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Growth, public investment and corruption with failing institutions

David de la Croix · Clara Delavallade

Abstract Corruption is thought to prevent poor countries from catching up with richer ones. We analyze one channel through which corruption hampers growth: public investment can be distorted in favor of specific types of spending for which rent-seeking is easier and better concealed. To study this distortion, we propose a dynamic model where households vote for the composition of public spending, subject to an incentive constraint reflecting individuals' choice between productive activity and rent-seeking. In equilibrium, the structure of public investment is determined by the predatory technology and the distribution of political power. Among different regimes, the model shows a possible scenario of distortion without corruption in which there is no effective corruption but the possibility of corruption still distorts the allocation of public investment. We test the implications of the model on a set of countries using a two-stage least squares estimation. We find that developing countries with high predatory technology invest more in housing and physical capital in comparison with health and education. The reverse is true for developed countries.

Keywords Public investment · Corruption · Political power

JEL Classification O41 · H50 · D73

D. de la Croix (✉)
Department of Economics and CORE,
Université catholique de Louvain, Louvain-la-Neuve, Belgium
e-mail: david.delacroix@uclouvain.be

Present Address:
C. Delavallade
J-PAL South Asia, Chennai, India
e-mail: clara.delavallade@ifmr.ac.in

0 Introduction

Wide-spread corruption seems to be one of the main factors preventing poor countries from catching up with richer ones. Improved institutional efficiency and corruption deterrence are now very high on the agenda of organizations dealing with economic development. The World Bank and the OECD are currently supporting anti-corruption programs to improve governance capacity, promote economic development and fight poverty.

The detrimental effect of corruption on the structure of public expenditure is of particular relevance. Indeed, it has been argued by Mauro (1997), Tanzi (1998) and Delavallade (2006) that education expenditure is scaled down in countries with widespread corruption. Lowering the provision of education has a negative effect on future income, and reinforces economic inequality. The distortion in public spending implied by corruption has been the subject of several empirical studies but has not yet received any attention on the theoretical side. Corruption enhances the proportion not only of military spending (Gupta et al. 2000), but also of public services and order, fuel and energy, and cultural expenditure relative to education and health spending (Delavallade 2006). In his influential paper, Mauro (1997) sketches a model based on Barro (1990) with different types of public spending; in his model, corruption acts as a proportional tax on the budget surplus, and does not distort the composition of public spending, contradicting to some extent his empirical results. There is no theoretical paper modelling the possible mechanisms through which corruption may distort the structure of public spending. While the empirical literature on the subject has been confined to estimating the effect of corruption on several types of public spending, and the effect of legal and political institutions on growth (de la Croix and Delavallade 2008), our empirical model sheds new light on the institutional determinants of corruption and their impact on growth through different kinds of budgetary distortions due to corruption.

In this paper, we propose a model which has three distinctive features. First, we define corruption technology as the ease with which rent-seekers can capture part of public spending. Different categories of spending have different corruption technologies, and there are specific types of public spending for which rent seeking is easier and better concealed. Second, individuals vote on the allocation of public investment and rent-seekers may have more political influence than other people. Third, the political economy problem is subject to an incentive constraint, representing the choice made by individuals between productive activity and rent-seeking. The solution to the model will display multiple "regimes". In one of them, rent-seekers have considerable political weight, and if the corruption technology is sufficiently efficient, the allocation of public investment will be distorted in favor of specific types of spending (those subject to corruption).

In the empirical part, we analyze how the distinctive features of our model translate into econometric estimates. Using a two-stage least squares estimation based on a set of countries, we examine how the concentration of political power and predatory technology affects the composition of public investment. We find that countries with a high predatory technology invest more in housing and physical capital and less in health and education. A distinctive feature of our approach is to make the marginal

effect of corruption technology depend on the level of development. Its effect on the distribution of public spending tends to be weaker in countries with a GDP per capita greater than $2700 which is in line with the theoretical viewpoint that there are several different regimes.

The paper is organized as follows. Section 1 presents the structure of the model. The resolution of the voting problem is introduced in Sect. 2, with a characterization of the different regimes and some numerical illustrations. In Sect. 3, we report empirical estimate of the main implications of the model, including the description of data, instruments, and tests. Section 4 interprets the results further and provides robustness analyzes of the definition of the public spending variable and the choice of instruments. Section 5 presents our conclusions.

1 A dynamic model of corruption

First consider the following assumptions and definitions. Time is discrete and goes from 0 to infinity. At each date, the economy is populated by a mass of identical households N_t growing at rate n. Households choose between working either in the productive sector or in a rent-seeking activity. We denote by $1 - x_t$ the share of the population in the productive sector, and by x_t the share in the rent-seeking sector.

1.1 Technology

There are two types of productive public capital: education and health, H_t, and physical capital, K_t. Investment spending in these two types is G_t and I_t. Investment in the first type is free from corruption, while investment in the second type is subject to corruption.[1] Indeed, the first type of investment is composed of predetermined spending like teachers' wages. Investment I_t is mainly composed of spending occurred through public procurement and massive spending (see Tanzi and Davoodi 1998. Examples: road, pipelines, construction,[2] housing, water provision...). This type of investment involves a less transparent and lesser controlled spending process than investment included in G_t. Assessing the impact of G_t (additional schools, teachers or vaccines) is easier. Thus, investment spending G_t does not leave public officials much room for maneuver and is less subject to arbitrary decisions than investment in the second type of capital (I_t) which concerns more rent-generating capital. And high rents for firms imply high embezzlement for public officials, since those of them who are rent-seekers get a share of the procurement contract or of the profits. Hence, corruption at the budgetary level is easier to exert on investment I_t.

Corruption acts as a tax on investment I_t.[3] Rent-seekers are able to extract part of the public investment I_t which is proportional to their share in the population. Only

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[1] This extreme assumption is meant to capture the idea that the degree of exposure to corruption is not identical across categories of public investment (Mauro 1998; Delavallade 2006).

[2] See Kenny (2007) on construction industry as one of the most corrupt.

[3] This is a difference between our model and that developed by Mariani (2007) and Acemoglu (1995). In their model, corruption acts as a tax on producers' income.

a share $1 - \nu x_t$ of investment spending is effectively invested while $\nu x_t I_t$ accrues as income for rent-seekers. The parameter $\nu \geq 0$ reflects the corruption technology of the economy. It is positively related to the easiness with which rent-seekers can divert resources. The value $1/\nu$ should be interpreted as the share of rent-seekers "needed" to divert 100% of investment. The laws of motion of the two types of capital are:

$$H_{t+1} = (1 - \delta_H)H_t + G_t$$
$$K_{t+1} = (1 - \delta_K)K_t + (1 - \nu x_t)I_t$$

with parameters δ_H and δ_K being the depreciation rates (δ_H, $\delta_K \in (0, 1)$). Denoting the per-capita variables as $h_t = H_t/N_t$, $g_t = G_t/N_t$, $k_t = K_t/N_t$ and $i_t = I_t/N_t$, the laws of motion of capital can be rewritten as:

$$(1 + n)h_{t+1} = (1 - \delta_H)h_t + g_t \tag{1}$$

$$(1 + n)k_{t+1} = (1 - \delta_K)k_t + (1 - \nu x_t)i_t. \tag{2}$$

There is one physical good which is used for consumption and investment in either of the two capital goods. Total production Q_t depends positively on labor input $N_t(1 - x_t)$ and on services from the two types of capital. The production function is written as the product of two terms:

$$Q_t = b[N_t(1 - x_t)]f[H_t, K_t].$$

The function $b[.]$ is increasing and concave, and satisfies the Inada conditions $\lim_{L \to 0} b'[L] = +\infty$ and $\lim_{L \to +\infty} b'[L] = 0$. The production function $f[.]$ is increasing and concave. As in Arrow and Kurz (1970) and Barro (1990), public capital directly enters the production function. One difference with the previous literature is that here we have two different types of public capital with different exposure to corruption.

We assume that the product $b[N_t(1 - x_t)]f[H_t, K_t]$ is homogeneous of degree one with respect to labor input $N_t(1 - x_t)$ and capital inputs H_t and K_t which allows us to write the output per person $q_t = Q_t/N_t$ as:

$$q_t = b[1 - x_t]f[h_t, k_t].$$

This is another difference with Barro (1990). We do not assume constant returns to scale with respect to the factors h_t and k_t, which makes our results comparable to those in the standard neo-classical growth model of Solow (1956) and Arrow and Kurz (1970). Assuming constant return to scale with respect to h_t and k_t would generate endogenous growth with the usual problems (scale effect of population N_t and indeterminacy of the variables in levels) without giving additional insights to those we will find by assuming standard neo-classical growth.

Public investment spending is financed by a lump sum tax T_t paid by every citizen:

$$N_t T_t = G_t + I_t \Rightarrow T_t = g_t + i_t.$$

An alternative would have been to introduce a proportional income tax. This would have led to additional effects.The distortionary nature of the proportional income tax would affect the choice of households between productive activities and hidden ones. Higher taxes to fund expenditures subject to corruption would increase corruption twice: first because there is now more pie available for extraction, and, second, because legal activities would be taxed more. Additionally, corruption itself would reduce the fiscal basis of the government which depends on productive activities only. Since we do not need these additional effects to make the main point of the paper, we keep them away. Notice moreover that lump-sum taxation in our model where there is no consumption-saving trade-off is equivalent to introducing a consumption tax, which is the main source of income for governments in developing countries.

To keep the model as simple as possible we abstract from other types of public spending and from public debt.

1.2 Household behavior

At each date, households consume their income. Income includes either the product of corruption or the return from the productive activity. Their preferences are represented by a utility function $u[.]$ which is assumed to be of the Constant Intertemporal Elasticity of Substitution (CIES) class with inter-temporal elasticity of substitution σ. Households maximize utility, which amounts here to maximize income, by allocating their time between production and rent-seeking. As a consequence, the return from these two activities must be equal at an interior equilibrium.

The utility of working in the productive sector U_t is equal to the utility of the income in this sector. We assume that firms operating in this sector are owned by the workers, or, in other words, that everybody is self-employed. Workers are thus paid the average product

$$\frac{b[N_t(1 - x_t)]f[H_t, K_t]}{N_t(1 - x_t)} = \frac{b[1 - x_t]}{1 - x_t}f[h_t, k_t] = \Gamma[1 - x_t]f[h_t, k_t]$$

with $\Gamma[1 - x_t] = b[1 - x_t]/(1 - x_t)$. They also pay taxes T_t. Net income per person is thus

$$y_t = \Gamma[1 - x_t]f[h_t, k_t] - T_t = \Gamma[1 - x_t]f[h_t, k_t] - g_t - i_t.$$

Hence,

$$U_t = u[y_t]. \tag{3}$$

The utility in the rent-seeking sector V_t is the utility associated with the income from corruption, net of taxes. Since total income from corruption is $\nu x_t i_t$, the income per person is νi_t, as long as $x_t \leq 1/\nu$. If $x_t = 1/\nu$, all spending i_t is diverted by rent-seekers and there is no incentive for the marginal person to move into rent-seeking.

$$V_t = u\left[\nu i_t - g_t - i_t\right] \quad \text{if } x_t \leq 1/\nu$$
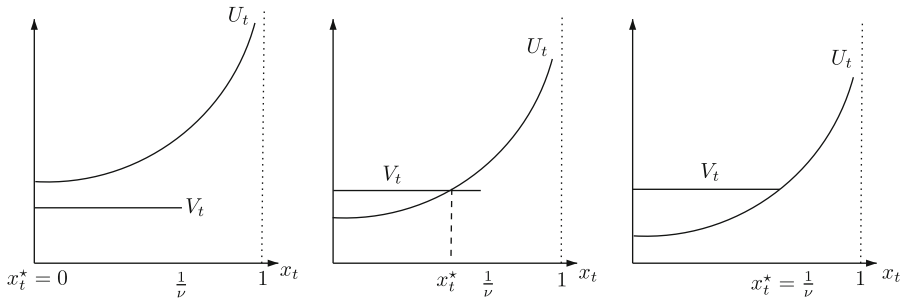$$V_t = 0 \quad \text{otherwise.}$$

Fig. 1 Endogenous corruption: three regimes

In Fig. 1 we represent the payoffs of the two activities. The individual utility from corruption V_t does not depend on the share of the population which is corrupt for $x_t \leq 1/\nu$ but decreases to 0 as soon as x_t is larger than $1/\nu$.[4] The utility from the productive sector U_t is a positive function of x_t. Indeed, because of marginal decreasing returns to labor, the function $\Gamma[1 - x_t]$ is decreasing in $1 - x_t$. It decreases from $+\infty$ when $1 - x_t = 0$ to $\Gamma[1]$. Three cases may arise.

In the first case (left panel of Fig. 1), the return in the rent-seeking sector is always dominated by that in the productive sector, even when the whole workforce is in the productive sector. In this case, we have

$$x_t^* = 0$$

and

$$\nu i_t < \Gamma[1] f[h_t, k_t]. \tag{4}$$

In such a situation, corruption does not exist at all. Condition 4 can be understood as a condition on the parameter ν relative to the function $b[.]$. If ν is large enough, i.e. if the corruption technology is efficient enough, this corner situation will never prevail.

In the second case, represented in the central panel of Fig. 1, there is a value $x_t^\star \in (0, 1)$ for which households are indifferent between the two activities. Equalizing the two utilities, we obtain the following result.

Proposition 1 *If corruption at equilibrium satisfies $x_t \in (0, 1/\nu)$, then the following constraint holds:*

$$U_t = V_t \quad \Rightarrow \quad \Gamma[1 - x_t] f[h_t, k_t] = \nu i_t. \tag{5}$$

Condition (5) states that, at equilibrium, there is a relation between the share of the population in the rent-seeking sector and public capital (h_t and k_t), the effectiveness of corruption technology (ν), and the amount of public spending subject to corruption

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[4] Interpreting x as the share of time devoted by a representative individual to corruption activities, i.e. effort allocated to extraction activities, our model implies that the level of corruption νx depends linearly on the effort. This is of course a simplifying assumption. The results are not necessarily robust to it. For example, assuming increasing return to corruption effort (V_t increasing in x) might lead to multiple equilibria, and this would modify the nature of the results. On the contrary, assuming decreasing returns (V_t decreasing in x) would on the contrary not modify the results.

(i_t). This relation, which describes the choice of activity by households, will act as a constraint for the political economy problem. We label it the *incentive constraint*.

Condition (5) makes the level of corruption endogenous at equilibrium. It is similar to that found in the models of corruption presented by, *inter alia*, Shleifer and Vishny (1993), Banerjee (1997), and Acemoglu and Verdier (2000). Compared to this literature, our set-up makes two contributions. First, we model corruption explicitly by modeling which resources are captured by rent-seekers and by distinguishing between the two types of government spending. Second, our model is a dynamic model, bridging the gap between the standard theory of growth and the mostly static theory of corruption.

In the third case (right panel of Fig. 1), the income possibilities from rent-seeking are exhausted: $x_t^* = 1/\nu$. In this case we have

$$\nu i_t = \Gamma[1 - 1/\nu]f[h_t, k_t]. \tag{6}$$

In this case, investment i is entirely diverted, implying that the stock of capital k shrinks. Finally, there is a fourth possibility with $\nu i_t > \Gamma[1 - 1/\nu]f[h_t, k_t]$; this would represent a situation where rent-seeking was more profitable than productive activity, but the corruption possibilities were completely exhausted, so that those who worked in the productive sector had a lower income which was still better than the zero income they would have got if they had chosen rent-seeking for themselves.

If the situation described in the latter two cases persists, income in the productive sector tends to zero, which cannot be an optimal solution. Hence these regimes can only appear temporarily. In the following sections we will assume that $x_t < 1/\nu$ at equilibrium, i.e. we will rule out the possibility of maximum corruption because it is unrealistic and cannot be a long-run equilibrium.

1.3 Voting on public investment

The levels of public investment g_t and i_t are chosen through probabilistic voting. Taxes T_t are related to public spending through the budget constraint $T_t = g_t + i_t$. Hence, the government decides not only on the allocation but also on the tax rate that is the size of the fiscal pie.

Assume that there are two political parties, a and b. Each one proposes a policy. Instead of assuming that an individual votes for party a with probability one every time party a's policy gives him/her higher utility (as in the median voter model), probabilistic voting theory supposes that this vote is uncertain. More precisely, the probability that a person votes for a given party a is a smooth function of the utility gain associated with the implementation of policy a. This function captures the idea that voters care about an "ideology" variable in addition to the specific policy measure at hand. The presence of a concern for ideology, which is independent of the policy measure, makes the political choice less predictable (see Persson and Tabellini 2000 for various formalizations of this approach). The probability that a given voter will vote for party a increases gradually as the party's platform becomes more attractive. Party a maximizes its expected vote share. Party b acts symmetrically, and, at equilibrium, the

two proposed policies coincide. The maximization program of each party implements the maximum of the following weighted social welfare function:[5]

$$\max \sum_{t=0}^{\infty} \rho^t W_t \text{ subject to (1), (2), (8), and given } h_0, k_0$$

with

$$W_t = (1 - x_t)U_t + (1 + \theta)x_t V_t \tag{7}$$

and

$$v i_t \leq \Gamma[1 - x_t] f[h_t, k_t]. \tag{8}$$

The parameter θ is the additional weight attached to the people in the rent-seeking sector. From probabilistic theory, it captures the responsiveness of voters to the change in utility. In particular, a group that has little ideological bias cares relatively more about economic policy. Such groups are therefore targeted by politicians and enjoy high political power.[6] If $\theta = 0$ the problem can be interpreted as that of a benevolent social planner giving equal weight to all citizens but which would have access to a limited set of policy instruments; if $\theta = \infty$, the social planner is the kleptocratic government envisioned by Kanczuk (1998), maximizing the discounted flow of income from corruption. Notice that this maximization problem can alternatively be interpreted in the light of the lobbying literature (see Bernheim and Whinston 1986).

2 Solution characteristics

To solve the planning problem we write the following infinite Lagrangian:

$$\sum_{t=0}^{\infty} \rho^t \left\{ W_t + \rho \lambda_{t+1} \left[(1 - \delta_H)h_t + g_t - (1 + n)h_{t+1} \right] \right.$$
$$+ \rho \mu_{t+1} \left[(1 - \delta_K)k_t + (1 - v x_t)i_t - (1 + n)k_{t+1} \right]$$
$$\left. + \phi_t \left[\Gamma[1 - x_t] f[h_t, k_t] - v i_t \right] + \omega_t x_t \right\}.$$

The variables λ_t and μ_t are the Lagrange multipliers associated with the equality constraints (1) and (2). The variables ϕ_t and ω_t are the Kuhn–Tucker multipliers associated with the constraints:

$$v i_t \leq \Gamma[1 - x_t] f[h_t, k_t]$$
$$0 \leq x_t.$$

[5] This result was first derived by Coughlin and Nitzan (1981).

[6] An alternative view is that households can gain political power by purchasing votes (see, for example, Docquier and Tarbalouti 2001).

The multiplier ϕ_t associated with the incentive constraint is the shadow price of corruption, reflecting the idea that the choice of the allocation of public spending has an effect on the type of activity chosen by households. For example, if the government increases the amount of spending subject to corruption more households will work in the rent-seeking sector (ϕ_t is higher).

At each date, four possible cases are *a priori* possible, depending on which constraint is binding. Among these, only three are logically possible. Let us consider these cases in turn, which we label by the sign of the vector (ϕ_t, ω_t).

1. (0, 0) This case is not possible because $\omega_t = 0 \rightarrow x_t > 0$ which implies that the incentive constraint should be binding, and thus $\phi_t > 0$.
2. (+, 0) This is the **interior regime** with $0 < x_t$ (central panel of Fig. 1).
3. (0, +) This is the regime where Eq. (4) holds, so that the incentive constraint is not binding. There is no corruption and public investment is not distorted (left panel of Fig. 1). We label this case the **benchmark regime**.
4. (+, +) This case corresponds to a situation without corruption, where Eq. (4) does not hold. The incentive constraint holds with equality at $x_t = 0$ reflecting the fact that the government has to lower investment i_t in order to deter households from rent-seeking (left panel of Fig. 1). We label this case **distortion without corruption**.

To prevent possible confusion let us stress the difference between the existence of our three cases and a model with multiple equilibria. Here, for a given set of parameters, the equilibrium is unique, but can be of one of the three different types, depending on the value of the parameters. On the contrary, with multiple equilibria, different outcomes would be possible for the same set of parameters, and coordination between agents becomes a central feature of the model, since it would allow to determine which of the equilibria would materialize. Such multiple equilibria usually arise in decentralized economies when the level of corrupt activity influences its return (Bardhan 2006), as for example if, when many others are rent-seekers, it was in one's interest to be a rent-seeker as well.

The optimality conditions are derived in Appendix A for the three possible regimes. From these conditions we can derive one relation between the marginal productivity of the two types of capital. Let us consider the different regimes in turn.

2.1 Benchmark regime

The case without corruption can be seen as a benchmark against which we can evaluate the cases with corruption. From the first-order conditions analyzed in Appendix A we derive:

$$\lambda_t = \mu_t, \quad \forall t. \tag{9}$$

Here, there is no distortion, and the shadow price of both types of capital should be equal at all times. From Appendix A we also find that:

$$1 - \delta_H + \Gamma[1] f'_H[h_t, k_t] = 1 - \delta_K + \Gamma[1] f'_K[h_t, k_t]. \tag{10}$$

At equilibrium the marginal productivity of the two types of capital should be equal. This condition is comparable to that in Arrow and Kurz (1970). They propose an optimal growth model with two types of capital, one of which contributes directly to the utility of households. The optimal condition from the political problem states that the marginal productivity of the first type of capital should equal the marginal productivity of the second type plus its marginal effect on utility. This last term is not present in our set-up since capital does not affect utility directly.

The benchmark case arises if Condition (4), which can be interpreted as an upper bound on the corruption technology ν, holds. Moreover, there is another condition for this regime to prevail. It is derived in Appendix A from the positivity of the Kuhn–Tucker multiplier ω_t associated with $x_t \geq 0$. This condition is written:

$$1 + \theta < \frac{u[y_t] + u'[y_t] \left(\nu i_t + \Gamma'[1] f[h_t, k_t] \right)}{u[\nu i_t - g_t - i_t]}. \tag{11}$$

It requires θ not to be too large. For a given corruption technology ν, if θ is large, rent-seekers have much more political weight than productive workers, and it is less likely that the equilibrium without corruption could prevail. The precise conditions on the parameters under which the interior regime arises can be established for long-run equilibria. In the long-run, all the variables H_t, K_t, G_t, I_t and Y_t grow at the same rate n. All the per capita variables converge to a constant level. The following proposition establishes the two essential properties of the equilibrium without corruption and the conditions to reach it.

Proposition 2 *In a long-run equilibrium, if*

$$\nu < \frac{\Gamma[1] f[h, k]}{(n + \delta_K) k} \tag{12}$$

and

$$1 + \theta < \frac{u[y] + u'[y] \left(\nu(n + \delta_K)k + \Gamma'[1] f[h, k] \right)}{u[(\nu - 1)(n + \delta_K)k - (n + \delta_H)h]}. \tag{13}$$

with h and k given by (14) and (15), then.

1. *There is no corruption*: $x = 0$.
2. *The marginal productivity of both types of capital is equal*:

$$1 - \delta_H + \Gamma[1] f'_H[h, k] = 1 - \delta_K + \Gamma[1] f'_K[h, k]. \tag{14}$$

3. *The Modified Golden Rule holds*:

$$1 - \delta_H + \Gamma[1] f'_H[h, k] = \frac{1 + n}{\rho}. \tag{15}$$

Proof See Appendix A.

Equation (15) is a Modified Golden Rule. The marginal productivity of capital is equal to the growth in population divided by the discount factor ρ. Equation (14) determines the optimal mix of investment at steady state. Conditions (12) and (13) show that such a regime with no distortion will prevail if the corruption technology is not too efficient, and if the political weight of rent-seekers is not too high. In the next section, we present, through a numerical example, the zone in the space $\{v, \theta\}$ for which this regime holds.

2.2 Distortion without corruption

In this regime, the incentive constraint holds with equality at $x_t = 0$ reflecting the fact that the government has to lower investment i_t in order to deter households from rent-seeking. This is reflected by the following relation from Appendix A:

$$\lambda_{t+1} = \mu_{t+1} - \frac{\phi_t v}{\rho}. \tag{16}$$

Comparing this with Eq. (9) shows that the shadow prices of capital are no longer equal. The value of h (λ) is reduced compared to the value of k (μ), indicating that there is less capital k in the economy as a consequence of the drop in investment i necessary to deter corruption. The term $\phi_t v/\rho$ represents the distortion brought about by the possibility of corruption. In this regime, corruption acts like a negative externality which can be limited at a certain cost.

At steady state, we obtain a modified "Modified Golden Rule" that incorporates corruption:

$$1 - \delta_H + \Gamma[1 - x] \, f'_H[h, k] = \frac{1 + n}{\rho} - \phi \frac{\Gamma[1] \, f'_H[h, k]}{u'[y]}.$$

The net marginal productivity of capital is equal to the discounted growth rate of population minus a term depending on the shadow price of corruption. As $\phi > 0$, the incentive constraint has a positive impact on investment in h, given the stock k, and makes the productive sector more rewarding which allows corruption to be kept out of the economy.

To assess the effect of the possibility of corruption on the composition of public investment, consider the ratio g/i at steady state:

$$\frac{g}{i} = \frac{n + \delta_H}{n + \delta_K} \frac{h}{k}.$$

Compared to the benchmark case, we have seen above that h/k is higher when the incentive constraint is binding. As a consequence the ratio g/i will be higher too: potential corruption leads to inflate the share of health and education investment relative to physical capital investment. In this regime, the possibility of corruption increases the share of public spending free from corruption. This shows that the possibility of

corruption does not always distort public investment in favor of specific types of spending for which rent-seeking is easier and better concealed as suggested in the empirical literature.

2.3 Interior regime

In this case, Constraint (4) holds. The relation linking the shadow prices of capital becomes:

$$\left(1 - \frac{\nu x_t(1+\theta)}{1+\theta x_t}\right)\lambda_{t+1} = \mu_{t+1}(1 - \nu x_t) - \frac{\phi_t \nu}{\rho}. \tag{17}$$

To better understand this relation compared to (9) and (16), it is useful to compute its value when rent-seekers do not enjoy additional political power, i.e. $\theta = 0$. Then we have:

$$\lambda_{t+1} = \mu_{t+1} - \frac{\phi_t \nu}{\rho(1 - \nu x_t)}.$$

This relation is quite similar to (16). We have the same mechanism: the choice of capital is distorted in favor of that which is not subject to corruption in order to deter households from working in the rent-seeking sector. When $\theta > 0$, however, there is a force which will work in the opposite direction: since rent-seekers have more weight than workers, the government has a tendency to increase the spending subject to corruption in order to "feed" the rent-seekers. This tendency is reflected by the term on the left-hand-side,[7]

$$1 - \frac{\nu x_t(1+\theta)}{1+\theta x_t}.$$

Hence two forces work in opposite directions: the interest of having households working in the productive sector against the additional utility drawn from the presence of rent-seekers.

To better understand the role of the incentive constraint, we look at the optimal value of the corresponding multiplier, ϕ_t, the shadow price of corruption. From the optimality conditions of Appendix A, we obtain:

$$\phi_t = \frac{-\theta u[y_t] + \nu\rho\mu_{t+1}i_t - (1 - x_t)u'[y_t]|\Gamma'[1 - x_t]|f[h_t, k_t]}{|\Gamma'[1 - x_t]|f[h_t, k_t]} > 0. \tag{18}$$

The shadow price of corruption is the sum of three terms. The first term $-\theta u[y_t]$ is the direct effect of x_t on the objective function W_t. For a correct interpretation of this term, we need to assume that the utility function is positive which requires $\sigma > 1$ with the CIES functional form. When corrupt individuals carry more political weight($\theta > 0$), the cost of the constraint is decreased. The second term $\nu\rho\mu_{t+1}i_t$ is positive and

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[7] This term decreases from $1 - \nu x_t$ to $1 - \nu$ as θ goes from 0 to $+\infty$. It therefore increases λ compared to μ as θ rises (*ceteris paribus*) which goes against the effect of the incentive constraint, $\phi_t \nu/\rho(1 - \nu x_t)$.

reflects the loss of investment and future capital because of corruption. This second term weighs more if the corruption technology (ν) is more efficient. The third term is negative: if there is more corruption, fewer people work in the productive sector, but their individual productivity is higher because of decreased marginal returns to labor.

At steady state, the modified "Modified Golden Rule" is:

$$1 - \delta_H + \Gamma[1-x] \, f'_H[h,k] = \frac{1+n}{\rho} - \phi \frac{\Gamma[1-x] \, f'_H[h,k]}{(1-x)u'[y]}.$$

As in the previous case, the incentive constraint has a positive impact on investment in h, given the stock k. To assess the effect of corruption on the composition of public investment, consider the ratio g/i at steady state:

$$\frac{g}{i} = (1 - \nu x) \frac{n + \delta_H}{n + \delta_K} \frac{h}{k}.$$

Compared to the previous regime, there is now a term $(1 - \nu x)$ involved in the relation between the two ratios. This term shows that some investment is diverted from its purpose, highlighting how corruption acts as a tax. Even if h/k is increased compared to the benchmark, g/i may well be decreased if corruption νx is strong enough (investment i raises artificially whereas actual investment in capital k does not).

2.4 Numerical illustration

In the above sections, we have discussed the role of potential corruption on the allocation of public spending by comparing the outcome of the voting process across the three different regimes.[8] To illustrate further the properties of the model, we ran a numerical example. We first gave the following specific forms to our functions:

$$b[1-x] = (1-x)^{\alpha}, \quad f[k,h] = k^{\beta} h^{\epsilon}.$$

We assume population growth at rate $n = 0.005$, a discount factor of 0.96, and depreciation rates of $\delta_H = \delta_K = 0.04$. The technology parameters are set at $\alpha = 1/2$, $\beta = 1/4$ and $\epsilon = 1/4$. The intertemporal elasticity of substitution is set at $\sigma = 2$. Figure 2 shows where each of the three possible long-run regimes occurs in the $\{\theta, \nu\}$ plane. The numerical values corresponding to points A, B, and C are presented in Table 1.

We first observe in Fig. 2 that, if θ is low enough, possibly zero, the interior regime cannot prevail. In that case, either the technology of corruption is not very effective, i.e. ν is low, and the benchmark regime without distortion prevails, or the technology of corruption is efficient, i.e. ν is high, and the economy experiments the regime without corruption but with distortion.

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[8] Notice that we are not able to consider effects of small changes in the parameters within regimes, given the non-linearity of the first-order conditions.
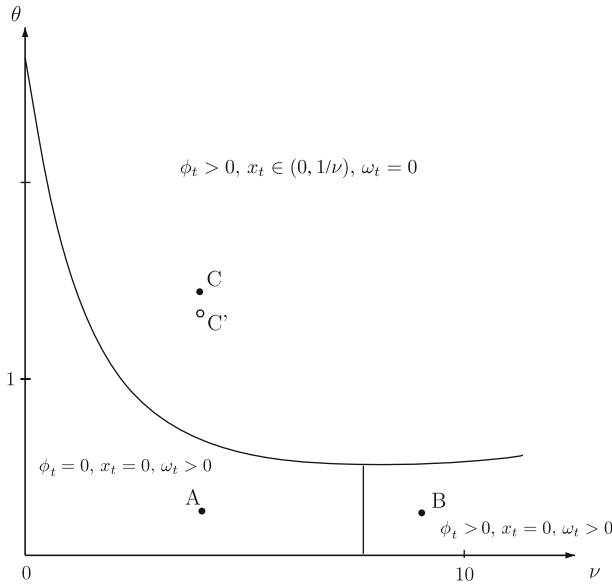
Fig. 2 Regime zones in the $\{\theta, \nu\}$ plane

Table 1 Steady state comparisons

	ν	θ	ϕ	x	g	i	g/i	h/k	y
A	4	1/4	0	0	0.37	0.37	1	1	2.13
B	9	1/4	0.015	0	0.36	0.30	1.19	1.19	2.04
C	4	3/2	0.262	0.20	0.24	0.54	0.45	2.02	1.38

The benchmark regime arises when ν and θ are small enough (from Conditions (12) and (13)). Since, in the numerical example, the two types of capital have the same depreciation and productivity parameters ($\delta_H = \delta_K$ and $\beta = \epsilon$), the optimal capital ratio h/k is equal to one in this regime, as is the optimal investment ratio g/i. Point A represents such a situation. Assuming the same low political weight attached to rent-seekers ($\theta = 1/4$) but increasing the efficiency of the corruption technology ν, the economy switches to a regime where corruption is still absent, but public investment is distorted (point B). As highlighted by the analytical results, the government reduces the investment subject to corruption in order to lower the income from rent-seeking and prevent corruption from occurring at equilibrium. The ratio of public spending g/i is now equal to 1.19, reflecting that the possibility that corruption distorts the composition of public spending in favor of investment for which rent-seeking is not possible. This distortion entails a loss of productive efficiency, as reflected in the lower value of income per capita y.

The interior regime arises for high values of θ. In this case, for example at point C, the rent-seekers have such a high political weight that public spending subject to corruption is encouraged. policy makers can more effectively please the rent-seekers
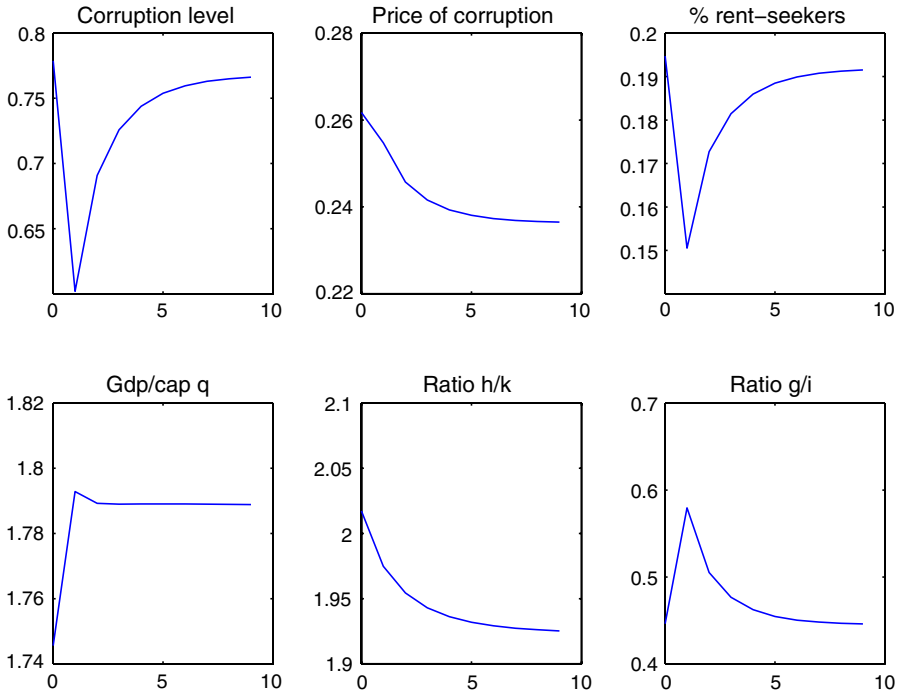
Fig. 3 Transition from C to C′ with a permanent drop in θ

by increasing investment i. The ratio g/i is equal to 0.45. Notice that this does not imply that capital h is low compared to k because the major part of the investment in k does not reach its target. In fact, both capital stocks are lower than in the economy without corruption, but the ratio h/k is higher. As a consequence of low investment levels and distorted allocation, output per person y is lower than in the two previous cases.

In order to illustrate the dynamic behavior of the economy and check for the local stability of the steady state, consider steady state C. Assume that there is a permanent unanticipated change in one parameter, say a decrease in θ from 1.5 to 1.375. The new steady state is represented by point C′. The dynamics around C′ can be represented by a system of four first-order difference equations with two pre-determined variables k and h. The eigenvalues of the linearized system around C′ are 0.5553, 0.849, 1.227, and 1.876, indicating that C′ is a stable saddle-point (the Blanchard–Kahn conditions are satisfied). Hence there is a unique trajectory converging to the steady state. To simulate the transition from one steady state to one another, we use the method developed by Boucekkine (1995) and Juillard (1996). Figure 3 represents the transition path.[9] We observe that the control variables (% rent seekers, corruption level, ratio g/i) rise on the new saddle path at the time of the shock, and then converge slowly to the new

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[9] The difference between the simulated path and the constant solution should be interpreted as the difference between an economy which has experienced such a shift and one which has not.

steady state. The predetermined variable (ratio h/k) adjusts monotonically to the new steady state. The price of corruption, computed from (18), and GDP per capita are functions of both control (jump) and state variables. The effect of the decrease in θ is to decrease corruption, mostly in the short run, but to increase GDP per capita permanently. In the long-run, the investment ratio returns to its initial level, but the ratio of the capital stocks k/h is now higher, because less investment spending on k has been diverted by rent-seekers.

3 Empirical analysis

In our model, the composition of public investment is endogenous and depends on a set of parameters. Theory suggests that the way this ratio is affected by the different parameters is not the same in the three main regimes described above. The different kinds of steady states we have identified can be mapped into development levels. High income (y) countries are more likely to be either in the benchmark regime (if the predatory technology (ν) and the concentration of power (θ) are low), or in the regime with distortion but no corruption (if they have a more efficient predatory technology (higher ν) but still a well distributed political power (low θ)). In this latter case, there is no corruption at equilibrium, but public spending is biased towards those for which corruption is more difficult. Developing countries are more likely to be in the interior regime, with high ν and θ, widespread corruption and public spending biased towards areas in which corruption is easier.

Hence a clearcut prediction of our theory is that a rise in corruption technology entails a rise in the investment ratio g/i for developed countries in the regime with distortion but no corruption, but a fall in the investment ratio g/i for developing countries (interior regime).

In this section, we present observed variables which correspond to these parameters and investigate their effects on the ratio of public investment. Two different strategies could a priori be pursued to take into account the non-linearities caused by the presence of different regimes. Strategy I is to interact our measures of ν and θ in the regressions. This poses two problems. One is that such an interaction term imposes a strong symmetry between the effect of the two variables: the coefficient of the interaction term would appear both in the marginal effect of ν on the ratio g/i and in the marginal effect of θ on g/i. The second is related to the benchmark regime. This regime appears for a range of values for ν and θ; in this range, both variables have no effect at all on the endogenous variables. This can hardly be capture by an interaction term between ν and θ. Strategy II is to introduce interaction terms between the variables measuring ν and θ and initial development levels. The initial development level will be measured by initial income per capita and will hopefully capture the idea stressed above that high income countries are more likely to be either in the benchmark regime, or in the regime with distortion but no corruption, and that developing countries are more likely to be in the interior regime. The disadvantage of this method is that it may introduce some more noise into the estimation, given that an initial low development level could be related to variables we have left outside the model. Letting the data speak, it appears that the interaction term between ν and θ is never significant, implying that the effects

of corruption technology on public investment varying with the concentration of political power may only be visible when mapping countries into different development levels. To simplify the exposition, we only presents the results following strategy II.

3.1 Measurement

The four parameters ν, θ, ρ, n and productivity $\Gamma[.]$ are measured with the following variables. Descriptive statistics of all the variables and the list of countries used in the econometric analysis are provided in Appendix B (see Tables 3, 4, 5). Since the variables are imperfect measures of the parameters and since there might be simultaneity, we may face endogeneity biases. We also present the instruments we use to control for endogeneity.

1. **Techcor**: The effect of ν is estimated by using the *Rule of Law* index available in the Governance Research Indicator Country Snapshot (GRICS). This index is an aggregate of perceptions of the incidence of crime, of the effectiveness and predictability of the judiciary, and of the enforceability of contracts. To use this index as a proxy for ν, we assume that the technology of corruption is as efficient as the legal (penal and judicial) system is inefficient (Becker and Stigler 1974; Jacquemet 2006). Therefore, we operate the following transformation: $Techcor = 2.5 - Rule\ of\ Law$, so that $Techcor$ varies between 0 and 5. Hence, the higher the variable *Rule of Law*, the higher is the probability of a corrupt public agent being caught and punished, and the smaller the technology of corruption ($Techcor$). On the contrary, the lower the value of *Rule of Law*, the easier it is for rent-seekers to have recourse to corruption and the higher the value of $Techcor$.

2. **Polbias**: As a proxy for θ, that is the political weight given to rent-seekers in the objective function, we use an indicator of the lack of political rights taken from Freedom House. Few political rights for the population indicate a strong concentration of power in the hands of a few. And those who hold the power are presumably rent-seekers (because of purchasing votes as mentioned above). Hence, if political rights are weak, rent-seekers concentrate power, which means θ is high. We subtract 1 from the original index in order to obtain a variable ranging from 0 (if the country provides very extended political rights to its citizens) to 7 (if the citizens have no political rights).

3. **Patience**: This variable indicates the number of years the party of the chief executive has been in office,[10] taken from the Database of Political Institutions (Beck et al. 2001). It is used as a proxy for the discount factor ρ. We assume that political groups anticipate their term of office relatively well. Thus, if the political group has been in power for a long time, it is considered more patient and values the future more than parties who have been in power for a shorter period.

4. **Pop**: The rate of growth of the total population, taken from the World Development Indicators (WDI) database, stands for n.

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[10] A "forward-looking" variable indicating how many years would elapse before the next elections would have fitted better with the discount factor but, to the best of our knowledge, it is not available.

5. $\Gamma[.]$: We use a first dummy variable (**Tropic**) which is equal to 1 if the country is located between the tropic of Cancer and the tropic of Capricorn, 0 otherwise; and a second one (**Ldlock**) equal to 1 for landlocked countries, and to 0 otherwise. This enables us to control for geographic conditions affecting productivity $\Gamma[.]$. These two variables are taken from the Global Development Network Growth Database, edited by the Development Research Institute of New York University.

To control for initial conditions, we introduce the logarithm of the 10 year-lagged constant PPP GDP per capita, ln $\mathbf{Y_0}$ which is provided by the WDI database.

The endogenous variable is measured by **Ratio**: g/i relates public investment spending free from corruption to investment spending subject to corruption. g is the proportion of health and education spending in total public expenditure. Expenditure on these two sectors has been shown to decrease with the extent of corruption (Mauro (1998); Gupta et al. (2002); Delavallade (2006)). That does not mean that the education and health sectors are free from corruption (see, for example, Reinikka and Svensson 2004) but that corruption in these sectors is less beneficial for top-ranking officials and politicians who decide the budgetary allocation. i covers expenditure on housing, fuel and energy, agriculture, mining and manufacture, transport (and other economic activities) as a percentage of total government spending.[11] The proportion of total public spending in each sector is taken from Government Finance Statistics Yearbooks provided by the International Monetary Fund. For checking robustness, we try alternative measures of g and i in Sect. 4.2. When data are missing, we use the figures for the following (odd) year when they are available. If not, we use the mean of the ratio for a given country.

3.2 Estimation results

Using an instrumental variables regression, we estimate an equation where the endogenous variable is a function of the instrumented parameters and initial conditions. From theory we know that the benchmark regime is more likely to fit developed countries whereas the two other regimes (with corruption) correspond to developing countries. To control for the possibility that the values of parameters ν and θ may differ according to the initial level of GDP, we add interaction terms to the list of regressors: $\frac{Techcor}{\ln Y_0}$ and $\frac{Polbias}{\ln Y_0}$.

The estimated equation is thus:

$$Ratio_{it} = \alpha_1 + \alpha_2 Techcor_{it} + \alpha_3 \frac{Techcor}{\ln Y_{0it}} + \alpha_4 Polbias_{it} + \alpha_5 \frac{Polbias}{\ln Y_{0it}}$$
$$+ \alpha_6 Patience_{it} + \alpha_7 Pop_{it} + \alpha_8 Tropic_{it} + \alpha_9 Ldlock_{it} + \alpha_{10} \ln Y_{0it} + \varepsilon_{it}.$$

Estimates are run on even-year data[12] for the period 1996–2004 on 62 countries using a two-stage least squares (2sls) procedure. We first estimate an unrestricted

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[11] In a sequel to this paper we will also investigate results with g composed only of education spending, and with expenditure on defense, and culture and recreation included in i.

[12] The Rule of Law index is only available from the World Bank for even years.

model. At each step, we perform a Wald test that the least significant parameter of each equation is null. If the p-value of a coefficient is over 0.15, we reject the coefficient at the following step. Hence, at the end of the procedure, we retain a restricted model for which all coefficients have a low p-value (below 0.15).

As mentioned above, the variables $Techcor$, $Polbias$ and $Patience$ suffer from substantial measurement error with respect to the actual technology of corruption, the lack of political rights and the discount factor. Hence, to reinforce the treatment of endogeneity, we introduce external instrumental variables which are used in the first stage of the procedure to provide predicted values of endogenous variables, then considered as their instrumented values.[13] These excluded instruments are defined as follows:

1. **antiq** is an index of the depth of experience of state-level institutions, or state antiquity. It was developed by Bockstette et al. (2002)[14] and we use it here as an instrument for political and legal infrastructure. We also use the same index adjusted by a mobility matrix estimating for each country the proportion of the ancestors in 1500 of that country's population today that were living within what are now the borders of the country, provided by Putterman and Weil (2007).
2. **yrind** stands for the logarithm of the number of years of independence of the state. It measures the autonomy of the political and legal system and its capacity to influence or resist foreign influence.
3. **legsoc**, **legfr** and **legbr** are dummies equal to 1 if the country's legal system has a socialist, a French or a British origin, respectively.[15]
4. **polbiaslag** is the 10-year lagged index of political rights.
5. **poplag** is 10-year lagged index of growth rate of the population.
6. **natres** is the percentage of natural-resource exports in GDP one year earlier. Natural resources include agricultural raw materials, fuel, food, ores and metals. This index is often used as an instrument for the level of corruption since abundant natural resources create strong incentives to rent-seeking, and hence to corruption (Leite and Weidmann 1999). The exploitation of natural resources strengthens corruption *via* its impact on the predatory technology, v: we expect the technology of corruption to be more developed when the index of natural-resource exports is high. However, these exports being given as a percentage of GDP, we suspect this instrument of being too endogenous.

We perform two tests for evaluating the validity of using instrumented estimations. The first one is a Sargan overidentification test (see Sargan 1958). of the correlation of instrumental variables with error terms. If the null hypothesis is not rejected, the instruments are not correlated with the error terms, i.e. the instruments are not invalid.

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[13] The results of this first-stage regression are presented in Table 6 in Appendix C.

[14] The index was developed from the answers for each country to the following three questions for each period of 50 years: (a) Was there a government above the tribal level? (b) Was this government foreign or locally based? (c) How much of the territory of the modern country was ruled by this government?

[15] These indicators are available on New York University's web site.

Table 2 From the unrestricted to the restricted model: a three-step procedure

Model	1	2	3
Explanatory variables	Dependent variable $Ratio.10^{-1}$		
$Techcor$	1.57*	1.60*	0.79***
	(0.87)	(0.83)	(0.24)
$\frac{Techcor}{\ln Y_0}.10$	−1.50*	−1.54*	−0.68***
	(0.90)	(0.85)	(0.20)
$Polbias$	−0.71**	−0.71**	−0.47***
	(0.35)	(0.35)	(0.18)
$\frac{Polbias}{\ln Y_0}.10$	0.63**	0.64**	0.42***
	(0.32)	(0.32)	(0.16)
$Patience.10^{-1}$	−0.12	−0.13*	−0.08**
	(0.09)	(0.07)	(0.04)
$Pop.10^{-1}$	0.06		
	(0.57)		
$Tropic$	0.17	0.18**	0.12***
	(0.11)	(0.09)	(0.04)
$Ldlock$	0.09	0.09	0.08**
	(0.06)	(0.06)	(0.04)
$\ln Y_0$	−0.31	−0.32	
	(0.31)	(0.30)	
Observations	304	304	304
Instruments	*antiq yrind legsoc legfr legbr poplag polbiaslag Tropic Ldlock* $\ln Y_0$		
Sargan test	1.38	1.31	6.02
p-value	(0.24)	(0.52)	(0.11)
Cragg–Donald F stat.	0.40	0.57	1.29

Standard errors in parentheses: ***, ** and * denote coefficients significantly different from zero at the 1, 5 and 10% level, respectively

Second, we test whether the instruments are strong or weak, i.e. whether the instruments predict the endogenous regressors well or not. Traditionally, the first-stage F test is used to do this. Staiger and Stock (1997) suggest that an F statistic exceeding 10 enables inference from instrumented estimations. But recent literature argues that in the presence of multiple endogenous regressors, the first-stage F test is not sufficient and is less powerful than a test based on the Cragg–Donald (CD) F statistic (see Cragg and Donald 1993; Stock and Yogo 2002; Stock et al. 2002). Hence, we provide a test of the null hypothesis that the instruments are weak using the CD F statistic (for critical values, see Stock and Yogo 2002). These two tests are presented at the bottom of Table 2. We also report the t-statistics associated with the coefficients of the instrumental variables in the first-stage regressions in Appendix C (see Table 6).

4 Interpretation and robustness

4.1 Interpretation of the results

The two tests run on the instruments lead us to think that these instruments are valid. The results of Sargan's overidentification test reveal that the instruments are not significantly correlated with error terms.[16] However, when substituting the adjusted state antiquity index to the raw one, the null hypothesis that instruments are not correlated with error terms has to be rejected. As for the second-stage results, they are not modified by such a substitution. Hence, we use the raw index of state antiquity and our instruments are valid insofar as they only affect the dependent variables through explanatory variables. Whether our instruments are strong or weak is less clear cut. For computational issues, the critical values corresponding to 6 endogenous regressors have not been tabulated. But, by extrapolating from those tabulated for 1, 2 and 3 endogenous variables (see Stock and Yogo 2002), we are able to comment on the values of the CD F statistic. The first stage regression provides quite low values of the Cragg–Donald F statistic (1.29), which indicates that some combinations of the coefficients may be badly identified (because of multicollinearity between the instruments and between the instrumented variables). Hence, inferences based on the coefficients may not be strictly valid (Stock and Wright 2000) and, in particular, counterfactuals might not be fully reliable. However, when the multicollinearity between the instrumented variables is reduced by dropping $\frac{Techcor}{\ln Y_0}$ and $\frac{Polbias}{\ln Y_0}$ from the calculation of the Cragg–Donald F statistic,[17] it rises up to 7.08. Given that, for 3 endogenous variables and 7/8 excluded instruments, the critical values are 4.44/4.46 for a 5% significance level, our instruments can be considered as strong. On the other hand, high values of t statistics (see Table 6 in Appendix C) show that the instrumental variables are individually significant. Thus, if some linear combinations of coefficients are badly identified, some others are well identified, the confidence intervals of the coefficients are reliable and our instruments are not irrelevant.

The first stage regressions of the endogenous regressors on instrumental variables presented in Table 6 suggest a few commentaries. First, the state antiquity reinforces the predatory technology and the lack of democracy. At the same time, states which became independent more recently tend to have weaker legal systems (favoring corruption) and to be weaker democracies. Indeed, when the state was colonized for a long time, a deeper experience of state-level institutions may strengthen mechanisms aiming at circumventing the legal system as well as authoritarian regimes which flout citizens' political rights. But a longer experience of independent state and autonomy helped build a stronger political and legal system. As regards to the origin of the legal system, our results are in line with legal origins theory comparing noticeably the effects of common law and civil law (La Porta et al. 1998; Beck and Levine 2003). Indeed,

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[16] The p-value of 0.24 associated with the test statistic in the first column should be read as follows: if the null hypothesis is true, i.e. if the instruments and the error terms are not correlated, we would obtain a test statistic at least as high as 1.38 in 24 estimations out of 100.

[17] For the purpose of this calculation of the Cragg–Donald statistic we treat these interaction terms as exogenous regressors.
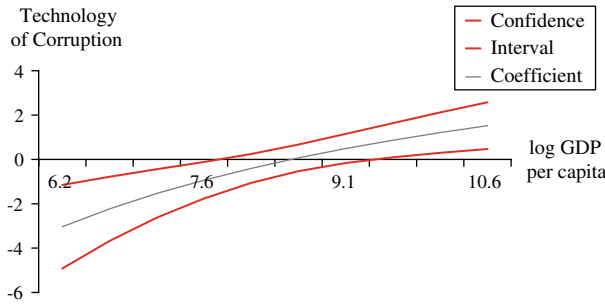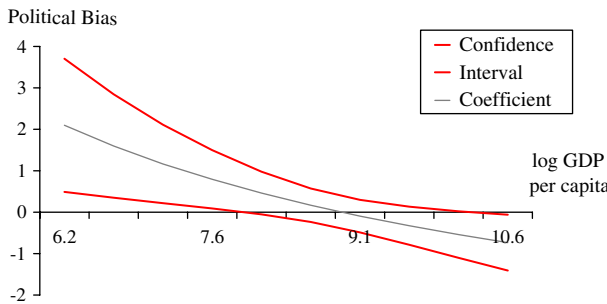
Fig. 4 Partial effect of v on ratio g/i

Fig. 5 Partial effect of θ on ratio g/i

legal systems with a French or Socialist origin provide significantly less efficient legal regimes (in particular to protect property rights) than those of British origin.

Let us now comment on the estimated coefficients in Table 2. As interaction terms with coefficients α_3 and α_5 are included in the regressions, the partial effects of $Techcor$ and $Polbias$ on the ratio g/i, when both single and interaction terms are significant, are given by $\alpha_2 + \alpha_3/\ln Y_{0i}$ and $\alpha_4 + \alpha_5/\ln Y_{0i}$ respectively for each country i. Figures 4 and 5 display the value of these derivatives from the coefficients estimated in Eq. (3) for the relevant range of $\ln Y_{0i}$, from $\min \ln Y_0 = 6.18$ to $\max \ln Y_0 = 10.57$.

The results presented in Table 2 reveal first that the **ratio of spending** g/i is negatively affected by the *technology of corruption* in the poorest countries, but positively affected in the richest ones. Its coefficient is significant at the 1% level and it ranges between -3.04 and 1.09 according to the initial level of GDP: the negative effect of v on g/i gets stronger as the initial GDP decreases.

Figure 4 indicates that the 95%-confidence interval contains both positive and negative values of $\frac{\partial(g/i)}{\partial v}$ for GDP per capita between \$2,700 and \$11,000, but only negative ones for GDP per capita lower than \$2,700, and positive ones for initial GDP higher than \$11,000. In low-income countries, easier access to corruption (or lesser punishment for corruption) increases the part of the budget dedicated to rent-generating spending (mostly physical-capital spending) at the expense of social spending (mostly on human capital). In middle-income countries, the impact of the technology of corruption on the ratio of spending g/i is undetermined. In high-income countries, the higher

the technology of corruption, the higher the social spending (free from corruption) relative to capital spending (subject to corruption).

The technology of corruption entails two opposite distortions according to the initial level of GDP per capita. This is in line with the main findings of the model. Indeed, given the effect of v on g/i, richer countries may be in the regime with distortion but without corruption: easier access to corruption makes effective corruption more plausible. But, the outcome of probabilistic voting is near that of a benevolent social planner (θ is low),[18] so it reduces investment spending subject to corruption in order to lower the income from rent-seeking and prevent corruption. On the contrary, poorer countries seem to fit better with the interior regime with corruption and with distortion. Here, the government is more kleptocratic and corruption is not only potential but effective and distorts the structure of the budget in the opposite way, i.e. in favor of rent-generating spending.

The variable *lack of political rights* (standing for θ) has a coefficient between 2.1 and -0.5. Figure 5 also shows that countries can be divided into two categories according to the initial level of GDP per capita. In high- and middle-income countries (with a GDP per capita over \$2,700) the effect of the concentration of political power is not significant. The short term effects described in Sect. 2.4 suggest a negative and significant coefficient, at least for high-income countries. The most democratic ones (with the lowest θ) would distort the structure of public spending in favor of education and health (increasing g/i) to deter corruption, as exemplified by the regime with distortion but without corruption. On the other hand, in low-income countries, which experience the regime with corruption, θ has a significantly positive effect on the ratio g/i: the more concentrated the power, the higher the proportion of government spending devoted to education and health. This positive coefficient contradicts the effects described in Sect. 2.4. This might be due to "poverty reduction strategies"[19] developed by these countries which lead them to raise their expenditure on education and health policies. In this case, this variable can be considered as a proxy for such strategies, more common to countries lacking in political rights. If we could control for poverty reduction strategies, we should also see that corruption increases rent-generating expenditure relatively to social expenditure.

Considering the combined effects of failing legal and political institutions, simulations show that if Zimbabwe had Denmark's technology of corruption and index of democracy in 2004, that is 0.6 and 0 instead of 3.04 and 3, respectively, then its ratio of investment g/i would be 1.91 instead of 1.22.

4.2 Robustness tests

In this section, we perform robustness tests on the components of the ratio g/i and on the set of instruments.

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[18] The pairwise correlation coefficient between θ and initial GDP per capita is -0.64 and significant at the 1% level. However, when we introduce the interaction term $v\theta$, its coefficient is not significantly different from 0. This might be due to high correlations with v and θ, which capture all the effect on the ratio of spending.

[19] Poverty reduction strategies are in place in most countries benefiting from foreign aid. They noticeably consist of reinforcing public investment in health and education.

4.2.1 Robustness to the definition of g/i

We undertake sensitivity tests relative to the specification of the ratio g/i of public investment. This is defined in Table 2 as g/i, where g is composed of that part of public spending invested in education and health and i is composed of expenditure on housing, fuel and energy, agriculture, mining and manufacture, transport and other economic activities as a percentage of total government expenditure. Table 7 in Appendix C reports the results of estimating Eq. 3 in which i includes expenditure on defense first (Eq. 3.1), then expenditure on defense and culture (Eq. 3.2) in addition to housing and economic activities. Indeed, the proportions of these sectors were shown to be those likely to rise with increasing levels of public corruption (Delavallade 2006). The global effects of the predatory technology and the concentration of power on g/i, when i includes the percentages of expenditure not only on economic activities and housing but also on defense, are similar to those observed for the main estimations. We note that the negative impact of a failing legal system, favoring corruption, on the ratio g/i is a little less clear cut than in the main analysis. This finding is in line with Delavallade (2006) which shows that the lack of freedom, rather than the extent of corruption, strengthens the proportion of defense spending in the budget. On the other hand, the lack of democracy provides very similar results to those obtained for Eq. 3. The significance of the coefficients has decreased very slightly but is still higher than 10%. This implies that defense and culture are also sectors subject to corruption, hence favored by a weak legal system and a strong concentration of power within rent-seekers, although a little less so than economic activities and housing.

Finally, in Eq. 3.3, g is only composed of education expenditure. The estimated effects of the different explanatory variables are very close to those of the main model, as are the results of the relevance tests for instruments. This reinforces the robustness of the results presented above.

4.2.2 Robustness to the choice of instruments

We now provide a test of sensitivity to the set of instruments. The results are presented in the last column of Table 7. In Eq. 3.4, we substitute the percentage of natural-resource exports in GDP for the 10-year lagged index of political rights. Estimates are very close to our main estimation. All the coefficients are significant at least at the 10% level and their values are very similar to the previous ones. Tests of validity of the instruments are satisfactory as well. A noticeable difference lies in the higher values of the Sargan test statistic when using natural-resource exports as an instrument, which indicates a higher correlation between the instruments and the error terms. We expected this instrument not to be valid because it was given as a percentage of GDP.

5 Conclusion

Corruption affects economic growth through many channels, one of them consisting of a modification of the structure of public expenditure in favor of specific types of spending. This distortion has not previously been clearly characterized. There is no

theoretical study of the possible mechanisms through which this distortion could operate, and the empirical literature has been confined to estimating the effect of corruption on several types of public spending. In this paper we propose a coherent theoretical and empirical view of the effects of corruption on the allocation of public investment, their legal and political determinants. We show that corruption leads to different kinds of budgetary distortions according to the quality of the legal and political institutions and to the level of development.

In order to inspect the mechanisms linking corruption to public investment and growth, we provide an optimal growth model with endogenous rent-seeking. Households choose between being producers or rent-seekers. Voters choose the composition of public spending taking into account the behavior of households (incentive constraint). At equilibrium, the level of corruption, the ratio of spending and GDP per capita depend on the predatory technology and the concentration of power in rent-seekers' hands. We make several regimes, with and without corruption, at equilibrium explicit.

A contribution of our model is to show that the effect of corruption is not always the same: it may distort the distribution of public expenditure in two different ways. The type of distortion depends on the extent to which political power is concentrated in the hands of rent-seekers. When power is strongly concentrated, a high predatory technology leads to high levels of actual corruption and distorts the structure of public spending in favor of investment in physical capital, at the expense of investment in human capital. On the contrary, in a more democratic regime, a greater technology of corruption makes potential corruption higher but has no effect on its actual level; and it leads to an increase in expenditure in human capital relative to physical capital.

The third contribution of this paper is to provide empirical evidence of the main implications of the model. We show that, in line with theory, the effect of a poor legal system on the structure of public investment varies with the level of development. In richer countries, when corruption is made possible by a failing legal system (i.e. which provides a well-developed predatory technology), public expenditure is distorted in favor of human capital spending, in order to discourage rent-seekers from corruption. In contrast, a failing legal system in a poor country entails a fall in the ratio of human capital to physical capital spending.

Appendix A: Solution to the voting problem

We follow McKenzie (1986) and de la Croix and Michel (2002) and use the Lagrangian of period t $\mathcal{L}_t$, which has the interest of being simpler and more intuitive (and yielding the same results as the infinite Lagrangian). The Lagrangian $\mathcal{L}_t$ is composed of the

terms of the infinite Lagrangian which depends on h_t, g_t, k_t, i_t and x_t. Replacing W_t by its value from (7), U_t by its value from (3) and $V_t = u[vi_t - g_t - i_t]$, we obtain:

$$
\begin{aligned}
\mathcal{L}_t = {} & (1 - x_t)u[\Gamma[1 - x_t]f[h_t, k_t] - g_t - i_t] + (1 + \theta)x_t u[vi_t - g_t - i_t] \\
& + \rho\lambda_{t+1}\left[(1 - \delta_H)h_t + g_t\right] - \lambda_t(1 + n)h_t \\
& + \rho\mu_{t+1}\left[(1 - \delta_K)k_t + (1 - vx_t)i_t\right] - \mu_t(1 + n)k_t \\
& + \phi_t\left(\Gamma[1 - x_t]f[h_t, k_t] - vi_t\right) + \omega_t x_t.
\end{aligned}
\tag{19}
$$

It is equal to the instantaneous utility plus the increase in the value of the two capital stocks, $\rho\lambda_{t+1}h_{t+1} - \lambda_t(1 + n)h_t$ and $\rho\mu_{t+1}k_{t+1} - \mu_t(1 + n)k_t$ minus the cost of the inequality constraints. For an optimal solution, the derivatives of $\mathcal{L}_t$ with respect to the five variables are zero:

$$
\begin{aligned}
\frac{\partial \mathcal{L}_t}{\partial h_t} = {} & \left((1 - x_t)u'[y_t] + \phi_t\right)\Gamma[1 - x_t]f'_H[h_t, k_t] \\
& + \rho(1 - \delta_H)\lambda_{t+1} - (1 + n)\lambda_t = 0,
\end{aligned}
\tag{20}
$$

$$
\frac{\partial \mathcal{L}_t}{\partial g_t} = -(1 - x_t)u'[y_t] - (1 + \theta)x_t u'[vi_t - g_t - i_t] + \rho\lambda_{t+1} = 0,
\tag{21}
$$

$$
\begin{aligned}
\frac{\partial \mathcal{L}_t}{\partial k_t} = {} & \left((1 - x_t)u'[y_t] + \phi_t\right)\Gamma[1 - x_t]f'_K[h_t, k_t] \\
& + \rho(1 - \delta_K)\mu_{t+1} - (1 + n)\mu_t = 0,
\end{aligned}
\tag{22}
$$

$$
\begin{aligned}
\frac{\partial \mathcal{L}_t}{\partial i_t} = {} & -(1 - x_t)u'[y_t] + (1 + \theta)(v - 1)x_t u'[vi_t - g_t - i_t] + \rho\mu_{t+1}(1 - vx_t) \\
& - \phi_t v = 0,
\end{aligned}
\tag{23}
$$

$$
\begin{aligned}
\frac{\partial \mathcal{L}_t}{\partial x_t} = {} & -u[y_t] + (1 + \theta)u[vi_t - g_t - i_t] - v\rho\mu_{t+1}i_t \\
& - \left((1 - x_t)u'[y_t] + \phi_t\right)\Gamma'[1 - x_t]f[h_t, k_t] + \omega_t = 0
\end{aligned}
\tag{24}
$$

with

$$
y_t = \Gamma[1 - x_t]f[h_t, k_t] - g_t - i_t.
$$

The multipliers of the inequality constraints should satisfy:

$$
\phi_t \geq 0,
$$

$$
\phi_t\left(\Gamma[1 - x_t]f[h_t, k_t] - vi_t\right) = 0,
$$

$$
vi_t \leq \Gamma[1 - x_t]f[h_t, k_t],
$$

$$
\omega_t \geq 0,
$$

$$
\omega_t x_t = 0,
$$

$$
-x_t \leq 0.
$$

The transversality conditions are:

$$\lim_{t\to\infty} \rho^t \lambda_t h_t = 0, \quad \text{and} \quad \lim_{t\to\infty} \rho^t \mu_t k_t = 0. \tag{25}$$

Benchmark regime

We first consider the regime where $x_t = 0$, $\phi_t = 0$, and $\omega_t > 0$. Equation (4) holds and the incentive constraint is not binding. There is no corruption and public investment is not distorted. The first order conditions become

$$\frac{\partial \mathcal{L}_t}{\partial h_t} = u'[y_t]\Gamma[1]f'_H[h_t, k_t] + \rho(1 - \delta_H)\lambda_{t+1} - (1 + n)\lambda_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial g_t} = -u'[y_t] + \rho\lambda_{t+1} = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial k_t} = u'[y_t]\Gamma[1]f'_K[h_t, k_t] + \rho(1 - \delta_K)\mu_{t+1} - (1 + n)\mu_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial i_t} = -u'[y_t] + \rho\mu_{t+1} = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial x_t} = -u[y_t] + (1 + \theta)u[vi_t - g_t - i_t] - v\rho\mu_{t+1}i_t$$
$$- u'[y_t]\Gamma'[1]f[h_t, k_t] + \omega_t = 0.$$

First notice that $\lambda_{t+1} = \mu_{t+1}$. The Keynes–Ramsey rule can be derived by replacing λ_t and λ_{t+1} in the first equation by their value computed from the second equation.

$$\lambda_{t+1} = u'[y_t]/\rho \qquad \rightarrow$$
$$\frac{u'[y_{t-1}]}{u'[y_t]} = \frac{\rho\left(\Gamma[1]f'_H[h_t, k_t] + 1 - \delta_H\right)}{1 + n}.$$

The relation between the marginal productivities of the two types of capital is derived by combining the Keynes–Ramsey rule derived above with the expression obtained by replacing μ_t and μ_{t+1} in the third equation by their value computed from the fourth equation.

$$\mu_{t+1} = u'[y_t]/\rho \qquad \rightarrow$$
$$1 - \delta_H + \Gamma[1]f'_H[h_t, k_t] = 1 - \delta_K + \Gamma[1]f'_K[h_t, k_t],$$

which is Eq. (10) of the main text.

The last equation can be used to derive an expression for the multiplier ω_t:

$$\omega_t = u[y_t] - (1 + \theta)u[vi_t - g_t - i_t] + v\rho\mu_{t+1}i_t + u'[y_t]\Gamma'[1]f[h_t, k_t].$$

Imposing $\omega_t > 0$ on it gives an upper bound on the parameter θ:

$$1 + \theta < \frac{u[y_t] + v\rho\mu_{t+1}i_t + u'[y_t]\Gamma'[1]f[h_t, k_t]}{u[vi_t - g_t - i_t]},$$

which is Eq. (11) of the main text.

Distortion without corruption

This is regime where $x_t = 0$, $\phi_t > 0$, and $\omega_t > 0$. This case corresponds to a situation without corruption, but where Eq. (4) does not hold. When the incentive constraint holds with equality, $-u[y_t] + (1+\theta)u[vi_t - g_t - i_t]$ simplifies into $\theta u[y_t]$. The first order conditions are:

$$\frac{\partial \mathcal{L}_t}{\partial h_t} = \left(u'[y_t] + \phi_t\right)\Gamma[1]f'_H[h_t, k_t] + \rho(1 - \delta_H)\lambda_{t+1} - (1+n)\lambda_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial g_t} = -u'[y_t] + \rho\lambda_{t+1} = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial k_t} = \left(u'[y_t] + \phi_t\right)\Gamma[1]f'_K[h_t, k_t] + \rho(1 - \delta_K)\mu_{t+1} - (1+n)\mu_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial i_t} = -u'[y_t] + \rho\mu_{t+1} - \phi_t v = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial x_t} = \theta u[y_t] - v\rho\mu_{t+1}i_t - \left(u'[y_t] + \phi_t\right)\Gamma'[1]f[h_t, k_t] + \omega_t = 0.$$

From the second and fourth conditions, the shadow prices of capital are no longer equal:

$$\lambda_{t+1} = \mu_{t+1} - \frac{\phi_t v}{\rho}.$$

A modified Keynes–Ramsey rule can be derived by replacing λ_t and λ_{t+1} in the first equation by their value computed from the second equation.

$$\lambda_{t+1} = u'[y_t]/\rho \qquad \rightarrow$$

$$\frac{u'[y_{t-1}]}{u'[y_t]} = \frac{\rho(\Gamma[1]f'_H[h_t, k_t] + 1 - \delta_H)}{1+n} + \frac{\rho\Gamma[1]f'_H[h_t, k_t]}{1+n}\frac{\phi_t}{u'[y_t]}.$$

Interior regime: $0 > x_t > 1$ and $\phi_t \neq 0$

This is the interior regime with $0 < x_t < 1/v$. The multiplier $\phi_t > 0$, but $\omega_t = 0$. When the incentive constraint holds with equality, $-(1-x_t)u'[y_t] + (1+\theta)(v-1)x_tu'[vi_t - g_t - i_t]$ simplifies into $(vx(1+\theta) - (1+\theta x))u'[y_t]$, and $u'[y_t] = u'[vi_t - g_t - i_t]$.

The first order conditions are:

$$\frac{\partial \mathcal{L}_t}{\partial h_t} = \left((1 - x_t)u'[y_t] + \phi_t\right)\Gamma[1 - x_t]f'_H[h_t, k_t]$$
$$+ \rho(1 - \delta_H)\lambda_{t+1} - (1 + n)\lambda_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial g_t} = -(1 + \theta x_t)u'[y_t] + \rho\lambda_{t+1} = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial k_t} = \left((1 - x_t)u'[y_t] + \phi_t\right)\Gamma[1 - x_t]f'_K[h_t, k_t]$$
$$+ \rho(1 - \delta_K)\mu_{t+1} - (1 + n)\mu_t = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial i_t} = \nu x(1 + \theta) - (1 + \theta x))u'[y_t] + \rho\mu_{t+1}(1 - \nu x_t) - \phi_t\nu = 0,$$

$$\frac{\partial \mathcal{L}_t}{\partial x_t} = \theta u[y_t] - \nu\rho\mu_{t+1}i_t - \left((1 - x_t)u'[y_t] + \phi_t\right)\Gamma'[1 - x_t]f[h_t, k_t] = 0.$$

From the second and fourth conditions, the shadow prices of capital are no longer equal:

$$\left(1 - \frac{\nu x_t(1 + \theta)}{1 + \theta x_t}\right)\lambda_{t+1} = \mu_{t+1}(1 - \nu x_t) - \frac{\phi_t \nu}{\rho}.$$

The shadow price of corruption can be computed by solving the fifth equation for ϕ_t:

$$\phi_t = \frac{\theta u[y_t] - \nu\rho\mu_{t+1}i_t - (1 - x_t)u'[y_t]\Gamma'[1 - x_t]f[h_t, k_t]}{\Gamma'[1 - x_t]f[h_t, k_t]}.$$

The Keynes–Ramsey rule can be derived by replacing λ_t and λ_{t+1} in the first equation by their value computed from the second equation.

$$\lambda_{t+1} = (1 + \theta x_t)u'[y_t]/\rho \qquad\qquad \rightarrow$$

$$\frac{1 + \theta x_{t-1}}{1 + \theta x_t}\frac{u'[y_{t-1}]}{u'[y_t]} = \frac{\rho(\Gamma[1 - x_t]f'_H[h_t, k_t] + 1 - \delta_H)}{1 + n} + \frac{\rho}{1 + n}\frac{\phi_t}{u'[y_t]}$$

$$\times \frac{\Gamma[1 - x_t]}{1 - x_t}f'_H[h_t, k_t].$$

Appendix B: Descriptive statistics

Table 3 reports the list of countries in the study. In Table 4 we report the descriptive statistics of the variables used in the estimation. Table 5 provides the main statistics of the dependent variable *Ratio*.

Table 3 List of the countries studied

Argentina	China	Greece	Malaysia	Spain
Australia	Colombia	Iceland	Mauritius	Sri Lanka
Austria	Costa Rica	India	Mexico	Sweden
Bangladesh	Cyprus	Indonesia	Nepal	Syria
Belgium	Denmark	Iran	Netherlands	Thailand
Bolivia	Dominican Rep.	Ireland	New Zealand	Tunisia
Botswana	Egypt	Israel	Norway	Turkey
Brazil	El Salvador	Jamaica	Pakistan	Uganda
Burundi	Ethiopia	Kenya	Panama	United Kingdom
Cameroon	Fiji	Korea, Rep.	Papua New Guinea	United States
Canada	Finland	Lesotho	Peru	Uruguay
Chile	Germany	Madagascar	Philippines	Venezuela
			Singapore	Zambia

Table 4 Summary statistics of the variables used in the estimations

Variable	Observation	Mean	SD	Min	Max
Dependent variable					
Ratio	304	1.63	1.08	0.10	7.13
Explanatory variables					
Techcor	304	2.08	1.04	0.26	4.00
Polbias	304	1.71	1.92	0	6
Patience	304	10.32	12.62	1	71
Pop	304	1.39	0.79	−0.03	4.00
Tropic	304	0.45	0.50	0	1
Ldlock	304	0.13	0.33	0	1
ln Y_0	304	8.63	1.09	6.21	10.31
Instruments					
antiq	304	0.46	0.26	0.07	1
yrind	304	4.63	0.89	3.30	7.71
legsoc	304	0.02	0.13	0	1
legfr	304	0.47	0.50	0	1
legbr	304	0.38	0.49	0	1
polbiaslag	304	1.94	1.94	0	6
poplag	304	1.68	0.98	−0.46	4.09
natres	266	1,387.69	1,196.11	108.32	8,020.70

Table 5 Yearly statistics of the dependent variable: *ratio*

Year	Observations	Mean	SD	Min	Max
1996	58	1.48	1.01	0.10	4.97
1998	62	1.60	1.04	0.11	4.83
2000	62	1.64	1.00	0.11	5.45
2002	62	1.80	1.28	0.11	7.13
2004	60	1.63	1.03	0.11	5.19

Appendix C: Robustness of the estimation results

See Tables 6 and 7.

Table 6 Relevance test: Do the instruments predict well the endogenous regressors?

	$Techcor$	$\frac{Techcor}{\ln Y_0}.10$	$Polbias$	$\frac{Polbias}{\ln Y_0}.10$	$Patience.10^{-1}$	Pop
$antiq$	0.26*	0.17	1.30***	1.35***	0.69**	−0.14
	(1.88)	(1.12)	(3.97)	(3.26)	(2.08)	(−1.21)
$yrind$	−0.16***	−0.12***	−0.36***	−0.32***	−0.27***	−0.05
	(−3.83)	(−2.68)	(−3.67)	(−2.60)	(−2.78)	(−1.55)
$legfr$	0.61***	0.46***	0.58**	0.42	0.49**	0.20**
	(6.14)	(4.11)	(2.42)	(1.39)	(2.03)	(2.40)
$legbr$	0.16	0.07	0.30	0.27	0.28	0.22***
	(1.60)	(0.62)	(1.26)	(0.92)	(1.15)	(2.69)
$legsoc.10$	0.10***	0.07**	0.34***	0.39***	0.46***	−0.02
	(3.67)	(2.45)	(5.27)	(4.84)	(7.09)	(−0.86)
$poplag$	0.11**	0.11**	0.67***	0.81***	0.16	0.51***
	(2.45)	(2.21)	(6.25)	(6.00)	(1.46)	(13.84)
$polbiaslag$	−0.02	−0.01	0.41***	0.53***	0.33***	−0.02
	(−0.77)	(−0.42)	(7.52)	(7.73)	(5.97)	(−1.30)
$natres.10^{-3}$	−0.06**	−0.07**	−0.08	−0.09	−0.19***	0.01
	(−2.53)	(−2.41)	(−1.39)	(−1.26)	(−3.32)	(0.46)
$Ldlock$	−0.23**	−0.15	−0.06	0.12	0.46*	−0.17**
	(−2.25)	(−1.32)	(−0.23)	(0.39)	(1.85)	(−2.00)
$Tropic$	0.51***	0.49***	−0.33*	−0.56**	0.90***	−0.01
	(6.59)	(5.66)	(−1.78)	(−2.40)	(4.80)	(−0.16)
$\ln Y_0$	−0.59***	−1.04***	−0.25**	−0.53***	0.77***	−0.20***
	(−11.68)	(−18.23)	(−2.06)	(−3.47)	(6.25)	(−4.71)
Observations	266	266	266	266	266	266

T-statistics in parentheses: ***, ** and * denote coefficients significantly not null, respectively, at the 1, 5 and 10% level

Table 7 Robustness tests for the estimation of the reduced model

Explanatory variables	3.1	3.2	3.3	3.4
	Dependent variables			
	$Ratio.10^{-1}$	$Ratio.10^{-1}$	$Ratio.10^{-1}$	$Ratio.10^{-1}$
$Techcor$	0.40***	0.37***	0.31***	1.03***
	(0.14)	(0.13)	(0.12)	(0.31)
$\frac{Techcor}{\ln Y_0}.10$	−0.33***	−0.31***	−0.26***	−0.84***
	(0.12)	(0.11)	(0.10)	(0.24)
$Polbias$	−0.25**	−0.23**	−0.16*	−0.68***
	(0.11)	(0.10)	(0.09)	(0.26)

Table 7 continued

Explanatory variables	3.1	3.2	3.3	3.4
	Dependent variables			
	$Ratio.10^{-1}$	$Ratio.10^{-1}$	$Ratio.10^{-1}$	$Ratio.10^{-1}$
$\frac{Polbias}{\ln Y_0}.10$	0.21**	0.19**	0.15*	0.58***
	(0.09)	(0.09)	(0.08)	(0.22)
$Patience.10^{-1}$	−0.03	−0.03	−0.04**	−0.09***
	(0.02)	(0.02)	(0.02)	(0.03)
$Tropic$	0.07***	0.06***	0.07***	0.10*
	(0.03)	(0.02)	(0.02)	(0.05)
$Ldlock$	0.03	0.03	0.04**	0.08*
	(0.02)	(0.02)	(0.02)	(0.04)
Observations	304	304	304	266
				antiq yrind
Instruments	*antiq yrind legsoc legfr legbr*			*legsoc legfr legbr*
	poplag polbiaslag Tropic Ldlock $\ln Y_0$			*poplag natres*
				Tropic Ldlock $\ln Y_0$
Sargan test stat.	3.99	3.54	6.32	3.12
p-value	(0.26)	(0.32)	(0.10)	(0.37)
Cragg–Donald	1.29	1.29	1.29	2.00

Standard errors in parentheses: ***, ** and * denote coefficients significantly not null, respectively, at the 1, 5 and 10% level.

In the ratio of model 3.1, i includes expense on economic activities, housing and defense. In the ratio of model 3.2, i includes expense on economic activities, housing, defense and culture. In the ratio of model 3.3, g only includes expense on education. In model 3.4, the instrument *natres* is substituted for *polbiaslag*

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