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Does high indebtedness increase natural resource exploitation?

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ABSTRACT. The debt-resource-hypothesis suggests that high indebtedness leads to increased natural resource exploitation as well as more unsustainable patterns of resource use. Countries with high debt burdens supposedly increase their extraction of fossil fuels and mineral resources as well as their production of so-called cash crops in order to service their debt obligations. In spite of its popularity, there have been few attempts to systematically test the hypothesis. Existing analyses refer to deforestation only and come to mixed results. This study fills a gap in testing the hypothesis more comprehensively for 23 natural resources and cash crops. It uses first differencing, period-specific time dummies, and a lagged dependent variable to mitigate omitted variable bias. No evidence is found that would support the debt-resource-hypothesis.

1. Introduction

Many environmentalists believe that the high indebtedness of developing countries triggers increased exploitation and more unsustainable use of their natural resources. Indeed, the validity of what we will refer to as the debt-resource-hypothesis, or the DRH for short, seems to be taken for granted by many as a matter of fact. In this article we will attempt to test the DRH quantitatively and we fail to find evidence in its favour. Whilst not providing a conclusive proof against the DRH, our results shed doubt on its validity and should warn environmentalists and policy makers alike against believing too easily that high indebtedness spurs exploitation of natural resources.

Astonishingly, in spite of its popularity, there have been few attempts to systematically empirically test the DRH. There only seem to exist studies examining the link between debt and deforestation, but none that looks at other forms of natural resource exploitation. Indeed, even more generally, Pearce *et al.* (1995: 29) contend that ‘the impact of indebtedness on other environmental indicators such as pollution, biodiversity or depletion of other resources has not been tested’. This article cannot address pollution or biodiversity loss, but it attempts to fill the gap in the literature with

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respect to natural resources, namely subsoil fuel and mineral resources as well as export-oriented agricultural crops, so-called cash crops. To the best of our knowledge, this is the first study testing the DRH on a comprehensive range of natural resources. It thus complements the existing studies on the link between indebtedness and deforestation.

We start with an illustration of the widespread popularity of the DRH and a presentation of the reasons why high indebtedness might increase resource exploitation. After a review of the existing empirical literature and a discussion of our research design we report results that are subjected to a range of sensitivity tests. In the light of the reported results, the concluding section warns against taking the DRH simply for granted, but also cautions against taking our results as definite proof against the hypothesis.

2. The potential impact of indebtedness on resource exploitation

Whilst existing empirical studies seem to have exclusively focused on deforestation, the DRH is certainly not confined to deforestation in the eyes of its proponents. Calvert and Calvert (1999: 9), for example, suggest debt to be 'a driving force leading to overexploitation of soil and subsoil resources in the process of seeking to maximize foreign exchange earnings'. Similarly broadly, George (1989: 156) argues that high debts are repayed 'by cashing in natural resources'. The Philippine's Freedom from Debt Coalition believes that its country's indebtedness leads to 'destroying our forests to export wood, ruining our coral reefs to export fish, and exhausting our soils by applying heavy pesticides and chemical fertilizers to facilitate export-oriented agriculture' (cited in De la Court, 1992: 92).[1] The DRH has even been adopted by official bodies. It has been taken on board by, for example, the World Commission on Environment and Development (the so-called Brundtland Commission). Its famous 'Our Common Future' report states that 'debtors are being required to use trade surpluses to service debts, and are drawing heavily on non-renewable resources to do so' (WCED, 1987: 18). Even more drastically, the Commission maintains that 'debts that they cannot pay force African nations relying on commodity sales to overuse their fragile soils, thus turning good land to desert' (ibid.: 6).

The DRH has been particularly popular amongst environmentalist groups. The US branch of the World Wide Fund for Nature (WWF), for example, warns that 'demand for foreign exchange to service debts... has provided an impetus for developing countries to mine their natural resources' (WWF–US, 2000: 5). Friends of the Earth asked governments in the run-up to the World Summit on Sustainable Development in Johannesburg in 2002 'to note that external debt fuels the depletion of natural resources' (FoE, 2002: 2). The Worldwatch Institute (2001) suggests that 'debt pressure has spurred increases in export-oriented mining and

[1] Note that even if the DRH was valid, the environmental implications would not always be clear-cut. For example, the mere swap from crops produced for domestic consumption to cash crops for export purposes need not imply more environmental degradation, since cash crops such as coffee and cocoa might be less environmentally destructive than other non-cash crops such as potatoes or manioc (Gerster, 1992: 233).

logging in developing countries'. The Global Legislators Organization for a Balanced Environment (GLOBE), an association of members of parliament from over 100 national parliaments, also maintains that 'pressure of debt repayments often causes overexploitation of natural resources' in their resolution to the Johannesburg summit (GLOBE, 2002).

The most common explanation of why high indebtedness might trigger increased resource exploitation and more unsustainable resource use seems to be that high indebtedness is seen as forcing countries to earn more and spend less in order to finance their debt obligations – if not a reduction of their debts, then at least servicing the interest on their debts. As a result, developing countries 'will give priority to what they can easily produce: primary products that sell at low prices on the world market. They have every incentive to use intensive agriculture to produce cash crops and to exhaust mineral resources as quickly as possible' (Calvert and Calvert, 1999: 205). Moreover, since many developing countries try to earn higher export revenues via exploiting their natural resources, the proponents of the DRH suggest this is leading to a vicious circle: 'With so many jostling for a share of limited world markets, prices plummet, forcing governments to seek ever-higher levels of exports in a desperate attempt to keep their hard currency revenues stable' (George, 1992: 2).

There have also been a few attempts at formally modelling the DRH (see, for example, Kahn and McDonald, 1995; Rauscher, 1989, 1990, 1997; Strand, 1995, 1997). As the focus of this article is empirical rather than theoretical, we will merely present the main results of these models. Kahn and McDonald (1995) in their analysis suggest that one needs to demonstrate why high indebtedness should change the rate of deforestation if a particular rate was seen as optimal and income maximizing before. They show in a dynamic optimization framework that high indebtedness might drive a wedge between deforestation strategies that are optimal in the short run as opposed to the long run and induce countries to pursue myopic policies resulting in 'excessive' deforestation. The intuition behind this result is that if one assumes that policy makers are constrained in their inter-temporal trade-off, such that current consumption must not fall beyond a certain minimum level, then high levels of indebtedness can induce policy makers to resort to deforestation in order to meet this minimum level of consumption. More generally, variables contributing to income and therefore to meeting the minimum level of consumption, such as a high labour force participation rate, decrease deforestation. Conversely, variables that compete for the use of income (investment, government spending, debt service) increase deforestation. Note that their model has been developed with respect to deforestation, but it is generally transferable to the exploitation of other natural resources. Rauscher's (1989, 1990, 1997) dynamic optimization models do not assume a minimum level of consumption. Instead he shows how higher indebtedness can lead to increased renewable resource exploitation in the presence of imperfect capital markets. The intuition behind this result is that in imperfect capital markets the interest rate to be paid on a marginal increase in debt is likely to be an increasing function of the existing total debt stock. In other words, the higher the existing debt stock, the higher the marginal cost of being indebted. To reduce this cost, natural resource owning countries can resort to exploiting their resources more than they would otherwise do in order to pay back some of the debt. The high initial indebtedness therefore induces the indebted country to deviate from the rate of resource extraction, which would otherwise be socially efficient. In the two-period models of Strand (1995, 1997) increased resource exploitation is also shown to be a rational response of countries with a high level of initial debt in order to reduce new borrowing.

3. Existing empirical evidence

What does the empirical evidence tell us on the DRH? The fervour with which the DRH is put forward by some of its proponents stands in stark contrast to the lack of systematic empirical evidence in its support. Mostly, anecdotal evidence and examples are presented (see, for example, George, 1989, 1992; Calvert and Calvert, 1999). Susan George believes that with respect to deforestation the figures simply 'speak for themselves' and that therefore no systematic quantitative analysis is needed. George (1992: 9) suggests that:

- Third world countries that deforested the most or the fastest in the 1980s were also, on the whole, the largest debtors.
- In a number of smaller countries with less significant forest reserves, the fastest deforesters were also the most heavily indebted.
- Countries with the highest 'debt service ratios' or subject to the highest levels of IMF 'conditionality' also tend to be the largest and fastest deforesters.

Not all qualitative empirical evidence supports the DRH, however. A 1992 report commissioned by the World Wildlife Fund (formerly World Wide Fund for Nature, WWF) consists of three case studies from Côte d'Ivoire, Mexico, and Thailand (Reed, 1992) and fails to find clear evidence in favour of the DRH. For example, with respect to Côte d'Ivoire, a country with one of the highest deforestation rates in the world, 'the research team was unable to establish any evidence that debt directly aggravated or eased environmental degradation in general or in the forestry sector in particular' (Reed, 1992: 145). Similarly, the Mexican case study failed to provide any evidence in favour of the DRH and in the case of Thailand, 'although rampant deforestation occurred during the mid-1980s, modelling analysis did not suggest that this problem was triggered or accelerated in any direct way by national debt obligations' (Reed, 1992: 146).

Quantitative econometric analyses exist with respect to deforestation only and they also fail to provide a clear-cut picture.[2] Some studies provide evidence in favour of the DRH. For example, Kahn and McDonald (1994, 1995) in ordinary least squares (OLS) estimation find a statistically significant effect of the debt service to export ratio on deforestation rates in the period 1981 to 1985. Kant and Redantz (1997: 77) find no

[2] Note that we can only review studies here, which included a variable of indebtedness. For reviews of quantitative studies of deforestation more generally, see Angelsen and Kaimowitz (1999) and Barbier (2001).

statistically significant relation between indebtedness and deforestation in Latin America in OLS estimation. Only in maximum likelihood (ML) estimation, which can be problematic in small samples (Long and Freese, 2001: 65), do they find that one million US$ of debt typically leads to 8.4 hectares of annual deforestation in Asia and 27.2 hectares of deforestation in Latin America. Capistrano (1994) and Capistrano and Kiker (1995), on the other hand, find in OLS estimation that a higher debt service to export ratio is associated with *less* rather than more forest depletion for the period 1972–1975 only and is not statistically significantly related to forest depletion during either 1967–1971, 1976–1980, or 1981–1985. Shafik (1994) also finds debt per capita to be highly insignificant in his OLS estimation analysis of the average annual rate of deforestation over the period 1962–1986. A couple of other, often unpublished, studies also provide rather ambiguous evidence, as summarized in Angelsen and Kaimowitz (1999).

Overall, therefore, the existing evidence for the DRH is limited and rather inconclusive (for a similar conclusion see, for example, Barrow, 1995: 291 and Pearce *et al.*, 1995). Most importantly, it is confined to examining deforestation. The following sections therefore try to test the DRH systematically for a wide range of other natural resources, thus complementing the existing literature on deforestation.

4. Research design

To estimate the underlying causal mechanisms or driving forces behind natural resource exploitation is a very difficult task because of two problems. First, on a conceptual level, it is not entirely clear which factors can be expected to drive exploitation. Even for deforestation, the topic that has attracted most attention, there is no agreement on which factors should be included. Most would include population growth/density, macroeconomic variables such as income, trade openness, and the real exchange rate, as well as variables relating to wood production and agriculture (subsidies, productivity, export value). But there is no consensus on which variables need to be included and how they should be defined. If anything, modelling the determinants of exploitation of a wide range of natural resources is even more complicated than modelling the determinants of deforestation, which might be one of the reasons for the focus on deforestation in existing studies. Second, on a practical level, many of the variables, which theoretical analysis might suggest as important determinants, are not available at all or only for a few countries and for small time periods. A country's extraction of natural resources is likely to be a function of numerous factors besides a country's extent of indebtedness. Such factors include the total reserve stock and resource discoveries, the quality of the mineral ore, fossil fuel deposit, or the productivity of land, the availability or emergence of substitute resources, capital and labour costs, the state of extraction technology, the size of the domestic market, the costs of transportation to foreign markets, the real effective exchange rate, and the existence of producer cartels such as the Organization of Petroleum Exporting Countries (OPEC) or the Association of Tin Producing Countries. It will also be affected by political interventions such as taxation and subsidies, price and exchange rate controls, environmental and trade regulations, the type of ownership (government or private, domestic, or multinational), political events, and strikes (Siebert, 1985; Rees, 1990; Dobozi, 1993). State ownership of the resource is an important variable, as such ownership makes it easier to channel the profits from resource exploitation directly into repaying public debts. Dobozi (1993) provides evidence from the copper industry that suggests that governments use state-owned copper mining firms as a macroeconomic tool to cope with balance of payments difficulties. However, the share of state ownership is impossible to establish for many markets. More generally, there can be no pretence that the factors determining resource exploitation could be adequately included in empirical estimation. As a consequence of both problems, empirical tests of the DRH are likely to suffer from omitted variable bias if the debt variable is correlated with one or more omitted variables.

Panel data estimation techniques are ideally suited for mitigating the problem of omitted variables. With panel data, the technique of first differencing the data can wipe out any time-invariant country effect, which eliminates already one important source of potential omitted variable bias. Period-specific dummy variables account for temporal changes in worldwide demand for natural resources such that the potential simultaneous increase in resource exploitation and indebtedness over time does not result in spurious regression results. Most importantly, as Nair-Reichert and Weinhold (2001: 162) note, panel data analysis allows the inclusion of a lagged dependent variable, which provides 'an excellent proxy variable for many omitted variables' as these variables are likely to be strongly correlated with the lagged dependent variable (see also Finkel, 1995). In addition, since panel data draw upon both cross-sectional and over-time variation in the data, one can capture both an 'acute' and a 'chronic' potential effect of indebtedness on resource exploitation.[3] The 'acute' effect would show in the dynamics of resource exploitation over time, with an increase in indebtedness triggering increased resource exploitation. The 'chronic' effect would show in the cross-sectional dimension of the data as highly indebted countries would have higher resource exploitation at any moment of time.

We therefore estimate the following dynamic model for each resource

$$P_{it} = \alpha + \gamma_t T_t + \delta P_{i-1} + \phi_1 X_{it} + \phi_2 X_{it-1} + \epsilon_{it}, \text{ where } \epsilon_{it} = u_i + v_{it}.$$

P_{it} and P_{it-1} is production (extraction) in country i in period t and $t-1$, respectively. The T_t capture any period specific effects not included in the regressors, for example temporal changes in worldwide demand for the resource. As mentioned above, P_{it-1} can function as a proxy of omitted variables. In addition, it can also account for inter-temporal persistence ('sluggishness') in resource extraction. The X_{it} and X_{it-1} include our explanatory vairables, namely the extent of indebtedness as our major variable of interest as well as possibly other control variables. Inclusion of the two terms together allows for both a current as well as lagged effect

[3] Such a distinction between 'acute' and 'chronic' effect is inspired by epidemiology. I am thankful to an anonymous referee for suggesting it.

of the debt variable on resource production. We use different specifications of the lag length as well as the type of lag included in sensitivity analysis. The u_i are supposed to capture any country specific time-invariant effects not included in the explanatory variables.

Estimating equation (1) with either OLS or a fixed-effects or first-differenced panel estimator is problematic. This is because of the inclusion of the lagged dependent variable as a regressor. Since P_{it} is a function of u_i, so is P_{it-1}. The correlation of a regressor with the error term renders the OLS estimator both biased and inconsistent. The same is true for the fixed-effects or first-differenced estimator, as first noted by Nickell (1981) and Anderson and Hsiao (1981). Whilst in the process of estimation the u_i are wiped out, biasedness and inconsistency is a consequence of the correlation between P_{it-1} and v_{it-1} (Baltagi, 1995: 126).

There are two ways to estimate equation (1) without bias and consistently. One is to follow Anderson and Hsiao (1981) and to use a two-stage least squares (2SLS) first-differenced estimator, that is, a first differenced estimator with instrumental variables. First differencing wipes out the u_i and using either P_{it-2} or ΔP_{it-2} (that is, $P_{it-2} - P_{it-3}$) as an instrument for P_{it-1} solves the problem since neither instrument is correlated with Δv_{it}. In addition, further lags can be included. Alternatively, one can use the so-called Arellano and Bond (1991) Generalized Method of Moments estimator. The basic idea of this estimator is to use all prior dependent variables that are valid instruments, not just P_{it-2}. We will use the Arellano and Bond dynamic panel estimator for the main estimations and the 2SLS first-differenced estimator in sensitivity analysis. When employing the 2SLS first-differenced estimator we follow Arellano's (1989) advice and use the levels P_{it-2} and P_{it-3} rather than the differences ΔP_{it-2} and ΔP_{it-3} as instruments. In sensitivity analysis, we further use a fixed-effects estimator, a random-effects estimator, which draws upon both cross-sectional and over-time variation in the data, and a between estimator, which is purely cross-sectional.

Natural resource extraction data in thousand metric tons for bauxite, copper, gold, hardcoal, iron, lead, lignite, natural gas, nickel, oil, phosphate, silver, tin, and zinc are taken from World Bank (2001a). Production data in thousand metric tons for the following most important cash crops come from FAO (2002): bananas, cashew nuts, cocoa beans, coffee, cotton, natural rubber, soybeans, sugar cane, tea, and tobacco.[4] Whilst the FAO data cover practically all countries in the world, some very small countries are missing from the World Bank data set. Estimations refer to countries with some positive amount of extraction of a natural resource or production of a cash crop only. It is clear that our dependent variable captures the level of resource extraction, but covers unsustainable resource use only to the

[4] We did not use net export data as for some natural resources no such data were available or are less reliable than production data. However, there is a very strong correlation between production and export of natural resources since the domestic market can only take up a very limited amount of these products, beyond which any production increases need to be exported. It is in the nature of these products that they are mainly produced for export.

extent that increased extraction goes hand in hand with unsustainable resource use. The problem is that there are no international data available, indicating the sustainability of resource use.

Our data cover the period 1979–1999, but the first two years are lost in the process of estimation due to the inclusion of the lagged dependent variable and the need for instrumenting it. We use the net present value of the total debt service to exports ratio as our variable of indebtedness in the main analysis and three other variables in sensitivity analysis: first, the total debt service to gross national income ratio; second, the total debt stock to exports ratio; third, the total debt stock to the gross national income ratio. Apart from the net present value of total debt service to exports ratio, which is computed by Easterly (2001), all variables are taken from World Bank (2000). To control for the effect of endowments on natural resource extraction and production, we use estimates of the available reserve stock for the energy and mineral resources. Data are taken from a variety of sources, including WRI (various years), US Bureau of Mines (various years), British Petroleum (various years), and OPEC (various years). Note that no data for silver and gold reserves could be established. For cash crops no crop-specific endowment data are available. As an admittedly crude proxy, we use the percentage of a country's land area that is considered arable, with data taken from World Bank (2001b). In sensitivity analysis, we replaced this variable with the share of permanent cropland as a percentage of arable land, without finding any major change of results.

As further control variables, we included the real effective exchange rate and the gross domestic product (GDP) in constant US$ prices of 1995 as a proxy for domestic market size. Following Kahn and McDonald (1994, 1995), as discussed in the section above, we also included the labour force participation rate, the gross domestic investment rate, and the ratio of government spending to GDP, even though we find their theoretical argument for the inclusion of these variables not compelling. Apart from the exchange rate data, which were taken from IMF (various years), all other data came from World Bank (2001b). As control variables specific for each resource, we used very crude estimates of the unit resource rent for fossil fuel and mineral resources (World Bank, 2001a) and the unit export value for cash crops (FAO, 2002). Due to gaps in data availability, these further control variables are included in sensitivity analysis only in order to keep the sample size for the main estimations as large as possible.

5. Results

Table 1 presents the estimates for all energy and mineral resources. Table 2 presents the results for the cash crops. Estimations are based on the Arellano–Bond dynamic panel estimator with the indebtedness variable entered both contemporaneously as well as in lagged form. As mentioned above, to have the greatest sample possible, indebtedness and endowments are the only explanatory variables other than the lagged dependent variable in these estimations. In sensitivity analysis, we entered the other control variables as well. For the estimates to be consistent, it is important that there is no second-order autocorrelation. As can be seen from table 1 and table 2, in all estimations but for bauxite, gas, and zinc, the hypothesis

Table 1. *Natural resource extraction*

	Bauxite	*Copper*	*Gas*	*Gold*	*Hardcoal*	*Iron*	*Lead*
P_{t-1}	0.31	1.08***	0.79***	0.97***	0.89***	0.91***	0.86***
	(1.37)	(33.40)	(8.60)	(30.98)	(37.30)	(26.00)	(37.31)
(NPV of TDS/exports)$_t$	24.5	2.8	−25.0	0.087	−763.2	86.5	0.083
	(1.19)	(0.92)	(1.54)	(0.35)	(1.14)	(0.28)	(0.15)
(NPV of TDS/export)$_{t-1}$	−37.1*	−1.7	−11.4	0.53	792.2	458.4	1.98
	(1.82)	(0.68)	(1.23)	(1.03)	(1.14)	(1.51)	(1.25)
Reserve stock	0.50	5.11***	39.8*	n.a.	1.34**	−10.4***	2.52
	(0.65)	(4.18)	(1.73)		(2.29)	(4.22)	(1.04)
combined p-value debt variables	0.2354	0.6514	0.2956	0.5474	0.5123	0.3086	0.3925
observations	284	475	686	656	596	468	414
countries	22	38	51	47	45	36	32
Test of autocovariance in residuals of order 2 is zero	0.0612	0.4316	0.0925	0.7734	0.1115	0.2802	0.9633

	Lignite	*Oil*	*Phosphate*	*Silver*	*Tin*	*Zinc*
P_{t-1}	0.73***	0.72***	0.75***	0.76***	0.92***	0.98***
	(12.15)	(10.17)	(7.38)	(9.04)	(39.53)	(32.56)
(NPV of TDS/exports)$_t$	−236.7	220.3	−47.2	0.003	−0.30	3.7
	(0.41)	(0.56)	(0.64)	(1.03)	(1.05)	(1.60)
(NPV of TDS/export)$_{t-1}$	−253.3	479.9	128.8	−0.004	0.41	−0.27
	(0.44)	(1.27)	(1.37)	(1.01)	(1.19)	(.19)
Reserve stock	0.057	306.3*	−28.95***	n.a.	−2.20	5.04
	(0.22)	(1.87)	(3.83)		(1.57)	(1.31)
combined p-value debt variables	0.4683	0.3396	0.2405	0.4295	0.4898	0.1411
observations	244	776	375	509	272	427
countries	24	54	28	39	23	32
Test of autocovariance in residuals of order 2 is zero	0.1404	0.2225	0.2734	0.3379	0.6489	0.0846

Note: Coefficients of constant and time dummies not reported. Robust standard errors. Absolute z-values in parentheses. n.a.: not applicable. *statistically significant at 10% level. **at 5% level. ***at 0.1% level.

Table 2. *Cash crop production*

	Bananas	*Cashewnuts*	*Cocoa*	*Coffee*	*Cotton*
P_{t-1}	1.0***	0.84***	0.88***	−0.30**	0.30*
	(12.36)	(6.08)	(22.10)	(2.11)	(1.71)
(NPV of TDS/exports)$_t$	0.93	−0.04	−3.4	−4.6	0.45
	(0.60)	(0.34)	(1.55)	(1.19)	(0.15)
(NPV of TDS/export)$_{t-1}$	1.57	0.00	1.9	0.86	6.0
	(0.73)	(0.01)	(1.38)	(0.20)	(1.22)
Arable land as % of total land	−17.3	−1.21	3.1	−8.1	3.5
	(1.24)	(1.19)	(1.50)	(1.55)	(0.23)
combined p-value debt variables	0.6806	0.9301	0.2987	0.0781	0.4391
observations	1,092	443	696	934	1,169
countries	66	28	38	56	75
Test of autocovariance in residuals of order 2 is zero	0.2109	0.1916	0.2208	0.1230	0.2696

	Rubber	*Soybeans*	*Sugarcane*	*Tea*	*Tobacco*
P_{t-1}	0.98***	0.29*	0.85***	0.92***	0.43***
	(41.96)	(1.71)	(28.95)	(26.64)	(54.08)
(NPV of TDS/exports)$_t$	−2.7	0.45	−42.2	−0.05	2.9
	(0.85)	(0.15)	(1.36)	(0.25)	(0.94)
(NPV of TDS/export)$_{t-1}$	0.86	6.0	19.4	−0.00	−2.6*
	(0.22)	(1.22)	(0.90)	(0.02)	(1.84)
Arable land as % of total land	4.45	3.4	−19.4	−0.28	2.3
	(0.67)	(0.22)	(0.42)	(0.60)	(0.60)
combined p-value debt variables	0.6967	0.4413	0.3529	0.9279	0.1195
observations	394	1,190	886	623	1,419
countries	24	76	65	39	94
Test of autocovariance in residuals of order 2 is zero	0.2470	0.2696	0.9623	0.3334	0.3072

Note: Coefficients of constant and time dummies not reported. Robust standard errors. Absolute z-values in parentheses.
*statistically significant at 10% level. **at 5% level. ***at 0.1% level.

of no second-order autocorrelation cannot be rejected at the 10 per cent confidence level. Even in the cases of bauxite, gas, and zinc, the hypothesis fails to become rejected at the more demanding 5 per cent level. Note that one of the indebtedness variables tests significantly only in two cases out of the 23 estimations reported in tables 1 and 2. For both bauxite and tobacco, the estimated effect of indebtedness on production is actually negative, which would contradict the DRH. More importantly, there is not a single case where the indebtedness variable is estimated significantly in concordance with the DRH. Even the combined p-value is above the 10 per cent confidence level in all cases but coffee.

The endowment variables are statistically significant with the expected positive sign only in few cases. For two minerals the estimated coefficient is significant with a negative sign. The most likely reason for this failure to test more in accordance with expectation is that for most mineral resources the reserve stock data are derived from rather crude estimates that change little over time. They are therefore subject to measurement error. In as much as they change little over time, they are also captured to a great extent by the country-specific fixed effects. It is notable that the reserve stock variable is significant with the expected positive sign for the cases of gas, oil, and hardcoal, for which reserve stock estimates are generally better available. The percentage of arable land is never statistically significant in the cash crop estimations. This variable hardly changes over time and is therefore already captured by the country-specific effects such that its effect is almost wiped out in the process of estimation. This is not problematic in our context since we merely want to control for the effect of endowments, but have no further interest in their effect on resource extraction.

6. Sensitivity analysis

Given the importance of the DRH and the rather striking results from table 1 and table 2 failing to find any evidence in its favour, the results were subjected to a whole battery of sensitivity analyses.[5] For example, the results reported in these tables remain valid if one of the other proxies for a country's indebtedness – the total debt service to gross national income, total debt stock to exports, total debt stock to gross national income – is used instead. The same is true if the variables are entered in combination with each other. Results remain valid if the variables are entered in logged form. Introducing the other control variables does not change results either. Results also remain valid if the 2SLS first-differenced estimator is used instead of the Arellano–Bond estimator, if no lags are used or further lags are included, if instead of lagged debt variables, which create problems with multicollinearity, moving averages are used that include the contemporaneous value and two prior years.

Whilst instrumenting the lagged dependent variable avoids its correlation with the error term, the estimation can be very inefficient if the instruments are weak. In other words, estimation is inefficient if further lags are bad predictors of the lagged dependent variables. Researchers therefore

[5] Detailed results are available from the author upon request.

sometimes estimate models such as equation (1) with a fixed-effects or first-differenced estimator without using instruments, trading off biasedness against inefficiency. If we do so, our results do not change. Sometimes, researchers even hesitate to include a lagged dependent variable as it absorbs much of the variation in the data, leaving little to the other independent variables. However, our results did not change if the lagged dependent variable is dropped from the model, which is then estimated with a fixed-effects or first-differenced estimator. The same is true if the model is estimated with a random-effects or between estimator.

In each of these sensitivity tests, naturally it happens that in very few cases the proxy variable for indebtedness assumes some marginal significance, sometimes with a positive sign, sometimes with a negative sign. However, with hundreds of estimations undertaken this is of course not further surprising given the nature of hypothesis testing with confidence intervals. That these few incidences are likely to be down to chance is supported by the fact that indebtedness does not become consistently marginally significant for any specific resource. The major result is therefore robust: there is no evidence for a statistically significant effect of indebtedness on natural resource exploitation.

7. Conclusion

There is a tendency in the applied econometric literature to report analyses only if they have found statistically significant results with respect to the variables of interest. Sometimes, however, the finding that a particular variable does not have a statistically significant influence on a dependent variable can be equally important. Arguably, this is the case here. We clearly fail to reject the hypothesis of no relationship between indebtedness and the extent of resource extraction. Our results reported above therefore fail to provide evidence for the DRH. We did not find evidence that countries with higher debt levels or higher debt service burdens have higher exploitation of subsoil fossil fuel and mineral resources or higher production of cash crops than other countries.

Our findings support the doubt expressed by others – for example, Reed (1992), Barrow (1995), and Pearce *et al.* (1995) – with respect to the validity of the DRH. It should warn us against accepting the DRH too easily. The widespread popularity of the hypothesis stands in stark contrast to the rather shaky empirical evidence it is built upon. Equally well, however, one must warn against taking the results as definite proof against the DRH. To start with, due to data constraints, we cannot really assess whether higher indebtedness has prompted countries to resort to more unsustainable resource use without an increase in the level of resource extraction. It is unlikely that a switch to (more) unsustainable resource use would not be accompanied by higher resource exploitation, but its possibility cannot be ruled out either. Further, as mentioned already, testing the determinants of natural resource exploitation is a complicated task, rendered difficult by conceptual uncertainty and poor data availability. First differencing, inclusion of year-specific time dummies and a lagged dependent variable can mitigate omitted variable bias, but it cannot fully avoid it. If indebtedness is correlated with variables that are still omitted, then our results can be biased. Furthermore, our resource endowment data are rather crude and often subject to measurement error. Perhaps there are limits to large-scale quantitative testing of such hypotheses. But our results demonstrate that there is no systematic quantitative evidence for the DRH, the validity of which is simply taken as a given by many.

One might wonder whether it really matters that there is little evidence for the DRH. Shilling (1992: 28) believes it does, since continued belief in the DRH in spite of the absence of empirical evidence in its favour 'is potentially dangerous, because it confuses the causes and cures, and thus, if acted upon, might lead to inequitable solutions, validate inappropriate behaviour, and create moral hazards'. Debt forgiveness, for example, might be desirable for any number of other reasons, but this analysis has shown that there is no reason to expect that it will lead to reduced natural resource exploitation.

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