationships (8) - (10) would boil down to the corresponding results in Romer (1990). Especially, *K* would then be constant, and *X* would grow at the same rate as *A*, i.e., growth would only be fueled by knowledge formation. An important difference, however, is that in the present, more general, framework *K* may rise or fall. According to (9), *K* rises/falls if the labor endowment (population) is large/small relative to the elasticity of marginal utility and the rate of time preference (assuming the denominator is positive).

Considering Equations (9) and (10), we first note that the scale effect is present with respect to both capital formation and knowledge formation. The scale effect with respect to knowledge may be called a primary effect, since it is an immediate consequence of the greater incentive that a larger population provides for R&D (given the public-good character of knowledge). The scale effect with respect to capital accumulation is a secondary one, derived from the circumstance that a larger stock of knowledge makes physical capital more productive.

The respective numerators of (9) and (10) determine how the rate of growth of output is composed in terms of the growth of the capital stock and the growth of knowledge. It can be seen that an economy invests more in knowledge relative to physical capital if the elasticity of marginal utility, η, is large. This effect is related to the utilization of natural resources: It can be derived that a sufficiently large value of η implies a declining trajectory of resource utilization.[12] In such circumstances, a long-term decline in output can only be avoided by knowledge formation rather than capital formation, since capital is subject to decreasing marginal productivity while knowledge is not.[13]

We can now address the role of natural-resource intensity, β, for growth. The numerators of Equations (8) and (9) reveal that high resource dependence implies low (high) growth of output as well as of capital if the pure rate of time preference is large (small). This is intuitively plausible: The more impatient people are, the less they are willing to forego present consumption in order to avoid low levels of future consumption that may arise as a result of increasing natural-resource scarcity. In a similar logic, the

[12] Observe that $\hat{X} = (r - \rho)/\eta$ (Ramsey rule) and $\hat{p} = r$ (Hotelling rule). It then follows from Equation (4) that $\eta > 1 - \rho / r$ implies $\hat{N} < 0$.

[13] Note that $\hat{K}$ can be eliminated from Equation (B5) to yield: $\hat{X} = \hat{A} + (\beta/(1-\gamma))\hat{N}$. Thus, in the case of decreasing *N* it is only through increased knowledge formation that a decline in *X* can be avoided.

respective denominators show that high natural-resource dependence has a negative impact on the rate of growth of output and capital if the elasticity of marginal utility is sufficiently large, i.e., if people are relatively unwilling to substitute consumption inter-temporally.

With respect to the rate of knowledge accumulation, the situation is more ambiguous, see Equation (10). On the one hand, the effect just described is present here as well, as captured by the denominator. However, according to the numerator, β has a negative effect on knowledge accumulation only if the elasticity of marginal utility is sufficiently *low*. This partial effect derives from the circumstance discussed above that a large value of η implies a declining trajectory of resource utilization whose long-term negative effect on output can only be avoided by knowledge formation. As a result of these two partial effects, a sufficient condition for a negative overall effect of resource intensity on knowledge formation is $(2+u/\alpha)\eta > 1 > \eta$, i.e., the elasticity of marginal utility is less than unity, but not too small. Outside of this range, the effect may have either sign.

A tentative conclusion from the above discussion is that - in the perspective of this model - low growth of resource-dependent economies is essentially a result of the relatively low productivity of any unit of consumption foregone when natural-resource intensity (the production elasticity of natural resources) is high and capital intensity, accordingly, is low.

Below, an empirical version of the model will be estimated. Observable exogenous determinants of growth to be considered there are the population size and natural-resource intensity. For reference in the empirical part, the above discussion with respect to these two variables can be summarized as follows.

Prediction 1: Larger economies have higher rates of (a) capital accumulation, (b) knowledge accumulation and, hence, (c) output (GDP) growth.

Prediction 2: Assuming that the pure rate of time preference and the elasticity of marginal utility are sufficiently large, more resource-intensive economies have lower rates of (a) capital accumulation and (b) output growth.

Prediction 3: The impact of resource intensity on knowledge accumulation is ambiguous unless the elasticity of marginal utility is less than unity but not too small, in which case the impact is certainly negative.

It may be noted that these predictions are largely consistent with the stylized facts discussed in section 2, especially the facts that countries with negative growth rates are small countries, and that slow growers tend to be characterized by low levels of capital formation and R&D which, in turn, go along with high natural resource intensity.

4. EVIDENCE

This section formulates and estimates the econometric counterpart to Equations (4), (9) and (10) discussed above. To start with, it should be noted that the theoretical rigor of the present approach implies a rather parsimonious empirical model in terms of meaningful variables. No attempt will thus be made at capturing the plethora of factors that have been included in more orthodox growth regressions (see, e.g., Sala-i-Martin (1997)). Notwithstanding this general strategy, however, robustness checks will be performed with respect to three issues that have played a major role in studies of the natural resource curse. First, the composition of the natural resource input in terms of renewable and non-renewable resources will be considered. Second, the possibility of convergence will be addressed. Third, the role of institutional quality will be examined. However, these extensions will be postponed to subsection 4.3.

4.1. Empirical Specification and Data

The Equations (4), (9) and (10) can be written in a concise way as follows:

$$growth = \hat{K} + \hat{A}\,, \tag{11}$$

$$\hat{K} = f(population, natcap)\,, \tag{12}$$

$$\hat{A} = g(population, natcap)\,. \tag{13}$$

In this formulation, *growth* stands for the rate of growth of output (per capita), $\hat{X}$; *population* stands for the size of the country, *L;* and *natcap* represents the natural resource intensity, β. This formulation implies that β is allowed to vary across countries, whereas the other technology and preference parameters are identical across countries.

The empirical counterpart to this system of equations will be estimated on a cross-section of countries (1965-1998), and the empirical specification needs to take account of data availability. As it will be discussed below in more detail, data or proxies for *growth*, *population*, and *natcap* are readily available for a large sample of countries. The variables $\hat{K}$ and $\hat{A}$ are more problematic. They will be captured as follows.

The rate of change of the capital stock can be written according to the usual accounting relationship: $\hat{K} = I/K - \delta = (Y/K)\cdot(I/Y) - \delta$. While it is difficult to obtain I/K for a large enough sample over the time span considered, data on the investment-GDP ratio I/Y are available (see below). Thus, upon postulating a common GDP-capital ratio (Y/K), I/K will be proxied by I/Y. In the empirical counterpart to (20), $\hat{K}$ will therefore be captured by the expression $\alpha_1 + \alpha_2 \cdot investment$, in which $investment \equiv I/Y$ and the parameters α_1 and α_2 correspond to the depreciation rate δ and GDP/capital ratio, respectively. Note that these latter correspondences will prove useful in checking the plausibility of the estimation results.

A similar strategy will be pursued with respect to the variable $\hat{A}$. It is inherent in the analytical model (see Equation (2)) that $\hat{A}$ is proportional to the number of scientists and engineers (*researchers*) in a country. Thus, $\hat{A}$ will be captured by the expression $\alpha_3 \cdot researchers$.

In accordance with this approach to capturing the right-hand-side variables of Equation (11), the left-hand-side variables of (12) and (13) will be proxied by *investment* and *researchers*, respectively. Upon linearizing, the complete model to be estimated thus reads:

$$growth = \alpha_1 + \alpha_2 \cdot investment + \alpha_3 \cdot researchers\,, \tag{11$'$}$$

$$investment = \beta_1 + \beta_2 \cdot population + \beta_3 \cdot natcap\,, \tag{12$'$}$$

$$researchers = \gamma_1 + \gamma_2 \cdot population + \gamma_3 \cdot natcap\,. \tag{13$'$}$$

The definitions and sources of the data employed in estimating the above model are shown in Table 1.

Table 1. Data

Variable Name	Description	Unit	Source
Growth	Per-Capita Growth 1965-1998	Percent	World Bank (2000)
Investment	Investment Ratio 1965-1998	Percent	World Bank (2000)
Researchers	Number of Scientists and Engineers 1965	Thousand Persons	UNESCO (1999), World Bank (2003)
Population	Population 1965	Million Persons	World Bank (2003)
Natcap	Share of Natural Capital in National Wealth 1994	Percent	World Bank (1997)

Note: The variable *researchers* is obtained from the “number of R&D scientists and engineers per million population” from UNESCO (1999) and the population in 1965.

It should be noted that unlike several other studies of the natural resource curse, the present paper does not use the share of primary products in exports or GDP, or the share of the primary sector in total employment, to proxy natural-resource dependence. Rather, it uses the share of natural capital in national wealth. The advantages and disadvantages of this choice have been discussed in section 2.

4.2. Basic Estimation Results

The recursive nature of the system ($11'$)-($13'$) suggests that the method of Seemingly Unrelated Regressions (SUR) is an appropriate estimation procedure. This method takes care of heteroskedasticity and of correlation of the error terms across the equations and produces unbiased, efficient and consistent parameter estimates (see Davidson and MacKinnon (1993)). The estimation results are shown in Table 2.

Table 2. Estimation Results

	Growth	Investment	Researchers
Constant	-4.2605	22.6212	34.7594
	(6.14)	(31.85)	(2.44)
Investment	0.2744		
	(8.15)		
Researchers	0.0028		
	(2.82)		
Population		0.0099	1.4090
		(2.13)	(15.11)
Natcap		-0.2381	-2.0298
		(5.05)	(2.15)
Adj. R^2	0.432	0.246	0.751

The second column shows the results for Equation ($11'$). As discussed above, the *constant* corresponds to the depreciation rate. The estimated value of about 4.3 percent is in good agreement with this interpretation. The coefficient on *investment* is the GDP/capital ratio, which also takes a plausible value. Both of these coefficients are highly significant. The coefficient on *researchers* is positive and significant (at the 1-percent level), suggesting that the growth rate is positively linked to the number of scientists and engineers. Notwithstanding the robustness checks to be considered below, the empirical results thus far support the theoretical result that growth is fuelled by capital accumulation plus knowledge accumulation.[14]

The third column presents the results for Equation ($12'$). It can be seen that the

[14] It was mentioned above (see footnote 3) that for the OECD countries (as of the mid-1990s) there is no support of the prediction that a higher scale of R&D input increases the growth rate (Jones (1995)). Re-estimating Equation (11) for this subset of countries confirms this finding, as the variable *researchers* becomes insignificant (while *investment* retains its significance). This seems to suggest that the present model is more appropriate for explaining growth differences within and between OECD and non-OECD countries than differences within OECD.

investment ratio is positively and significantly related to the population size. This is a confirmation of the scale effect noted in section 3.4. Furthermore, the investment ratio is negatively and significantly linked to the natural capital share, supporting the predicted role of natural resource dependence for capital formation.

In the fourth column we have the results for Equation ($13'$). Of course, larger countries have more researchers. More interestingly, countries with a higher natural capital share have fewer researchers. Both of these linkages are significant.

The estimation results presented so far are consistent with the model of endogenous technological change with natural resources presented in section 3. The next subsection will examine the robustness of these results with respect to additional factors not formally captured by that model.

4.3. Robustness

In this subsection we address the robustness of the basic estimation results with respect to (a) the composition of the natural resource input, (b) the possibility of economic convergence, and (c) the possible role of institutional quality (social capital).

As described in Appendix C, the composition of the natural resource input in terms of renewable and non-renewable resources affects the growth equations for output, capital and knowledge through the evolution of the resource price. As Equations ($8'$), ..., ($10'$) in Appendix C show, the qualitative considerations concerning the role of natural resources for growth (see subsection 3.3) remain valid; they would remain valid even if all resources were renewable ($\lambda = 0$). However, though not affecting these mechanisms, the fraction of non-renewable resources could have a separate effect on the growth rates.

To examine this possibility, the fraction of non-renewable resources was included as a separate regressor in the equations for *investment* and *researchers*. The results of the extended regression are shown in column (1) of Table 3. It can be seen that this regressor is insignificant in the equation for researchers, but positive and significant in the equation for investment. The latter may indicate that non-renewable resources (fuels, minerals) require capital as a complementary input. Notwithstanding this result, the overall natural capital share (*natcap*) retains its role as a negative and significant contributor to both capital and knowledge formation.[15]

[15] The marginal significance level in the *researchers* equation is 5.1 percent.

Table 3. Extended Regression Results

	(1)	(2)	(3)	(4)	(5)	(6)
			Dependent Variable: Growth			
Constant	-3.4516	0.0243	-3.9765	-4.2828	5.4139	2.2473
	(4.89)	(0.02)	(5.34)	(5.99)	(3.27)	(1.40)
Investment	0.2349	0.3179	0.2593	0.2756	0.2484	0.2923
	(6.86)	(9.65)	(7.10)	(7.82)	(8.06)	(9.07)
Researchers	0.0027	0.0017	0.0028	0.0027	0.0016	0.0022
	(2.74)	(1.83)	(2.86)	(2.71)	(1.93)	(2.45)
Initial Income		-0.6447			-1.1650	-0.8847
		(4.33)			(6.14)	(4.53)
Corruption			-0.1490		-1.1460	
			(0.89)		(5.63)	
Civil Rights				-0.0017		0.8115
				(0.01)		(3.41)
Adj. R^2	0.441	0.481	0.424	0.424	0.588	0.517
			Dependent Variable: Investment			
Constant	21.6301	23.5089	22.5973	22.6220	22.8798	20.8596
	(25.71)	(5.61)	(31.79)	(31.84)	(5.45)	(4.92)
Population	0.0091	0.0094	0.0100	0.0096	0.0096	0.0102
	(0.12)	(1.98)	(2.15)	(2.14)	(2.03)	(2.16)
Natcap	-0.1911	-0.2564	-0.2361	-0.2383	-0.2479	-0.2395
	(3.41)	(5.03)	(5.00)	(5.05)	(4.85)	(4.68)
Share of	5.3966					
Non-Renew.	(2.26)					
Initial Income		-0.0798			-0.0131	0.2273
		(0.16)			(0.03)	(0.46)
Adj. R^2	0.170	0.231	0.246	0.245	0.236	0.245
			Dependent Variable: Researchers			
Constant	32.1243	-22.1743	34.4378	34.5478	-22.3719	-21.9012
	(1.83)	(2.70)	(2.41)	(2.42)	(2.78)	(2.67)
Population	1.4990	1.4780	1.4111	1.4097	1.4789	1.4774
	(9.85)	(16.19)	(15.13)	(15.10)	(16.20)	(16.19)
Natcap	-2.2840	-0.4931	-2.0062	-2.0123	-0.4506	-0.5282
	(1.96)	(0.50)	(2.13)	(2.13)	(0.45)	(0.53)
Share of	3.2174					
Non-Renew.	(0.06)					
Initial Income		300.063			301.943	297.100
		(3.14)			(3.16)	(3.11)
Adj. R^2	0.583	0.771	0.743	0.744	0.771	0.771
Dependent Variable:			Corruption	Civ. Rights	Corruption	Civ. Rights
Constant			-0.6717	0.5887	-0.7046	0.6103
			(4.19)	(4.17)	(4.40)	(4.33)
Population			0.0005	-0.0015	0.0005	-0.0015
			(0.47)	(1.60)	(0.51)	(1.63)
Natcap			0.0482	-0.0314	0.0512	-0.0334
			(4.51)	(3.34)	(4.83)	(3.57)
Adj. R^2			0.174	0.115	0.172	0.114

Notes: The sources of the additional variables are as follows. The share of non-renewable resources is taken from World Bank (1997), the initial income from World Bank (2000), the corruption index from Kaufmann *et al.* (1999) and the civil liberties index from Freedom House (2000). The corruption index and the civil liberties index are expressed as Z-scores (deviation from mean, divided by standard deviation).

Table 3 also shows the results of testing for convergence and for the role of institutional quality. It is known that in a cross-national context, convergence is more likely to arise in the form of conditional convergence than in the form of absolute convergence.[16] This means that countries with lower initial income tend to grow faster, conditional on variables that control for differences in the respective steady states. In the current context, important conditioning variables are those that relate to institutional quality, since adverse effects of natural resource dependence on social capital are one channel through which the 'natural resource curse' is frequently thought to be operating (see the introduction). This, of course, implies that institutional quality is an endogenous variable.

In the current framework, initial income may influence growth directly, at given rates of capital and knowledge formation, or indirectly, by affecting these rates. The direct effect would mean that the effective productivity increase brought about by the formation of capital and knowledge is lower in initially rich countries. Likewise, the productivity increase at given rates of capital and knowledge formation may be diminished by low institutional quality. With respect to possible indirect effects of initial income, a relevant mechanism might be that poor countries engage less in the creation of new technology because, for them, adoption and imitation of existing technology is more effective.

We examine these possible mechanisms through several regressions. Regression (2) includes the log of initial income in all three equations. We find that it is negative and significant in the *growth* equation, insignificant in the *investment* equation, and positive and significant in the equation for *researchers*. Regressions (3) and (4) include in the *growth* equation two variables that capture institutional quality, namely *corruption* and *civil rights*. Both turn out to be insignificant. However, regressions (5) and (6) combine these variables with the log of initial income, and the result is that growth is linked to corruption negatively and significantly and to civil rights positively and significantly. The results for initial income are qualitatively the same as in regression (2): growth is negatively related to initial income through the direct productivity channel, unrelated to initial income through the investment rate, and positively related to initial income through research.

With respect to regressions (3)-(6) it should be noted that we performed some supplementary regressions (shown at the bottom of Table 3) with institutional quality as the dependent variable, which suggest that institutional quality is negatively related to natural resource dependence.

[16] In endogenous growth frameworks the main channel through which convergence may arise involves technology diffusion (see, e.g., Aghion and Howitt (1998), chapter 12, and Barro and Sala-i-Martin (2004), chapter 8).

4.4. Discussion

The basic regression results from subsection 4.2 suggest that, consistent with the theoretical framework, (a) growth is fuelled by the accumulation of capital and knowledge and (b) the accumulation of capital and knowledge are positively related to the size of the population and negatively related to the degree of natural resource dependence.

The robustness checks of the preceding subsection have unambiguously confirmed result (a): growth is positively and significantly linked to the investment ratio and the number of researchers. With respect to (b), they confirmed that the investment ratio is positively and significantly linked to the population size and negatively and significantly to natural resource dependence. However, regarding the number of researchers, inclusion of initial income implies that natural resource dependence becomes insignificant, whereas initial income affects knowledge formation *positively*.

The latter result could be reconciled with the hypothesis that knowledge formation is negatively related to natural resource dependence if the latter, being a structural feature of the respective economies, were not only a reason for low growth in the period considered, but also for low initial income. In fact, it has been shown by Sachs and Warner (1997) that growth from some initial date (1970) is positively linked to growth before that date. Perälä (2003) found that all countries with negative growth in 1990-1999 had negative growth from 1980 or earlier, implying that growth failure is a persistent problem. To the extent that growth (or the lack of it) is a persistent phenomenon and is linked to natural resource dependence, low initial income could thus act as a proxy for high natural resource dependence with respect to knowledge formation.

With respect to convergence, an interesting result is that growth, while being negatively related to initial income through the productivity channel, may be positively related to initial income through research. With respect to institutional quality there is support for the 'social capital channel' of the natural resource curse, since growth is positively linked to institutional quality, and institutional quality is negatively linked to natural resource dependence.

Overall, in spite of some remaining ambiguity concerning the way in which knowledge formation is related to natural resource dependence, the predictions from the proposed theoretical framework are supported by the econometric evidence presented.

5. CONCLUSION

This paper has studied a growth model with natural resources and endogenous technological change. For suitable values of the rate of time preference and the elasticity of marginal utility, the model implies that knowledge accumulation as well as capital formation are inversely related to natural-resource intensity, thus providing an explanation of the ‘curse of natural resources’. An important factor involved in these predictions is the relatively low productivity of any unit of consumption foregone in favor of investment when the economy depends heavily on natural resources. Estimation results on cross-sectional data for 77 countries (1965-1998) are consistent with these predictions. In spite of the paper’s focus on the ‘hard’ drivers of growth, that is, the formation of capital and knowledge, the basic results of the paper remain valid when institutional aspects (corruption, democracy) are included.

Appendix A. Equilibrium R&D

Because the firms in the technology sector are monopolies, analysis of the technology sector requires to consider the demand functions facing these firms. These demands are derived from the optimization problem of the manufacturing firm. This problem can be stated as one of maximizing current profit at any point in time because no purchase and accumulation of capital is involved.[17] This implies the usual equations between factor prices and marginal products, which can be written as follows:

$$w = \alpha \frac{X}{L_X}, \tag{A1}$$

$$p = \beta \frac{X}{N}, \tag{A2}$$

$$z_i = \gamma \cdot L_x^{\alpha} \cdot N^{\beta} \cdot K_i^{\gamma-1}. \tag{A3}$$

The wage rate *w*, the natural-resource price *p*, and the rental rate z_i are endogenous variables, to be determined below.

Since the unit cost of producing a specific capital good of type *i* equals the rental price of general capital, $R = r + \delta$, the present value profit from capital good *i*, invented at date *t*, is given by:[18]

$$V_i(t) = \int_t^{\infty} \left[z_i(\tau) - (r(\tau) + \delta) \right] \cdot K_i(\tau) \cdot e^{-\bar{r}(\tau,t)\cdot(\tau-t)} d\tau\,, \tag{A4}$$

where $\bar{r}(\tau,t)$ is the average interest rate between times *t* and τ.

The inventor of a capital good *i*, being the holder of a perpetual monopoly right over

[17] The dynamics of capital accumulation are captured by the household’s budget constraint.

[18] In the remainder of this section the time dependence of variables is explicitly referred to in the notation, for the sake of clearness.

the production of the good, seeks to maximize the present value of the flow of profits by setting the rental price z_i appropriately. We follow Romer (1990) in assuming that at every point in time capital of type *i* can be converted back into general capital. Then the rental price $z_i(\tau)$ can be selected to maximize monopoly profit *at each date* $\tau \geq t$. Observing the conditional demand function obtained from rearranging Equation (A3),

$$K_i = \left[\gamma \cdot L_X^{\alpha} \cdot N^{\beta} / z_i\right]^{\frac{1}{1-\gamma}}, \tag{A5}$$

the profit-maximizing rental price for specific capital is a simple markup over the rental price of general capital:

$$z_i(\tau) = \frac{(r(\tau) + \delta)}{\gamma}. \tag{A6}$$

From this it follows that z_i is the same for all *i*. Furthermore, because of Equation (A5), the profit-maximizing input quantities K_i are the same for all *i* (at a given point in time), i.e., $K_i(\tau) \doteqdot K(\tau)$.

By substituting for $z_i(\tau)$ from Equation (A6) into Equation (A4) we obtain the following expression for the inventor's present value of profit from capital good *i*, as of invention time *t*:

$$V_i(t) = \int_t^{\infty} \frac{1-\gamma}{\gamma} \cdot (r(\tau) + \delta) \cdot K(\tau) \cdot e^{-\bar{r}(\tau,t)\cdot(\tau - t)} d\tau. \tag{A7}$$

In order to determine the *R&D* cost of making an invention at time *t*, we solve the research function in Equation (2) for L_A to obtain the amount of labor required to raise *A* by the amount $\dot{A}$ (i.e., to invent a new capital good). Multiplying by the wage rate *w* and dividing by $\dot{A}$ gives the cost of an invention in terms of the wage rate. Observing that the wage rate equals the marginal product of labor in manufacturing (A1), and using Equations (A5) and (A6) in the expression for the marginal product of labor in manufacturing, the *R&D* cost incurred in *t* can then be written as

$$\frac{w(t) \cdot L_A(t)}{\dot{A}(t)} = \frac{w(t)}{\theta \cdot A(t)} = \frac{(r(t) + \delta) \cdot \alpha}{\gamma^2 \cdot \theta \cdot L_X(t)} \cdot K(t). \tag{A8}$$

By equating the expression for the monopoly profit from Equation (A7) and for the unit *R&D* cost from Equation (A8) the condition for equilibrium *R&D* is:

$$(1-\gamma)\cdot\int_t^{\infty}(r(\tau)+\delta)\cdot K(\tau)\cdot e^{-\bar{r}(\tau,t)\cdot(\tau-t)}d\tau=\frac{(r(t)+\delta)\cdot\alpha}{\gamma\cdot\theta\cdot L_X(t)}\cdot K(t)\,. \tag{A9}$$

Appendix B. Solving the Model

We solve the model for a steady state in which all variables change at constant rates.

(a) Due to Equation (2), L_A and, hence, L_X are constant in the steady state. The steady-state interest rate *r* is constant because of the Ramsey rule displayed in Equation (3). Therefore the integral in Equation (A9) can be solved, and the result can be rearranged as follows:

$$\hat{K}=r-\frac{(1-\gamma)\cdot\gamma\cdot\theta\cdot L_X}{\alpha}\,. \tag{B1}$$

(b) Observing Equation (A3), Equation (A5) implies:

$$\hat{N}=\frac{1-\gamma}{\beta}\cdot\hat{K}\,. \tag{B2}$$

From the Equations (A2) and (2), respectively, we get:

$$\hat{X}=\hat{N}+\hat{p}=\frac{1-\gamma}{\beta}\hat{K}+\hat{p}\,, \tag{B3}$$

$$\hat{A}=\theta\cdot L_A=\theta\cdot(L-L_X)\,. \tag{B4}$$

(c) Because $K_i=K$, the production function (1) can be rewritten as $X=A\cdot L_X^{\alpha}\cdot N^{\beta}\cdot K^{\gamma}$, which, together with Equation (B2), implies:

$$\hat{X}=\hat{A}+\beta\cdot\hat{N}+\gamma\cdot\hat{K}=\hat{A}+\hat{K}\,. \tag{B5}$$

(d) Substituting for $\hat{X}$ from Equation (B3) into Equation (B5) yields a relationship between $\hat{A}$, $\hat{K}$ and $\hat{p}$. Then substituting for $\hat{K}$ from Equation (B1) and for $\hat{A}$ from Equation (B4) and solving for L_X gives

$$L_X=\frac{1}{\theta\cdot(u-\beta)}\cdot\left(\beta\cdot\hat{p}+\alpha\cdot r-\beta\cdot\theta\cdot L\right),\text{ where } u=\gamma\cdot(1-\gamma)\,. \tag{B6}$$

(e) Using Equation (B6) in Equations (B1) and (B4), respectively, yields

$$\hat{K} = \frac{\beta}{u-\beta}\left(\frac{u}{\alpha}\cdot\theta\cdot L - \frac{u}{\alpha}\cdot\hat{p} - r\right), \tag{B7}$$

$$\hat{A} = \frac{1}{u-\beta}\left(u\cdot\theta\cdot L - \beta\cdot\hat{p} - \alpha\cdot r\right). \tag{B8}$$

Equation (B5) then implies

$$\hat{X} = \frac{1}{u-\beta}\left(\left(1+\frac{\beta}{\alpha}\right)\cdot u\cdot\theta\cdot L - \left(1+\frac{u}{\alpha}\right)\cdot\beta\cdot\hat{p} - (\alpha+\beta)\cdot r\right). \tag{B9}$$

(f) Output is used for consumption and (gross) capital formation. Hence, given a constant depreciation rate for each capital variety:

$$X = C + A\cdot(\dot{K} + \delta K) = C + A\cdot K\cdot(\hat{K}+\delta)\,. \tag{B10}$$

Since $A\cdot K\cdot(\hat{K}+\delta)$ grows at the rate $\hat{A}+\hat{K}=\hat{X}$ in the steady state, so does C, that is $\hat{C}=\hat{X}$.

(g) It now remains to eliminate the interest rate *r* by using the Ramsey rule and the fact that $\hat{X}=\hat{C}$. This then yields the results (5)-(7) in the main text.

Appendix C. Accounting for Resource Composition

If a fraction $\lambda \le 1$ of natural resources consists of non-renewable resources, the resource price evolves according to $\hat{p} = \lambda r$. The counterparts to Equations (8)-(10) then read:

$$\hat{X} = \frac{u\theta L - \alpha\rho + [\frac{u}{\alpha}\theta L - (1+\lambda+\frac{\lambda u}{\alpha})\rho]\cdot\beta}{u+\alpha\eta+[(1+\lambda+\frac{\lambda u}{\alpha})\eta-1]\cdot\beta}\,, \tag{8'}$$

$$\hat{K} = \frac{[\frac{u}{\alpha}\theta L - (1+\lambda\eta+\frac{\lambda u}{\alpha})\rho]\cdot\beta}{u+\alpha\eta+[(1+\lambda+\frac{\lambda u}{\alpha})\eta-1]\cdot\beta}\,, \tag{9'}$$

$$\hat{A} = \frac{u\theta L - \alpha\rho + [(\eta - 1)\lambda\rho] \cdot \beta}{u + \alpha\eta + [(1 + \lambda + \dfrac{\lambda u}{\alpha})\eta - 1] \cdot \beta}. \tag{10'}$$

Appendix D.

COUNTRY	GROWTH	INVESTMENT	NATCAP	POP65	RDPERS
Argentina	0.4	23.0	6.7	22.283	1.5
Australia	1.7	24.0	11.9	11.393	4.2
Austria	2.6	24.0	2.6	7.271	2.5
Bangladesh	1.4	20.0	14.1	58.501	1.0
Belgium	2.3	20.0	0.0	9.464	3.1
Benin	0.1	15.0	7.7	2.430	1.1
Botswana	7.7	27.0	6.3	0.549	1.3
Brazil	2.2	21.0	7.9	84.328	1.1
Burkina Faso	0.9	21.0	16.9	4.861	0.9
Burundi	0.9	12.0	19.9	3.213	0.9
Cameroon	1.3	21.0	21.1	5.882	0.9
Canada	1.8	22.0	11.1	19.678	3.6
Central African Republic	-1.2	10.0	30.2	1.677	1.0
Chile	1.9	19.0	9.8	8.572	1.3
China	6.8	31.0	7.2	729.191	1.3
Colombia	2.0	19.0	7.2	19.591	0.9
Costa Rica	1.2	21.0	8.2	1.481	1.4
Denmark	1.9	23.0	3.8	4.758	4.1
Dominican Republic	2.3	21.0	12.4	3.805	1.4
Ecuador	1.8	19.0	17.0	5.144	1.1
Egypt	3.5	21.0	4.5	31.563	1.4
El Salvador	-0.4	16.0	2.8	3.013	0.9
Finland	2.4	24.0	6.6	4.564	3.6
France	2.1	22.0	2.7	48.758	3.5
Ghana	-0.8	12.0	7.2	7.803	1.1
Greece	2.4	25.0	3.7	8.551	1.7
Guatemala	0.7	14.0	3.3	4.566	1.0
Haiti	-0.8	11.0	6.7	4.143	0.5
Honduras	0.6	20.0	9.9	2.244	1.2
India	2.7	19.0	19.8	495.157	1.1
Indonesia	4.7	26.0	12.4	106.650	1.1
Ireland	3.0	21.0	8.1	2.876	3.2
Italy	2.5	22.0	1.3	52.112	2.2
Jamaica	-0.4	25.0	6.8	1.760	0.9
Japan	3.5	31.0	0.8	98.881	4.9
Jordan	-0.4	29.0	1.6	1.106	1.0

Kenya	1.3	17.0	9.4	9.666	0.8
Madagascar	-1.8	11.0	41.9	6.114	0.9
Malawi	0.5	17.0	11.8	3.975	0.2
Malaysia	4.1	28.0	8.6	9.502	1.0
Mali	-0.1	18.0	41.0	4.922	0.2
Mauritius	3.8	22.0	1.2	0.753	1.3
Mexico	1.5	20.0	5.9	43.144	1.1
Morocco	1.8	20.0	4.1	13.323	1.3
Mozambique	0.5	13.0	12.7	8.222	0.0
Nepal	1.1	18.0	17.7	10.790	0.7
Netherlands	1.9	22.0	1.5	12.295	3.1
New Zealand	0.7	22.0	18.5	2.628	2.5
Nicaragua	-3.3	20.0	13.9	1.809	1.1
Niger	-2.5	11.0	54.2	3.622	0.0
Norway	3.0	27.0	10.0	3.723	4.5
Pakistan	2.7	16.0	5.6	54.771	1.0
Panama	0.7	20.0	6.5	1.303	1.2
Papua New Guinea	0.5	23.0	19.3	2.078	1.0
Paraguay	2.3	21.0	11.5	2.081	1.2
Peru	-0.3	21.0	7.8	11.467	1.1
Philippines	0.9	22.0	6.2	31.568	1.1
Portugal	3.2	27.0	2.3	8.999	2.1
Rwanda	0.0	13.0	21.7	3.183	0.9
Senegal	-0.4	12.0	16.8	3.627	0.9
South Africa	0.1	22.0	5.0	19.832	1.9
South Korea	6.6	29.0	1.7	28.530	3.0
Spain	2.3	23.0	2.9	32.056	2.2
Sri Lanka	3.0	22.0	7.4	11.007	1.1
Sweden	1.4	20.0	5.6	7.734	4.6
Switzerland	1.2	25.0	0.9	5.857	3.8
Thailand	5.0	29.0	6.5	31.190	1.0
Togo	-0.6	17.0	15.2	1.638	1.0
Trinidad and Tobago	2.6	21.0	9.5	0.896	1.9
Tunisia	2.7	26.0	7.9	4.630	1.0
Turkey	2.1	19.0	5.0	31.151	1.2
United Kingdom	1.9	18.0	1.9	54.350	3.3
United States	1.6	18.0	4.1	199.796	4.5
Uruguay	1.2	14.0	11.6	2.693	1.6
Venezuela	-0.8	22.0	18.9	9.094	1.1
Zambia	-2.0	18.0	37.8	3.614	0.4
Zimbabwe	0.5	17.0	8.5	4.375	1.1

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