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# *Endogenous Probability of Detection in a Simple Model of Corruption and Growth*

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**Abstract**

Economic and rent-seeking outcomes are determined jointly in a dynamic general equilibrium model of corruption, public spending and growth. In an economy with government intervention and capital accumulation, state-appointed bureaucrats are responsible for providing public goods, which contribute to productive efficiency. Corruption arises because of an opportunity for bureaucrats to appropriate public funds with an endogenous probability of being detected and punished. Given this probability, which depends on aggregate outcomes, each agent maximises her expected lifetime utility by choosing consumption and savings. The model produces multiple development regimes, which yield different predictions about corruption, public spending and investment depending on initial conditions. These predictions accord strongly with the empirical evidence on corruption and development.

**JEL classification:** D73, H41, K42, O11, O17

**Keywords:** Corruption, Public Spending, Probability of detection, Development

**Outline**

## Non-Technical Summary


Over the last decade, a substantial volume of research has been devoted to understanding and explaining the link between corruption and real economic activity. At the empirical level, a number of authors have found evidence of a strong negative correlation between corruption and long-run growth, which is essentially two-way causal. At the macro-theoretical level, various models have been developed to account for this correlation. In most of the cases, the approach has been to treat corruption as exogenous and to focus on its role in influencing growth by diverting the resources away from productive to unproductive sector, and/or by reducing the fraction of savings channelled to investment. In other cases, the approach has been to model corrupt activity as an endogenous outcome of the growth process itself and to focus on the co-evolution of real and corrupt activity. In both cases, however, the probability of detection is either not considered or treated as exogenous.

The purpose of the present paper is to provide a simple illustration of how an already corrupt economy might evolve when the probability of detecting corruption both influences and is influenced by the process of economic development. Here, we are not interested in the issue whether country would be corrupt or not per se, rather we are focusing on the specific role of probability of detecting corruption on development. We do this by endogenising the detection probability in the basic overlapping generations model of capital accumulation and growth. Our analysis is based on a simple neo-classical growth model in which public agents (bureaucrats) are delegated the responsibility for the provision of public goods (e.g., roads, building, ports) on behalf of the political elite (the government). Bureaucrats have the opportunity to appropriate the public funds due to their administrative discretion and information advantage, which are difficult for the government to monitor. Thus our model incorporates the essential features that government intervention requires public officials to have discretion and insider information in allocating public resources.

As our focus is on causes and consequences of probability of detecting corruption, we abstract away from incentive to be corrupt and assume that all bureaucrats are corrupt in the sense of appropriating public funds. The effect of corruption, itself, is to reduce the amount of resources available for productive investments as bureaucrats seek other (less conspicuous, but costly) ways of disposing of their illegal income. An exogenous increase in probability detection has two opposing effects: on the one hand, it leads to higher fines on bureaucrat's illegal income causing lower savings by the bureaucrat; on the other had, it raises household's savings as government can afford to tax them (who are more productive than bureaucrats) at a lower rate for the same amount of productive public spending. The increase in savings is converted into an increase in capital accumulation and growth. Thus the model predicts a positive correlation between detection probability, savings and investment.

We endogenise the probability of detection by allowing it to depend on the level of development of the economy, itself. As well as motivating this in general terms, we provide a specific justification for it based on the provision of monitoring corruption by the government. Our analysis demonstrates how endogenising the probability of detection can radically alter the implications of even the simplest of growth models. As development now takes place, there is an increase in detection probability, which feeds back onto the growth process. This produces multiple development regimes such that limiting outcomes depend critically on parameter values and initial conditions. Under some circumstances, the economy evolves smoothly from a low development regime, in which detection probability is also low, to a high development regime, in which detection probability is high. Under other circumstances, there is no such transition and the economy is destined to remain in the regime where it started.

## 1. Introduction

Over the last decade, a substantial volume of research has been devoted to understanding and explaining the link between corruption and real economic activity. At the empirical level, a number of authors have found evidence of a strong negative correlation between corruption and long-run growth, which is essentially two-way causal (See Mauro, 1995; Ades and deTella, 1999; Treisman, 2000). At the macro-theoretical level, various models have been developed to account for this correlation. In most of the cases, the approach has been to treat corruption as exogenous and to focus on its role in influencing growth by diverting the resources away from productive to unproductive sector (Ehrlic and Lui, 1999), by reducing the fraction of savings channelled to investment (Sarte, 2000), or by lowering the amount and quality of public infrastructure and services supplied to the private sector (Del Monte and Papagni, 2001). In other cases, the approach has been to model corrupt activity as an endogenous outcome of the growth process itself and to focus on the co-evolution of real and corrupt activity (e.g., Blackburn *et al* 2002; Mauro, 2004). In both cases, however, the probability of detection is either not considered or treated as exogenous. In this paper we develop such a model, the hallmark of which is the joint, endogenous determination of the probability of detecting corruption and capital accumulation in dynamic general equilibrium.

We are aware that at the micro level, several authors have pointed to strategic complementarities as a major factor in determining a country's institutional efficiency and economic performance where the probability a corrupt official will be reported to higher authorities is a decreasing function of the proportion of his colleagues who are also corrupt (see for example, Andvig and Moene, 1990; Putnam, 1993; Tirole, 1996).[1] All these models have shown the possibility of multiple self-fulfilling equilibrium levels of corruption in a partial equilibrium analysis, not necessarily relating the phenomenon with economic development.

The purpose of the present paper is to provide a simple illustration of how an already corrupt economy might evolve when the probability of detecting corruption both

[1] The incidence of crime has been explained in a similar way. In Sah (1991), for example, an individual is more (less) likely to engage in criminal activity if there are many (few) others engaged in such activity because the chances that he will be caught are lower (higher).

influences and is influenced by the process of economic development. Here, we are not interested in the issue whether country would be corrupt or not per se, rather we are focusing on the specific role of probability of detecting corruption on development. We do this by endogenising the detection probability in the basic overlapping generations model of capital accumulation and growth. Our analysis is based on a simple neo-classical growth model in which public agents (bureaucrats) are delegated the responsibility for the provision of public goods (e.g., roads, building, ports) on behalf of the political elite (the government)[2]. Bureaucrats have the opportunity to appropriate the public funds due to their administrative discretion and information advantage, which are difficult for the government to monitor. Thus our model incorporates the essential features that government intervention requires public officials to have discretion and insider information in allocating public resources.

As our focus is on causes and consequences of probability of detecting corruption, we abstract away from incentive to be corrupt and assume that all bureaucrats are corrupt in the sense of appropriating public funds.[3] The effect of corruption, itself, is to reduce the amount of resources available for productive investments as bureaucrats seek other (less conspicuous, but costly) ways of disposing of their illegal income. An exogenous increase in probability of detection has two opposing effects: on the one hand, it leads to higher fines on bureaucrat's illegal income causing lower savings by the bureaucrat; on the other had, it raises household's savings as government can afford to tax them (who are more productive than bureaucrats) at a lower rate for the same amount of productive public spending. In equilibrium, the latter (positive) effect dominates over the former (negative) one and the (net) increase in savings is converted into an increase in capital accumulation and growth. Thus the model predicts a positive correlation between detection probability, savings and investment.

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[2] Bureaucratic Corruption can reduce growth also by reducing the investible resources through tax evasion, which has been investigated in Blackburn *et al* (2002) within dynamic general equilibrium framework.

[3] If we allow incentive to be corrupt within our analysis, it will strengthen our results since incentive to be corrupt should be decreasing in probability of detection. Accordingly, as probability of detection increases, incentive to be corrupt would decline, letting more investible resources to be invested rather than being wasted due to corruption and the economy would end up with growth higher than that we show in our model. Alternatively, we can think of a certain proportion of the bureaucrats to be corrupt while others being non-corrupt. This will also lead to essentially the same results. See also footnote 14 for the necessary condition for all bureaucrats to be corrupt.

We endogenise the probability of detection by allowing it to depend on the level of development of the economy, itself. As well as motivating this in general terms, we provide a specific justification for it based on the provision of monitoring corruption by the government. Our analysis demonstrates how endogenising the probability of detection can radically alter the implications of even the simplest of growth models. As development now takes place, there is an increase in detection probability, which feeds back onto the growth process. This produces multiple development regimes such that limiting outcomes depend critically on parameter values and initial conditions. Under some circumstances, the economy evolves smoothly from a low development regime, in which detection probability is also low, to a high development regime, in which detection probability is high. Under other circumstances, there is no such transition and the economy is destined to remain in the regime where it started.

From a broader perspective, our paper may be seen as continuing the literature on corruption and growth, where probability of detecting corruption is endogenous to the process of development. Our analysis is not meant to provide a complete account of this process, but rather is intended to draw attention to the role of the probability of detection and to illustrate this formally in a simple and intuitive way within the context of a standard benchmark model. The paper may be viewed as a contribution to the wider literatures on corruption, poverty traps and development (Blackburn *et al* 2002; Mauro, 2004).

The remainder of paper is organised as follows. In Section 2 we present a description of the model along with the optimal decision on savings. In Section 3 we solve the model and show the implications of endogensing probability of detecting corrupt activities. Section 4 offers some concluding remarks.

## 2. The Model

Time is discrete and indexed by $t = 0, \ldots, \propto$. There is a constant population of two-period-lived agents belonging to overlapping generations of dynastic families. Agents of each generation are divided into two groups of citizens – private individuals (or households) and public servants (or bureaucrats).[4] To fix the ideas, we normalise total population to 1, of which there are $m$ proportion of households and $n$ proportion of bureaucrats, where $n < m$. All agents are risk neutral, working only when young and consuming in both periods. Households work for firms in the production of output, while bureaucrats work for the government in the administration of public policy. Public policy consists of taxes and expenditures designed to make available public goods and services, which contribute to the efficiency of output production. Corruption arises when bureaucrats appropriate (steal) public funds that reduce the provision of public services. Firms, of which there is a unit mass, hire labour from households and rent capital from all agents in perfectly competitive markets.

### 2.1. The Government and the Public Service

We envisage the government as providing public services, which contribute to the efficiency of output production (e.g., Barro 1990). The government incurs expenditures on public goods (services) and bureaucrats' salaries. The government finances its expenditures each period by running a continuously balanced budget. Its revenues consist of lump sum taxes, $\tau_t$, collected by bureaucrats from households, plus any fines imposed on bureaucrats who are caught engaging in corruption.

We assume that the households are endowed with $\lambda > 1$ units of labor and are liable to taxation, while the bureaucrats are endowed with only one unit of labor and are exempt from paying tax. Taxes are lump sum and are collected by bureaucrats on behalf of the government, which requires funding for public expenditures. Any bureaucrat can work for a firm, supplying one unit of labor to receive a non-taxable income equal to the wage paid to households. Any bureaucrat who is willing to accept a salary less than this wage must be expecting to gain through theft and is therefore immediately identified as being corrupt. As in other analyses (e.g., Acemoglou and Verdier 1998), we assume that a bureaucrat who is discovered to be corrupt is subject to the maximum fine of having all

[4] We assume that agents are differentiated at birth according to their abilities and skills. A population of $m$ agents lack the skill necessary to become bureaucrats, while a population of $n$ agents possess these skills. The latter are induced to become bureaucrats by an allocation of talent condition established below. This approach to determining occupational choice serves as a convenient compromise between the case in which no agent has the option of making such a choice (e.g., Barreto 2000; Sarte 2000) and the case in which all agents have this option (e.g., Acemoglu and Verdier 1998, 2000).

of his legal income (salary) confiscated (i.e., he is dismissed without pay). Given this, then no corruptible bureaucrat would ever reveal himself in the way described above. As such, the government can minimize its labor costs, while ensuring complete bureaucratic participation, by setting the salaries of all bureaucrats equal to the wage paid by firms to households.[5]

Each bureaucrat is provided with public fund (spending) $g_t$, which is assumed to be a fixed proportion, $\phi \in (0,1)$, of output. The bureaucrat may be corrupt in the sense of appropriating public funds when they have been given the responsibility by the government for the provision of public services[6]. He appropriates $(1-\delta)<1$ fraction of the public fund that he is responsible for, and the economy ends up with total public service that the government can provide for the output-producing firms is $G_t = n\delta g_t$, while government spends $ng_t$.[7]

## 2.2. The Firm

Each firm combines $l_t$ units of labour with $k_t$ units of capital to produce $y_t$ units of output according to

$$y_t = A(l_t G_t)^{\alpha} k_t^{1-\alpha}, \qquad A>0, \alpha, \beta \in (0,1) \qquad (1)$$

where $G_t$ denotes the aggregate public services.[8] The firm hires labour at the competitively determined wage rate $w_t$ and rents capital at the competitively determined rental rate $r_t$. Profit maximization implies, $w_t = \alpha A l_t^{\alpha-1} G_t^{\alpha} k_t^{1-\alpha}$, and

[5] This has the same interpretation as the allocation of talent condition in Acemoglou and Verdier (2000). The government cannot force any of the n potential bureaucrats to actually take up public office, but it is able to induce all of them to do so by paying what they would earn elsewhere.

[6] We assume that there is no tax evasion in order to focus particularly on appropriation (theft) of public funds. The formalisation of corruption in this way follows that of the models of corruption and growth such as Del Monte and Papagni (2001), and Mauro (2004).

[7] This assumption can be justified from the kind of incidence reported in "Statesman", an Indian National Newspaper stated in 14 June 1993 "… large craters in several important streets of Kolkata including Russel Street, Middleton Street, Sudder Street, Chowringhee Lane, Mirza Ghalib Street had been patched up with stone chips of such inferior quality that they turned to dust within two days of repair". However our analysis would remain the same if we allow for positive but less than one unit of productive public services out of one unit of public spending.

[8] As in other models as well, we treat public goods as providing productive services, which raise the efficiency of other inputs in private production (e.g., Barro 1990).

$r_t = (1-\alpha)Al_t^{\alpha}G_t^{\alpha}k_t^{-\alpha}$. The assumption of $g_t = \phi y_t$ provides us with the total public service, $G_t = n\delta\phi y_t$. Since $l_t = l = \lambda m$ in equilibrium[9], we may write these conditions as

$$w_t = \left(\frac{a\alpha}{l}\right)k_t \tag{2}$$

$$r_t = r = a(1-\alpha) \tag{3}$$

where, $a = \left[A(nl\delta\phi)^{\alpha}\right]^{\frac{1}{1-\alpha}}$. Thus the equilibrium wage is proportional to the capital stock, while the equilibrium interest rate is constant.

## 2.3. Agents

The lifetime utility of an agent of generation t is given by

$$U^t = \frac{\left[c_t^t + v(b_t)\right]^{1-\sigma} - 1}{1-\sigma} + \theta\frac{\left(c_{t+1}^t\right)^{1-\sigma} - 1}{1-\sigma}; \qquad \sigma > 0, \theta \in (0,1] \tag{4}$$

where $c_t^t$ denotes consumption in young-age, $c_{t+1}^t$ denotes consumption in old-age, and $b_t$ denotes bequests to offspring. The function $v(\cdot)$ is assumed to be strictly concave that satisfy the usual Inada conditions.[10] Bequests are made by parents during young-age, being invested in the capital market and becoming available to children when they, themselves, reach maturity. Our particular specification of young-age felicity implies that the marginal rate of substitution between consumption and bequests is independent of the level of consumption. As we shall see, this leads to the convenient result that bequests are constant across generations.

A young household earns income by supplying $\lambda > 1$ units of labor to firms in return for wage earning, $\lambda w_t$, out of which he is liable to pay tax at a proportional rate, $\tau \in (0,1)$. In addition, the agent is entitled to her inheritance which is equal to the wealth bequeathed by her parent, plus the interest earned on the bequest: that is $(1+r_t)b_{t-1}$,

[9] The latter expression defines equilibrium in the labour market, where the total supply of labour is equal to the labour supply of households, $\lambda m$.

[10] This function captures the 'warm-glow', or 'joy-of-giving' motive for making bequests (e.g., Andreoni 1989). We choose this simple way of modelling altruism since the main role of bequests in our model is merely to ensure the existence of a non-degenerate steady state equilibrium along a linear (rather than concave) capital accumulation path. Nevertheless, our results are equally valid for the case in which this equilibrium is reached at zero (rather than positive) levels of production and consumption.

where $r_t$ is the rate of interest. Given these resources, the agent consumes, saves and makes bequests to her own offspring. Denoting saving by $s_t$, the budget constraint for a young agent is

$$c_t^t + s_t + b_t = (\lambda - \tau)w_t + (1 + r_t)b_{t-1} \quad (5)$$

In the old age, she no longer works but finances her consumption entirely from savings. Accordingly, the budget constraint of an old agent is

$$c_{t+1}^t = (1 + r_{t+1})s_t \quad (6)$$

A bureaucrat, when young, is endowed with one unit of labour, which he supplies inelastically to the government to earn a salary of $w_t$. For simplicity, we assume that bureaucrats have no other source of legal income and are exempt from paying any tax.[11] While the bureaucrat's budget constraint at his old age is the same as in (6), his 1st period budget constraint would differ from that of households (as in 5) as it involves his corrupt behaviour and the risk associated with it. As mentioned above, a bureaucrat appropriates $(1-\delta) < 1$ fraction of the public fund ($g_t$) that he is responsible for. The government investigates the behavior of bureaucrats using an imprecise monitoring technology.[12] This technology implies that a bureaucrat who is corrupt faces a probability, $p_t \in (0,1)$, of being detected, and a probability, $1 - p_t$, of avoiding detection. In general, corrupt bureaucrats may try to remain inconspicuous by concealing their illegal income, by investing this income differently from legal income and by altering their patterns of expenditure. For the purposes of the present analysis, we make the simple assumption that a bureaucrat must consume their illegal income immediately if they are to stand any chance of avoiding detection.[13] Detection of corruption occurs before a bureaucrat has the chance to dispose of (i.e., consume) his appropriated fund. If not detected, he consumes his illegal income $(1-p_t)(1-\delta)g_t$ immediately and hence it would not affect his lifetime decision-making. But in the event when he is caught (with probability $p_t$), he

[11] The fact that bureaucrats have only one unit of labour (as opposed to $\lambda$ units) may be used to justify this assumption.

[12] The model is extended to allow for costly monitoring (in an attempt allow $p$ to be a function of monitoring expenditures) in Section 3.3, which essentially supports our result.

[13] An alternative way of modelling this is to assume that bureaucrats must store his illegal income in hiding (rather than invest in capital) and consume in the next period, if he is to stand any chance of not being caught. This assumption would essentially lead us to same qualitative conclusion with little more complicated calculation. See footnote 16 for the relevant capital accumulation path.

would lose his total income (both legal and illegal), $w_t + (1-\delta)g_t$. Accordingly, the bureaucrat's expected lifetime legal earning would be $(1-p)w_t$ that he would be able to save and invest.[14] Given these outcomes, we may write the budget constraint of a young bureaucrat as

$$c_t^t + s_t + b_t = (1-p_t)w_t + (1+r_t)b_{t-1} \quad (7)$$

The linchpin of our analysis is the endogenous determination of the risk of being corrupt, $p_t$. It is this feature that accounts for our main results and which distinguishes our analysis from most of the existing literature. In general, one may think of the risk as being determined by factors that are both internal and external to an individual's decisions. Examples of the former are personal expenditures on hiding illegal income, or on fostering corruption at other levels (e.g., to ensure non-interference from the legal authorities),[15] while examples of the latter may include public expenditures on monitoring, improvement of rule of law, better democracy all of which are directly or indirectly related to development itself. We return to some of these issues later on in the paper. For the moment, we note that, if the risk is determined primarily by factors that are external to individuals, then it will be rational for an individual to treat her risk of being detected as essentially given and beyond her control. This is the approach that we follow in our analysis and, for this reason; we find it convenient to postpone further discussion on $p_t$ until a more appropriate juncture and to turn our immediate attention to the choices that do confront agents in our model.

The decision problem for our representative agent of generation t is to choose $c_t^t \geq 0, c_{t+1}^t \geq, s_t \geq 0, \text{and } b_t \geq 0$ so as to maximize (4) subject to (5) and (6) for the households and (7) and (6) for bureaucrats. The first order conditions for this problem yield interior solutions for all individuals and may be summarized as

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[14] Note that we abstract from any incentive condition for a bureaucrat to be corrupt or not. Rather we assume that all the bureaucrats decide to be corrupt and aim to analyse the effect of the risk (i.e., probability of being detected and punished) associated with it. However, in a world where bureaucrats are faced with the incentive problem, he would always appropriate public funds if his expected payoff from doing so (i.e., $(1-p)[w_t + (1-\delta)g_t]$) is no less than his payoff from not doing so (i.e., $w_t$). This gives rise to the necessary condition for a bureaucrat to be always corrupt (i.e., steal) is, $p \leq p^* \equiv \frac{l(1-\delta)}{\alpha + l(1-\delta)} \in (0,1)$ in our model, which is plausible.

[15] Discussions of these issues can be found in Rose-Ackerman (1996) and Wade (1985), among others.

$$v'(b_t)=1 \tag{8}$$

$$\frac{1}{\left[c_t^t + v(b_t)\right]^{\sigma}} = \frac{\theta(1+r_{t+1})}{\left(c_{t+1}^t\right)^{\sigma}} \tag{9}$$

The condition in (8) implies that $b_t = b$ for all t, which confirms our earlier assertion that the optimal size of bequest is the same for every agent of every generation. The condition in (9) equates the current marginal loss with the future marginal gain of an additional unit of savings. Together with (5), (6), and (7), these conditions may be used to establish the following optimal decision rules for savings of households ($s_t^h$) and bureaucrats ($s_t^b$) respectively,

$$s_t^h = \Phi[B + (\lambda - \tau)w_t] \tag{10}$$

$$s_t^b = \Phi[B + (1 - p_t)w_t] \tag{11}$$

where, $\Phi = \dfrac{\left[\theta(1+r_{t+1})^{1-\sigma}\right]^{\frac{1}{\sigma}}}{1+\left[\theta(1+r_{t+1})^{1-\sigma}\right]^{\frac{1}{\sigma}}}$, and $B = r_t b + v(b)$. Here both $\Phi$ and B are constant as $r_{t+1} = r_t = r$ according to (3). The key feature of (10) and (11) is that they depend on the economy-wide variables, $w_t$ and $\tau$ along with probability of detection, $p_t$. An increase in the wage has an unambiguously positive effect on savings of both households and bureaucrats. While the higher probability of detection ($p$) reduces bureaucrat's savings, the higher tax rate reduces household's savings. As we shall see that there is another effect of $p$ that reduces the tax rate, which in turn, increases the household's savings. In equilibrium, this positive effect of $p$ on household's savings will dominate over the negative effect on bureaucrat's savings and total savings (capital accumulation) will increase as probability of detection increases.

## 3. General Equilibrium

The solution of the model is a dynamic, competitive general equilibrium which describes aggregate economic activity based on the optimal decision rules that solve agents' and firms' maximization problems. The equilibrium is computed by combining the relationships obtained so far with the relevant market clearing conditions in the economy.

In order to compute total capital accumulation, we first determine the government budget constraint. The government obtains the tax revenue of $m\tau w_t$ which is used to finance its expenditures on public services and bureaucrats' salaries. As mentioned earlier, with probability $p_t$, government can detect corruption and imposes a punishment on bureaucrat, which equals $w_t + (1-\delta)g_t$. With probability ($1-p_t$), bureaucrat can avoid detection and retains all legal and illegal earnings. Hence, government's total expected spending is $(1-p)nw_t + [1-p(1-\delta)]ng_t$. Given this, we can express the government budget constraint as

$$m\tau w_t = (1-p)nw_t + [1-p(1-\delta)]ng_t \qquad (12)$$

Clearing of the capital market requires, $k_{t+1} = ms_t^h + ns_t^b + b$, where $s_t^h$ and $s_t^b$ are given in (10) and (11). Together with foregoing results, these expressions may be used to establish the following dynamic equation for capital:

$$k_{t+1} = \Phi[B + (\gamma + \beta p_t)ak_t] + b \qquad (13)$$

where, $\gamma = (\alpha - n\phi), \text{ and } \beta = (1-\delta)n\phi$, all of which are positive and constant.[16, 17] This equation shows that, *ceteris paribus*, an increase in the probability of detection has a positive effect on capital accumulation. The reason for this follows from our previous result that a higher probability of detection leads to lower level of savings by the bureaucrats but the households are taxed at a lower rate who are more productive than bureaucrats. Precisely how this probability, itself, is determined is a matter to which we now turn with the view to providing a complete characterization of the equilibrium path of development of the economy.

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[16] The necessary condition for $\gamma > 0$ is $\alpha > n\phi$, *i.e.*, this condition holds as long as the proportion of bureaucrats in the population ($n$) is low.

[17] If we assume, as in footnote 13, that the bureaucrats must store his illegal income in hiding and consume in the next period, we end up with $k_{t+1} = \Phi B + b + \frac{\alpha}{1+r+\Pi}[\alpha\Pi + np(1-\delta)(1+\Pi)\phi - n(1+\Pi-\delta)\phi]k_t$, where, $\Pi = [\theta(1+r)]^{\frac{1}{\sigma}}$.

## 3.1 Exogenous Probability of Detection

If the probability of detection is constant, $p_t = p$ for all $t$, then (13) describes a simple linear transition path along which the economy converges towards a unique steady state of either zero or positive long-run growth, depending on whether $\Phi(\gamma + \beta p)a \in (0,1)$, or $\Phi(\gamma + \beta p)a > 1$. In the case of the former, an increase in $p$ raises the steady state level of capital, as given by $\frac{\Phi B}{1 - \gamma - \beta p}$. In the case of the later, an increase in $p$ raises the steady state growth rate of capital, as determined by $\lim_{t \to \infty}\left(\frac{k_{t+1}}{k_t}\right) = \Phi(\gamma + \beta p)a$. Either way, the model predicts that exogenous improvements in detection probability lead to improvements in the prospective fortunes in the economy. This is consistent with the predictions of earlier studies by several key authors, such as Bardhan (1997), Rose-Ackerman (1998), among others.

## 3.2 Endogenous Probability of Detection

As argued earlier, it is more natural to think of detection probability as being endogenous, rather than exogenous, to the process of development. Both conceptually and empirically, there are good reasons for supposing that changes in detection probability are not only a cause, but also a consequence, of changes in prosperity. Allowing for such a possibility is the main innovation of our analysis. As we shall see, the implications of the model can change dramatically with the introduction of this additional new dimension.

We treat probability of detection as being determined primarily by factors that are largely external to individuals and which correlate positively with the level of development. Some specific examples of this are provided later when we consider public expenditure on monitoring, probability of punishment and number of corrupt bureaucrats, etc. For now we choose not to be so precise, but rather seek to establish some basic principles and key implications from a broader, more inclusive perspective.[18] To this end, we take the most immediate approach towards endogenising the detection

[18] An alternative approach would be to model the detection probability as a function of monitoring expenditures by the government. We do this in Section 3.3 with a formal illustration of how $p_t$ might depend initially on factors that lie within the realm of public policy.

probability by making the fairly general assumption that the probability of detection is an increasing, but bounded, function of the (aggregate) stock of capital: that is, $p_t = p(k_t)$, where $p'(\cdot) > 0$, $p(0) = \underline{p} > 0$ and $\lim_{k\to\infty} p(k_t) = \overline{p} \le 1$. Essentially, $p(\cdot)$ may be thought of as a reduced form of some other underlying relationships through which probability of detection is linked to economic activity.[19] Given this, then (13) is now understood to define a transition function, $F(\cdot)$, such that

$$k_{t+1} = F(k_t) = \Phi[B + [\gamma + \beta p(k_t)]ak_t] + b \tag{14}$$

where $F'(\cdot) > 0$ and $F''(\cdot) \gtrless 0$. A steady state equilibrium with zero growth corresponds to a fixed point of this mapping, $k^* = F(k^*)$. Such a point is stable (unstable) if $\lim_{k\to k^{*-}} F(\cdot) > (<) k^*$, but unstable (stable) if $\lim_{k\to k^{*+}} F(\cdot) < (>) k^*$. A steady state that is stable entails zero long-run growth, while a steady state that is unstable admits the possibility of non-stationary long-run equilibrium in which growth occurs at a positive, constant rate.

The key implication of endogenising detection probability is the existence of multiple development regimes, which may lead to multiple steady state equilibria such that the limiting outcomes of the economy depend crucially on initial conditions. The clearest illustration of this is provided by the case in which $p(\cdot)$ takes the form of a simple step function, such as

$$p(k_t) = \begin{cases} \underline{p} & \text{if } k_t < k^c \\ \overline{p} & \text{if } k_t \ge k^c \end{cases} \tag{15}$$

for some critical level of capital, $k^c > 0$. The transition function may then be written as

$$F(k_t) = \begin{cases} \underline{f}(k_t) \equiv \Phi[B + (\gamma + \beta \underline{p})ak_t] + b & \textit{if } k_t < k^c \\ \overline{f}(k_t) \equiv \Phi[B + (\gamma + \beta \overline{p})ak_t] + b & \textit{if } k_t \ge k^c \end{cases} \tag{16}$$

[19] This is illustrated in our subsequent examples of public policy. Since $y_t = Ak_t$ in equilibrium, it makes no difference as to whether one specifies $p(\cdot)$ in terms of capital or output.

where $\underline{f}(0) < \overline{f}(0)$ *and* $\underline{f}'(0) < \overline{f}'(0)$. Based on (16), we are led to distinguish between two types of development regime: the first – a low development regime – is characterised by low levels of capital and detection probability (i.e., $k_t < k^c$ *and* $p_t = \underline{p}$); the second – a high development regime – is characterised by high levels of capital and detection probability (i.e., $k_t \geq k^c$ *and* $p_t = \overline{p}$). Figure 1 shows the possible outcomes, where we assume that $\underline{f}'(\cdot) \in (0,1)$. An economy with an initial capital stock below $k_c$ converges to a low steady state, $k_L^* = \underline{f}(k_L^*)$, while an economy with an initial capital stock above $k_c$ either converges to a high steady state, $k_H^* = \overline{f}(k_H^*)$, or grows perpetually at a constant rate depending on whether $\overline{f}'(\cdot) \in (0,1)$, or $\overline{f}'(\cdot) > 1$. [20]

Precisely which of these eqilibria the economy converges to depends essentially on the initial stock of capital, $k_0$, and the relationship between $k_c$ and $k_L$. Suppose that $k_0 < k_c < k_L^*$. In this case the economy starts off in a situation where agents have a relatively small probability of being detected, $\underline{p}$, and development takes place along the low capital accumulation path, $\underline{f}(\cdot)$. At some point in time, $k_t$ reaches $k_c$ and the detection probability increases to $\overline{p}$. This propels the economy onto the high capital accumulation path, $\overline{f}(\cdot)$, by causing it to jump from $\underline{f}(k_c)$ to $\overline{f}(k_c)$, after which it then either converges to the high steady state equilibrium, $k_H^*$, or grows perpetually at a constant positive rate. This chain of events describes a process of transition from the low development regime to the high development regime. But there is nothing in the model to guarantee such an outcome. To be sure, suppose that $k_0 < k_L^* < k_c$. In this case the economy is destined for the low steady state equilibrium, $k_L^*$, being locked forever on the low capital accumulation path, $\underline{f}(\cdot)$, without any improvement in the detection scenario. To the extent that the high steady state equilibrium, $k_H^*$, or the positive growth

[20] The precise expression for these terms are obtained from (16) as $\underline{f}'(\cdot) = \Phi a[\gamma + \beta \underline{p}]$, $\overline{f}'(\cdot) = \Phi a[\gamma + \beta\overline{p}]$, $k_L^* = \dfrac{\Phi B + b}{1 - \Phi(\gamma + \beta \underline{p})a}$, and $k_H^* = \dfrac{\Phi B + b}{1 - \Phi(\gamma + \beta\overline{p})a}$.

equilibrium would be attained if $k_0 > k_c$, the model now presents a situation in which limiting outcomes depend fundamentally on initial conditions.

The above results are preserved under more general specifications of $p(\cdot)$ for which changes in detection probability occur smoothly, rather than discontinuously. Naturally, the transition function, $F(\cdot)$, is also continuous in these circumstances, the implications of which may be conveyed broadly as follows. Given the restrictions on $p(\cdot)$, then there must exist a $\hat{k} \geq 0$ such that $p''(\cdot) < 0 \text{ for all } k > \hat{k}$, with $\lim_{k\to\infty} p'(\cdot) = \lim_{k\to\infty} p''(\cdot) = 0$. Given that $\lim_{k\to\infty} kp'(\cdot) = 0$ as well, then it may be verified that $\lim_{k\to\infty} F'(\cdot) = \Phi a[\gamma + \beta\overline{p}(\cdot)]$ and $\lim_{k\to\infty} F''(\cdot) = 0$. Thus, as in the step function, long run growth is either zero or positive according to whether $\Phi a[\gamma + \beta\overline{p}(\cdot)] \in (0,1)$ or $\Phi a[\gamma + \beta\overline{p}(\cdot)] > 1$. A fixed point of the transition mapping satisfies $k^* = F(k^*)$. Sufficient conditions for a unique, stable equilibrium are that $p(\cdot)$ is strictly concave and $\Phi a[\gamma + \beta\overline{p}(\cdot)] \in (0,1)$. In Figure 2, we illustrate the cases of an equilibrium pair, $\{k_L^*, k_c\}$, and an equilibrium triple, $\{k_L^*, k_c, k_H^*\}$. Under such circumstances, $F(\cdot)$ crosses the $45^0$ line only once and from above.[21] If either or both of these conditions are not satisfied, however, then there may be more than one equilibrium, which alternate between stability and instability. For example, if $\Phi a[\gamma + \beta\overline{p}(\cdot)] \in (0,1)$ but $p''(\cdot) > 0$ $\text{for all } k < \hat{k}$, then $H''(\cdot) > 0 \text{ for all } k < \hat{k}$ as well, implying the possibility of an equilibrium triple $\{k_L^*, k_c, k_H^*\}$ such that $G'(k_L^*) > H'(k_L^*)$, $G'(k_c) < H'(k_c)$ and $G'(k_H^*) > H'(k_H^*)$. Alternatively, if $\Phi a[\gamma + \beta\overline{p}(\cdot)] > 1$, then there is also the possibility of just the equilibrium pair $\{k_L^*, k_c\}$ which implies positive long-run growth for an economy that starts off with $k_0 > k_c$.

As development now takes place, there is a gradual improvement in detection probability, which feeds back on to savings and capital accumulation. Precisely where the economy ends up depends critically on precisely where the economy starts off at: if

[21] To see this, write the steady state transition mapping as $G(k^*) = H(k^*)$, where $G(\cdot) = k^*$ and $H(\cdot) = \Phi[B + [\gamma + \beta p(k^*)]ak^*] + b$. Under the stated restrictions, $H''(\cdot) < 0$. Since $H(0) > G(0)$, it follows that $H(\cdot)$ crosses $G(\cdot)$ only once (from above), implying a unique steady state equilibrium. Since $F(0) > 0$, then $F(\cdot)$ must also cross the $45^0$ line only once and from above, implying a stable equilibrium.

$k_0 < k_c$, then the limiting outcome is the low steady state equilibrium, $k_L^*$, associated with low detection probability; if alternatively, $k_0 > k_c$, then the limiting outcome is the low steady state equilibrium, $k_H^*$, associated with high detection probability. Poverty or prosperity to begin with implies poverty or prosperity in the future.

### 3.3 Public Policy on Detecting Corruption

Suppose that the government undertakes various types of monitoring expenditures that increases the probability of detecting the corrupt activity (in our model, the appropriation of government fund). For simplicity, we consolidate these expenditures into a single term, $x_t$, and assume that they are financed each period by an additional proportional tax on the labour incomes of households at a rate $\tau^x \in (0,1)$. The government's additional spending for monitoring would be, $x_t = m\tau^x w_t$, while the budget constraint facing a young household reads $c_t^t + s_t + b_t = (\lambda - \tau - \tau^x)w_t + (1+r_t)b_{t-1}$. Given the latter (together with (4) and (6)), each household chooses an optimal level of savings equal to $s_t^h = \Phi[B + (\lambda - \tau - \tau^x)w_t]$. The probability of detection is specified initially as $p_t = q(x_t)$, where $q'(\cdot) > 0, q(0) = \underline{q} > 0$ and $\lim_{x\to\infty} q(\cdot) = \overline{q} \le 1$. As before, (2) and (3) yield $w_t = \left(\frac{a\alpha}{l}\right)k_t$ and $r_t = a(1-\alpha)$ in equilibrium. Thus we may write $x_t = m\tau^x\left(\frac{a\alpha}{l}\right)k_t$, implying $p_t = q\left(m\tau^x\left(\frac{a\alpha}{l}\right)k_t\right) = p(k_t)$, where $p'(\cdot) > 0$, $p(0) = \underline{p} > 0$ and $\lim_{x\to\infty} p(\cdot) = \overline{p} \le 1$. It follows that the equilibrium path of capital accumulation satisfies

$$k_{t+1} = F(k_t) = \Phi[B + [\gamma + \beta p(k_t)]ak_t] + b \qquad (13')$$

Evidently, all of our previous results are preserved in this modified version of the model, where the relationship between probability of detection and development is derived from a more explicit and specific set of micro foundations relating to public policy. An additional parameter is the new tax rate, $\tau^x$, changes in which have ambiguous effects on capital accumulation because of ambiguous effects on savings: on the one hand, an increase in $\tau^x$ means that agents have less disposable income which causes a fall in savings; on the other hand, an increase in $\tau^x$ implies bureaucrats face higher risk of being corrupt which induces an increase in savings.

## 4. Conclusions and Future Directions

Economists and policy makers agree that the probability of detecting corrupt activities is an important factor in determining the impact of corruption on savings and economic growth. At the same time, it is true that this probability is endogenous to economic conditions. Until now, models of corruption and growth have been based on the former presumption abstracting away from the later. The model developed in this paper is a first attempt at filling in some of the gaps by allowing for endogenous probability of detecting corruption and two-way causality in the relationship between detection of corruption and economic activity.

Our analysis indicates how endogenising probability of detecting corruption can radically alter the implications of even the simplest of growth models. Depending on the initial conditions, there may be multiple equilibria associated with threshold effects, which imply that the limiting outcomes in the economy are determined by historical, or initial, conditions. An economy that is poor to begin with may be destined to remain poor unless there are major changes in the circumstances which allow the threshold to be breached or which eliminate the threshold altogether. The implications of the model are distinct but complementary to those found in the existing literature on poverty traps, growth miracles and threshold externalities, being derived from a different perspective that shed new light on the issue of why some countries may permanently lag behind others in capital accumulation due to poor mechanism of detecting corruption. On the basis of our results, we view our analysis as a promising first step in untangling the corruption-development nexus showing the probability of detecting corruption as the main driving force that determine the joint and complementary evolution of lower resource loss due to corruption and higher capital accumulation.

We are aware that there are limitations of the models considered here. First, there is no explicit effort taken by bureaucrats to avoid detection in the model [22]. Once one admits this possibility, then it would influence the probability of detection in the

[22] Note that in Footnote 14, we have shown that as long as the probability of being detected is below an upper value p* (closed to 1), our model works in the sense that it is always beneficial for bureaucrats to choose to be corrupt.

direction opposite to what we have analysed. For example, if we consider the bureaucrat spending a proportion of his stolen money to reduce the probability of detection, then according to our model, as development takes place (i.e., capital increases) bureaucrat would be able to increase the spending on reducing the detection. This might lead to lower detection of corruption associated with higher level of development. Our argument is that this detection probability is not only a function of bureaucrat's hiding effort; it also depends on the government's monitoring expenditure. As long as the later effect is higher than the former, which is most probable case according to our model, detection probability would be a positive function of capital in net. Another point to be noted is that as development takes place, information flow becomes higher, which may cause more and more difficulty in hiding illegal income whereas detection would become more and more likely. Second, we have not considered the strategic complementarity effect that has been emphasized in Andvig and Moene (1990), Tirole (1996) and Putman (1993) among others. This view suggests that the probability a corrupt official will be detected is a decreasing function of the proportion of his colleagues who are also corrupt. The arguments similar to the first case hold for this case. However, we hope to keep these issues for further research.

Given these qualifications, our only claim is to have formalized, and we hope illuminated, an effect that is potentially important. Our model captures the general idea that corruption is detrimental to growth as it reduces the investible resources due to its illegality. We go even further to show that increase in probability of detection (i.e., risk of corruption) not only increases growth through reducing corruption but also this probability itself is increased by the level of economic development of the country.

The relationship between corruption and development is an issue on which much less has been written but about which there is still much to learn. To a large extent, measurement remains ahead of theory, though there are signs that the gap is being closed. Our intention in this paper has been to take a further step in this direction.

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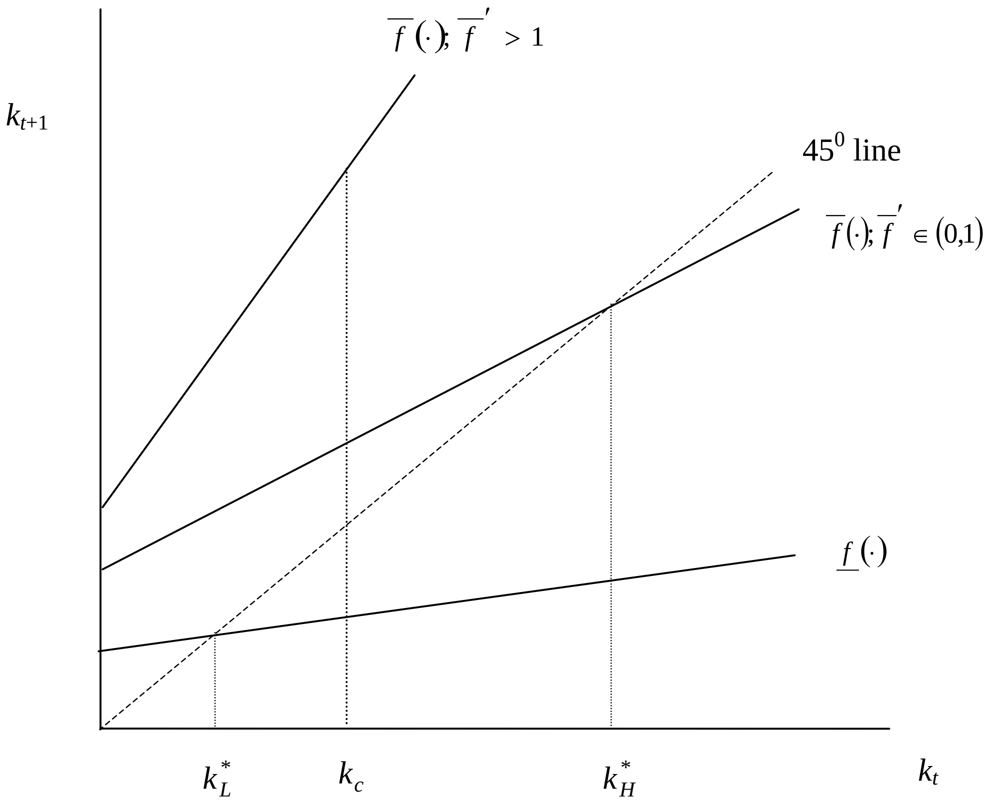
# Figure 1




# Figure 2