To Save a Dollar or a Tree

A Microeconomic Perspective on Sustainable Development, Saving and Institutions

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Abstract

The article investigates the impact of institutions on the saving of different forms of capital. It aims to explain the different effects found in the literature by presenting a model where ownership risk has ambigous effects on the extraction rate of some resources, while it exerts an accelerating impact for others and decreases investment in most parts of produced capital. The framework allows to contribute to the discussion of sustainable development and institutions and it may help to explain some of the mixed results found in the institutions and growth literature.

Keywords: sustainable development, institutions, ownership risk, exhaustible resource extraction, Adjusted Net Saving /Genuine Saving

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Contents

1 Introduction

Institutions can play a large role not only for economic development in general, but more specifically for sustainable development. This has been suggested among others by **?**. In the first part of my thesis, I have shown empirically that there is a negative effect of a weak institutional environment on sustainable development.[2] Furthermore, this effect channels mainly through the non-physical part of capital, that is through natural and human capital (**?**). This suggests that the saving of non-physical capital (such as for example forests and education) is influenced more strongly by institutional quality than the saving of physical capital (such as for example buildings). Surprisingly, the effect of institutional quality on physical capital alone turns out not to be statistically significant in my calculations.

In the present article I want to explain where this difference in the effects could originate. As my former analysis was conducted empirically, the present article now aims to uncover the underlying (microeconomic) mechanisms at work. This should help to explain and disentangle the two different effects of institutions, the one on physical and the one on non-physical capital.

The two questions I aim to answer are hence

- Are there mechanisms that can explain the difference in the effects of institutions on saving between different forms of capital found in the empirical analysis?
- If so, can this help explaining the 'non-effect' of institutions on physical capital and/or the mixed results found in the "institutions and growth" literature?

For this I need to first carve out the differences in saving decisions for different forms of capital and to include institutions in a model for saving of different forms of capital, thereby describing their role and impact in this framework.

With this article I firstly hope to shed light on the debate about institutions and sustainable development. Secondly, I hope to potentially contribute to the discussion on institutions and growth/economic development.

The rest of the paper is structured in the following way: The following section introduces the concepts of sustainable development and institutions and discusses their relationship including the debate on institutions and growth. In the subsequent third section I describe a framework in which the impact of institutions on saving decisions differs for different forms of capital in a model for saving and investment decisions. In

[2] In this paper I quantify the effect of institutional quality on sustainable development.

the fourth section I show how this can potentially explain the surprising effects found in the empirical analysis in Stoever (2012). The last section concludes.

2 Sustainable Development and Institutions

Sustainable Development

Defining as well as measuring sustainable development has been a long and hotly debated issue. Still, there are different and sometimes even contradicting usages of the term in different circumstances. In our approach we follow the established economic theory which is based among others on **?** [3] and which in turn goes back to the so-called Brundtland Commission's definition of SD as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (**?**, p.54). In this context, sustainable development is defined as *non-declining human welfare over time* (**?**).

The approach is based on the assumption that as long as the average per capita wealth is non-declining, the average individual has the same amount or more consumption possibilities and is therefore not worse off. On a national level, this implies that as long as the average individual is not becoming worse off, a country is developing in a sustainable way. Since the stock of natural resources and their depletion rates play a vital role for the rate of future returns, the population's welfare and the wealth of a country, it is essential to include them as assets both when dealing with the concept of wealth and in national accounting (**?**). In this way, development that can sustain at least equivalent future consumption possibilities is called sustainable

Following the *constant capital rule*, a country develops sustainably if capital per capita does not non-decline over time, independent of the initial capital stock (e.g. **?**). This implies that a modified savings rule can be used to determine if a country is developing in a potentially sustainable way. That is, if capital is defined broadly and includes natural and intangible capital in addition to physical capital, its change - savings or dissavings of the entire asset base - indicates whether an economy is developing sustainably.
Obviously, it is crucial that the term capital is understood in a broad sense and includes everything that influences individuals' well-being (source) and therefore different forms of capital, one among them being natural capital. The **?** has introduced a measure of wealth that includes natural and intangible capital in addition to the 'traditional' physical capital. If capital is defined in a sufficiently broad way - i.e. if it includes everything that affects the well-being of individuals - changes in capital can be interpreted as changes in

[3] This approach is commonly used in the literature e.g. in **?**, where the authors develop a theoretical framework for assessing whether economic growth is compatible with sustaining well-being over time.

welfare.

As only the change in overall capital determines if a development is called sustainable, this approach follows the concept of weak sustainability. ANS, which measures sustainable development as the change in comprehensive wealth, will be used as an indicator for SD in this article.[4] This also implies that different forms of capital can in principle be substituted for each other (albeit depending on the MRS terms/elasticities of substitution). The so-called Hartwick rule implies that it may be in line with sustainbale development to deplete natural resources as long as the rents are invested equivalently in other forms of capital (strictly speaking the exchange can also take place within the natural capital category) e.g. in human capital (**?**).

Sustainable development can hence be expressed as saving of all forms of capital and a development is sustainable if the following condition holds:

$$\Delta K = \Delta K^P + \Delta K^N + \Delta K^H + \ldots \geq 0 \tag{1}$$

Where K=overall capital, K_P=produced/physical capital, K_N=natural capital, K_H=human capital. Expressed in a national accounting framework this yields the indicator Adjusted Net Saving (ANS) which includes natural, physical and human capital:

$$ANS = \Delta K^P + \Delta K^N + \Delta K^H \tag{2}$$

Applying this concept to data, the World Bank (**?**) estimates ANS in the following way: Net national saving is used as an approximation for ΔK_p and education expenditure for ΔK_H. Natural capital includes rents from oil and mining activities as well as de- or aforestation and estimated losses due to CO^2 and $PM10$.[5] **?** ANS hence reflects the change in overall capital by subtracting (dis)savings of natural capital from and adding investment in human capital to the savings rate of physical capital.

Institutions

There exists a large and well-established literature on the effects of institutional quality on economic growth.[6] Before we turn to this discussion the nature of 'institutions' needs to be accurately defined. Institutions can be conceptualized as written and unwritten rules and norms that organize the life of individuals and thereby affect their welfare (**?**).

[4] ANS can be seen as a lower bound: If the rate is negative, development is not sustainable following weak sustainability, but also not sustainable in the concept of strong sustainability (**?**).

[5] PM10 stands for particulate matter that is smaller than 10 μm in diameter. PM10 damage is the estimated damage stemming from this form of particulate matter.

[6] For an introduction see e.g. Acemoglu (2009).

North (1981) defines institutions as "a set of rules, compliance procedures, and moral and ethical behavioral norms designed to constrain the behavior of individuals in the interest of maximizing the wealth or utility of principals".
In this way they provide the framework in which interactions in an economy take place; (**?**) this as opposed to policies, which are defined as rules that imply goals and desired outcomes. Following **?**, institutions are first and foremost constraints and one of their key features is their permanent character, while **?** stresses the difference between de jure and de facto political institutions and **?** states that institutions can be classified in three dimensions, with respect to their degree of formality, their level of hierarchy or the area of analysis (such as economics, politics or law).

In response to the discussion of its measurement scholars have suggested a number of indicators in an effort to represent institutional quality. The three most common measures for institutional quality are the relative risk of expropriation by the government, the level of government effectiveness and quality of constraints on the executive. While the former two measures concentrate on the constraints placed on individuals external to the government, the latter one reports restrictions for the executive body. Therefore, they measure conceptually different things, although all three display parts of what can be thought of as underlying 'true' institutions.

There are a number of approaches to measure institutions, among them protection against expropriation, the governance indicators by **?** and measures that report the level of constraints on the executive. The measure of expropriation risk uses data from the International Country Risk Guide that indicates the protection against expropriation by the government in order to provide information to international investors. It therefore measures the enforcement/security of property rights in a country. The second measure, governance indicators developed by **?**, combines a large number of indicators to six measures of governance. The third measure, constraints on the executive, uses Polity IV Data that contains annual information on authority and regime characteristics for all independent states. Although it makes an attempt to measure the political environment, it is highly volatile and can therefore not serve as an indicator for permanent rules and norms.

The fact that countries with higher income per capita have better institutions measured in the way presented above has raised the question of causality and lead to lively discussions in development economics and beyond. Surveys on political institutions and growth such as **?** present mixed results.[7] [8]

The approaches on institutions and growth share the assumption that e.g. property rights and political stability are important for investments in capital to occur. As institutionas can be seen as determining the risk or uncertainty about future development/environment, we investigate their effect on saving and investment decisions, and institutional changes will be modeled accordingly.

For our purpose, the effects of insecure ownership, risk of expropriation and generally imperfect property rights are the most straightforward examples how institutions can influence SD for all forms of capital.).

This motivates to take a closer look on the different effects of institutions for different forms of capital in the following section.

3 Investment and Ownership Risk for Different Forms of Capital

This paper uses the approach presented in **?** to model the effect of insecure ownership on ordinary investment as well as on natural resource extraction/use. In the following framework it can be explained how differences in capital can cause the effect of ownerhship to differ by resource and that greater ownership risk can lead to slower exploitation for some resources and faster exploitation for others. After that I describe how this can yield the surprising empirical facts presented in the introduction.

In the ANS framework, we have produced/physical, human and natural capital and the sum of their changes from one period to the next (ΔK), i.e. the change in the stock, can be seen (dis-) investment in total capital. Similarly, ΔK^i is interpreted as (dis-)investmenr in a particular form of capital K^i.

The impact of ownership risk on investment in all forms of capital can generally be of the form presented in **?**: Ownership risk includes any event that keeps the investor from claiming the 'earnings' of his/her investment. It is an all-or-nothing event: With the probability π_t, the investor loses all claims to his/her investment at the start of $t+1$. With the probability $1-\pi_t$ no expropriation will occur in $t+1$. A small open economy is assumed , so that the world interest rate r is exogenously given and assumed to be positive.
The expropriation event can be described by the 0-1 variable ξ_t which indicates 'whether

[7] In this footnote, a number of papers on institutions and growth that come to different results will be listed.

[8] Generally, institutions, geography, as well as culture are often discussed as drivers of economic growth. A number of papers on the three drivers will be listed here.

period-t profits are expropriated or not'. Furthermore, the evolution of (π, ξ) follows a bivariate Markov process with the transition function $G((\pi_{t+1}, \xi_{t+1}|\pi_t, \xi_t)$ (cf. **?**). Persistence is ensured as for $\xi_{t+1} = 0$, π_{t+1} is a function of π_t. For $\xi_{t+1} = 1$, $\pi_{t+1} = 1$, so that for all future periods $\xi_{t+s} = 1$, for $s > 0$, i.e. all future profits are zero after an expropriation in period t.

The investor then maximizes his current profits (PR_t) plus the discounted value of the project's future payoff:

$$V_t(\pi_t, \xi_t, \ldots) = max\left\{PR_t + \frac{1}{1+r} * V_{t+1}(\pi_{t+1}, \xi_{t+1}, \ldots)dG(\pi_{t+1}, \xi_{t+1}|\pi_t, \xi_t)\right\} \quad (3)$$

for $\xi_t = 0$ and $V_t(\pi_t, \xi_t, \ldots)$ for $\xi_t = 1$ (expropriation in period t), where V_t is the value function and ... stands for potential additional state variables.

This general framework can be applied to the different forms of capital. For this, some explanation on the assumptions on the different forms of capital are in order.

For natural capital, in line with the literature, I distinguish between natural capital that is drawn down using ordinary labor (K_N^N) and natural capital for whose exploitation special equipment is needed (K_O^N).

Within produced capital I distinguish between produced capital that is used for exploiting these forms of capital (such as e.g. oil or mining capital) (K_P^O) and all other forms of produced capital (K_P^P) (similar e.g. to Arrow (1968)).

We can therefore rewrite equation 2 as

$$ANS = \Delta K_P^P + \Delta K_O^P + \Delta K_H + \Delta K_N^N + \Delta K_O^N \quad (4)$$

For general produced capital (K_P^P) **?** show that investment in this form of capital is decreasing in π, i.e. insecure ownership causes agents not to invest or to invest less in produced capital. [9]

For natural capital that is 'drawn down and consumed using ordinary labor' , e.g. forests (their example). The authors show that when property rights are insecure and the risk of losing one's resources is high, future returns are discounted more heavily, which yields to disinvestment in the stock of K_N^N. This is in line with 'conventional wisdom' of resource economics (quote Laurent-Lucchetti and Santugini (2012)) based on a large literature and shown e.g. in Ngo (1974).

[9] A similar exercise should be conducted for human capital (K_H), but this is not the focus of this paper.

But in other cases, e.g. for mining and oil extraction, a firm decides on its optimal level of extraction which involves both 'special' produced mining/oil capital (K_O^P) and natural capital (K_O^N). The effect of ownership risk on (dis-)investment decisions of these two forms of capital is not as straightforward as in the two cases above and will therefore be investigated in detail in the following paragraph. Again, Bohn and Deacon (2000) provide the framework for the analysis. [10]

[*The following presentation of the model contains all information, but is not yet in its final shape (i.e. in complete sentences). I hope that this does not complicate the understanding too much.*]

- Γ: total quantity of oil in the ground at the start (i.e. before production and exploration)
- H_t: "hidden" undiscovered reserves in t
- assumption: most easily accessible reserves are discovered first, i.e. marginal discoveries diminish by additional exploration as exploration proceeds
- $F(.)$: cumulative quantity discovered, increasing, bounded, concave in D_t
- D_t: cumulative number of wells drilled uo to time t
- $F(0) = 0, F' > 0, F'' < 0, F(D) \to \Gamma$ as $D \to \infty$

hidden reserves (no distinction between different forms of wells):

$$H_t = \Gamma - F(D_t) \tag{5}$$

- R_t: known reserves that have not yet been extracted
- Z_t: production

$$R_{t+1} = R_t + \underbrace{F(D_{t+1}) - F(D_t)}_{new\ discoveries} - Z_t \tag{6}$$

- assumption: oil production is assumed to require sepcialized capital, various inputs (goods and labour) and known reserves

[10] Oil/Mining production typically involves decisions on exploration as well as on optimal extraction. For our purpose, we focus on the extraction part and leave out the optimal drilling/exploitation decision as our research question focuses on the former. However, in the formulation at the beginning it is included to show the whole decision problem the agent faces.

- Cobb-Douglas production function, constant returns to scale
- K_t^P: oil (or mining, hereafter only use the term 'oil' to includes both) extraction capital, can only be used to produce oil (e.g. pumps, processing equipment, pipelines). Notation: When a time dimension is included, the subscript 'O' will be left out in K_O^P for better readability.
- important note: oil extraction capital becomes productive in the period after it is purchased ("installation lag")
- Cobb-Douglas function implies(?): per unit variable cost of production increases in the ratio of capital to known reserves:

unit production cost:

$$\chi : (Z_t/R_t)^{\beta} \cdot (K_t^O/R_t)^{-\nu}, \beta > 0, \Gamma > 0 \tag{7}$$

- χ: function of production function parameters and wage rate, cost function derived in annex of **?**
- assumption: oil production labour is internationally mobile → wage rate is fixed to each country
- cost function for drilling: $c(D_{t+1} - D_t) : c(0), c' > 0, c'' < 0$
- p_t: price of oil in terms of consumption goods, follows a Markov process (with positive autocorrelation)

Current profit from drilling and production

$$PR_t = Z_t[p_t - \chi(Z_t/R_t)^{\beta} \cdot (K_t^P/R_t)^{\nu}] + (1-\delta)K_t^O - K_{t+1} - c(Dt + 1 - D_t) \tag{8}$$

Value function

$$V_t(\pi_t, \xi_t) = max\left\{PR_t + \frac{1}{1+r} \cdot \int V_{t+1}(\pi_{t+1}, \xi_{t+1})dG(\pi_{t+1}, \xi_{t+1})\right\} \tag{9}$$

inserting equations 5 and 6 yields

$$\begin{aligned}
&V(R_t, H_t, K_t^P, p_t, \pi_t, \xi, \Gamma) = \\
&\max_{R_{t+1}, \pi_{t+1}, K_t^P}\Bigg\{p_t(R_t - R_{t+1} + H_t - H_{t+1}) - \frac{(R_t - R_{t+1} + H_t - H_{t+1})^{1+\beta}}{R_t^{\beta}} \cdot \chi(K_t^P/R_t)^{-\nu} \\
&+ (1-\delta)K_t^P - K_{t+1}^P - c(F^{-1}(\Gamma - H_{t+1}) - F^{-1}(\Gamma - H_t)) \\
&+ \frac{1}{1+r} \cdot \int V(R_{t+1}, H_{t+1}, K_{t+1}^P, p_{t+1}, \pi_{t+1}, \xi_{t+1}; \Gamma)dG(p_{t+1}, \pi_{t+1}, \xi_{t+1}|p_t, \pi_t, \xi_t))
\end{aligned} \tag{10}$$

From here on we focus solely on the optimal production , with given (known) reserves R, (thereby abstracting from the opitimal drilling problem that determines the optimal reserves).

- optimal production: price of oil = marginal production costs + marginal opportunity costs of foregone reserves (="reserves not created")
- note: period t production capital and reserves are given → production costs (7) are decreasing in K_t^P/R_t (capital-to-reserves ratio)
- future periods: capital can be adjusted, oil production funciotn (Cobb-Douglas function) → linear homogeneity implied, optimal level of K^P/R and Z/R are independent of the level of reserves
- given: oil price and ownership risk → optimal scale of future oil production **proportional** to the level of reserves
- → future profits are then also proportional to the level of reserves → present value of profits per unit of reserves (PV(PR_t/Γ) → independent of level of reserves

We now need to solve for the optimal ratio of production to reserves and the optimal ratio of oil capital (→ K_O^P) to reserves. for this, the first order conditions are derived:

(1) for $z_t = Z_t/R_t$:

$$p_t - \chi(1+\beta)(\frac{K_t^P}{R_t})^{-\nu}(\frac{Z_t}{R_t})^{\beta} = \frac{1}{1+r}\int V_R \, dG \tag{11}$$

where V_R denotes the returns from the resource

This shows that the "current net revenue from pumping and selling a unit of the resource equals the expected present value of future profits from leaving the oil in the ground".

(2) for $k_{t+1}^P = K_{t+1}^P/R_{t+1}$

$$1 = \frac{1}{1+r}\int V_K \, dG \tag{12}$$

where V_K denotes the returns from (oil) capital

This shows that "the marginal cost of oil-extraction capital (unity) equal the expected PV of marginal return of oil-extractive capital".

? show that the optimal ratio of capital to reserves is a function of the price of oil and ownership risk:

$$k_{t+1}^P = k^P(\underbrace{p_t}_{+}, \underbrace{\pi_t}_{-}) \tag{13}$$

- They derive that k^P is increasing in p_t and decreasing in π_t
- Reasoning: higher future oil prices → incentive to increase k^P to exploit known resources faster
- Reasoning: higher ownership risk → reduces expected payoff from oil capital
- shadow value of reserves depends positively on p_t and negatively ond π_t

The optimal current production rate depends on price, ownership risk and capital-to-reserves ratio:

$$z_t = z(\underbrace{p_t}_{+}, \underbrace{\pi_t}_{+}, \underbrace{k_t^P}_{+}) \tag{14}$$

- ownership risk reduces the value of leaving the reserves in the ground

Summarize again:

- They subsequently show that the optimal ratio of capital to reserves is a function of the price of oil and ownership risk: $k_{t+1}^P = k^P(p_t, \pi_t)$, which is increasing in p_t and decreasing in π_t.
- Reasoning: higher oil prices → incentive to increase k^P to exploit known reserves faster AND higher ownership risk → reduction of expected future payoffs from oil capital
- Secondly, they show that the optimal current production rate depends on the oil price, ownership risk and on the capital-to-reserves ratio: $z_t = z(p_t, \pi_t, k_t^P)$.
- reasoning: ownership risk reduces the value of leaving reserves in the ground

Combining these two, the optimal extraction yields the following relationship:

$$Z_{t+1} = z(p_{t+1}, \underbrace{\pi_{t+1}}_{a>0}, k^P(p_t, \underbrace{\pi_t)}_{b<0})) \tag{15}$$

The essential part for our purpose is that π_t and π_{t+1} in this expression have opposing effects on z_{t+1}. That is while higher π_{t+1} increases the production before expropriation takes place, increasing π_t reduces the investment in oil capital, thereby raises extraction costs and slows extraction (volume) in the future.

In a slightly different model Farzin (1984) shows that the negative effect dominates the positive one "if the sum of the present value of capital requirements in the substitute and resource sectors exceeds the present value of the resource stock" (p.848). That is, if the extraction is very capital-intensive it may be that a higher ownership risk (expressed by a higher discount rate) actually slows down resource extraction. (Lasserre's (1985) work yields similar results.) [11]

Two effects of ownership risk on natural resource extraction of this type (using heavy and specialized machinery): The first is an increase in production before potential expropriation due to a higher dicsount rate for a more uncertain future and therefore a lower value of leaving the resources in the ground. The second (counter)effect, a higher owenerhisp risk decreases the investment in oil capital, by this raises the extraction costs and slows extraction in future periods.

In this section it has been shown how institutions/ownership risk can influence the saving and investment of different forms of capital - and combinations of those - differently. The next section puts these results into the ANS framework.

4 Results

We can now use expression 4 to investigate the effect of ownership risk on the produced and natural capital in a national accounting framework:

1. K_P^P decreases in π_t, i.e. higher ownership risk reduces investment in K_P^P
2. Higher ownership risk leads to heavier discounting and therefore higher exploitation of K_N^N
3. The aggregated effect of π_t and π_{t+1} on z_{t+1} and hence on K_O^P and K_O^N is ambiguous (and depends on capital intensity).

Therefore, when divided into the national accounting framework, lower ownership risk can lead to a positive overall effect on K^N and to a 'non-effect' on overall K^P.

Better institutions are able to yield the results that seemed at first surprising. This is caused by the different effects on different parts of K^P that are able to neutralize each other in the empirical outcome.
For overall K^N however, it seems that the dominant impact from higher ownership risk is the acceleration of resource extraction.

[11] The empirical question of which impact dominates is investigated Bohn & Deacon (2000).

5 Conclusion

- Differences of savings due to different responses to higher ownership risk have been shown.

- Changes in institutions have been formalized for investment decisions in general and for different forms of capital.

- The different effect of institutions on different forms of capital can be explained in this framework, as the national accounting framework divides forms of capital such that the parts of capital that are joint in production (such as $K_O^P and K_O^N$) are displayed in different aggregates.

- Therefore, it is possible that positive and negative effects of institutions on saving may cancel each other out in the aggregate.

- Further research on this issue may explain parts of the mixed results also in the discussion on institutions and growth, due to the exclusion of K_N (and K_I). (The last point will be elaborated further within this paper at a later stage).

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