Corruption, institutions, and sustainable development: theory and evidence from inclusive wealth

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Abstract

Institutional quality has been known to be a key factor explaining economic growth, and more recently, sustainable development. We first theoretically consider how institutions affect natural capital degradation, in a model where forest is converted into agricultural land. Corruption in resource extraction may have positive or negative impacts on the change of renewable natural capital, depending on whether regeneration surpasses extraction, while corruption in land development always has a negative impact. We then empirically study how corruption control affects both non-renewable and renewable natural capital, using data from the *Inclusive Wealth Report 2014*. Panel data estimates show a significantly positive effect of corruption control on the change of non-renewable resources and increasing renewable resources in developing countries, partially supporting the theory. In addition, we find significantly positive effects of resource abundance, plausibly proxied by recoverable stock, on the change of non-renewable resources in developing countries, and on the change of declining renewable resources in developed countries.

JEL codes: D73; O43; Q20; Q30

Keywords: natural capital; institutional quality; genuine savings; inclusive wealth; corruption; resource curse

1 Introduction

The search for the drivers of economic growth other than factors of production has been a central theme of modern economic growth theory. In recent decades, an active area of research has been the relationship between various institutions and economic growth. The literature is vast and collated in modern economic growth textbooks (e.g., Barro and Sala-i-Martin 2004; Acemoglu 2008; Aghion and Howitt 2009). As one aspect of institutions, the corruptive behavior of bureaucrats involving the private sector has been widely debated.

As well summarized by Aidt (2009), it is known that the causal relationship between corruption and economic growth could be in either direction. Corruption can grease the wheel of economic transactions, leading to more investment that would not have taken place in the absence of bribery. This is in line with anecdotal accounts that bribery corrects prevailing governmental inefficiencies in autocratic or communist regimes. On the contrary, corruption can sand the wheel of transactions to create more inefficiencies, resulting in stagnant investment and growth. This idea seems consistent with the view that government officials are rent-seeking, rather than maximizing social well-being, agents (e.g., Murphy et al. 1993). Recent evidence is still mixed. For example, Sala-i-Martin and Subramanian (2013) argue that oil endowment negatively affects institutional quality, which then drives down growth. Alexeev and Conrad (2009) in contrast show that large endowments of non-renewable resources increase GDP per capita without improving institutions. A related claim is that oil rents erode institutions (e.g., Bhattacharyya and Hodler 2010; Arezki and Brückner 2011).

These discussions are centered on the nexus between corruption and economic growth, but it is increasingly recognized that intergenerational well-being is improved by the increase in comprehensively aggregated wealth of produced, human, and natural capital (e.g., Hamilton and Clemens 1999; World Bank 2011; Arrow et al. 2012). In the latter literature, institutions are considered to play the role of enabling assets to make capital assets work well (Dasgupta 2001/2004; 2009). Thus, it is worth exploring theoretically and empirically how institutional quality affects the increase in capital assets.[1]

A separate, but closely related body of literature is that on what is termed resource curse. This huge strand of literature studies the paradoxical hypothesis that (non-renewable) resource-rich nations are likely to experience sluggish

[1] There is mixed evidence on the effects of institutions on forest growth (e.g., Ferreira and Vincent 2010; Galinato and Galinato 2012; 2013).

growth[2]. However, if long-run growth is partially determined by the change in capital assets, as was pointed out by Hartwick (1977) and successive studies, the curse, if any, should be traceable to the underinvestment into capital assets. In this context, institutions come into play to explain the change in capital assets, and indeed, some studies find that good governance and resource abundance could work to turn a potential curse into a blessing (Brunnschweiler and Bulte 2008)[3]. Thus, a nexus that should be studied is that from governance and institutions to the change in capital assets, potentially given resource abundance. Atkinson and Hamilton (2003) conducted a cross-sectional analysis to find that governance facilitates investing rents into capital assets, namely, genuine savings. Dietz et al. (2007) extended the analysis to panel data, showing that the interaction of resource dependence on the one hand and lack of corruption and rule of law on the other hand significantly reduces the negative impact of resource dependence on genuine savings.

Against this background, we first show the theory on the relationship between corruption and the increase in inclusive wealth, mainly extending Barbier's (2010) corruption-resource model and assuming that the sum of bribery and well-being is dynamically maximized. We ensure that corruption puts downward pressure on overall sustainability, but it has varied effects on specific components of natural capital. We then check the theoretical implications using an inclusive wealth dataset.

Our contribution is three-fold. First, our theoretical model assumes a capital-resource economy in a political setting, following Barbier (2010), but it extends to renewable resource extraction and land development. We find asymmetry between the case for extraction-linked corruption and that for land development-linked corruption, although in both cases, greater corruptibility is likely to translate into degrading natural capital with a few exceptional cases, implying that sustainable development is at greater risk. Although we assume dynamic optimality in the sense that the social planner maximizes the weighted sum of social well-being and bribery benefit, this assumption means that capital and shadow price dynamics are prevalent in imperfect resource-dependent economies, and is not an assumption of agathotopia.

Second, we provide new, albeit limited, evidence on the corruption–wealth nexus, indicating that corruption control could facilitate sustainable development,

[2] Van der Ploeg (2011) summarizes the literature, and makes the link with genuine savings as an indicator of sustainable development.

[3] Van der Ploeg and Poelhekke (2010) find that resource-revenue volatility is the key to such a curse.

in line with the theoretical models. Aidt (2009) was the first to empirically establish the relationship between corruption and growth in wealth per capita. Given that the nexus from corruption to growth in GDP per capita is ambiguous, this result is illuminating. However, since the dependent variable is made up of several components, it would be of much more help to decompose it and trace the channels by which investment is affected by corruption. Moreover, it has been only a few years since wide panel data on inclusive wealth have become available from both the World Bank and UNU-IHDP and UNEP (2014), and to the best of our knowledge, few studies have dealt with the effect of corruption on natural capital components and other important capital assets in a parallel fashion.

Third, we also show the effect of resource abundance, following the resource curse literature. In an effort to study the effect of resource abundance on economic growth, and to avoid the use of endogenous resource dependence, Brunnschweiler and Bulte (2008) found that resource abundance affects economic growth positively. Van der Ploeg (2011), however, argued that some of the variables that are claimed to be resource abundance are constructed from the present value of resource rents, which are endogenous in explaining growth. We extend their work to study the effect of natural capital abundance on its growth, instead of economic growth, by employing the natural capital recoverable stock data, rather than the present value of resource rents.

The outline of the rest of the paper is as follows. In Section 2, we present our basic model of corruption and sustainable development and study characteristics of the change in wealth. The resource extraction case and the land development case are separately argued and compared. Section 3 presents the empirical analysis using natural capital data reported in UNU-IHDP and UNEP (2014). Section 4 presents concluding remarks and future research directions.

2 Model

2.1 Model 1: Corruption in resource extraction

To examine the relationship between corruption and the change in natural capital, we employ the objective function of Barbier (2010), who in turn referred to Grossman and Helpman (1994), López and Mitra (2000), and Barbier et al. (2005).[4] The resource-allocation mechanism of our economy is corrupt to a cer-

[4]Mason et al. (2018) extended this line of literature to include stock dynamics and strategic interactions.

tain extent. That extent of corruptibility is expressed by the parameter, $0 \leq \gamma \leq 1$. The social planner has the following objective function:

$$V(t) = \int_t^{\infty} (\gamma B(R(s)) + (1-\gamma)U(C(s)))\, e^{-\delta(s-t)} ds, \tag{1}$$

where $B(R(s))$ is the benefit function of the government, contingent on the volume of resource extracted at s, $R(s)$. The objective function is a weighted sum of bribery benefit and social well-being. As in Barbier (2010), the benefit function is assumed to be convex, so that $B_R > 0$ and $B_{RR} \geq 0$[5]. $U(C(s))$ is the usual utility function of consumption, C, and $\delta > 0$ is the utility discount rate. Population change is assumed away throughout.

In order to keep our framework tied in to that of inclusive wealth accounting in practice (World Bank 2011; UNU-IHDP and UNEP 2014), we assume renewable resource capital, along with conventional physical capital, K. To fix ideas, we follow Hamilton and Atkinson (2006) and consider agricultural land, A, forestland L, and forest resource stock, S. We describe capital asset dynamics in order. Production from capital, agricultural land, forest resource, and forestland is the output of the economy. Output net of consumption and resource extraction cost is invested in physical capital:

$$\dot{K} = F(K, A, R, L) - f(R) - C, \tag{2}$$

where extraction cost function satisfies $f_R > 0$. In each period, an area D of forestland is developed into agricultural land, A. The total land area is fixed at T, so that $A + L = T$.[6] Thus, we have

$$\dot{A} = D, \tag{3}$$
$$\dot{L} = -D. \tag{4}$$

In other words, forestland is an exhaustible resource. Finally, forest resource stock is subject to its regeneration $G(S)$, extraction R, and development D:

$$\dot{S} = G(S) - R - DS/L, \tag{5}$$

[5]The subscript of a function signifies the first-order derivative of the function with regard to the variable. Likewise, the second-order derivative of function F is expressed, for example, as F_{xx}.

[6]There is a vast literature on forest transition. Lambin and Meyfroidt (2011) and Meyfroidt and Lambin (2011), for example, showed that although net reforestation has been observed in the tropics recently, deforestation remains alarmingly high and is an important driver of land conversion to agriculture.

where the last term is the product of the developed area and forest volume density per hectare. Assume also that the productivity of the renewable resource satisfies the usual properties, that is, $G_S > 0$ and $G_{SS} < 0$. Initial conditions regarding stock variables are given: $K(0) = K_0$, $L(0) = L_0$, $A(0) = A_0$, and $S(0) = S_0$. In addition, we follow Grossman and Helpman (1996) and Barbier (2010) to assume "local truthfulness" of resource-extracting firms and political equilibrium between the government and the resource firm. A key assumption here is that government officials use received bribes for wasteful, conspicuous consumption overseas, rather than for domestic consumption or expenditure.

Our economy is "optimal" in the sense that the social planner maximizes the sum of bribery benefit and social well-being, (1). It goes without saying that this should be suboptimal from the standpoint of a benevolent government that cares only about the well-being of citizens, namely, the case of $\gamma = 0$. Let us call the full optimum of the economy when $\gamma = 0$ the first best, which is distinct from the dynamic optimality with regard to bribery benefit and social well-being. Writing the shadow prices of K, A, L, and S as p_i for $i = K, A, L$, and S, respectively, the current-value Hamiltonian is

$$\begin{aligned} H =& \gamma B(R) + (1-\gamma)U(C) \\ &+ p_K(F(K, A, R, L) - f(R) - C) + (p_A - p_L)D + p_S(G(S) - R - DS/L). \end{aligned} \tag{6}$$

Static efficiency conditions are

$$(1-\gamma)U_C = p_K, \tag{7}$$
$$\gamma B_R + p_K(F_R - f_R) = p_S, \tag{8}$$
$$p_A = p_L + p_S S/L. \tag{9}$$

(7) shows that, given the shadow price of physical capital, consumption is determined at a level lower than without corruption. (8) shows that the shadow price of the resource stock does not equal the resource rent accruing to the private sector. The former now includes the marginal bribery benefit for the government. It also holds from (9) that, on an efficient path, forestland is developed into agricultural land, to the point where the shadow price of agricultural land exactly matches the opportunity cost of development: the sum of the shadow prices of original forestland and timber harvests weighted by the volume density of forest[7].

[7]We could interpret the right-hand side (RHS) of equation (9) to represent regulating service and provisioning service of forest.

Dynamic conditions for optimality include

$$p_K F_K = \delta p_K - \dot{p_K}, \tag{10}$$
$$p_K F_A = \delta p_A - \dot{p_A}, \tag{11}$$
$$p_K F_L + p_S DS/L^2 = \delta p_L - \dot{p_L}, \tag{12}$$
$$p_S(G_S - D/L) = \delta p_S - \dot{p_S}. \tag{13}$$

These equations of motion for co-state variables are all subject to the usual interpretations.

As we have seen in eq (8), resource rent as usually discussed is distinctive from the shadow price of resource in this model, since the latter is inclusive of marginal benefit of bribery. One can derive the dynamics of pure resource rent in this economy from the optimality conditions. Combining equations (7), (8), (10), and (13), it is straightforward to show that

$$\begin{aligned}\frac{\dot{\overline{F_R - f_R}}}{F_R - f_R} =& \frac{(\delta - G_S + D/L)(p_S - \gamma B_R) + (\delta - G_S + D/L)\gamma B_R - \gamma \dot{B}_R}{p_S - \gamma B_R} - (\delta - F_K)\\ =& F_K - G_S + D/L + \frac{\gamma}{1-\gamma}\frac{B_R}{U_C(F_R - f_R)}\left(\delta - G_S + D/L - \frac{\dot{B}_R}{B_R}\right)\end{aligned} \tag{14}$$

Eq (14) is what could be called a corrupted version of the Hotelling rule. Set against the increase rate of the resource rent is the rate of return on investment into physical capital, net of the marginal resource productivity of the forest resource less the developed area of the former forestland, adjusted by an extra corruption-related term. This fourth term on the RHS is the product of the relative corruptibility ($\frac{\gamma}{1-\gamma}$), the marginal benefit of resource extraction as bribery relative to that as pure resource, and the effective discount rate of the resource. It can easily be checked that, when the only resource is exhaustible and there is no land, the term $(-G_S + D/L)$ on the RHS disappears. In addition, when $\gamma = 0$, it collapses to the original Hotelling rule.

However, the change in social well-being, $\dot{V}$, not the change in resource rent, matters to sustainable development. Taking the change rate in social well-being, inclusive wealth accounting reports the following well-being improvement index:

$$\frac{\dot{V}}{V} = \frac{\dot{H}}{H} = \frac{p_K}{V}\left(\dot{K} + \frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L} + \frac{p_S}{p_K}\dot{S}\right). \tag{15}$$

The first equality in (15) is due to the well-known result since Weitzman (1976) that the current-value Hamiltonian is the return on social well-being, thereby holding a linear relationship with the latter. The term within the bracket is often called "genuine savings," or the dollar value of the change in inclusive wealth. Corruption is expected to decrease the value of (15), by wasting real resources that could otherwise have been either (rightfully) consumed to raise current well-being, or saved to raise future well-being. When the RHS of (15) is negative, social well-being (plus the resources for bribery) is bound to decrease.

Non-negativity of (15) is a necessary condition for sustainable development. It also helps to keep track of each and every component of the RHS of (15), for at least two reasons. Corruption is expected to decrease genuine savings in general, but given that savings are considered to be not a mere residual of consumption but a proactive investment, it helps to observe the channels in which institutions have an affect. Moreover, negative genuine savings are a violation of the weak sustainability criterion, and thus, delving into the bracket of the RHS of (15) would also be beneficial from a strong sustainability perspective, which looks at the changes in specific natural capital components.

Thus, in the following part, we summarize the effect of corruption on each component of natural capital change, in consumption numeraire in (15), all of which can be derived with ease from (7)–(9).

- The change in agricultural land:

$$\frac{p_A}{p_K}\dot{A} = \frac{p_A}{(1-\gamma)U_C}D \geq 0. \tag{16}$$

  The value of agricultural land increases by assumption.

- The change in forestland:

$$\frac{p_L}{p_K}\dot{L} = -\frac{p_L}{(1-\gamma)U_C}D = \left(\left(F_R - f_R + \frac{\gamma B_R}{(1-\gamma)U_C}\right)\frac{S}{L} - \frac{p_A}{(1-\gamma)U_C}\right)D \leq 0. \tag{17}$$

  By contrast, the value of forestland decreases, again by the assumption of the model.

- The change in total land (agricultural land and forestland):

$$\frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L} = \left(F_R - f_R + \frac{\gamma B_R}{(1-\gamma)U_C}\right)D\frac{S}{L} \geq 0. \tag{18}$$

Although total land change is not reported in inclusive wealth accounting, it is of theoretical interest. The change in the value of agricultural land and forestland moves in opposite directions, but their combined change should be non-negative, even though the total land mass is constant. This is because, along the optimum, the net change in the value of total land is equal to the opportunity cost of not using the forest for timber harvesting. Furthermore, the greater is corruptibility, the more this increase becomes, since it holds that $\partial\left(\frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L}\right)/\partial\gamma = (B_R/[(1-\gamma)^2 U_C])DS/L \geq 0$.

- The change in timber resources:

$$\frac{p_S}{p_K}\dot{S} = \left(F_R - f_R + \frac{\gamma B_R}{(1-\gamma)U_C}\right)\left(G(S) - R - \frac{DS}{L}\right). \tag{19}$$

As is also clear from (5), the sign of eq (19) is subject to whether timber and non-timber forest resources are extracted and developed beyond the regenerative capacity. The shadow price of timber resource now includes the marginal relative bribery benefit. When the net change of the resource is negative, one can observe in the same way as the total land change that greater corruptibility translates into more degradation of the resources, that is, $\partial\left(\frac{p_S}{p_K}\dot{S}\right)/\partial\gamma = (B_R/[(1-\gamma)^2 U_C])(G(S) - R - DS/L)$.

- The change in total forest (forestland and timber resources):

$$\frac{p_L}{p_K}\dot{L} + \frac{p_S}{p_K}\dot{S} = \left(F_R - f_R + \frac{\gamma B_R}{(1-\gamma)U_C}\right)(G(S) - R) - \frac{p_A}{(1-\gamma)U_C}D. \tag{20}$$

Forest resources, broadly defined, indicate timber resources as well as non-timber forest benefits (World Bank 2011; UNU-IHDP and UNEP 2014). The latter non-timber forest benefits are deemed to be roughly proportional to forestland area, so the value in (20) can be a proxy for the change in total forest resources[8]. However, the sign of this aggregate is ambiguous in the model.

[8]Note, however, that the non-timber forest benefits are being evaluated with increasingly scrutiny, so that they might not be considered to be proportional to forest land area in a more recent accounting. UNU-IHDP and UNEP (2014) apply separate shadow prices for temperate and tropical non-timber forest benefits, for example.

- The change in total natural capital (agricultural land, forestland, and forest resources):
$$\frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L} + \frac{p_S}{p_K}\dot{S} = \left(F_R - f_R + \frac{\gamma B_R}{(1-\gamma)U_C}\right)(G(S) - R). \tag{21}$$
This is the bottom-line renewable natural capital change, which can be obtained by a simple sum of (18) and (19). The sign of (21) depends on whether timber resources are on the increase, barring the deforestation part DS/L.

A noteworthy point from the abovementioned accounting predictions is that controlling corruption and making regimes cleaner (a smaller value in γ) would change the shadow prices of all the natural capital assets in this economy. In this sense, corruption control as an institution works as an enabling asset (Dasgupta 2014; UNU-IHDP and UNEP 2014). This affects the value of total land change through the land–resource nexus (condition (9)). In addition, forest loss due to land development (DS/L) is absent from the change in total natural capital, because the former is compensated by the rise in total land value, (18). This can be observed by comparing (18), (19), and (21). In other words, the sign of the total natural capital change depends on the sign of $(G(S) - R)$, not $(G(S) - R - DS/L)$. Finally, by setting $\gamma = 0$, all the equations (16)-(21) would reduce to the first-best case.

By partial differentiation of (21), we have
$$\frac{\partial}{\partial \gamma}\left(\frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L} + \frac{p_S}{p_K}\dot{S}\right) = \frac{B_R}{(1-\gamma)^2 U_C}(G(S) - R). \tag{22}$$
In an interesting case, where the resource is extracted beyond the level of regeneration, so that the sign of $G(S) - R$ becomes negative, it is confirmed that greater corruptibility would lead to more depletion. The flip side of the same coin is that, as long as extraction remains within regenerative capacity barring land development (i.e., $G(S) - R > 0$), a small change in γ works to push up the change in natural capital. In sum, corruption can theoretically work both ways, depending on whether the resource is on the rise or not.

2.2 Model 2: Corruption in land development

Informal reporting in some Asian and Latin American countries suggests that there is rampant corruption in land development, not necessarily linked to resource extraction. It is then helpful to study the modification of our model, since natural capital in wealth accounting, as it stands, is comprised of resources and land (forestland, crop land, and pasture land). Past research does not necessarily study corruption in land trading and sustainable development. The objective function is changed to

$$V^d(t) = \int_t^\infty \left(\phi B^d(D(s)) + (1-\phi)U(C(s))\right) e^{-\delta(s-t)} ds, \tag{23}$$

where ϕ represents, by the same token as bribery on resource extraction of Model 1, the weight of bribery reception depending on the land area developed. $B^d(D)$ is the bribery benefit arising from land development, which satisfies $B^d_D > 0$ and $B^d_{DD} > 0$. All the stock equations of motion (2)–(5), and therefore, co-state equations of motion (10)–(13), hold. Static efficiencies (7)–(9) are now replaced by

$$(1-\phi)U_C = p_K, \tag{24}$$

$$p_K(F_R - f_R) = p_S, \tag{25}$$

$$\phi B^d_D + p_A = p_L + p_S S/L. \tag{26}$$

Equations (25) and (26) show, respectively, that resource rents are now typical Hotelling rents and that the marginal social benefit of developing forestland now includes private benefit to the bureaucrats. They straightforwardly imply that resource rents, or shadow prices of the resource, move according to

$$\frac{\dot{\overline{F_R - f_R}}}{F_R - f_R} = F_K - G_S + D/L, \tag{27}$$

which is explicitly free from the degree of corruption, ϕ; the level of land developed is now distorted in the presence of corruption. The change in natural capital per capita can be described as follows.

- The change in agricultural land:

$$\frac{p_A}{p_K}\dot{A} = \frac{p_A}{(1-\phi)U_C} D \geq 0. \tag{28}$$

- The change in forestland:

$$\frac{p_L}{p_K}\dot{L} = -\frac{p_L}{(1-\phi)U_C} D = \left((F_R - f_R)\frac{S}{L} + \frac{-p_A - \phi B^d_D}{(1-\phi)U_C}\right) D \leq 0. \tag{29}$$

- The change in total land (agricultural land and forestland):

$$\frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L} = \left((F_R - f_R)\frac{S}{L} + \frac{-\phi B_D^d}{(1-\phi)U_C}\right)D. \tag{30}$$

  By assumption, the change in agricultural land is positive and the change in forestland is negative, but the sign of the combined change in total land value is ambiguous, in contrast to Model 1. In particular, if the marginal payment of bribery is so large that it eats up the resource opportunity cost of land development ($(F_R - f_R)\frac{S}{L}$), the value of total land change could be negative, even if the total land area is fixed, and even if development in general is meant to raise the value of capital assets.

- The change in forest resources:

$$\frac{p_S}{p_K}\dot{S} = (F_R - f_R)\left(G(S) - R - \frac{DS}{L}\right). \tag{31}$$

  As (25) and (27) show, there is no direct effect of corruption on the increase in forest resources as biomass, in the case of corruption related to land development.

- The change in total forest (forestland and forest resources):

$$\frac{p_L}{p_K}\dot{L} + \frac{p_S}{p_K}\dot{S} = (F_R - f_R)(G(S) - R) + \frac{-p_A - \phi B_D^d}{(1-\phi)U_C}D. \tag{32}$$

  The change in total forest is composed of regeneration net of extraction, minus the social value of land development. The latter includes (the negative of) the loss of forest mass due to land development.

- The change in total natural capital (agricultural land, forestland, and forest resources):

$$\frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L} + \frac{p_S}{p_K}\dot{S} = (F_R - f_R)(G(S) - R) - \frac{\phi B_D^d D}{(1-\phi)U_C}. \tag{33}$$

  The change in overall natural capital is now adjusted downwards to such an extent that corruption takes place with regard to land development. Without any corruption, natural capital changes exactly by the value of forest mass regeneration net of its extraction, and accounting for pure deforestation would be double-counting, since the marginal benefit of land development would equal its cost owing to (26).

As is the case with the extraction-corruption model, (28)-(33) collapse to the first-best case by setting $\phi = 0$. More importantly, increasing the corruptibility of the economy would worsen the increase in natural capital, by observing that

$$\frac{\partial}{\partial \phi}\left(\frac{p_A}{p_K}\dot{A} + \frac{p_L}{p_K}\dot{L} + \frac{p_S}{p_K}\dot{S}\right) = -\frac{B^d_D D}{(1-\phi)^2 U_C} < 0. \tag{34}$$

2.3 Implications for empirics

Let us summarize predictions from the above argument in Models 1 and 2 for the empirical testing in the next section. In both models, the sign of the total natural capital change is ambiguous ((21) and (33)). In Model 1, however, total natural capital change hinges on the sign of $G(S) - R$, rather than $G(S) - R - DS/L$, because in an efficient state, the negative effect of pure land development (aside from pure timber logging) is completely made up for by the land value change.

More importantly, the corruption's effect on total natural capital change is not symmetric. In Model 1, it affects natural capital degradation through the shadow price effect, so that the overall effect again depends on the sign of $G(S) - R$, that is, whether the pure resource use is within regenerative capacity. Meanwhile, in Model 2, corruption worsens natural capital change in a clearly negative fashion, because it distorts land development. This is somewhat intuitive, as in Model 2, corrupt practices appear in the development of land, whose amount is fixed. Which model of the two approximates the economy cannot be determined a priori in a general context, but as long as $G(S) - R < 0$, corruption always exacerbates the overall renewable resource depletion.

Predictions. (I) *If resource extraction is corrupt, the effect of corruption on the change in total natural capital is non-negative (negative) if*

$$G(S) - R \geq (<)\ 0, \tag{35}$$

that is, if resource renewal exceeds (falls short of) pure resource use, aside from deforestation.

(II) *If land development is corrupt, the effect of corruption on the change in total natural capital is negative.*

A few caveats are in order. First, by assumption, agricultural land increases and forestland decreases in both models, but the effect of corruption is not symmetric. On the one hand, in the extraction-corruption model (Model 1), the change in total land value is positive and greater corruptibility increases total land value. On the other hand, the change in total land value could be positive or negative in Model 2, and corruption is likely to put downward pressure on the total land value. This asymmetry is because land is a sort of exhaustible resource[9].

Second, if we apply Model 1 to the case of a non-renewable resource, it trivially holds from setting $G(S) = 0$ and no land that more corruption is expected to have an unambiguously negative effect on the degradation of the resource from (21). In the empirical section, we interpret the non-renewable resource results in this reduced-form framework of Model 1.

3 Evidence from inclusive wealth index

3.1 Data

Our dependent variables are the growth rates in capital assets per capita, extending Aidt (2009), who studied growth rates in wealth per capita[10]. Specifically, we attempt to explain growth rates in natural capital, both non-renewable (fossil fuels and mineral resources) and renewable (forest and agricultural land), all reported in the *Inclusive Wealth Report 2014* (UNU-IHDP and UNEP 2014). In the theoretical models, we have distinguished timber harvesting from pure deforestation. In our dataset, however, these cannot be differentiated, so that R implicitly includes both timber extraction and deforestation.

Several macroeconomic indicators of corruption are often cited. Of them, we use "corruption control" of Kaufmann et al. (2010) and "The Worldwide Governance Indicators, 2015 Update"[11]. We use the dataset of inclusive wealth and natural capital 1990–2010, but the availability of the corruption control data in Kaufmann et al. (2010) reduces the number of observations to half of the potential size (i.e., data for years 1996, 1998, 2000, and 2002–2009).

Following the resource curse literature, which demonstrates that resource dependence or abundance has a role to play in explaining economic performance

[9]This point should be noted, since in the *Inclusive Wealth Report* and other publications on natural capital, agricultural land and forestland are classified under renewable resources. The latter categorization is justified by their characteristic of what is on the land, not the land itself.

[10]Note that the dependent variables are not the share of genuine savings in output, or the increase in capital assets.

[11]The Worldwide Governance Indicators also report rule of law, regulatory quality, government effectiveness, political stability, and voice and accountability.

of resource-rich nations, we also include an index of resource abundance. Resource abundance has been proxied by resource dependence in terms of the share of exhaustible resources in total exports, but ideally, resource stock data should be used (Bulte et al. 2005). Accordingly, Brunnschweiler and Bulte (2008) found that resource abundance rather than resource dependence actually affects growth positively. Van der Ploeg (2011), however, argued that some of the variables that are claimed to be resource abundance are constructed from the present value of resource rents, which are endogenous in explaining growth. Fortunately, the capital stock data that we use, including renewable and non-renewable resources, are provided in the *Inclusive Wealth Report 2014*, and are calculated as the product of shadow price and recoverable *stock* data[12]. We use 1 and 3 years of lagged natural capital stock, to represent resource abundance.

The other usual independent variables included in the regressions are population growth rate and regional dummies from the ACLP Political and Economic Database.[13]

3.2 Results

The econometric model is

$$\begin{aligned} g_{it}^{j} =& \beta_0 + \beta_1 CorruptCtrl_{i,t-s} + \beta_2 Stock_{i,t-1}^{j} + \beta_3 CorruptCtrl_{i,t-s} \times Stock_{i,t-s} \\ &+ \beta_4 k_{i,t} + \beta_5 popgrowth_{i,t} + \epsilon_{it}, \end{aligned} \tag{36}$$

where g_{it}^{j} is the growth rate of capital assets per capita of type j in country i in year t. $CorruptCtrl_{i,t-s}$ for $s = 1, 3$ is the focus of our study, with 1- or 3-year lagged corruption control. Note that, the cleaner the regime is, the larger the corruption control index becomes. To account for the effect of resource abundance, $Stock_{i,t-1}^{j}$ is included; it is the level of the stock per capita under study. The fourth term on the RHS represents the interaction between corruption control and resource abundance. $k_{i,t}$ is the level of produced capital per capita, which controls the

[12]This is in contrast to World Bank (2011), where the value of natural capital is calculated as the present value of resource rents.

[13]Following the literature, we initially used the Polity2 score from the Polity IV project (Marshall and Jaggers 2005), one of the most commonly used measures of democracy. However, it turned out that it is positively correlated with corruption control, and that dropping Polity IV did not affect the robustness of corruption and its interaction with resource abundance. Thus, we decided not to include Polity2 from our analysis.

extent of economic development. Since the dependent variable is the growth rate of capital assets per capita, it should be natural to add the population growth rate ($popgrowth_{i,t}$). Finally, ϵ_{it} is the error term.

Before moving on to the panel data, Table 1 presents the preliminary regression results on the change rates of inclusive wealth, as well as produced, human, and natural capital, using just a 1-year lag of corruption control. A positive significant effect of corruption control on the growth rate of produced capital can be detected, which is in line with the literature on corruption and economic growth. Overall, there is an insignificant effect of corruption control on natural capital. A negative effect of resource abundance on growth rates is observed only for inclusive wealth and human capital. That neither corruption control nor resource abundance does not affect the growth of natural capital is not surprising, because natural capital is a sum of non-renewable and renewable resources, in contrast to produced and natural capital.[14] Table 2 as well as our theoretical models tells us that we need to delve into natural capital to study the influence of corruption control.

We proceed to the panel data analysis with fixed-effects estimates, to address unobserved time-invariant variation in country-specific factors, with robust standard errors. Detailed results for specific non-renewable and renewable capital stock are presented in Tables 2–5.

Columns (1) and (2) in Table 2 demonstrate that corruption control has a positive impact on the growth rates of non-renewable resources, confirming our theoretical predictions (Model 1 with no regeneration). Interaction with resource abundance ("CorruptCtrl × Stock(nonrenew)") is negative, indicating that a positive impact of corruption control is discounted for countries with high endowment of non-renewable resources. Produced capital per capita has a negative impact on the change rate of non-renewables. Notably, non-renewable resource stock does have a significantly positive effect on its growth, suggesting that resource abundance (RA) attenuates its depletion. This is similar to the opposite of the resource curse (Brunnschweiler and Bulte 2008). In contrast to their study, our dataset on non-renewable resource stock does not have an endogeneity problem (van der Ploeg and Poelhekke 2010), as it is calculated as the current resource rents multiplied by resource stock, instead of the net present value of resource rents. These results are very robust, being insensitive to different lags, random-effect models, or fixed-effect models.

[14]Produced capital is computed as the accumulated investment net of depreciation, while human capital is estimated by the lifetime income value of population who have gone through education.

Table 1: Corruption control and inclusive wealth

	(1) inclusive wealth	(2) produced capital	(3) human capital	(4) natural capital
CorruptCtrl_{-1}	0.000	0.031**	-0.000	-0.003
	(0.07)	(2.42)	(-0.06)	(-0.19)
polity2_{-1}	0.000***	0.001***	0.000	0.000
	(3.96)	(4.15)	(0.99)	(0.33)
$\text{Stock(inclusive wealth)}_{-1}$	-0.000**			
	(-2.53)			
$\text{Stock(human capital)}_{-1}$			-0.000***	
			(-4.79)	
$\text{Stock(natural capital)}_{-1}$				-0.000
				(-0.41)
k_{-1}	-0.000	-0.000	0.000**	-0.000
	(-0.55)	(-1.42)	(2.38)	(-0.99)
popgrowth	-0.369***	-0.507***	0.122***	-1.097***
	(-12.89)	(-8.46)	(3.14)	(-12.31)
constant	0.010***	0.015**	0.031***	-0.002
	(2.92)	(2.12)	(4.84)	(-0.20)
N	1401	1401	1401	1401
R^2	0.135	0.070	0.022	0.131

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Turning to renewable resources (columns (3)–(6)), the results are more mixed and ambiguous. $G < R$ subsample suggest a negative impact of corruption control, which is inconsistent with our theoretical prediction. It is interesting to note that, for the $G > R$ subsample, resource abundance seems to work significantly to reduce the growth rate, which we may call a resource curse for the renewable resource. Conventionally, the resource curse literature has suggested that a resource-abundance effect tends to be relevant for point-source resources, rather than more dissipative resources, like agricultural land. In addition, the interaction between corruption control and resource abundance is significantly positive only for the $G < R$ sample. Finally, since the dependent variables are the growth rates in natural capital per capita, it is not surprising that all the coefficients of population growth rate are significantly negative.

Table 2: Corruption and resource growth

	(1) non-renew	(2) non-renew	(3) renew($G < R$)	(4) renew($G < R$)	(5) renew($G > R$)	(6) renew($G > R$)
CorruptCtrl$_{-1}$	0.057***		-0.022		0.152	
	(0.011)		(0.017)		(0.113)	
CorruptCtrl$_{-3}$		0.070***		-0.030**		0.084
		(0.012)		(0.013)		(0.137)
Stock(nonrenew)$_{-1}$	0.098*	0.105*				
	(0.053)	(0.063)				
CorruptCtrl$_{-1}$ × Stock(nonrenew)$_{-1}$	-0.177**					
	(0.087)					
CorruptCtrl$_{-3}$ × Stock(nonrenew)$_{-3}$		-0.202*				
		(0.106)				
Stock(renew)$_{-1}$			0.017	0.302	-89.682***	-107.273***
			(0.345)	(0.274)	(11.759)	(16.059)
CorruptCtrl$_{-1}$ × Stock(renew)$_{-1}$			1.274***		4.395	
			(0.460)		(15.380)	
CorruptCtrl$_{-3}$ × Stock(renew)$_{-3}$				1.042***		12.493
				(0.361)		(20.318)
k	-0.560***	-0.583***	0.115	0.070	0.557	1.151
	(0.077)	(0.093)	(0.155)	(0.129)	(0.634)	(0.815)
popgrowth	-1.360***	-1.391***	-0.888***	-0.940***	-1.751***	-1.800***
	(0.058)	(0.060)	(0.155)	(0.135)	(0.310)	(0.356)
N	1044	855	1125	925	340	275

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 3 takes a closer look at the results for non-renewable resources. In particular, it divides the sample into developed (columns (1)–(2)) and developing (columns (3)–(4)) countries. The positive effects of corruption control and resource abundance, as well as their interaction effect, now appear only in the developing country sample. Their coefficients become insignificant in the developed country sample, whereas they become even more significant in the developing country sample than the pooled sample in Table 2. It is straightforward to conclude that the negative effect of corruption on non-renewable resource is significant only in developing countries, in light of both theory and evidence.

Table 3: Corruption and non-renewable resources: developed vs. developing

	(1) non-renew developed	(2) non-renew developed	(3) non-renew developing	(4) non-renew developing
CorruptCtrl_{-1}	-0.023		0.076^{***}	
	(0.024)		(0.013)	
$\text{Stock(nonrenew)}_{-1}$	-2.281	-2.302	0.128^{**}	0.134^{**}
	(1.596)	(1.703)	(0.055)	(0.066)
$\text{CorruptCtrl}_{-1} \times \text{Stock(nonrenew)}_{-1}$	2.090		-0.216^{**}	
	(1.563)		(0.092)	
CorruptCtrl_{-3}		-0.026		0.095^{***}
		(0.025)		(0.014)
$\text{CorruptCtrl}_{-3} \times \text{Stock(nonrenew)}_{-3}$		1.821		-0.234^{**}
		(1.653)		(0.112)
k	-0.613^{***}	-0.701^{***}	-0.496^{***}	-0.406^{**}
	(0.101)	(0.112)	(0.166)	(0.192)
popgrowth	-1.926^{***}	-2.003^{***}	-1.351^{***}	-1.386^{***}
	(0.432)	(0.502)	(0.060)	(0.063)
N	270	220	774	635

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Table 4 separates the $G < R$ sample (i.e., net growth of renewable resource is negative) into developed (columns (1)–(2)) and developing (columns (3)–(4)) countries. In this table, it still seems difficult to detect a significant effect of corruption control. However, it is worth noting that resource abundance positively and significantly affects the growth of renewable resources only in developed countries, which was not apparent in the pooled sample in Table 2 (columns (3)–(4)). Observe also that the positive effect of produced capital per capita appears only in the developed country sample, implying that even higher income countries tend to manage renewable resource better.

Table 4: Corruption and renewable resources, $G < R$ sample, developed vs. developing countries

	(1) renew developed	(2) renew developed	(3) renew developing	(4) renew developing
CorruptCtrl_{-1}	0.110		-0.013	
	(0.069)		(0.018)	
Stock(renew)_{-1}	1.729**	2.593***	-0.058	-0.379
	(0.734)	(0.803)	(0.420)	(0.295)
$\text{CorruptCtrl}_{-1} \times \text{Stock(renew)}_{-1}$	1.258*		-0.032	
	(0.728)		(0.679)	
CorruptCtrl_{-3}		0.087		-0.026**
		(0.076)		(0.012)
$\text{CorruptCtrl}_{-3} \times \text{Stock(renew)}_{-3}$		0.817		0.482
		(0.845)		(0.443)
k	0.592***	0.536**	0.051	0.146
	(0.225)	(0.264)	(0.443)	(0.320)
popgrowth	-1.714*	-0.768	-0.820***	-0.888***
	(0.916)	(1.022)	(0.154)	(0.119)
N	146	123	979	802

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

Finally, Table 5 presents the $G > R$ sample (i.e., net growth of renewable resource is positive) into developed (columns (1)–(2)) and developing (columns (3)–(4)) countries. Corruption control positively affects growth of renewable resources only in developing countries, with a 1-year lag (column (3)). This is not in line with the theoretical prediction, which says that corruption likely enhances the growth of renewable resources as long as they are on the rise. However, this unexpected effect does not last long, as it has not been detected with a 3-year lag (column (4)).

Moreover, it is also interesting to note that the significantly negative effect of resource abundance is preserved only for the developed country sample, when compared with Table 2 (columns (5)–(6)). Given the coefficients in the $G < R$ sample (Table 4, columns (1)—(2)), combined with the significantly positive coefficients in the $G > R$ sample (Table 5, columns (1)–(2)) in developed countries, it follows that the larger the endowment, the smaller the absolute value of the growth rate tends to be. Put differently, renewable resources are so managed that extraction tends to be close to regeneration in developed countries. The magnitude of the absolute value of the coefficients of columns (1)—(2) in Table 5 tells us that even a small difference in the corruption control can make a difference, as both of the mean and variance of the growth rates are small in developed countries.

Table 5: Corruption control (CC), resource abundance (RA), and renewable resources, $G > R$ sample, developed vs. developing countries

	(1) renew developed	(2) renew developed	(3) renew developing	(4) renew developing
CorruptCtrl_{-1}	0.066		0.105**	
	(0.247)		(0.047)	
Stock(renew)_{-1}	-104.398***	-108.177***	0.019	1.967
	(21.394)	(26.180)	(9.532)	(14.970)
$\text{CorruptCtrl}_{-1} \times \text{stock(renew)}_{-1}$	13.359		-7.683	
	(32.116)		(6.459)	
CorruptCtrl_{-3}		0.121		0.063
		(0.282)		(0.059)
$\text{CorruptCtrl}_{-3} \times \text{Stock(renew)}_{-3}$		2.220		-6.571
		(37.473)		(10.289)
k	-0.595	0.260	0.876*	1.148*
	(1.013)	(1.351)	(0.483)	(0.608)
popgrowth	6.791	4.567	-1.668***	-1.662***
	(4.227)	(5.786)	(0.105)	(0.123)
N	205	164	135	111

Standard errors in parentheses

* $p < .1$, ** $p < .05$, *** $p < .01$

In summary, our 21×140 panel data demonstrate that, corruption control positively affects growth of non-renewable and renewable (but increasing) resource in developing countries, partially backing our theoretical predictions. We observe the most significant results for non-renewable resources in developing countries, in line with the theoretical Model 1 with no regeneration. Regarding resource abundance, its effect is asymmetric but often significant: it is positive for non-renewables in developing countries, positive (negative) for decreasing (increasing) renewables in developed countries. These results show that the implications of corruption, as well as of resource abundance, differ to a great extent between developed and developing countries.

4 Concluding remarks

We have shown theoretical implications that corruption could work on various types of natural capital in a different manner. Corruption in resource extraction positively affects natural capital growth if resource regeneration exceeds extraction (aside from deforestation), while it negatively affects natural capital growth otherwise. Corruption in land development always has a negative effect on natural capital growth. We also present some, albeit limited, evidence that corruption control indeed affects natural capital degradation. Our estimates using panel data show significantly positive effects of corruption control (as well as resource abundance proxied by recoverable stock) on the change of non-renewable resources in developing countries, reaffirming the theoretical prediction. Some corruption control effects are observed for renewable resource change, but only in the sample of developing countries where resources are on the increase, thus the evidence is more mixed and asymmetric than for non-renewables. Moreover, we also found significantly positive effects of resource abundance, plausibly proxied by recoverable stock, on the change of non-renewable resources in developing countries, and on the change of renewable resources on the decline in developed countries.

This study has the following limitations. Some of the subtlety of our empirical observation is partly traceable to our economy-wide institutional variables. Ideally, cross-country data on institutional variables, separately addressing each and every class of natural capital, should be collected to explain growth rates in natural capital, but such data are currently sparse[15]. The assumption that land is developed as agricultural land may not be typical in developed countries, for which we should also include urban land development to improve the model. Incorporating resource abundance into the theoretical model, in line with our empirical findings, is also pertinent. Finally, the channels and lead time of the effect of corruption control should be more closely examined, including the possibility of endogenous

[15]See, for example, Smith et al. (2003) for Indonesian forest and Zinnes et al. (2007) for Romanian forest.

institutional change in the long run. These are major challenges of our current study, to which we should return in our future research agenda.

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