Modelling Corruption in a Cobb-Douglas Production Function Framework*

Moe Farida and
Fredoun Ahmadi-Esfahani+

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+ The authors are respectively a PhD candidate and an Associate Professor in the Discipline of Agricultural and Resource Economics, University of Sydney, NSW 2006

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Abstract

In this paper, we extend the Solow growth model to include corruption as a determinant of the multifactor productivity using a Cobb-Douglas production function framework. In addition to the classical components of any growth model (output, labor, capital), we incorporate corruption as a determinant of government expenditure, investment and foreign aid. It is proposed that output and growth are influenced by the level of corruption. This model is to be tested empirically to trace the corruptive behaviour in Lebanon based on the available time series data.

Key words*:* Corruption, economic growth, investment, government expenditure, foreign aid.

1. Introduction

The body of theoretical and empirical research on corruption has grown considerably in recent years (Elliot 1997; Rose-Ackerman 1999; Gill 1998; Girling 1997; HDC 1999; Kaufmann and Sachs 1998; Mauro 1995; Paul and Guhan 1997; Shleifer and Vishnay 1993; Stapenhurst and Kpundeh 1999; Vittal 1999; World Bank 1997). A preliminary analysis of the literature shows that corruption is recognised as a complex phenomenon, as the consequence of more deep seated problems of policy distortion, institutional incentives and governance. It thus cannot be addressed by simple legal acts proscribing corruption. In this paper, we explore several theories and models that explicitly incorporate the potential impact of corruption on output via the indirect effects of corruption on the arguments of the production function. Then, we present a model that will be used to measure the impact of corruption on economic growth in Lebanon. The focus will be on mathematical derivations, data sources, model extensions, limitations, and estimation techniques. Further, we will develop the empirical framework, and specify the estimation equations that will be used for our analysis. We then discuss the challenges and opportunities of employing the available data prior to conclusion.

2. Literature review

The old myth that corruption by its "intrinsic nature" is impossible to measure delayed the emergence of serious empirical analysis of corruption. There is a consensus that real magnitude of corruption cannot be measured. Nonetheless, the obvious difficulties in measuring corruption have not kept a number of entrepreneurs, multilateral development banks, and academics from attempting to do so. Conceptually, it is often difficult to accept the many limitations of the various measures of corruption. All widely used 'scientific' methods in the field of corruption evaluation hold value in achieving the goal, that is, to estimate the spread and map the structure of corruption. First, the general perception can be, and is regularly used as a sensitive core indicator of the feeling the 'lack of justice' in public transactions (Akerlof 1985). On the other hand, the incidence-based approach is more independent from media agenda, and the general sense of society. Finally, in the most cited and probably respected cross-country comparison of the "Transparency International Framework", corruption was primarily based on expert evaluation. The approach taken now is to transform the computation of corruption perception index (CPI), as a common index derived from different general polls and expert interviews (Knack 1995, Murphy 1993, Bardhan 1997, and Mandapaka 1995). In general, experience-based indicators appear to offer the greatest potential for comparability, since they avoid some of the problems associated with perception-based indicators.

Corruption is often modelled as a principal – agent problem. A principal delegates some decision power to an agent, where the principal's rules of preference in exercising the power are known to the agent, and the principal's problem is that the agent may serve his/her own interests rather than the principal's (Bardhan 1997). The literature also contains several different approaches that have been used in modeling corruption. The influence of corruption on economic growth has been modelled using economic growth models (Krueger 1974; Murphy 1993; Mandapaka 1995; Mauro 1995). In addition, corruption has been modelled using the game theoretic approach with three players: principle, agent, and hidden principal (Andvig 1990; Laffont 1991; Basu 1992; Mookherjee 1995; Acemoglu 2000). In addition, Swarm, as programming language, has been widely used (Turnovsky 1995; Jain 1998; Stapenhurst 1999) to simulate corruption models, and analyse the dynamic and evolutionary process of corruption on various parameters. Falling short of empirical evidence and profound experience, there is not even a theory available that may potentially assist in putting the various approaches into comparative perspective. The table below summarises the previous approaches used in modeling corruption:

Table 1 Previous models of corruption

Approach	Scholars	Models	Methods	Limitations	Findings
Economic growth It explores the relationship between corruption and economic growth	(Murphy 1993) (Mandapaka 1995) (Triole 1996) (Mauro 1997) (Bardhan 1997) (Hellman 2000)	Lucas type Rent Seeking Keynesian Neoclassical	OLS 2 stage LS	Subjective Surveys Endogeneity bias Sample size sensitivity	Only few were able to empirically prove the negative relationship between corruption and growth
Game theory It identifies the conditions that are necessary for corruption and those that are conductive to it	(Andvig 1990) (Laffont, 1991) (Basu 1992) (Mookherjee 1995) (Dixit 1997) (Elliot 1997) (Acemoglu 2000)	Principle / Agent Heterogeneous bureaucrats (Agents)	One stage game	Models the demand side Ignores the government involvement Corruption occurs in continuing relationships	This approach yields some useful insights into the notion of corruption
Multiple indicators multiple causes It considers observable data on potential indicators to predict values for unobservable (corruption)	(Weck 1983) (Frey 1984) (Balasa 1985) (Salvatore 1991) (Greenaway 1994) (Loayza 1996) (Schneider 1997) (Giles 1999)	LISREL MIMIC	MLE	Co-linearity between indicators Weak estimation techniques Lacks structural interdependence	The output of this model is a time series index that can be used to construct ordinal and cardinal time series of corruption
Simulation It tests the effectiveness of some proposed solutions to combat corruption	(Turnovsky 1995) (Jain 1998) (Stapenhurst 1999) (Hammond 2000) (Luna 2002) (Situngkir 2003)	Agent-based	SWARM STELLA	No way to detect unstable equilibrium Total convergence is not achieved in finite time	Many showed the strength of the cause-effect relationship between corruption and growth

As indicated in table 1, every approach has strengths and weaknesses. Different models (Lucas type, Keynesian, Agent-based …) and methods (OLS, 2 stage LS, MLE…) have been used. Only few who used the economic growth approach were able to empirically support the negative relationship between corruption and growth. This may be due to the endogeneity bias, subjective surveys and sample size sensitivity. On the other hand, although utilizing the game theory yields some useful insights into the notion of corruption, this approach ignores government involvement, models only the demand side of corruption, and involves one stage game while corruption occurs in continuing relationships. As for the MIMIC, where the output is a time-series index that can be used to construct ordinal and cardinal time series of corruption, this model lacks structural interdependence in addition to co-linearity between indicators. Finally, simulation models showed the strength of the cause-effect relationship between corruption and growth, but could not detect unstable equilibrium, and the total convergence was not achieved in finite time.

The economic growth approach has the ability to test the relationship between economic growth and corruption, but its main limitation lies in using the correct index of corruption in the objective function. Most of indexes of corruption that have been used (Mauro 1995, Knack 1995, Murphy 1993, Bardhan 1997, and Mandapaka 1995) were based on surveys. These indexes reflect either the general perception of the people on the level of corruption present in the country or the expertise perception, and they both fail to reflect the actual level of corruption present in the country. The current literature on the impact of corruption lacks a theoretical framework that incorporates the potential effect of corruption on output through its impact on the arguments to the production function. Nor does it address the effect of corruption through its impact on economic growth and development. The literature to date, has only examined the hypothesised influences separately, ignoring the larger potential aggregate impact of corruption on output. While the potential influence of corruption on output is not one of the conventional arguments for anti-corruption efforts, ignoring this potential effect would inject a priori bias into the model.

The key findings in the reviewed literature show a fragile negative relationship between corruption and economic growth (Mauro, 1995). However, many empirical findings proved that corruption discourages investment (Brunetti 1997), alters the composition of government spending (Wei, 1997), reduces the effectiveness of foreign aid through diversion of funds (Alesina, 1999), creates loss of tax revenues and monetary problems leading to adverse budgetary consequences (Murphy, 1993), and is likely to produce certain composition of capital flows that makes a country more vulnerable to shifts in international investors' sentiments and expectations (Lambsdorff, 2000). Although, the damaging effects of corruption on investment and economic growth are widely recognized, corruption also has adverse effects on human development, and increases the cost of basic social services (Kaufman, 1998). Hence, our research examines this fragile negative relationship between corruption and growth in the case of the Lebanese economy. Specifically, we intend to answer some basic research questions, if a change in the level of corruption leads to a change in:

- The steady state level of output per worker
- The per capita rate of growth in output
- Output through reducing the effectiveness of government spending, foreign aid, and investment

3. Theoretical framework

3.1 The basic model

In response to the various shortcomings in the theoretical reviews, we develop a neoclassical model of economic growth that explicitly includes human capital accumulation and the direct and indirect effects of corruption on economic growth. The neoclassical growth modelling approach to the question of the impact of corruption on economic growth may be superior to previous studies employing a variety of approaches that ignore the potential indirect effect of corruption on economic growth and development. Our theoretical model suggests that output and growth are influenced by the level of corruption. If, as illustrated in the theoretical model, corruption influences growth, then if one of the physical inputs in the production function suffers a quality loss in the presence of corruption, then this will also affect growth and the steady state level of output. We use of the work of Mankiw, Romer and Weil (MRW) (1992). This research extends the Solow model to include corruption as a determinant of the multifactor productivity which is the government expenditure in this case, since our operational definition of corruption in this paper is: the abuse of public power for private benefit. For simplicity, we will consider an economy that produces only one good. Output is produced with a well-behaved neoclassical production function with positive and strictly diminishing marginal product of physical capital. The Inada conditions assure that the marginal products of both capital and labor approach infinity as their values approach zero, and approach zero as their values go to infinity. The functional form of the production function is Cobb-Douglas:

$$Y_t = K_t^{\alpha} H_t^{\beta} \left[G_t\left(\rho\right) L_t \right]^{1-\alpha-\beta} \tag{1}$$

where Y_t is the aggregate level of real income, K_t is the level pf physical capital, H_t is the level of human capital, L_t is the amount of labor employed, G_t is the level of government expenditure, and ρ is the level of corruption in the country, where $G'(\rho) < 0$. Let 0 < α <1, 0 < β <1 and $\alpha + \beta$ <1. These conditions ensure that the production function exhibits constant returns to scale and diminishing return to each point. Time is indexed by the continuous variable (t). With the omission of the corruption term, the model yields standard neoclassical results. That is, the growth rate of output per worker is accelerated with increases in investments in physical capital and decreases in population growth, depreciation rate of capital, and the initial level of output per worker. The steady state equations are:

$$\frac{dK}{dt} = s_K Y_t - \delta_K K_t \tag{2}$$

$$\frac{dH}{dt} = s_H Y_t - \delta_H H_t \tag{3}$$

where S_K, S_H, δ_H and δ_K are parameters that represent, respectively, shares of income that are allocated to human and capital investment, and depreciation rate of human and physical capital. Moreover, population is exogenously determined and defined as $L_t = L_0 e^{nt}$ so that population growth is constant over time $(\frac{dL}{dt}) \Big/ L_t = n$.

Assuming full employment implies that labor force growth rate is also given by n. Solving for the steady state reduced equation reveals:

$$\ln(Y_t/L_t) = \ln(G_0) + gt + [\alpha/(1-\alpha-\beta)]\ln[S_k/(n+\delta_k+g)] + [\beta/1-\alpha-\beta]\ln[S_H/(n+\delta_H+g)] + G_t(\rho) \qquad (4)$$

As equation (4) reveals, steady state output per worker is an increasing function of initial level of government expenditure and its growth rate, physical and human savings and government expenditure. An expression for the growth of output per worker can also be expressed by differentiating with respect to time around the steady state level to obtain:

$$\ln y_t - \ln y_0 = (1-e^{-\lambda t})\{\ln(G_0) + gt - [(\alpha+\beta)/(1-\alpha-\beta)]\ln(n+\delta+g) + [\alpha/(1-\alpha-\beta)]\ln(S_K) + [\beta/(1-\alpha-\beta)]\ln(S_H) + G_t(\rho)\} - (1-e^{-\lambda t})\ln y_0 \qquad (5)$$

As before, since increase in corruption reduces government expenditure, upward movements in corruption have an inverse relationship with growth of output per worker. However, with the omission of the corruption term, equation (5) yields the standard neoclassical results. That is, the growth rate of output per worker is accelerated with increases in investments in physical and human capital and decreases in population growth, depreciation rate of capital, and initial level of output per worker. In an effort to model the effect of corruption on multifactor productivity, a structural form for multifactor productivity will be assumed. Schleifer (1993) and Mandapaka (1995) show that the effect of corruption on the economy is nonlinear and bounded by a corrupt-free output and a subsistence level of output. Since every government agent in an economy will not leave the productive sector to become corrupt, some level of output will be produced. To allow for specificity in the government expenditure function, let

$$G_t(\rho) = \bar{G}_t e^{-\gamma\rho} \qquad (6)$$

where $0 \le \rho \le 1$, and $\bar{G}_t = G_0 e^{gt}$ (7)

The parameter ρ is the index of corruption that we will use. γ determines the magnitude of the effect of corruption on government expenditure. Conventional government expenditure $\bar{G}_t$ is exogenous and grows at rate g. We assume that $\frac{dG_t}{d\rho} < 0$, and $\frac{d^2 G_t}{d\rho^2} > 0$. Equation (6) shows that if there is no corruption $(\rho = 0)$, then $\tilde{G}_t = G_t$. The same holds true for $\gamma = 0$. Since corruption does not affect all production function in the same way, a higher value of γ increases the effect of corruption. Ceteris Paribus, as γ approaches zero, the corruption function approaches unity and output is maximized. Equations (1), (2), and (3) can be expressed in intensive form:

$$y_t^* = e^{-\gamma\rho} k_t^{*\alpha} h_t^{*\beta} \tag{8}$$

$$\frac{dk_t^*}{dt} = s_k y_t^* - (n + \delta_k + g) k_t^* \tag{9}$$

$$\frac{dh_t^*}{dt} = s_h y_t^* - (n + \delta_h + g) h_t^* \tag{10}$$

where y=Y/L, k=K/L, h=H/L, $y_t^* = y_t / \tilde{G}_t$ (output per worker per government expenditure), $k_t^* = k_t / \tilde{G}_t$ (physical capital per worker per government expenditure) and $h_t^* = h_t / \tilde{G}_t$ (human capital per worker per government expenditure). At the steady state, equations (9) and (10) are equal to zero. Thus, setting them to zero, Equations (8), (9) and (10) become a system of three equations in three unknowns. The steady state levels of physical and human capital are as follows:

$$k_t^* = [s_K/(n+\delta_k+g)]^{(1-\beta)/(1-\alpha-\beta)} [s_H/(n+\delta_H+g)]^{(\beta)/(1-\alpha-\beta)} e^{-\gamma\rho} \tag{11}$$

$$h_t^* = [s_K/(n+\delta_k+g)]^{(\alpha)/(1-\alpha-\beta)} [s_H/(n+\delta_H+g)]^{(1-\alpha)/(1-\alpha-\beta)} e^{-\gamma\rho} \tag{12}$$

Substituting (11) and (12) into (8) results in a steady state equation for output per worker:

$$y_t^* = [s_K/(n+\delta_k+g)]^{(\alpha)/(1-\alpha-\beta)} [s_H/(n+\delta_H+g)]^{(\beta)/(1-\alpha-\beta)} e^{-\gamma\rho} \tag{13}$$

Recall that $y_t^* = Y_t / (\tilde{G}_t L_t)$. Substituting this into equation (13), multiplying by $\tilde{G}_t$ and taking natural logs yields:

$$\begin{aligned} \ln(Y_t/L_t) &= \ln(G_0) + gt + [\alpha/(1-\alpha-\beta)]\ln[s_K/(n+\delta_K+g)] \\ &+ [\beta/(1-\alpha-\beta)]\ln[s_H/(n+\delta_H+g)] - \gamma\rho \end{aligned} \tag{14}$$

For simplicity, let us assume that human capital and physical capital depreciate at the same rate (δ). Employing that assumption yields:

$$\ln(Y_t/L_t) = \ln(G_0) + gt - [(\alpha+\beta)/(1-\alpha-\beta)]\ln(n+\delta+g) + [\alpha/(1-\alpha-\beta)]\ln(s_K) + [\beta/(1-\alpha-\beta)]\ln(s_H) - \gamma\rho \tag{15}$$

Equation (15) shows that steady state output per worker is increasing in initial level of multifactor productivity, the trend term (gt) and its growth, and physical and capital investment rates. Higher initial levels of multifactor productivity increases steady state output per worker and the higher the growth rate of multifactor the higher the steady state output per worker, as well. The investment rates work themselves through equations (11) and (12). Higher investment rates increase the levels of physical and human capital per worker, which then increases output per worker through equation (8).

Output per worker, however, is decreasing in capital per worker depreciation $(n+\delta+g)$ and corruption. The effect of corruption depends on the value of γ . A positive value of γ means that corruption is output debilitating while a negative value causes corruption to be output enhancing. A value of zero reduces the steady state output level equation to that of MRW. The effect of corruption on a country's steady state level and economic growth is depicted in Appendix A. An increase in corruption reduces the productivity of capital by rotating the production function to the right. At the point A, the initial level of capital stock per worker (k_0) cannot be maintained and the economy moves to a lower level of capital stock per worker (k_1). In this process, the economy faces negative growth as it moves to (k_1) along with a reduced level of output per worker.

3.2 Convergence to the steady state

In keeping with MRW, approximating around the steady state level of output can derive the speed of convergence to steady state. The speed of convergence is represented by the first order linear differential equation:

$$\frac{d\ln y_t}{dt} = \lambda(\ln y^{ss} - \ln y_t) \tag{16}$$

where $\lambda = (n + \delta + g)(1 - \alpha - \beta)$. To find a solution to equation (16), we can rewrite this as $e^{-\lambda t}[(dy_t / dt) + \lambda \ln y_t] = e^{-\lambda t}(\ln y^{ss})$ which leads to:

$$\ln y_t = (1 - e^{-\lambda t}) \ln y^{ss} - (1 - e^{-\lambda t}) \ln y_0 \qquad (17)$$

where y_0 is the initial level of output of the economy. Subtracting left and right hand sides of equation (17) by ln y^{ss} with equation (15) yields an equation for convergence:

$$\ln y_t - \ln y_0 = (1 - e^{-\lambda t})\{\ln(G_0) + gt - [(\alpha+\beta)/(1-\alpha-\beta)]\ln(n+\delta+g) + [\alpha/(1-\alpha-\beta)]\ln(s_K) + [\beta/(1-\alpha-\beta)]\ln(s_H) - \gamma\rho\} - (1 - e^{-\lambda t})\ln y_0 \qquad (18)$$

Since the speed of convergence (λ) is a constant, equation (18) states that economic growth is a function of the initial level of multifactor productivity and its growth rate, population growth rate, physical and human capital investment rates, the level of corruption and the initial level of output. As before, the trivial conditions are the positive relationships between the time trend and the initial level of technology. Additionally, the traditional Solow Neoclassical results are present with this model. There is a negative effect of exogenous parameters such as population growth and depreciation rate. Conditional convergence is captured with the negative relationship between initial level of output and the level of economic growth.

Corruption reduces economic growth by acting as an offsetting force to the efficiencies obtained through improvements in multifactor productivity. Corruption reduces the effectiveness of physical and human capital and output per worker. Lower levels of output necessitate a lower level of investments since investment rates $(s_K \,\&\, s_H)$ are fixed. This will result in a lower level of investment that further contributes to lower levels of output. Hence, there is a negative effect on the growth of output per worker. As with the level equation (15), note that the sign of gamma determines if corruption is either output enhancing or output-debilitating. A positive gamma produces a negative effect on multifactor productivity while a negative gamma produces output-enhancing results. For consistency, a zero value of gamma reduces equation (18) to that of MRW. An inherent contribution of equations (15) and (18) is that they can be tested directly using OLS. To do so, certain normality and other assumptions must be made about the data and the way they were generated.

3.3 Model extensions

As mentioned before, the model discussed above is designed to capture the effect of corruption on economic growth via incorporating corruption with the multifactor productivity in a Cobb-Douglas production function. This will capture the corruptive behaviour within government officials in allocating the government resources. But, those officials not only have control over the government's expenditure, but also interfere in allocating resources (funds) coming from other sources such as international organizations (WB, IMF, UN, FAO, and UNDP), foreign governments, and other NGO's in the form of a foreign aid or from the private sector as investments. Hence, our model can be modified to examine how the level of corruption slows the economic growth not only through reducing the government expenditure level, but also via affecting the level of foreign aid and investment. Therefore, equation (1) can be reproduced in two additional forms:

$$Y_t = K_t^{\alpha} H_t^{\beta} \left[F_t(\rho) L_t \right]^{1-\alpha-\beta} \qquad (19)$$

$$Y_t = K_t^{\alpha} H_t^{\beta} \left[I_t(\rho) L_t \right]^{1-\alpha-\beta} \qquad (20)$$

Recall equation (6), and replace G (government expenditure) with F (foreign aid), then we have

$$F_t(\rho) = \tilde{F}_t e^{-\gamma_f \rho} \qquad (21)$$

Similarly, $I_t(\rho) = \tilde{I}_t e^{-\gamma_i \rho}$ (22)

γ_f determines the magnitude of the effect of corruption on foreign aid, and γ_i determines the magnitude of the effect of corruption on investment. Let us assume for now that the conventional foreign aid $\tilde{F}_t$ and investment $\tilde{I}_t$ are exogenous and they grow at the rates f and I respectively ($\tilde{F}_t = F_0 e^{ft}$ & $\tilde{I}_t = I_0 e^{it}$), where $\frac{dF_t}{d\rho} < 0$, $\frac{dI_t}{d\rho} < 0$, $\frac{d^2 F_t}{d\rho^2} > 0$ and $\frac{d^2 I_t}{d\rho^2} > 0$.

Therefore, in the same mathematical manipulations that produced equation (15), the following equations will be estimated using the data on foreign aid and investment, respectively:

$$\ln(Y_t/L_t) = \ln(F_0) + ft - [(\alpha + \beta)/(1 - \alpha - \beta)]\ln(n + \delta + f) + [\alpha/(1 - \alpha - \beta)]\ln(s_K) + [\beta/(1 - \alpha - \beta)]\ln(s_H) - \gamma_f \rho \quad (23)$$

$$\ln(Y_t/L_t) = \ln(I_0) + it - [(\alpha + \beta)/(1 - \alpha - \beta)]\ln(n + \delta + i) + [\alpha/(1 - \alpha - \beta)]\ln(s_K) + [\beta/(1 - \alpha - \beta)]\ln(s_H) - \gamma_i \rho \quad (24)$$

3.4 Estimation equations

The base model of real GDP level without corruption will be used to estimate the elasticities of output (physical and human capital) using non-linear least squares as the estimating procedures in the following equation:

$$\ln(GDP_t) = \beta_0 + \beta_1 \ln(\delta + POP_t + g_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 t + \varepsilon_t \quad (25)$$

The differences in time period, sample size and sample selection may lead to different results from that of MRW. To answer our first research question (does a change in the level of corruption lead to a change in the steady state level of output per worker), we will add the corruption variable to the base model, and estimate the following equations

$$\ln(GDP_t) = \beta_0 + \beta_1 \ln(\delta + POP_t + g_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 CORRUPTION_t + \beta_5 t + \varepsilon_t \quad (26)$$

$$\ln(GDP_t) = \beta_0 + \beta_1 \ln(\delta + POP_t + g_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 CORRUPTION_t + \beta_5 CORRUPTIONSQ_t + \beta_6 t + \varepsilon_t \quad (27)$$

The results of the above equations will show evidence if a change in the level of corruption leads to a change in the steady state level of output per worker. Although adding CORRUPTIONSQ in equation (27) will create high collinearity with CORRUPTION, which increases the variances of their estimated coefficients, but this is only to check if the coefficient of CORRUPTIONSQ is statistically inferior or superior to that of CORRUPTION. Comparing the results of the base model (without corruption) with equations (26) and (27), we will have evidence if the corruption function does impact multifactor productivity and the production function; hence, we answer our second research question (does a change in the level of corruption lead to a change in output through reducing the effectiveness of government expenditure). Similarly, equations (28), (29), (30), and (31) will be used to answer our third and fourth research questions respectively (does a change in the level of corruption lead to a change in output through reducing the effectiveness of investment, and foreign aid).

$$\ln(GDP_t) = \beta_0 + \beta_1 \ln(\delta + POP_t + f_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 CORRUPTION_t + \beta_5 t + \varepsilon_t \quad (28)$$

$$\ln(GDP_t) = \beta_0 + \beta_1 \ln(\delta + POP_t + f_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 CORRUPTION_t + \beta_5 CORRUPTIONSQ_t + \beta_6 t + \varepsilon_t \quad (29)$$

$$\ln(GDP_t) = \beta_0 + \beta_1 \ln(\delta + POP_t + i_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 CORRUPTION_t + \beta_5 t + \varepsilon_t \quad (30)$$

$$\ln(GDP_t) = \beta_0 + \beta_1 \ln(\delta + POP_t + i_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 CORRUPTION_t + \beta_5 CORRUPTIONSQ_t + \beta_6 t + \varepsilon_t \quad (31)$$

As for our fifth research question (does a change in the level of corruption lead to a change in the per capita rate of growth in output), the following equations (32) and (33) will be estimated, where the dependent variable will be the log difference of GDP per worker.

$$\ln y_t - \ln y_0 = \beta_0 + \beta_1 (\delta + POP_t + g_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 \ln(CORRUPTION_t) + \beta_5 \ln y_0 + \varepsilon_t \quad (32)$$

$$\ln y_t - \ln y_0 = \beta_0 + \beta_1 (\delta + POP_t + g_t) + \beta_2 \ln(INV_t) + \beta_3 \ln(EDU_t) + \beta_4 \ln(CORRUPTION_t) + \beta_5 \ln(CORRUPTIONSQ_t) + \beta_6 \ln y_0 + \varepsilon_t \quad (33)$$

Based on the results of estimating equations (32) and (33) in comparison with equation (25), we can have evidence if changing the level of corruption leads to a change in the per capita rate of growth in output

3.5 Data

The theoretical models (equations 15), (18), (23) and (24) contain parameters for corruption, investment rate for physical capital, the saving rate for human capital, population growth, the depreciation rate and multifactor productivity (government expenditure, foreign aid and investment). To proxy these variables, several sources are used. The corruption index from Political Risk Service's International Country Risk Guide (ICRG) attempts to measure corruption by investigating whether high-ranking government officials are likely to demand special payments and if illegal payments are generally expected in lower levels of government. These payments typically take the form of bribes connected with import-export licenses, exchange controls, tax assessment, police protection, or loans. The ICRG provides a numeric measure (ς_t) ranging from 0 to 6 with 0 signifying the most corrupt. This data base has monthly ratings for over 100 countries dating back to 1984. It is used extensively for research in corruption, appearing recently in works by Knack and Keefer (1995), Tanzi and Davoodi (1997, 2000), Everhart and Sumlinski (2001), Knack (2001), and Rajkumar and Swaroop (2002), Abdiweli and Hodan (2003), Seldadyo and Haan (2006), among other. This database, as with most other sources of indices of corruption suffers from the risk that "experts" are biased in their opinions. Thus, while no index of corruption is perfect, we have chosen the one with the longest time series available on Lebanon, which is the ICRG index.

Recall that the index of corruption in equation (1) is expressed as ρ. We will convert the raw corruption data (ς_t) from ICRG to an index ranging from "0" to "1" (the higher the index the higher the average corruption). As its proxy, the function

$$CORRUPTION(\varsigma_t) = (1 - \varsigma_t/6) \qquad (34)$$

will be used for two reasons. First $CORRUPTION(\varsigma_t)$ makes output a negative function of corruption. Second, since (ς_t) is bounded by 0 and 6, therefore, $CORRUPTION(\varsigma_t)$ is bounded by 0 and 1. As a test of linearity of corruption, the corruption function will enter the production function both linearly and non-linearly. Therefore, ρ will take on two specific forms:

$$CORRUPTION = (1 - \varsigma_t/6) \qquad (35)$$

$$CORRUPTIONSQ = (1 - \varsigma_t/6)^2 \qquad (36)$$

The table below provides a list of the variables and parameters used in the analysis including their sources:

Table 2 Data description

Variable name	Source	Description
ς_t	ICRG – Compiled by Political Risk Services	Average corruption from 1985-2006 for Lebanon. Corruption survey data ranging from “0” to “6”, where “6” relates to the least
CORRUPTION	Derived using raw corruption variable, ς_t	Using equation 3.26, we convert raw corruption data to an index ranging from “0” to “1”. the higher the index the higher the
CORRUPTIONSQ	Derived using raw corruption variable, ς_t	CORRUPTIONSQ=CORRUPTION*CORRUPTION
GDP	IMF; Bank of Lebanon	Real per capita GDP at current prices in US Dollars
INV	World Bank	Real investment share of GDP
EDU	World Bank	Education expenditure as a percentage of GDP
POP	Penn World Table (2006)	Population growth
g	IMF; Bank of Lebanon	Government expenditure growth
f	Lebanese Ministry of Finance	Foreign aid growth
i	Lebanese Ministry of Finance	Investment growth
δ	IMF (2006)	Depreciation rate of capital assumed to be 4% (0.04)

4. Conclusion

Measuring corruption requires a model that pays special attention to the kind and level of corruption. Moreover, accurate data are needed to estimate any sophisticated model assessing the level of corruption. In this paper, we derived a model of corruption, using a Cobb-Douglas production function framework. Further, we identified the data sources, model extensions, limitations and estimation techniques. This model is to be tested empirically to trace the corruptive behaviour in Lebanon based on the available time-series data. The implications of the results for the further refinement of the model are yet to be explored.

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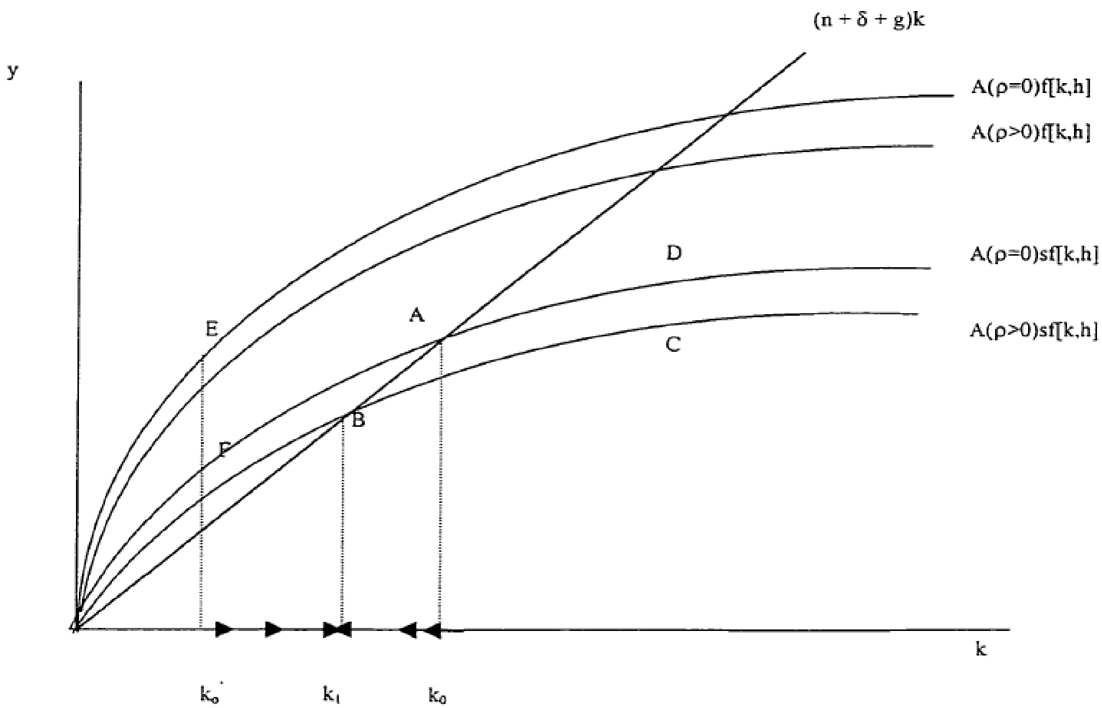
Appendix

Appendix A: Dynamics of Corruption on physical capital and output



The economy begins with a corruption-free level of production and savings function as denoted by subscript ρ. As the level of corruption increases, the sustainable level of capital falls from k_0 to k_1 and output falls accordingly. Therefore, increases in corruption reduce economic growth and output per worker.

Vita

Moe Farida
Agricultural and Resource Economics
University of Sydney
NSW 2006 - Australia
mfar4202@usyd.edu.au

Research: Economics of Corruption, Development Economics, and Environmental Economics
Dissertation Topic: The Impact of Corruption on Economic Growth in Lebanon

Papers: Australian Agricultural and Resource Economics society, 50th Annual Conference.
Paper: "Corruption and Economic Growth: A Critical Review of Literature"
February 8, 2006.

Australian Agricultural and Resource Economics society, 51st Annual Conference.
Paper: "Modelling Corruption in a Cobb-Douglas Production Function Framework"
February 13, 2007.

Education: PhD, Agricultural Economics
University of Sydney - Australia, 2005 – Present

MSc in Management
University of Surrey – UK, 2001 – 2002

B.S. Agricultural Engineering
American University of Beirut – Lebanon, 1997 – 2001

Experiences: University Tutor, Faculty of Agricultural and Resource Economics, University of Sydney, July 2005 – Present

Assistant General Manager, Fraick Bros – LEMCI, January 2004 – July 2005

Lieutenant, Lebanese Army, January 2003 – January 2004

References: Available upon request