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CORREPTION, PUBLIC EXPENDITURE, AND HUMAN CAPITAL ACCUMULATION

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Abstract

In this paper we investigate the effect of corruption on human capital accumulation through two channels. The first channel is through the effect of corruption on the public expenditure on education and the second channel is through the effect of corruption on the physical capital investment. Public expenditure on education affects positively human capital, while physical capital can obsolete human capital. Initially, we construct an endogenous two-sector growth model with human capital accumulation and by considering corruption as an exogenous variable we try to explore the impact of corruption on the allocation of public expenditure and as such on the distribution of human capital across different sectors. The theoretical model's results suggest that corruption has different effects on human capital accumulation through the two channels. Then we use a smooth coefficient semi-parametric model to capture possible non-linearities, and the results support the existence of non-linearities between human capital and corruption.

KEY-WORDS: Corruption; Public Expenditure; Economic Growth; Human Capital Investment; Semiparametric Estimation

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1. INTRODUCTION

The topic of corruption has received recently a lot of attention in the economic literature, with some recent surveys on the topic being the papers by Svensson (2005), Aidt (2009) and Campos et al. (2010). Corruption is closely related with rent-seeking behavior and the misallocation of talent. According to Murphy, Sleifer and Vishny (1991), Murphy and Vishny (1993) and Acemoglu and Verdier (1998) in the presence of corruption, investment in the more innovative sectors of the economy is less profitable due to higher transaction costs and this reduces the incentives for investment in R&D. Furthermore, due to corruption there is misallocation of public resources and in general public expenditures are less efficient, something that may also lead to a reduction of investment in physical capital. All the previous arguments formulate the general framework which examines the negative effect of corruption on economic growth. In this context important empirical contributions on this area are among others Mauro (1995), Mironov (2005) and Mo (2001). However, there are also arguments that support the idea that corruption can have a positive effect on economic growth and can be seen as a mechanism which increases efficiency in countries where institutions are not functioning well by reducing barriers due to high red tape, see Aidt et al. (2008).[1]

The theoretical literature of the corruption and economic growth nexus is very rich. Some papers in that context are that of Sarte (2000), who analyses the effect of bureaucratic corruption on growth, Angeletos and Kollintzas (2000), who investigate a broader definition of corruption which includes rent-seeking in an endogenous growth model with R&D and find that corruption slows down innovation and growth, without taking into account any additional effects that corruption may have in the composition of public expenditures. Mauro (2004) tries to explain the persistence of corruption in some countries by arguing that when corruption is widespread then there is no incentive for individuals to fight against it. In that case, in the presence of wide spread corruption a corrupted individual is more difficult to be caught and so he or she can allocate more time on rent-seeking activities than on more productive activities. An endogenous growth and corruption paper worth mentioning is that of Barreto (2000), who uses a neoclassical growth model to find that the effect of corruption is mainly to redistribute income and that it may also

[1] Some older papers that were making similar arguments are Leff (1964) and Huntington (1968).

have positive effects in the presence of much bureaucratic red tape as found by Aidt et al. (2008). Blackburn et al. (2006) show that corruption negatively affects growth since some public resources are being spent in mechanisms for corruption reduction and are not used directly for investment in physical capital. Finally, Ebben and Vaal (2011) show that in an environment of low quality of institutions, corruption can be useful for economic growth as it overcomes red tape.

The purpose in this paper is to investigate the effect of corruption on human capital accumulation. It is well known from the empirical literature that human capital has an unclear role in economic growth,[2] even if (endogenous) growth theories[3] consider human capital as the main engine of growth. In this context very little attention has been given to the effect of corruption on human capital accumulation. One of the very few attempts is Rogers (2008) who used standard OLS regression methods but his results are not robust to the change of sample or to alternatively measures of corruption.

One important theoretical paper which takes into account the effect of corruption on human capital accumulation is that of Ehrlich and Lui (1999). They investigate the negative effect of bureaucratic corruption on human capital accumulation by assuming that corruption affects negatively human capital because more time is invested in political capital to improve the bureaucratic power of individuals than on productive education sector. Pecorino (1992) investigates the impact of rent seeking on human capital accumulation, while Ghosh and Gregoriou (2010) find that corruption affects exogenously the productivity of different types of public spending but not the allocation of human capital among sectors as we do in our paper. Empirical papers of Devarajan et al. (1996) and Ghosh and Gregoriou (2008) justify empirically that public spending on sectors different from education has more positive impact on growth. That may be due to the fact that there may be already too much public investment on education and its marginal effect in that case would be small. Alternatively, it may be because of the presence of corruption in the education sector. However, contrary to our model, they do not use human capital accumulation and do not check for the impact of corruption in the allocation of government spending. Blackburn et al. (2011) consider an OLG model of economic growth with

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2 Benhabib and Spiegel (1994), Islam (1995) and Pritchett (1996) provide controversial empirical results for the role of human capital on economic growth.

3 Uzawa (1965), Lucas (1988) and Romer (1990) provide a very good exposition of theoretical models of endogenous growth.

endogenous corruption which arises due to the ability of bureaucrats to steal public funds and to reduce the quality of public goods provision. However, their model does not incorporate human capital accumulation as we do in our model.

The contribution of our paper is that we make two hypotheses for the formation of human capital: i) the allocation of public expenditure among different sectors affects the fraction of human capital that is distributed between final output sector and education sector and ii) we assume that the growth rate of physical capital[4] can affect positively or negatively human capital accumulation. Though these channels corruption can create distortions which can affect indirectly human capital accumulation. Furthermore, we check empirically our specification of human capital and we uncover a non-linear effect of corruption on the two determinants of human capital: public expenditure on education and growth rate of physical capital

Empirically, we try to investigate potentially the presence of non-linear effects of corruption on the two components of human capital. To carry out our empirical analysis we use semi-parametric methods in order to explore potentially non-linearities. Our results, suggest that public expenditures have a positive but declining effect on human capital accumulation. This may be due to the fact that either corruption cannot distort at the same level the effect of public expenditures on education as it does in other sectors or that because of corruption individuals have an incentive to accumulate more human capital. Furthermore, corruption is detrimental to human capital mainly through the deterioration of physical capital investment.

In section 2 we provide a theoretical model with exogenous corruption. In section 3 we provide the analytical framework needed for the empirical part and in section 4 we provide a brief exposition of the econometric methods that we use and the empirical results. Finally, in section 5 we conclude.

2. THEORETICAL MODEL WITH EXOGENOUS CORRUPTION

2.1 SET UP OF THE MODEL

In our economy total public expenditures are given as: $G = G_H + G_Y$ where (G_H) is the public expenditure on education and (G_Y) is the public expenditure on other activities, whereas

[4] For justification of physical capital entering in the accumulation of human capital see Albelo (1999).

$s_H = \frac{G_H}{G}$ and $s_Y = \frac{G_Y}{G}$ are the shares of public expenditures on total public expenditures which are used in education and final output respectively. A necessary constraint is: $s_H + s_Y = 1$. Corrupted bureaucrats are able to steal a fraction $(1-\zeta)s_H$ from the education sector and $(1-\delta)s_Y$ from the final output sector with $\delta, \zeta \in (0,1)$. So, the actual fraction which appears in the education sector is ζs_H and that in the final output sector is δs_Y. At a more general level of the analysis we assume that the corruption level is different between sectors or in other words that bureaucrats can steal more easily public resources from one sector than from another.[5] In our economy households take into account the actions of corrupted bureaucrats when they choose how to allocate their human capital but corruption in our model is exogenous and we do not analyze the incentives of bureaucrats to be corrupted and therefore how corruption appeared in the first place. Furthermore, we assume no population growth since we are not interested to examine demographic issues and also that the population level is normalized to one: ($\frac{\dot{L}}{L} = n = 0$ and $L = 1$) and as such the aggregate and per capita variables coincide. Individuals in order to allocate their human capital between sectors take into account the net fraction of resources which is provided in each sector after corruption. The fraction of human capital which enters into the education sector is:

$$u_1 = f(\zeta s_H), \tag{1}$$

The fraction of human capital which enters into the production of final output sector is:

$$u_2 = g(\delta s_Y) = g(\delta(1-s_H)), \tag{2}$$

One important assumption that guarantees a simultaneous determination of s_H and γ in the balanced growth path equilibrium (BGPE) as it is shown in proposition 4 is that the functions $f(\zeta s_H)$ and $g(\delta(1-s_H))$ are monotonic and therefore invertible functions, which in addition agrees with the constraint of the allocation of human capital across sectors: $f(\zeta s_H) + g(\delta s_Y) = 1$. An extra assumption which verifies that the Hamiltonian corresponds to a

5 For the different magnitude of corruption between sectors see Croix and Delavallade (2006). However, we prefer not to make any assumption regarding which the relative sizes of ζ or δ .

maximization problem is that the function $f(\zeta s_H)$ is concave $\left[f''(\bullet)<0\right]$. This assumption implies that we have smaller increase in the fraction of human capital which enters into education sector due to an increase in the net from corruption public resources which are oriented for education. An intuition is that individuals can postpone working by entering into education but this cannot be a situation which lasts for long period, since they need to find a job and to live into a more stable working environment. From the constraint $f(\zeta s_H)+g(\delta s_Y)=1$, if the function $f(\zeta s_H)$ is concave then the function $g(\delta s_Y)$ is convex. It can be shown that an extra necessary condition in order the solution of the Hamiltonian function to correspond to a maximum is that: $(1-\alpha)\left[g'(\delta(1-s_H))\right]^2 > g(\delta(1-s_H))\bullet g''(\delta(1-s_H))$. In order $f(\zeta s_H)$ to be both concave and monotonic increasing we need to assume that $f(\zeta s_H)$ is bounded from above. This condition in mathematical form is like: for $\zeta s_H \to 1 \Rightarrow f(1) \to f_{\max} < 1$ and similarly, $\delta s_Y \to 1 \Rightarrow g(1) \to g_{\max} < 1$. In order always to have an interior solution for the allocation of human capital across sectors we need $f(0)>0$ and $g(0)>0$. Another important implication of this assumption is that even if corruption is zero or at a maximum level or even if an economy has public expenditures or not to allocate among sectors always individuals will decide to distribute their human capital among sectors. The social planner indirectly affects the distribution of human capital among sectors through the functions $f(\zeta s_H)$ and $g(\delta s_Y)$ by deciding on s_H and taking as given the level of corruption. The restrictions for defining well the problem are the followings:

$$u_1+u_2=1 \Rightarrow u_2=1-u_1=1-f(\zeta s_H), \tag{3}$$

$$f(\zeta s_H)+g(\delta s_Y)=1, \tag{4}$$

$$f(\zeta s_H), g(\delta s_Y) \in (0,1) \ , \tag{5}$$

Together with $f'>0$, $g'>0$ and f, g are bounded and invertible functions. (6)

So in this economy the human capital accumulation is described from the following equation:

$$\dot{H}=\sigma H_H+\varphi\gamma_K H \Rightarrow \dot{H}=\sigma\left(f(\zeta s_H)\right)H+\varphi\gamma_K H \tag{7}$$

We have that $\left(H_H\right)$ is the human capital that is used in the education sector and its fraction into that sector is equal to: $\frac{H_H}{H}=f\left(\zeta s_H\right)$. The parameter $\sigma>0$ represents the productivity parameter of human capital and $\varphi\in\mathbb{R}$ represents a scale parameter that describes possible complementarities or substitutabilities between physical and human capital growth. Actually, as we shall show in section 2.2, this parameter plays a crucial role in the results we are going to derive in the long run equilibrium and should be negative and less than one in absolute value which means that the growth rate of physical capital plays the role of an endogenous depreciation rate. The fraction of human capital which is employed into the final output sector is a function as well of the net resources after corruption and equals to: $\frac{H_Y}{H}=g\left(\delta s_Y\right)=g\left(\delta\left(1-s_H\right)\right)$.

We consider an economy in which the social planner chooses consumption goods, how much to invest in physical capital and how to allocate public expenditures between sectors by taking into account that this choice affects indirectly the allocation of human capital between sectors.

The production function of the economy at the aggregate level is the following:

$$Y=AH_Y^{\alpha}K^{1-\alpha} \text{ with A=1 } \rightarrow Y=H_Y^{\alpha}K^{1-\alpha} \tag{8}$$

Where (A) is the total factor productivity and we normalize it equal to 1, since we have exogenous technological progress. The physical capital accumulation is described by:

$$\dot{K}=Y-G-C, \tag{9}$$

By following Barro (1990) we consider a balanced budget constraint for government and implement the following condition: $G=G_H+G_Y=\tau Y\Rightarrow$

$$\dot{K}=\left(1-\tau\right)H_Y^{\alpha}K^{1-\alpha}-C=\left(1-\tau\right)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha}H^{\alpha}K^{1-\alpha}-C, \tag{10}$$

Distortionary taxes are considered exogenous and τ is assumed to be constant over time.[6] In this model, we consider that both G_Y and G_H have only an indirect effect on the production function

6 In this model we are not interested in optimal taxation and we do not make any assumption on possible effects of corruption on taxes. For the connection between corruption and tax structure, see among others Fisman and Svensson (2002), Gordon and Li (2005), and Litina and Palivos (2011). Furthermore we avoid from the analysis to use total public expenditures because we are not interested in the optimal public size. For this literature see Johnson et al. (1999) and Tanzi and Davoodi (1997).

and on the equation of human capital accumulation through $s_Y = \frac{G_Y}{G}$ and $s_H = \frac{G_H}{G}$ respectively. This is a simplification assumption which is very useful in order to estimate later the equation of human capital accumulation. Furthermore, for simplicity we assume a zero depreciation rate for both human and physical capital.[7]

The instantaneous utility function of the representative agent is: $U(C) = \frac{C^{1-\theta} - 1}{1-\theta}$, with $\theta > 0$ to be the inverse of the inter-temporal elasticity of substitution. So the social planner has to maximize the following problem:

$$\underset{\{C_t, s_H, H_t, K_t\}_{t=0}^{+\infty}}{Max} U \equiv \int_0^{+\infty} \left(\frac{C_t^{1-\theta} - 1}{1-\theta} \right) e^{-\rho t} dt, \qquad \rho > 0; \qquad \theta > 0 \tag{11}$$

$$s.t.: \quad \dot{H} = \sigma\left(f\left(\zeta s_H\right)\right) H + \varphi \gamma_K H, \qquad \sigma > 0; \qquad f \in [0,1], \qquad \forall t \tag{12}$$

$$\dot{K} = (1-\tau) H_Y^{\alpha} K^{1-\alpha} - C = (1-\tau)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha} H^{\alpha} K^{1-\alpha} - C, \qquad \forall t \tag{13}$$

along with the transversality conditions: $\lim_{t\to\infty} \lambda_t H_t = 0$ and $\lim_{t\to\infty} \mu_t K_t = 0$ (14)

and the initial conditions: $\mathrm{H}(0) > 0$ and $\mathrm{K}(0) > 0$ given. (15)

For notational simplicity we avoid the time subscripts and we define the following current value Hamiltonian function that the social planner has to maximize:

$$\underset{\{C_t, s_H, H_t, K_t\}}{Max} J = \frac{C^{1-\theta} - 1}{1-\theta} + \lambda\left[\left[\sigma\left(f\left(\zeta s_H\right)\right) + \varphi\gamma_K\right]\right] H + \mu\left[(1-\tau)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha} H^{\alpha} K^{1-\alpha} - C\right] \tag{16}$$

DEFINITION: *BALANCED GROWTH PATH* (BGP) *EQUILIBRIUM*

A Balanced Growth Path (BGP) equilibrium in this economy is a framework where:

i) All time-dependent variables grow at a constant possibly positive exponential rate; ii) The ratio of the two endogenous state variables, K_t / H_t, remains invariant over time.[8]

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[7] One can say that the term $\varphi\gamma_K$ in the equation of human capital can play the role of a depreciation rate; however the concept of depreciation rate is broader than the term $\varphi\gamma_K$ in the equation of human capital accumulation. This term shows possible negative effects of corruption on human capital through the accumulation of physical capital and it's not just an obsolesence effect. Furthermore, the addition of a depreciation rate in the equation of physical capital accumulation will not add anything extra in the analysis.

[8] In a decentralized equilibrium framework it can be proved that the returns of the two assets (K and H) are equal and so in equilibrium the two assets should grow in the same way.

The reason of having the same growth rate for the human capital and the physical capital is because both factors are necessary for the aggregate production function. If for example physical capital grows faster than human capital then in the long run $(t \to \infty)$ human capital will become infinitely small relative to physical capital (especially in the case where physical capital acts as an endogenous depreciation rate for human capital). This assumption will lead in the long run in the coexistence of the two forms of capital in the aggregate production function.

2.2 BGP ANALYSIS

PROPOSITION 1

Along the BGP equilibrium, we have:

$$\gamma = \frac{\sigma\left[f(\bullet)\right]}{1-\varphi} \;, \; \varphi \neq 1 \text{ and } \varphi < 1, \text{ for } \gamma > 0 \tag{17}$$

Proof: It comes by considering $\gamma_H = \gamma_K = \gamma$ in the equation of human capital accumulation.■

The next proposition shows the growth rate of the economy described only from the parameters of the model and from values of variables which are in BGP. It is derived by using all the appropriate FOCS and the result of equation (17).

PROPOSITION 2

Along the BGP equilibrium, we have:

$$\gamma_Y = \gamma_C = \gamma_H = \gamma_K = \gamma = \frac{\sigma\left(f\theta - 1 + \varphi\right)}{(1-\varphi)\varphi} + \frac{\rho}{\varphi}, \tag{18}$$

Proof: This result comes by using the FOCS conditions of the maximization problem and also the equation (17). So it is the actual formula for the growth rate of the economy in BGP. For the derivations of this expression see *Appendix A*. ■

The next proposition shows under what conditions the growth rate from equation (18) is positive and both $\frac{d\gamma}{d\rho}<0$ and $\frac{d\gamma}{d\theta}<0$ and also that TVC holds.

PROPOSITION 3

Along the BGP equilibrium, we have:

For $\gamma>0$; $\frac{d\gamma}{d\rho}<0$ and $\frac{d\gamma}{d\theta}<0$, we need $\varphi<0$, $1\text{-}\varphi > f\bullet\theta$ and $\rho<\frac{\sigma(1-\varphi-f\theta)}{(1-\varphi)}$. The TVC always holds.

Proof: It comes immediate from Eq. (18). ■

The parameter restriction of $\varphi<0$,[9] implies that the human capital and the physical capital are substitutes. This is important condition for the structure of this model, otherwise if they are complements then in case that an economy is very impatient (high values of ρ and θ), then the growth rate of the economy will be negative, $\downarrow\gamma_K \Rightarrow \downarrow\gamma_H \Rightarrow \gamma_Y<0$.

The next proposition shows what extra restriction should exist on φ in order $\frac{d\gamma}{d\rho}<0$ and $\frac{d\gamma}{d\theta}<0$.

PROPOSITION 4

Along the BGP equilibrium, we need $|\varphi|<1$ in order $\frac{d\gamma}{d\rho}<0$ and $\frac{d\gamma}{d\theta}<0$.

Proof: The proof is mainly intuitive. When $\rho\uparrow$ and/or $\theta\uparrow \Rightarrow \downarrow savings \Rightarrow \downarrow\gamma_K \Rightarrow \uparrow\gamma_H$ (because physical and human capital are substitutes). In order $\frac{d\gamma}{d\rho}<0$ we need the increase of human capital accumulation to be less than the reduction of physical capital accumulation due to the reduction in savings. We know from equation (12) that $\frac{d\gamma_H}{d\gamma_K}=\varphi<0$ and in order the total effect of ρ to be negative on γ we need: $\left|\frac{d\gamma_H}{d\gamma_K}\right|<\left|\frac{d\gamma}{d\rho}\right| \Rightarrow |\varphi|<\frac{1}{|\varphi|} \Rightarrow |\varphi|<1$. Similary, for θ, in order $\frac{d\gamma}{d\theta}<0$ we need again the increase of human capital accumulation to be less than the

9 Bartel and Sicherman (1995) find empirically that human and physical capitals are substitutes, because it is a common practice to exist training on the job in the more advanced economies and therefore physical capital is a substitute of official education. Also, in our empirical part we find the same negative relationship between the growth rate of human and physical capital.

reduction of physical capital accumulation due to the reduction in savings. From equation (12) as usual we have $\frac{d\gamma_H}{d\gamma_K}=\varphi<0$ and in order the total effect of θ to be negative on γ we need:

$\left|\frac{d\gamma_H}{d\gamma_K}\right|<\left|\frac{d\gamma}{d\theta}\right|\Rightarrow|\varphi|<\frac{\sigma f(\bullet)}{|\varphi|(1-\varphi)}\ \Rightarrow|\varphi|^2<\frac{\sigma f(\bullet)}{(1-\varphi)}<1$, since $f(\bullet)\in(0,1)$ and $(1-\varphi)>1$ for $\varphi<0$, it is expected that the second restriction for satisfying $\frac{d\gamma}{d\theta}<0$ quarantees that $|\varphi|<1$ still holds.[10] ■

The intuition behind these conditions and this proposition is that the decrease of savings in a more impatient economy creates a higher decrease on physical capital accumulation than the possible increase on human capital accumulation due to the existence of substitutabilities of the two factors. The next proposition shows that there exists simultaneously an endogenous growth rate (γ) and an endogenous share of public expenditure on education (s_H).

PROPOSITION 5

Along the BGP equilibrium, we have a simultaneous determined value for (γ^*) and for (s_H^*) given by $\gamma^*=\frac{\sigma\left(f\left(\zeta s_H^*\right)\theta-1+\varphi\right)}{(1-\varphi)\varphi}+\frac{\rho}{\varphi}$, and $\left(1-s_H^*\right)=s_Y^*=\frac{\zeta-f^{-1}\left[\frac{(1-\varphi)[\varphi\gamma+\sigma-\rho]}{\sigma\theta}\right]}{\zeta}$ (19), respectively, when we have $\{\sigma>\rho$ and $\rho-\varphi>\sigma\ \}$, which is always true iff $\varphi<0$, and $\left\{0<\frac{\rho-\sigma}{\varphi}<\gamma\right\}$.

Proof: The proof is in the *Appendix A*. The important assumption for this proof is that the function $f(\bullet)$ is invertible. ■

The next proposition shows the effect of the parameters of the model $(\theta;\zeta;\rho;\sigma$ and $\varphi)$ on the endogenous share of public expenditure on education.

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10 Mulligan and Sala-i-Martin (1993) suggest that σ should have a value less than 1.

PROPOSITION 6

By using the results from the previous propositions along the BGP equilibrium, we have:

i) $\frac{ds_H}{d\zeta} < 0$ and $\frac{ds_Y}{d\zeta} > 0$, ii) $\frac{ds_H}{d\varphi} > 0$ and $\frac{ds_Y}{d\varphi} < 0$ if $\gamma > \frac{\sigma - \rho}{1 - 2\varphi} > 0$, otherwise $\frac{ds_H}{d\varphi} < 0$ and $\frac{ds_Y}{d\varphi} > 0$ if $\gamma < \frac{\sigma - \rho}{1 - 2\varphi}$, iii) $\frac{ds_H}{d\rho} < 0$ and $\frac{ds_Y}{d\rho} > 0$, iv) $\frac{ds_H}{d\theta} < 0$ and $\frac{ds_Y}{d\theta} > 0$ and finally

$\frac{ds_H}{d\sigma} > 0$ and $\frac{ds_Y}{d\sigma} < 0$.

Proof: The proof comes from an immediate differentiation of equation (19). Some derivations are provided in the *Appendix A*. ■

When due to corruption more public resources are stolen from the education sector then the public expenditure in education should increase in order to maintain enough fraction of human capital into education sector. If an economy has growth rate over $\frac{\sigma - \rho}{1 - 2\varphi}$ then if increases φ, which means that $\varphi \to 0$ since $\varphi < 0$, then the growth rate of physical capital is less detrimental for human capital, and in that case more public resources should be oriented into the education sector since human capital is the engine of growth for this group of countries. On the contrary, in countries with lower growth than $\frac{\sigma - \rho}{1 - 2\varphi}$, less public resources shoud go into the education sector relatively to the final output sector. The intuition behind this result is that in less developed countries the stock of physical capital is quite low and therefore there is no negative impact of physical capital on human capital. Economies which are more impatient (higher values of θ and ρ), have less savings and lower physical capital acccumulation and in that cases it is more important to increase the public resources which are attributed into the final output sector relative to the public resources for education. Finally, when the productivity of education sector is high (higher values of σ), then the higher is the public expenditure on education the higher are the potential positive externality effects of human capital into the economy.

The next proposition shows the effect of corruption in the two sectors in the growth rate of the economy.

PROPOSITION 7

$\frac{d\gamma}{d\delta}=-\frac{\sigma g'\theta s_Y}{(1-\varphi)\varphi}>0,$ for $s_Y\in(0,1); g'>0,$ $|\varphi|<1$ and $\varphi<0,$ which means

$\frac{d\gamma}{d(1-\delta)}<0$, and

$\frac{d\gamma}{d\zeta}=\frac{\sigma f'\theta s_H}{(1-\varphi)\varphi}<0,$ for $s_H\in(0,1); f'>0,$ $|\varphi|<1$ and $\varphi<0,$ which means $\frac{d\gamma}{d(1-\zeta)}>0$.

Proof: This result comes by differentiating equation (18) with respect to δ and ζ respectively. ■

We know from equation (13), that $\gamma_K=(1-\tau)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha}H^{\alpha}K^{-\alpha}-C/K$.

Then $\frac{d\gamma_K}{d\delta}=(1-\tau)\alpha\delta(1-s_H)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha-1}g'H^{\alpha}K^{-\alpha}>0$. In case that corruption increases in that sector $\left[\uparrow(1-\delta)\Rightarrow\downarrow\delta\right]$ we have a reduction on $\left(\downarrow\gamma_K\right)$ and since the physical capital and human capital are substitutes then $\frac{d\gamma_H}{d\delta}=\frac{\partial\gamma_H}{\partial\gamma_K}\frac{\partial\gamma_K}{\partial\delta}=\varphi\frac{\partial\gamma_K}{\partial\delta}<0$, because $\varphi<0$ and $\frac{\partial\gamma_K}{\partial\delta}>0$. But since $|\varphi|<1$ $\Rightarrow\left|\frac{d\gamma_H\uparrow}{d\delta\downarrow}\right|<\frac{d\gamma_K\downarrow}{d\delta\downarrow}\Rightarrow\frac{d\gamma}{d(1-\delta)}<0$,

because the increase of γ_H is smaller than the decrease of γ_K, the total effect of corruption that exists in the final output sector on economic growth is negative. Similarly, if we substitute in equation 13 the constraint:

$g\left(\delta(1-s_H)\right)=1-f\left(\zeta s_H\right)$,

then $\gamma_K=(1-\tau)\left[1-f\left(\zeta s_H\right)\right]^{\alpha}H^{\alpha}K^{-\alpha}-C/K$ and

$\frac{d\gamma_K}{d\zeta}=-(1-\tau)\alpha\zeta s_H\left[1-f\left(\zeta s_H\right)\right]^{\alpha-1}f'H^{\alpha}K^{-\alpha}<0$. In that case if corruption increases in the education sector $\left[\uparrow(1-\zeta)\Rightarrow\downarrow\zeta\right]$ it leads into more public resources in the final output sector relative to education sector and therefore we have an increase on $\left(\uparrow \gamma_K\right)$. However, since the physical and human capital are substitutes, $\frac{d\gamma_H}{d\zeta} = \frac{\partial \gamma_H}{\partial \gamma_K}\frac{\partial \gamma_K}{\partial \zeta} = \varphi \frac{\partial \gamma_K}{\partial \zeta} > 0$ because $\varphi < 0$ and $\frac{\partial \gamma_K}{\partial \zeta} < 0$. Together with the important parameter restriction for φ proven in proposition 4, $\left[|\varphi| < 1\right] \Rightarrow \left|\frac{d\gamma_H \downarrow}{d\zeta \downarrow}\right| < \frac{d\gamma_K \uparrow}{d\zeta \downarrow} \Rightarrow \frac{d\gamma}{d\left(1-\zeta\right)} > 0$,

because the decrease of γ_H is smaller than the increase of γ_K, the total effect of corruption that exists in the education sector on economic growth is positive.

The above analysis indicates that the lower is the corruption in the final output sector the higher is economic growth. On the contrary, the higher is the corruption in the education sector, the less detrimental are the effects on economic growth. This result comes from the assumptions of the model that the two inputs (human and physical capital) are rivals, and that the role of physical capital as a depreciation rate for human capital is quite small. However, we believe that these results can be more close to reality since it is expected that when corruption is high there are more incentives for individuals to acquire education in order to become bureaucrats and to have the possibility to steal public resources.[11] It is also easier to steal public resources oriented for the final output for example by reducing the quality of the constructed infrastructure, which is also proposed as an idea by De la Croix and Delavallade (2009).[12] An extension of the current model by incorporating R&D sector can capture also the case where human capital and physical capital are complements and therefore $\varphi > 0$ as well.

[11] According to Woodrow (1887) and other official definitions: bureaucracy is a group of specifically non-elected officials within a government or other institution that implements the rules, laws, ideas, and functions of their institution. In other words, a government administrative unit that carries out the decisions of the legislature or democratically-elected representation of a state. Because of this definition, a minimum level of education is required for someone to become bureaucrat.

[12] Tanzi and Davoodi (1997) confirm empirically that high corruption reduces the public expenditures on operations and maintenance and also reduces the quality of public infrastructure.

3. ANALYTICAL FRAMEWORK

In this section of the paper, we explain how important are some of the assumptions of the theoretical model in order the theoretical model to be consistent with the empirical part. First of all, as in Albelo (1999) the equation for human capital accumulation is:

$\dot{h} = \sigma(1-u)h + \varphi\dot{k}$, where $\varphi\dot{k}$ is known as the "learning by using" effect. Contrary, to Albelo (1999) we make the assumption that one of the key determinants of the allocation of human capital between sectors is the net of corruption share of public expenditure which is devoted to different sectors. We prefer to use the growth rate of physical capital $\left(\frac{\dot{k}}{k}\right)$, because it is more convenient empirically. Furthermore, in this paper the term $\varphi\gamma_K$ plays a role as an endogenous depreciation rate for human capital accumulation. The other component of our specification for human capital accumulation is public expenditure on education as a share of total public expenditures (s_{it}^h).

In the theoretical model, we assume that the public expenditure on education as a share of total public expenditures $\left(s_{it}^h = \frac{G_h}{G}\right)$ affects the decisions of individuals on how to allocate their human capital among sectors and not the public expenditure on education as a share of *gdp* $\left(s_{it}^h = \frac{G_h}{Y}\right)$. We follow this assumption for the following reasons: i) by following the reasoning of Delavallade (2006), since corruption increases the size of public sector $\left(\frac{G}{Y}\right)$,[13] and $\left[\frac{G_h}{G} = s_{it}^h\right]$ is expected to be reduced due to corruption, then $\left(\frac{G_h}{Y} = \frac{G}{Y} \times \frac{G_h}{G}\right)$ has potentially ambiguous sign, and ii) if we use the variable $\left(s_{it}^h = \frac{G_h}{Y}\right)$ instead of $\left(s_{it}^h = \frac{G_h}{G}\right)$ it is possible to exist endogeneity bias since Y and γ_{it}^h are correlated.

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[13] For the positive impact of corruption on total public expenditures as a share of *gdp* see among others: Tanzi and Davoodi (1997), and Tanzi (1998).

In the introduction we mentioned that according to the empirical literature both s_{it}^h and γ_{it}^k are negative functions of corruption. Here we introduce a flexible way to allow for a link between corruption and s_{it}^h and γ_{it}^k respectively by allowing corruption to be the main determinant of their regression coefficient. In that context we use a flexible semi-parametric econometric model that allows for an unknown smooth coefficient function of corruption for both s_{it}^h and γ_{it}^k to capture a potentially different effect of corruption among sectors. The equation we are going to estimate for human capital accumulation is:

$$\gamma_{it}^h = f\left(corrup_{it}\right) s_{it}^h + g\left(corrup_{it}\right) \gamma_{it}^k .$$

Where $f\left(corrup_{it}\right)$ is the coefficient of s_{it}^h estimated non-parametrically as a function of corruption, and $g\left(corrup_{it}\right)$ is the coefficient of γ_{it}^k estimated non-parametrically as a function of corruption.

The main point of this specification is that it captures simultaneously the two effects of corruption into the economy: i) distortion in the allocation of public expenditure (our interest is for public expenditure on education) and ii) on the physical capital investment due to barriers implemented to firms by bureaucrats and which is consistent with the existent empirical evidence.

4. DATA, ESTIMATION METHOD AND EMPIRICAL RESULTS

4.1 DATA

The main equation of interest that we want to estimate is the following:

$$\gamma_{it}^h = a_0 + \sum_{i=1}^{N-1} a_i D_i + \sum_{j=1}^{Z-1} a_j D_j + \sum_{t=1}^{T-1} a_t D_t + \sum_{s=1}^{2} b_s X_{sit} + \theta_1\left(corrup_{it}\right)\gamma_{it}^k + \theta_2\left(corrup_{it}\right) s_{it}^h + u_{it} , \qquad (1)$$

where (D_i) is a group dummy separating the sample into OECD and non-OECD countries, and (D_j) is a region dummy in order to capture specific characteristics of sub-Saharan, Latin America and Eastern-European countries which were in transition during the period of our sample. The data have been averaged over 5 years for the following periods: 1995-1999, 2000-

2004 and 2005-2010. We use time-specific dummy (D_t) in order to avoid business cycle effects. The vector of (X_{sit}) consists of two control variables that are used later in order to examine the robustness of our results. More specifically, the two variables are infant mortality (*infmort*) and political stability (*polstab*). The former is an important variable which affects human capital accumulation in the fertility and growth literature and as Gupta et al. (2000) and Rajkumar et al. (2008) argue, it is also affected by corruption due to the low public investment in health services. The latter variable captures the general political framework where corruption can thrive and have an important effect on human capital.[14] The data for infant mortality (*infmort*) come from the United Nations dataset (2010) and this variable is defined as the probability of dying between birth and the age of one. Moreover, it is expressed as deaths per 1000 births. The data for political stability (*polstab*) come from the work of Kaufmann et al. (2010). The higher values of this index correspond to less political instability.

As was mentioned earlier the growth rate of physical capital (γ_{it}^{k}) or alternatively physical investment is worsened by corruption and similarly is the public expenditure on education as a share of total public expenditures (s_{it}^{h}).[15] Our main goal is to check the two effects of corruption through the two variables (γ_{it}^{k}) and (s_{it}^{h}) on human capital accumulation simultaneously by allowing these effects to be non-linear and variable over time and for different group of countries. The two unknown functions $\theta_1(.)$ and $\theta_2(.)$ depend on the level of corruption and are estimated by a smooth coefficient semi-parametric model (see Fan (1992) and Fan and Zhang (1999)). The difference of this method with OLS in which corruption affects directly and linearly human capital accumulation is that now we assume that both of the coefficients of (γ_{it}^{k}) and (s_{it}^{h}) vary directly with the level of corruption. In that way, since countries have different levels of corruption it is expected that the effect of (γ_{it}^{k}) and (s_{it}^{h}) not to be constant across countries and time.

14 Mo (2001) finds that in countries with high corruption there exists higher political instability. The index of political stability has been used as a control variable of corruption by C. Bjørnskov (2003).

15 For the negative impact of corruption on physical capital investment see the paper of Mauro (1995) and for the impact of corruption on public expenditure on education as a share of total public expenditures see Delavallade (2006).

Before presenting briefly the mechanics of the smooth coefficient semi-parametric model we want to stress some other data-related points. First of all, the data for public expenditure on education as a share of total public expenditures come from the United Nations dataset (2010). This variable includes government spending on educational institutions (both public and private), educational administration as well as subsidies for private entities. It is expressed as a percentage. The variable of the growth rate of physical capital (γ_{it}^{k}) is constructed by using data from Heston et al. (2011).[16] Finally the data for corruption are obtained from the database of Kaufmann et al. (2010). This variable is defined in such a way as to capture the perceptions of the extent to which public power is exercised for private gain. The original scores range from -2.5 to 2.5, with higher values corresponding to better outcome.[17] For human capital accumulation (γ_{it}^{h}) (which is our dependent variable) we use enrollment rates for population aged between 25 and 65 years. The data for this variable come from the Barro–Lee (2010) dataset. The Barro–Lee (2010) dataset has been extensively used in recent years and as such allows us to make direct comparisons with other empirical studies that explore the role of human capital in economic growth.[18]

According to de la Fuente and Domenech (2000), the stock measure of human capital (total mean years of schooling data) suffer from serious measurement error problems, something that would be exacerbated if we were to obtain growth rates from differencing the stock series.

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[16] For the construction of $\gamma_{it}^{k} = \frac{k_{t+1} - k_t}{k_t}$, we have used the following formula: $k_{i,t} = k_{i,t-1}\left(1-\delta\right) + I_{i,t}$. We have set $\delta = 0.06$ which is standard in the literature. The initial value for physical capital has been constructed by $k_{i,t_0} = \frac{Y_{i,t_0}}{\alpha}$, where α takes the value 2 but we have tried different values around 2 and the results are the same and available upon request. $I_{i,t}$ is the total investment at 2005 constant prices, and $Y_{i,t}$ is the real GDP (Laspeyres), at 2005 constant prices. We have also used data for population in thousands from the same data base. Then we average the constructed series of γ_{it}^{k} in the following intervals: 1995-1999, 2000-2004 and 2005-2010.

[17] In order higher values of the index to represent higher corruption we have transformed the data according to the following formula: corruption=2.5-corruption [Index].

[18] We use total human capital, which is the sum of primary, secondary and higher education. This is done for two major reasons. Firstly, non-OECD countries exhibit very small participation rates at higher levels of education. Finally, because in every country participation at primary and secondary level of education is a necessary requirement in order for people to proceed into higher levels of schooling, we believe it is preferable to include also primary and secondary education in our measure of human capital. We have estimated our results for different categories of human capital and the non-linearities still appear and are even stronger in the tertiary level of education. These results are not presented here but are available upon request.

Hence, instead of measuring human capital accumulation in growth rates as it is the case for per-capita income, we prefer to use enrollment rates instead.

Finally, due to the possible existence of endogeneity bias which stems from the fact that corruption may relate to human capital in a two-way causality pattern, we also use an instrumental variable approach. Aidt et al. (2008) used the index of voice and accountability (*voaac)* as an appropriate instrument of corruption, variables that are also obtained from the Kaufmann et al. (2010) data set. Voice and accountability captures perceptions of the extent to which a country's citizens are able to participate in selecting their government, as well as freedom of expression, freedom of association and a free press. The higher the value of this index, the higher is the quality of institutions. We first proceed to perform a test of endogeneity,[19] and we do not find any evidence for its presence. However, we still proceed to follow a two stage least squares approach using the instrument mentioned above in order to compare the results with the case when we ignore the possibility of endogeneity. The first stage in the two stage approach that uses the following equation

$$corrup_{it} = f\left(D_i, D_j, D_t, \gamma_{it}^k, s_{it}^h, voacc_{it}\right) \qquad (2).$$

This is an OLS regression which includes all the exogenous variables and dummies plus the instrument which is the variable of voice and accountability (*voacc*). Then this regression provides us with fitted values for corruption ($\hat{corrup}$) which is the new index that we can use now for corruption in the second stage of the analysis. We will then compare the results from the two approaches, using *corrupt* and $\hat{corrup}$ to see how the results differ, if they differ at all. Given that our test failed to detect the presence of endogeneity we expect that the two sets of results will not differ by much

Now we provide a quick exposition of the semi-parametric method of smooth coefficients. Equation (1) in a more compact form becomes:

$$\gamma_{it}^h = \Psi_{it}\beta + \theta_1\left(corrup_{it}\right)\gamma_{it}^k + \theta_2\left(corrup_{it}\right)s_{it}^h + u_{it} \qquad (1'),$$

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[19] The Prob>chi2 value of Durbin-Wu-Hausmann test for endogeneity is 0.3724 which means that the initial hypothesis for the absence of correlation between "*corruption*" and the error term is not rejected, which means that there is no endogeneity bias of corruption. For the Durbin-Wu-Hausmann test for endogeneity see Davidson and MacKinnon (1993).

where $\Psi_{it} = \left(D_i, D_j, D_t, X_{sit}\right)$, X_{sit} is the vector of the two control variables (*polstab ,infmort*) which is used when we perform the robustness check, and the error term satisfies $E\left(u_{it}\left|\Psi_{it}, corrup_{it}, \gamma_{it}^k, s_{it}^h\right.\right)=0$. We define $z_{i,t}=\left(\gamma_{it}^k, s_{it}^h\right)$. The most important is to estimate $\theta_1(.)$ and $\theta_2(.)$. It is a generalized method of varying coefficient models and it is based on local polynomial regression.[20] For details of the method has been used extensively in the literature, see Li et al (2002), Mamuneas, Kalaitzidakis and Stengos (2006) among others.

The data are given as $\left\{Y_{i,} W_i\right\}$, given *i=1,…,n,* with $n = N \times T$, for notational simplicity.[21] Furthermore, we can define $V_i = \left(corrup_i\right)$, then $W_i = \left(V_i, \Psi_i\right)$. The regression function is given by:

$$E\left(Y\left|\Psi=\psi, V=v, Z=z\right.\right)=\psi\beta+\partial\left(v\right)z \qquad (3).$$

We use a standard multivariate kernel density estimator with Gausian kernel and the rule of thumb suggested by Silverman (1986) as the choice of the bandwidth. The non-parametric element of equation (1') will be examined graphically. Finally, we have performed the Hsiao *et al.* (2007) test in order to check if the linear model is well specified or alternatively to use a more flexible non-parametric model such as the smooth coefficient method described above.

4.2 EMPIRICAL RESULTS

In column A of Table 1B, there are the OLS results when we use the corruption index directly without the use of any control variable. From this table we observe that all the main variables of interest enter negatively and corruption moreover is statistically significant using robust standard errors.[22] In column B of Table 1B, we use the new index of corruption from the first stage in order to compare these results with those of using the corruption index directly. The results are qualitative similar with those in column 1. Finally, in column C of Table 1B, there are the results with the inclusion of the two control variables (political stability and infant mortality). The

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20 For taking into account the equivalence between the smooth coefficient method and the local polynomial method see among others, Stone (1977), Fan (1992), and Gozalo and Linton (2000).

21 Our sample consists of 101 countries. We have 244 observations in total, and the panel is not balanced.

22 In the paper of Lin (1998), someone can find a theoretical justification how an increase in public expenditure on education can lead into a reduction in the incentive of individual to accumulate human capital.

results are quantitatively similar both in OLS and in the semi-parametric framework.[23] Moreover, the results of Hsiao et al. (2007) test suggest that the linear specification is rejected.

In order to see the smooth coefficient semi-parametric results, we proceed to the graphical analysis. According to Figure 1, in low levels of corruption where the more developed countries belong, a marginal increase of corruption leads into a positive effect of public expenditure as a share of total public expenditure (s_{it}^{h}) on human capital accumulation. In general the impact of public expenditure on education is positive but decreasing for high levels of corruption. A possible explanation is that even in more corrupted environment the increase of public expenditure on education can be a signal to acquire more knowledge since this can be opening the way to enter into the bureaucrat[24] sector and to gain from rent reaping activities or people may simply want to improve their chances for better jobs.

In the case where we check for the impact of physical capital growth (γ_{it}^{k}) on human capital accumulation, Figure 2 still suggests the presence of a non-linear relationship. In low levels of corruption, where countries are more developed, an increase of corruption has negative but small impact on the coefficient of γ_{it}^{k} on human capital accumulation. However, for higher levels of corruption the impact of γ_{it}^{k} on human capital investment is negative and more severe. In that case, corruption is possible to have much more negative spillovers in the economy as a whole. Figure 3 and Figure 4 present the smooth coefficient semi-parametric results when we use the instrumented index of corruption. From a direct comparison of Fig. 3 and 4 with Fig. 1 and 2 respectively, it is easily observed that the results do not change when we have instrumented for corruption.

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[23] Even if the variable of political stability is not statistically significant it is important to mention that by including this variable as a control variable the non-linearities are prevalent but in countries with high corruption and high political instability the negative effect of public expenditure on education is more severe. The semi-parametric results for the control variables are not presented here but are available upon request.

[24] The various tasks of bureaucrats require minimum level of skills and education in order to be implemented according to Woodrow (1887).

5. Summary and Conclusions

In this paper we try to propose an endogenous growth model where corruption, which is considered as an exogenous variable, reduces the net amount of public resources which go to different sectors of the economy. This creates a distortion in the allocation of human capital across sectors since one of the main assumptions of our model is that individuals decide on how to allocate their human capital between sectors by considering the net (from corruption) amount of public resources. In that way, corruption affects human capital accumulation directly by reducing the share of public expenditure on education but also indirectly by deterring investment on physical capital. So even if, the fraction of human capital entering into education sector increases due to the fact that the net from corruption public resources oriented for education are more than those oriented for final output, corruption has negative effect on human capital through the deterioration of physical investment.

In the empirical section of the paper we use a semi-parametric smooth coefficient model in order to capture possible non-linearities of corruption on the important elements of human capital. The empirical results suggest the existence of non-linearities between corruption and human capital accumulation which means that the magnitude of the effect of corruption varies across different groups of countries. More specifically, corruption until an upper bound level has a declining but positive effect on the coefficient of the public expenditure on education. Moreover, it has mainly negative but non linear effect on the coefficient of private capital. This comes into line with our intuition that when corruption increases there is incentive for individuals to enter into education sector. It can be also the case that corruption has less negative effects on public expenditure on education relative to other kind of public expenditures. Another possible explanation is that corruption has damaged the final output sector to such an extent that individuals prefer to postpone their job career and to remain into education sector.

To conclude, corruption has negative and non-linear effects on human capital accumulation. From a policy perspective a higher index for educational achievement does not indicate always higher growth if corruption is a dominance practice in an economy, and it would be of paramount importance the existence of policy practices which reduce corruption firstly in order public expenditure to be enhancing factor for economic growth. Further, extensions of this paper for research are the followings: first of all, at the current stage we try to see how the theoretical results will change if we have an extra sector (sector of bureaucrats) which can have both positive effects on production function by performing useful activities for the private sector and negative effects as in the current version of the model by appropriating public resources. Secondly, an additional extension would be to introduce R&D activity and to check both theoretically and empirically the effect of corruption on R&D. In that case one could take into account the possible positive effects of corruption on R&D activity through the increase on market power for innovating firms and the negative effects through the misallocation of talented people into the bureaucrat sector. Another, important point that has been raised from the current paper is to check for conditions where human capital and hence higher public investment on education can reduce corruption. We think that for analyzing the above issue it would be useful to pursue a more micro founded model with generations' conflict.

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APPENDIX A: EQS. (17) – (19)

The current value Hamiltonian is:

$$J=\frac{C^{1-\theta}-1}{1-\theta}+\lambda\left[\sigma f\left(\zeta s_H\right)+\varphi\gamma_K\right]H+\mu\Big[\left(1-\tau\right)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha}H^{\alpha}K^{1-\alpha}-C\Big]$$

In the Hamiltonian function written above a_1 and C are the control variables and H and K are the state variables. The necessary first order conditions read as:

(A1) $\frac{\partial J}{\partial C}=0 \Leftrightarrow C^{-\theta}=\mu \Rightarrow \frac{\dot{C}}{C}=-\frac{1}{\theta}\frac{\dot{\mu}}{\mu}$

(A2) $\frac{\partial J}{\partial s_H}=0 \Leftrightarrow \lambda\sigma f'\zeta \mathrm{H}=\mu\alpha\left(1-\tau\right)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha-1}g'\delta H^{\alpha}K^{1-\alpha}$

(A3) $\dot{\mu}=\mu\rho-\frac{\partial J}{\partial K}=\mu\rho-\mu\left(1-\tau\right)\left(1-\alpha\right)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha}H^{\alpha}K^{-\alpha}$

(A4) $\dot{\lambda}=\lambda\rho-\frac{\partial J}{\partial H}=\lambda\rho-\lambda\left[\sigma f\left(\bullet\right)+\varphi\gamma_K\right]-\mu\alpha\left(1-\tau\right)\left[g\left(\bullet\right)\right]^{\alpha}H^{\alpha-1}K^{1-\alpha}$.

Divide (A3) with μ:

(A3’) $\frac{\dot{\mu}}{\mu}=\rho-\left(1-\tau\right)\left(1-\alpha\right)\left[g\left(\delta(1-s_H)\right)\right]^{\alpha}H^{\alpha}K^{-\alpha}$. With $g\left(\bullet\right)$ to be constant in BGP, in order $\frac{\dot{\mu}}{\mu}$ to be constant as well in BGP, we need: $\frac{\dot{K}}{K}=\frac{\dot{H}}{H}=\gamma$, (A3’’).

Divide (A4) with λ:

(A4’) $\frac{\dot{\lambda}}{\lambda}=\rho-\left[\sigma f\left(\bullet\right)+\varphi\gamma_K\right]-\frac{\mu}{\lambda}\alpha\left(1-\tau\right)\left[g\left(\bullet\right)\right]^{\alpha}H^{\alpha-1}K^{1-\alpha}$.

Log-linearize and differentiate (A2) wrt time:

$\frac{\dot{\lambda}}{\lambda}+\frac{\dot{H}}{H}=\frac{\dot{\mu}}{\mu}+\alpha\frac{\dot{H}}{H}+\left(1-\alpha\right)\frac{\dot{K}}{K}$ and together with (A3’’):

(A2’) $\frac{\dot{\lambda}}{\lambda}=\frac{\dot{\mu}}{\mu}$.

We solve (A2) wrt. $\frac{\mu}{\lambda}$:

(A2'') $\frac{\mu}{\lambda}=\frac{\sigma f'(\bullet)\zeta}{\alpha(1-\tau)\left[g(\bullet)\right]^{\alpha-1}g'\delta H^{\alpha-1}K^{1-\alpha}}$.

By replacing (A2'') into (A4') we get after some algebra:

(A4'') $\frac{\dot{\lambda}}{\lambda}=\rho-\left[\sigma f(\bullet)+\varphi\gamma_K\right]-\sigma g(\bullet)$. Which is constant is BGP.

Then we equate (A4'') with (A3') and solve wrt $\left(\frac{g(\bullet)H}{K}\right)^{\alpha}$:

(A5) $\left(\frac{g(\bullet)H}{K}\right)^{\alpha}=\frac{\sigma(f+g)+\varphi\gamma_K}{(1-\alpha)(1-\tau)}=\frac{\sigma+\varphi\gamma_K}{(1-\alpha)(1-\tau)}$, since $f+g=1$.

From the constraint of human capital and (A3'') we get:

(A6) $\gamma=\frac{\sigma f(\bullet)}{1-\varphi}$, with $\varphi\neq 1$ and $\varphi<1$, for $\gamma>0$.

From the definition of BGP and by log differentiating Eq. 8 from the text we get:

(A7) $\frac{\dot{Y}}{Y}=\frac{\dot{K}}{K}=\frac{\dot{H}}{H}=\gamma$.

From the definition of BGP, (A7), and by log differentiating Eq. 10 from the text we get:

(A8) $\frac{\dot{Y}}{Y}=\frac{\dot{C}}{C}=\frac{\dot{K}}{K}=\frac{\dot{H}}{H}=\gamma$.

By inserting (A3') into (A1), equating the resulting expression with (A6) and then solve wrt $\left(\frac{g(\bullet)H}{K}\right)^{\alpha}$:

(A9) $\left(\frac{g(\bullet)H}{K}\right)^{\alpha}=\frac{\sigma f(\bullet)\theta+\rho(1-\varphi)}{(1-\varphi)(1-\tau)(1-\alpha)}$.

Then by equating expression (A5) with (A9) we get:

(A10) $\gamma=\frac{\sigma(f\theta-1+\varphi)}{(1-\varphi)\varphi}+\frac{\rho}{\varphi}$.

In order $\frac{d\gamma}{d\rho}<0$ and $\frac{d\gamma}{d\theta}<0$ we need $\varphi<0$, we need 1-$\varphi>\theta f$, for $\frac{d\gamma}{d\sigma}>0$ and

for $\gamma>0\Rightarrow\rho<\sigma\frac{(1-\varphi-f\theta)}{(1-\varphi)}$.

We now check the two transversality conditions: $\lim_{t\to\infty}\lambda_t H_t=0$ and $\lim_{t\to\infty}\mu_t K_t=0$. Because of (A2') and (A7) if the transversality condition holds for the one state variable it holds for the other as well.

$$\lim_{t\to\infty} e^{-\rho t}\lambda_t H_t = \lambda(0)H(0)\lim_{t\to\infty} e^{\left(-\rho+\frac{\dot{\lambda}}{\lambda}+\frac{\dot{H}}{H}\right)t} = \lambda(0)H(0)\lim_{t\to\infty} e^{\left(-\rho+\frac{\dot{\lambda}}{\lambda}+\gamma\right)t}.$$

By replacing into the previous expression (A4''), $\sigma f+\varphi\gamma=\gamma$ from (A6) and the constraint $f+g=1$, we have:

$$\lim_{t\to\infty} e^{-\rho t}\lambda_t H_t = \lambda(0)H(0)\lim_{t\to\infty} e^{\left(-\rho+\frac{\dot{\lambda}}{\lambda}+\frac{\dot{H}}{H}\right)t} = \lambda(0)H(0)\lim_{t\to\infty} e^{-(\sigma(1-f(\bullet)))t}=0, \text{ since } f(\bullet)\in(0,1).$$

From (A10) we have: $\gamma=\frac{\sigma(f\theta-1+\varphi)}{(1-\varphi)\varphi}+\frac{\rho}{\varphi}$. Since $f(\bullet)$ is an invertible function by assumption, then from (A10) we get:

(A11) $\frac{(1-\varphi)[\varphi\gamma+\sigma-\rho]}{\sigma\theta}=f(\zeta s_H)\Rightarrow f^{-1}\left[\frac{(1-\varphi)[\varphi\gamma+\sigma-\rho]}{\sigma\theta}\right]=\zeta s_H\Rightarrow s_H=\frac{f^{-1}(\bullet)}{\zeta}$,

and (A12) $1-s_H=s_Y=\frac{\zeta-f^{-1}(\bullet)}{\zeta}$.

In order the expression inside the brackets in equation (A11) to be a positive number we need:
$\varphi\gamma+\sigma-\rho>0\Rightarrow<0<\frac{\rho-\sigma}{\varphi}<\gamma$, since $\varphi<0$ and $\sigma-\rho>0$ as it is shown below.

Since,
$1-s_H=s_Y\in(0,1)\Rightarrow\zeta>f^{-1};\ f^{-1}>0$, with $f'>0$ and since $f(\bullet)$ is invertible $\left(f^{-1}\right)'>0$ as well.

From equation (A10) by using the result from (A6) we get the following result:

(A10') $\gamma=\frac{\sigma(f\theta-1+\varphi)}{(1-\varphi)\varphi}+\frac{\rho}{\varphi}=\frac{\sigma f\theta-\sigma(1-\varphi)}{(1-\varphi)\varphi}+\frac{\rho}{\varphi}=\frac{\gamma\theta}{\varphi}-\frac{\sigma}{\varphi}+\frac{\rho}{\varphi}=\frac{\gamma\theta}{\varphi}+\frac{\rho-\sigma}{\varphi}$

We define:
$\Psi(\gamma)=\frac{\gamma\theta}{\varphi}+\frac{\rho-\sigma}{\varphi}$, so (A10') becomes $\Omega(\gamma)=\gamma-\Psi(\gamma)$. In order to exist an endogenous solution of γ, we need or $\{\Psi'(\gamma)>0 \text{ if } \Psi(0)<1\}\, or \,\{\Psi'(\gamma)<0 \text{ if } \Psi(0)>1\}$.

Since from (A9) $[(1-s_H)=s_Y]$ is constant on BGP, then $f(\bullet)$ and $g(\bullet)$ are constant on BGP as well.

$\Psi'(\gamma)=\frac{\theta}{\varphi}<0$ for $\varphi<0$. Then we need $\Psi(0)>1$.

$\Psi(0)=\frac{\rho-\varphi}{\varphi}>1\Rightarrow\{\sigma>\rho \text{ and } \rho-\varphi>\sigma\}$, these two inequalities hold simulataneously iff $-\varphi>0$ which is true since $\varphi<0$.

If the above conditions hold then an endogenous growth rate of the economy γ^* exists in BGP and if we replace γ^* inside (A11) it exists an endogenous

$\left(1-s_H^*\right)=s_Y^*=\dfrac{\zeta-f^{-1}\left[\dfrac{(1-\varphi)[\varphi\gamma+\sigma-\rho]}{\sigma\theta}\right]}{\zeta}$ as well. So, γ^* and $\left(1-s_H^*\right)=s_Y^*$, are determined simultaneously.

The comparative statics for equation (A11) are straightforward for the parameters $(\theta;\zeta;\rho;\sigma \text{ and } \varphi)$:

ii) $\dfrac{ds_H}{d\zeta}<0$ and $\dfrac{ds_Y}{d\zeta}>0$, ii) $\dfrac{ds_H}{d\varphi}=\dfrac{1}{\zeta}\left(f^{-1}(\bullet)\right)^{'}\bullet\left[\dfrac{(1-2\varphi)\gamma-(\sigma-\rho)}{\sigma\theta}\right]$.

$\dfrac{ds_H}{d\varphi}>0$ and $\dfrac{ds_Y}{d\varphi}<0$ if $\gamma>\dfrac{\sigma-\rho}{1-2\varphi}$ otherwise $\dfrac{ds_H}{d\varphi}<0$ and $\dfrac{ds_Y}{d\varphi}>0$ if $\gamma<\dfrac{\sigma-\rho}{1-2\varphi}$ since $\varphi<0$ and $\sigma>\rho$, iii) $\dfrac{ds_H}{d\rho}=-\dfrac{(1-\varphi)}{\sigma\theta\zeta}\left(f^{-1}(\bullet)\right)^{'}<0$ and $\dfrac{ds_Y}{d\rho}>0$,

iv) $\dfrac{ds_H}{d\theta}=-\dfrac{(1-\varphi)[\varphi\gamma+\sigma-\rho]}{\sigma\theta^2\zeta}\left(f^{-1}(\bullet)\right)^{'}<0$ and $\dfrac{ds_Y}{d\theta}>0$ and finally

$\dfrac{ds_H}{d\sigma}=\dfrac{\left[(1-\varphi)\rho-(1-\varphi)\varphi\gamma\right]}{\sigma^2\theta\zeta}\left(f^{-1}(\bullet)\right)^{'}>0$ for $\varphi<0$ and $\dfrac{ds_Y}{d\sigma}<0$.

The comparative statics for the equation (A10) are straightforward:

$\dfrac{d\gamma}{d\delta}=-\dfrac{\sigma g'\theta s_Y}{(1-\varphi)\varphi}>0,$ for $s_Y\in(0,1)$; $g'>0$ and $\varphi<0\Rightarrow\dfrac{d\gamma}{d(1-\delta)}<0$ and

$\dfrac{d\gamma}{d\zeta}=\dfrac{\sigma f'\theta s_H}{(1-\varphi)\varphi}<0,$ for $s_H\in(0,1)$; $f'>0$ and $\varphi<0\Rightarrow\dfrac{d\gamma}{d(1-\zeta)}>0$.

APPENDIX B

OECD COUNTRIES: Australia, Austria, Belgium, Canada, Chile, Czech Republic, Denmark, Finland, France, Greece, Hungary, Iceland, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Republic of Korea, Spain, Sweden, Switzerland, U.K., U.S.

NON-OECD COUNTRIES: Algeria, Argentina, Bahrain, Bangladesh, Barbados, Benin, Bolivia, Botswana, Brazil, Bulgaria, Burundi, Cameroon, Central African Republic, Colombia, Costa Rica, Cote d' Ivoire, Cuba, Cyprus, Dominican Republic, Ecuador, Egypt, El Salvador, Fiji, Ghana, Guatemala, Guyana, Hong Kong, India, Indonesia, Iran (Islamic Republic of), Israel, Jamaica, Kenya, Kuwait, Lao Republic, Latvia, Lesotho, Liberia, Malawi, Malaysia, Mali, Mauritius, Moldova, Morocco, Mozambique, Namibia, Nepal, Nicaragua, Niger, Pakistan, Panama, Paraguay, Peru, Philippines, Romania, Russian Federation, Rwanda, Saudi Arabia, Senegal, Sierra Leone, Singapore, South Africa, Swaziland, Tajikistan, Thailand, Togo, Trinidad and Tobago, Tunisia, United Ar. Emirates, Uganda, Uruguay, Yemen, Zambia.

LATIN AMERICA COUNTRIES: Argentina, Barbados, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Trinidad and Tobago, Uruguay.

SUB-SAHARAN AFRICA COUNTRIES: Benin, Botswana, Burundi, Cameroon, Central African Republic, Ghana, Cote d' Ivoire, Kenya, Lesotho, Liberia, Malawi, Mali, Mauritius, Mozambique, Namibia, Niger, Senegal, Sierra Leone, South Africa, Swaziland, Togo, Uganda, Zambia.

TRANSITION COUNTRIES: Bulgaria, Croatia, Cuba, Czech Republic, Estonia, Hungary, Latvia, Poland, Romania, Russian Federation, Slovak Republic

Table 1B: OLS Empirical Results

	OLS	OLS	OLS
Variables	(A)	(B)	(C)
constant	1.067*** (0.052)	1.149*** (0.070)	1.065*** (0.042)
oecd	0.036 (0.021)	0.001 (0.032)	0.024 (0.013)
la	0.148*** (0.024)	0.143*** (0.024)	0.106*** (0.020)
af	-0.136*** (0.040)	-0.136*** (0.043)	0.153*** (0.042)
tran	0.169*** (0.022)	0.123*** (0.022)	0.053*** (0.021)
d00	-0.082** (0.022)	-0.084*** (0.022)	-0.019 (0.020)
d05	-0.036 (0.021)	-0.037 (0.022)	-0.013 (0.018)
pubexp	-0.068 (0.259)	-0.171 (0.284)	-0.305 (0.193)
gk	-0.777* (0.398)	-0.911*** (0.405)	-1.060*** (0.411)
corruption	-0.096*** (0.012)	-0.116*** (0.020)	-0.012 (0.013)
polstab	-	-	-0.012 (0.015)
infmort	-	-	-0.006*** (0.000)
R2/R2adj.	58.15/56.54	54.25/52.49	73.08/71.81
Observations	244	244	244
F-test	36.13***	30.38***	57.27***
Heteroskedasticity	105.13***	94.33***	136.91***
P(Specific.)	2.22e-16***	2.22e-16***	2.22e-16***

Notes: ***,** and * denote the 1%,5% and 10% significance level. Heteroskedasticity is present by conducting Breusch-Pagan test. In the parentheses are the robust standard errors. Pubexpg is the public expenditure of education as a share of total public expenditures, and gk is the growth rate of physical capital. P(Specific) shows the p-values if the null of the parametric linear OLS is correctly specified in comparison to a fully non-parametric model, using the Hsiao *et al.* (2007) test for continuous and discrete data models after 399 Boostrap replications.

FIGURE 1: THE MARGINAL EFFECT OF PUBLIC EXPENDITURE ON EDUCATION ON HUMAN CAPITAL ACCUMULATION

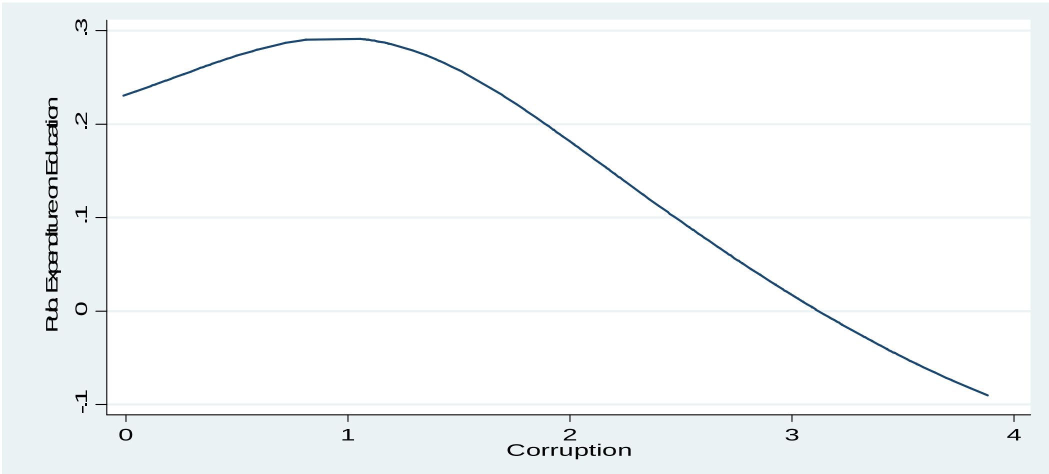

FIGURE 2: THE MARGINAL EFFECT OF THE GROWTH RATE OF PHYSICAL CAPITAL ON HUMAN CAPITAL ACCUMULATION

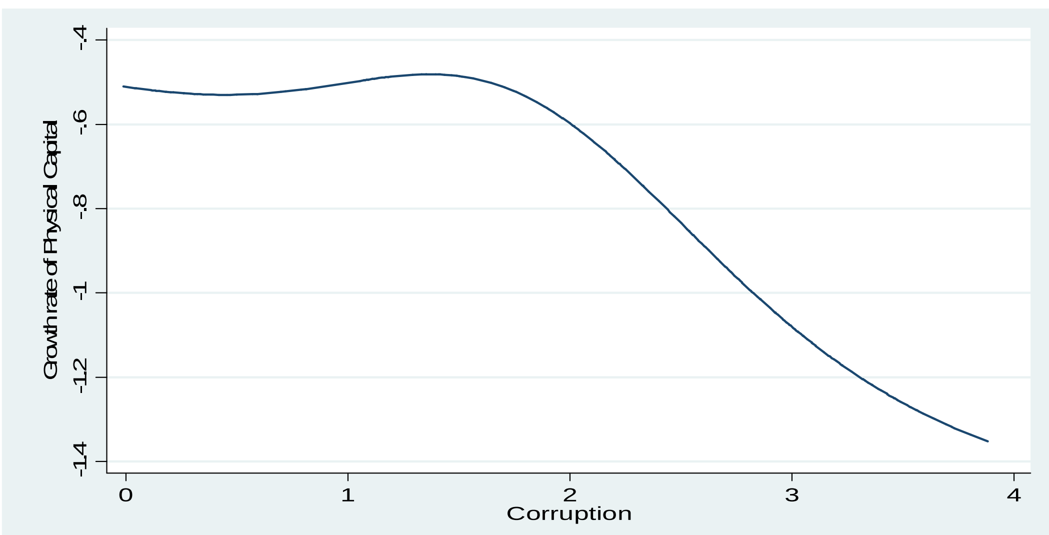

FIGURE 3: THE MARGINAL EFFECT OF PUBLIC EXPENDITURE ON EDUCATION ON HUMAN CAPITAL ACCUMULATION WITH INSTRUMENTED CORRUPTION

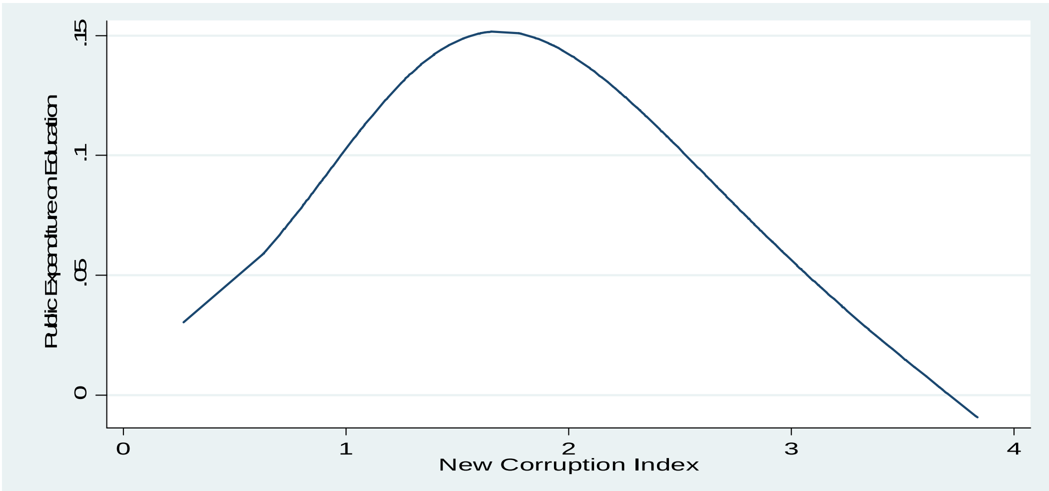

FIGURE 4: THE MARGINAL EFFECT OF THE GROWTH RATE OF PHYSICAL CAPITAL ON HUMAN CAPITAL ACCUMULATION WITH INSTRUMENTED CORRUPTION