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Abstract

Mortality and fertility rates have an important influence on economic development, while corruption also plays a role. This study examines the relationships among corruption, fertility and mortality rates, and economic development. The model is based on a three-period overlapping generations model in which agents are divided into two groups, households and bureaucrats. Households decide the number of children and bureaucrats supply public health services. All agents face mortality rates in the second period. As the empirical evidence indicates, we show that mortality and fertility rates affect development. We emphasize that corruption determines the mortality rate and that the mortality rate affects corruption. Moreover, a two-way causal relationship exists between corruption and economic development. Therefore, three steady states can arise: the steady state of the early stage of development is characterized by a high level of corruption and high mortality and fertility rates; the steady state of the late stage is characterized by no corruption and low mortality and fertility rates; and the steady state of the middle stage is characterized by bureaucrats' mixed strategy whether they engage in corruption.

Keywords: Bureaucratic corruption, Economic development, Mortality, Fertility

JEL Classification: D73, J18, O11

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1 Introduction

Economic development is promoted by numerous factors such as demography, education, innovation, political factors, and physical capital. In particular, the importance of mortality and fertility rates in determining economic development has been the focus of the macroeconomic literature. Studies that construct models with endogenous mortality and fertility rates can be classified into two groups in terms of the way in which they model changes in the mortality rate. One group of studies determines the mortality rate by using the level of human capital or private payment for health such as medical treatment and vaccinations; for example, see Cigno (1998), Blackburn and Cipriani (2002), Kalemli-Ozcan (2002), Lagerlöf (2003), Galor and Moav (2005), Hazan and Zoabi (2006), Cervellati and Sunde (2007), Fioroni (2010), and Futagami and Konishi (2017). Another group suggests that governments improve the mortality rate by increasing public spending on public health, such as Hashimoto and Tabata (2005) and Fanti and Gori (2014)[1].

Rajkumar and Swaroop (2008) find the surprising empirical evidence that a one percentage point increase in the share of public health spending in GDP has no impact on the under-five mortality rate in countries with weak governance[2]. This increase lowers the mortality rate by 0.32% in countries with good governance and 0.20% in countries with average governance. Thus, allocating public spending to public health does not necessarily lead to a decline in the mortality rate and the governance in each country determines the effectiveness of public spending on health. These findings concur with the arguments by World Bank (2003) that governments in developing countries struggle to translate public funds into effective services. The findings of Rajkumar and Swaroop (2008) and arguments of World Bank (2003) call for the need to reconsider the causes of changes in the mortality rate and imply that improving governance can reduce this rate.

[1]Blackburn and Cipriani (1998) and Fernandez-Villaverde (2001) are exceptions. In Blackburn and Cipriani (1998), both private and public health expenditure affects the mortality rate. In Fernandez-Villaverde (2001), the mortality rate depends on individual consumption.

[2]Rajkumar and Swaroop (2008) measure governance by using two indicators: quality of bureaucracy and level of corruption.

This research also links corruption with mortality and fertility rates, these rates with development, and development with corruption. We construct a three-period overlapping generations model in which agents live through childhood, adulthood, and old age. In each period, newly born agents are divided into two groups, households and bureaucrats. Households decide their number of children and work in the private sector. Bureaucrats produce public services and can engage in corruption by misallocating a share of public funds as illegal income. Public services contribute to the quality of public health that determines the mortality rate. All agents face the mortality rate during adulthood.

We obtain three main results. Firstly, as capital accumulates, the degree of corruption declines. This decline reduces mortality and fertility rates as well as causes capital accumulation. Secondly, a bureaucrat plays a game with other bureaucrats and changes his or her strategy whether he or she engages in corruption in response to the stages of development. Thirdly, three steady states that correspond to the respective development stages can exist. The steady state in the early stage of development is characterized by a high degree of corruption and high mortality and fertility rates. In this stage, all corruptible bureaucrats choose to be corrupt. The steady state in the middle stage is characterized by a mixed strategy by bureaucrats. Some bureaucrats engage in corruption and others do not. The steady state in the late stage of development is characterized by a low degree of corruption and low mortality and fertility rates.

In our model, two effects play vital roles in determining the relationship between development and corruption. One is the effect of labor income. High labor income implies high costs of corruption because corrupt bureaucrats uncovered by the government lose a share of their utility as punishment. As income increases, the utility loss rises. Thus, higher income decreases bureaucrats' incentive to engage in corruption. The other is the effect of the mortality rate. Corrupt bureaucrats receive illegal income in adulthood but only use it in old age to avoid being caught. Then, a low mortality rate implies a high probability that they derive utility from illegal income in old age. Thus, a lower mortality rate increases bureaucrats' incentive to engage in corruption. In the early (late) stage of development, income is low (high) and the mortality rate is high (low). Even if the probability of deriving utility from illegal income is low (high), the low (high) costs of corruption force bureaucrats to (not to) engage in corruption. In the middle stage, a bureaucrat engages in corruption if the others do not and the mortality rate is low. On the contrary, he or she does not engage in corruption if the others do and the mortality rate is high. Thus, a mixed strategy occurs in the equilibrium.

1.1 Related literature of corruption

Most empirical studies of the extent to which corruption affects development, such as Knack and Keefer (1995), Mauro (1995), Keefer and Knack (1997), Li, Xu, and Zou (2000), Gyimah-Brempong (2002), and Aidt (2009), find negative effects. These empirical works have encouraged theoretical studies that construct dynamic models with corruption or rent-seeking, such as Ehrlich and Lui (1999), Sarte (2001), Alesina and Angeletos (2005), Blackburn, Bose, and Haque (2006, 2011), Blackburn and Forgues-Puccio (2007, 2009), Blackburn and Sarmah (2008), Eicher, García-Peñalosa, and Van Ypersele (2009), Spinesi (2009), Blackburn (2012), Dzhumashev (2014a,b), Varvarigos and Arsenis (2015), and Akimoto (2018). They reveal various mechanisms through which corruption affects economic development. However, none of them considers the endogeneity of mortality and fertility rates.

The present analysis is closely related to notable two studies, namely Varvarigos and Arsenis (2015) and Blackburn and Sarmah (2008). To the best of our knowledge, Varvarigos and Arsenis (2015) is the first study of the corruption-development-fertility rate nexus and Blackburn and Sarmah (2008) is the first study of the corruption-development-mortality rate nexus.

Varvarigos and Arsenis (2015) construct a two-period overlapping generations model in which a child quantity-quality trade-off exists. An incidence of corruption decreases the supply of public services. The lower quality of public services hampers the human capital accumulation of children. Thus, households will have more children and allocate less time to the education of each child because of this quantity-quality trade-off. As human capital accumulates and bureaucrats' income increases, the degree of corruption and fertility rate decrease. In their model, corruption thus affects the fertility rate through the quantity-quality trade-off. By contrast, in our model, corruption affects the fertility rate through the mortality rate. In addition, their model does not capture the effect of the mortality rate on the relationship between corruption and development, while the income effect matters. These differences are driven by the lack of the endogeneity of the mortality rate in their model. Since Varvarigos and Arsenis (2015) focus on the trade-off rather than the mortality rate, they take a different approach to us.

Blackburn and Sarmah (2008) address the mortality rate as an endogenous variable. According to their work, corruption decreases public services, which increases the mortality rate. Hence, the channels through which corruption affects mortality are the same as in our model. However, they assume that bureaucrats do not face the mortality rate, while households do. Thus, bureaucrats' choices to engage in corruption are independent of the mortality rate; that is, the effect of the mortality rate does not exist. Furthermore, endogenous choices on the number of children and population growth do not exist.

1.2 Organization of the paper

The remainder of this paper is organized as follows. Section 2 constructs the model. Section 3 examines the dynamics of the economy by deriving the market equilibrium conditions, bureaucrat's strategy, and steady states. Section 4 discusses three topics: the effects of an increase in public spending, the existence of steady states, and the role of cultural norms in determining the steady states and transition paths. Section 5 presents concluding remarks.

2 Model

We construct a three-period overlapping generations model. The economy consists of firms, the government, and agents. Agents go through childhood, adulthood, and old age. Children do not make any decisions. Adult agents work, consume goods, and raise children. Old agents withdraw savings and consume goods. N_t stands for the labor force in period t; in other words, N_t is the number of adults in period t. In each period, newly born agents are divided into two groups, bureaucrats and households. The population of each group in period t, N_t^B and N_t^H, is as follows:

$$N_t^B = \lambda N_t \quad \text{and} \quad N_t^H = (1-\lambda)N_t, \tag{1}$$

where $0 < \lambda < 1$. In addition, two types of bureaucrats exist: corruptible and non-corruptible. The proportion $b \in (0,1)$ is corruptible and the remaining proportion $1-b$ is non-corruptible. Corruptible bureaucrats can engage in corruption. We call a corruptible bureaucrat who is actually corrupt a dishonest bureaucrat and a corruptible bureaucrat who is not corrupt an honest bureaucrat. The proportion σ_t becomes dishonest bureaucrats and the proportion $1-\sigma_t$ becomes honest bureaucrats. σ_t is an endogenous variable. Households, corruptible bureaucrats, and non-corruptible bureaucrats are represented by a superscript $i \in \{H, CB, NB\}$. All agents are endowed with one unit of labor and supply it inelastically. Households work for the private sector, while bureaucrats work for the public sector. In addition, agents face the mortality rate in adulthood determined by the quality of public health.

2.1 Production

Firms produce final goods by using labor and capital. The production function is $Y_t = AL_t^{1-\alpha}K_t^{\alpha}$, where $0 < \alpha < 1$. Y_t, L_t, and K_t denote total output, labor, and capital, respectively. Then, output per capita is represented by

$$y_t = Al_t^{1-\alpha} k_t^{\alpha}. \tag{2}$$

y_t, l_t, and k_t are Y_t/N_t, L_t/N_t, and K_t/N_t, respectively. Profit maximizing yields the first order conditions:

$$r_t = (1-\tau_t)\alpha A l_t^{1-\alpha} k_t^{\alpha-1}, \tag{3}$$

$$w_t = (1-\tau_t)(1-\alpha) A l_t^{-\alpha} k_t^{\alpha}. \tag{4}$$

r_t, w_t, and τ_t represent the interest rate, wage rate in the private sector, and tax rate, respectively. The tax rate is imposed on output.

2.2 Government

We explain the settings of the government and corruption in the public sector. The setting is the same as in Varvarigos and Arsenis (2015). The government devotes G_t units of output to public services. This spending is proportional to total output:

$$G_t = \theta Y_t, \quad \text{where} \quad 0 < \theta < 1. \tag{5}$$

The government delegates the production and supply of public services to bureaucrats. Each bureaucrat is provided with G_t/N_t^B units of funds. When producing and supplying public services, he or she can use two types of projects, Type-1 and Type-2. The return of a Type-1 project is random, while that of a Type-2 project is constant. If a bureaucrat invests one unit of funds in the Type-1 project, he or she obtains $\xi > 1$ units of public services with probability p and $\gamma < 1$ units with probability $1-p$. On the contrary, if a bureaucrat invests one unit of funds in the Type-2 project, he or she produces γ/δ units of services with probability 1. We assume that $0 < \gamma < \delta < 1$ so that $\gamma/\delta < 1$. Since the Type-1 project creates higher expected returns than the

Type-2 project, the government has an incentive to instruct bureaucrats to operate the Type-1 project.

Non-corruptible bureaucrats comply with the instructions, that is, they invest all their funds in the Type-1 project and supply $[p\xi + (1-p)\gamma](1-b)G_t$ units of public services. On the contrary, corruptible bureaucrats can engage in corruption following three steps. Firstly, each dishonest bureaucrat invests $\delta G_t/N_t^B$ units of funds in the Type-2 project and supplies $\gamma G_t/N_t$ units of public services. Secondly, dishonest bureaucrats insist that they conducted the Type-1 project but unfortunately achieved a bad result because of an idiosyncratic shock. Finally, they obtain illegal income $(1-\delta)G_t/N_t^B$. Thus, the public services supplied by dishonest bureaucrats are $\gamma b \sigma_t G_t$ units. On the contrary, honest bureaucrats who are not corrupt behave in the same way as non-corruptible bureaucrats. That is, they supply $[p\xi + (1-p)\gamma]b(1-\sigma_t)G_t$ units of public services. Then, the per capita public services supplied by all bureaucrats, f_t, are as follows:

$$f_t = \phi(\sigma_t)y_t, \quad \phi(\sigma_t) \equiv \{[p\xi + (1-p)\gamma] - \sigma_t bp(\xi - \gamma)\}\theta. \tag{6}$$

Bureaucrats apply for a job in the public sector if they can obtain a higher wage rate, ω_t, than that in the private sector (i.e., $\omega_t \geq w_t$). The government does not know the type of each bureaucrat. Then, to attract bureaucrats, the government offers a contract $\omega_t = w_t$. The government's budget stands by the following balanced budget rule:

$$\tau_t Y_t = G_t + \omega_t N_t^B. \tag{7}$$

2.3 Public health and the mortality rate

The public services supplied by bureaucrats affect the quality of public health. The quality of public health per capita is given by

$$h_t = \frac{f_t}{y_t}. \tag{8}$$

y_t in the denominator captures pollution or bad effects on public health from production. Public services can dilute the pollution level and increase the quality of public health.

The quality of public health determines the survival rate in period t, π_t, as follows:

$$\pi_t = \Pi(h_t), \quad 0 \leq \Pi(h_t) \leq 1, \quad \Pi'(h_t) > 0. \tag{9}$$

An improvement in the quality of public health in period t increases the survival rate in this period. That is, higher quality public health yields a lower mortality rate.

2.4 Agents

We consider agents born in period $t-1$. They face a mortality rate in adulthood. With probability $1-\pi_t$, the adults die.

The analysis of Blackburn and Sarmah (2008) assumes that households face a mortality rate, whereas bureaucrats enjoy their whole lifetime. This assumption simplifies their analysis. By removing this assumption, our study thus captures the effect of the mortality rate on bureaucrats' decision to become corrupt. Instead, following Varvarigos and Arsenis (2015)[3], we assume that only households give birth and raise their children because we focus on the corruption caused by bureaucrats' strategy and the effects of corruption on other factors such as public health and mortality and fertility rates. Thus, this assumption clarifies our focus and analyses.

[3]Varvarigos and Arsenis (2015) examine the case in which both households and bureaucrats are reproductive by extending their basic model.

2.4.1 Households

Households choose the number of children n_t as well as their consumption in adulthood $c^H_{a,t}$ and in old age $c^H_{o,t+1}$ to maximize the following utility:

$$a \ln n_t + (1-a)[\ln c^H_{a,t} + \beta \pi_t \ln c^H_{o,t+1}].$$

β is the discount factor and a is their preference between children and consumption. High a implies a high preference toward their children.

Households allocate their income between consumption, savings, and child rearing. Following Fioroni (2010), we assume that raising each child needs a proportion e of income. Then, the budget constraints of households are as follows:

$$c^H_{a,t} + s^H_t = w_t - e n_t w_t,$$
$$c^H_{o,t+1} = \frac{R_{t+1}}{\pi_t} s^H_t,$$

where s_t is savings and R_{t+1} is the gross interest rate. Maximizing the utility level subject to these two constraints yields the optimal level of consumption and savings:

$$c^H_{a,t} = \frac{1-a}{1+(1-a)\beta\pi_t} w_t, \qquad c^H_{o,t+1} = \frac{(1-a)\beta}{1+(1-a)\beta\pi_t} R_{t+1} w_t,$$

and

$$s^H_t = \frac{(1-a)\beta\pi_t}{1+(1-a)\beta\pi_t} w_t. \tag{10}$$

These equations indicate that the mortality rate affects households' choices. The optimal number of children is also influenced by the mortality rate:

$$n_t = \frac{a}{e[1+(1-a)\beta\pi_t]}. \tag{11}$$

The declining π_t increases n_t. The low π_t implies that households cannot live to old age with a high probability. Then, to derive higher utility in adulthood, they give birth to a lot of children.

2.4.2 Bureaucrats

As indicated earlier, bureaucrats derive their utility only from consumption in adulthood and old age because we assume that they do not raise children. Their utility is as follows:

$$\ln c_{a,t}^i + \beta\pi_t \ln c_{o,t+1}^i, \qquad i \in \{CB, NB\}. \tag{12}$$

Bureaucrats also face the survival rate π_t.

Firstly, the budget constraints of non-corruptible bureaucrats are as follows:

$$\begin{aligned} c_{a,t}^{NB} + s_t^{NB} &= \omega_t, \\ c_{o,t+1}^{NB} &= \frac{R_{t+1}}{\pi_t} s_t^{NB}. \end{aligned}$$

Then, the optimal levels of consumption and savings are given by

$$c_{a,t}^{NB} = \frac{1}{1+\beta\pi_t}\omega_t, \tag{13}$$

$$c_{o,t+1}^{NB} = \frac{\beta R_{t+1}}{1+\beta\pi_t}\omega_t, \tag{14}$$

$$s_t^{NB} = \frac{\beta\pi_t}{1+\beta\pi_t}\omega_t. \tag{15}$$

Secondly, we examine corruptible bureaucrats. If they do not engage in corruption, their choices and utility level are the same as those of non-corruptible bureaucrats. Thus, from (12) – (14), the expected indirect utility of honest bureaucrats becomes

$$EU_t^{CB(honest)} = \ln \frac{\omega_t}{1+\beta\pi_t} + \beta\pi_t \ln \frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t}. \tag{16}$$

On the contrary, when corruptible bureaucrats obtain illegal income from public funds, their utility depends on the government's monitoring. With probability $1-\eta$, they can avoid the accusation and punishment by the government. With probability η, they are caught and imprisoned in period t, thereby losing their illegal income. To avoid punishment, dishonest bureaucrats behave similarly to non-corruptible bureaucrats. That is, their consumption level in adulthood is equal to $c_{a,t}^{NB}$. In addition, they invest illegal income in a foreign market (e.g., an offshore bank) where it is difficult for the government to disclose their investment[4]. If they save this illegal income in the domestic market, they are caught by the government. The return of the foreign market is denoted by R_{t+1}^{F}. This leads to the following consumption level of dishonest bureaucrats in old age:

$$c_{o,t+1}^{CB(dishonest)} = \begin{cases} \frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t} & \text{if caught} \\ \frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t} + \frac{(1-\delta)R_{t+1}^{F}G_t}{N_t^B} & \text{if not caught} \end{cases} \tag{17}$$

Subsequently, from (12), (13), and (17), dishonest bureaucrats who avoid the accusation with probability $1-\eta$ obtain the following utility:

$$\ln\frac{\omega_t}{1+\beta\pi_t} + \beta\pi_t \ln\left[\frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t} + \frac{(1-\delta)R_{t+1}^{F}G_t}{N_t^B}\right]. \tag{18}$$

On the contrary, if dishonest bureaucrats are caught with probability η, their utility becomes

$$(1-\chi)\ln\frac{\omega_t}{1+\beta\pi_t} + \beta\pi_t \ln\frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t}. \tag{19}$$

$\chi \in (0,1]$ stands for psychological distress. If they are caught, they are imprisoned during adulthood. Thus, they lose a proportion χ of utility.

[4]This idea is similar to Varvarigos (2017). In the model of Varvarigos (2017), tax evaders use a storage technology such as offshore bank accounts to conceal their unreported income.

Here, we make the following assumption:

$$R_{t+1}^F = \rho R_{t+1}. \tag{20}$$

$\rho \in (0,1)$ represents the costs and risk of investing illegal income in the foreign market[5]. Lower ρ implies higher costs and risk. Then, from $(18)-(20)$, expected utility if they engage in corruption is represented by

$$\begin{aligned} EU_t^{CB(dishonest)} =& (1-\eta\chi)\ln\frac{\omega_t}{1+\beta\pi_t} \\ &+ (1-\eta)\beta\pi_t \ln\left[\frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t} + \frac{(1-\delta)\rho R_{t+1}G_t}{N_t^B}\right] \\ &+ \eta\beta\pi_t \ln\frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t}. \end{aligned} \tag{21}$$

Lastly, we consider the maximization problem of a corruptible bureaucrat. A corruptible bureaucrat j becomes a dishonest bureaucrat with probability $\sigma_{jt} \in [0,1]$ and an honest bureaucrat with probability $1-\sigma_{jt}$. He or she chooses his or her strategy σ_{jt} to maximize U_{jt} that is defined by

$$U_{jt} = \sigma_{jt} EU_t^{CB(dishonest)} + (1-\sigma_{jt})EU_t^{CB(honest)}. \tag{22}$$

3 Equilibrium

In this section, we (i) derive the market equilibrium conditions, (ii) describe a bureaucrat's strategy, (iii) show the effects of corruption on mortality and fertility rates in the development process, and (iv) derive the dynamic equations of per capita capital and examine the steady states of the economy.

[5]If $\rho > 1$, all agents invest their income in the foreign market. Then, the capital market of this economy becomes $K_{t+1} = 0$. This is not an equilibrium. In addition, if assumption (20) holds and the probability of being caught is 1 when dishonest bureaucrats invest their illegal income in the domestic market, it is optimal for them to invest labor income in the domestic market and illegal income in the foreign market. See Appendix A.

3.1 Market clearing conditions

Firstly, the labor market clearing condition is $L_t = (1-\lambda)N_t$. Therefore, per capita labor force becomes constant:

$$l_t = l = (1-\lambda). \tag{23}$$

Using equations (1), (2), (4), (5), and (7) with $\omega_t = w_t$ leads to the following tax rate:

$$\tau_t = \tau = \frac{\theta l + \lambda(1-\alpha)}{l + \lambda(1-\alpha)}. \tag{24}$$

Since $0 < \theta < 1$, $0 < \tau < 1$. Then, from equations (2) $-$ (4), (23), and (24), the per capita output, interest rate, and wage rate are derived:

$$y(k_t) = Al^{1-\alpha}k_t^{\alpha}, \tag{25}$$

$$r(k_t) = (1-\tau)\alpha Al^{1-\alpha}k_t^{\alpha-1}, \tag{26}$$

$$w(k_t) = (1-\tau)(1-\alpha)Al^{-\alpha}k_t^{\alpha}. \tag{27}$$

These variables depend only on the stock of per capita capital k_t.

We next consider public services, public health, and the survival rate. From equations (6) and (25), public services are as follows:

$$f(\sigma_t, k_t) = \phi(\sigma_t)y(k_t). \tag{28}$$

By substituting this equation into equation (8), we obtain the quality of public health:

$$h(\sigma_t) = \phi(\sigma_t). \tag{29}$$

Then, from (9) and (29), the survival rate is as follows:

$$\pi(\sigma_t) = \Pi(\phi(\sigma_t)). \tag{30}$$

Moreover, from (11) and (30), the optimal number of children becomes

$$n(\sigma_t) = \frac{a}{e[1 + (1-a)\beta\pi(\sigma_t)]}. \tag{31}$$

Lastly, the capital market clearing condition is $K_{t+1} = s_t^H N_t^H + s_t^{NB} N_t^B$. The amount of savings is the same among all bureaucrats despite their different types. From equations (1), (10), (15), and $\omega_t = w_t$, the condition is rewritten as follows:

$$K_{t+1} = \frac{(1-a)\beta\pi_t w_t}{1 + (1-a)\beta\pi_t}(1-\lambda)N_t + \frac{\beta\pi_t w_t}{1+\beta\pi_t}\lambda N_t.$$

Dividing both sides by N_t yields

$$k_{t+1}\frac{N_{t+1}}{N_t} = \beta w_t \left[\frac{(1-a)(1-\lambda)\pi_t}{1+(1-a)\beta\pi_t} + \frac{\lambda\pi_t}{1+\beta\pi_t}\right].$$

Since $N_{t+1} = n_t N_t^H$, we obtain $N_{t+1}/N_t = n_t(1-\lambda)$. Then, by using (27), (30), and (31) with $N_{t+1}/N_t = n_t(1-\lambda)$, the capital market clearing condition becomes

$$k_{t+1} = S(\sigma_t, k_t) \equiv \frac{\beta w(k_t)}{n(\sigma_t)(1-\lambda)}\left[\frac{(1-a)(1-\lambda)\pi(\sigma_t)}{1+(1-a)\beta\pi(\sigma_t)} + \frac{\lambda\pi(\sigma_t)}{1+\beta\pi(\sigma_t)}\right]. \tag{32}$$

Therefore, the dynamics of per capita capital depend not only on the stock of per capita capital k_t but also on the survival rate $\pi(\sigma_t)$ and the fertility rate $n(\sigma_t)$. Moreover, the degree of corruption σ_t affects the dynamics through mortality and fertility rates.

3.2 A Bureaucrat's Strategy on Corruption

From (16), (26), (27), and (30), $EU_t^{CB(honest)}$ is rewritten as follows:

$$EU^{CB(honest)}(\sigma_t, k_t) = \ln \frac{w(k_t)}{1+\beta\pi(\sigma_t)} + \beta\pi(\sigma_t) \ln \frac{\beta R(k_t) w(k_t)}{1+\beta\pi(\sigma_t)}. \tag{33}$$

From (5), (20), (21), (25) − (27), and (30), $EU_t^{CB(dishonest)}$ is rewritten as follows:

$$\begin{aligned} EU^{CB(dishonest)}(\sigma_t, k_t) =& (1-\eta\chi) \ln \frac{w(k_t)}{1+\beta\pi(\sigma_t)} \\ &+ (1-\eta)\beta\pi(\sigma_t) \ln \left[\frac{\beta R(k_t) w(k_t)}{1+\beta\pi(\sigma_t)} + \frac{(1-\delta)\rho\theta R(k_t) y(k_t)}{\lambda} \right] \\ &+ \eta\beta\pi(\sigma_t) \ln \frac{\beta R(k_t) w(k_t)}{1+\beta\pi(\sigma_t)}. \end{aligned} \tag{34}$$

These indirect utilities depend on the levels of corruption and capital stock. Note that $\partial EU^{CB(honest)}(\sigma_t, k_t)/\partial\sigma_t < 0$, $\partial EU^{CB(dishonest)}(\sigma_t, k_t)/\partial\sigma_t < 0$, and $\partial EU^{CB(honest)}(\sigma_t, k_t)/\partial\sigma_t > \partial EU^{CB(dishonest)}(\sigma_t, k_t)/\partial\sigma_t$. The proof is provided in Appendix B.

Then, the maximization problem of corruptible bureaucrat j is affected by other corruptible bureaucrats' choices. Hence, from (22), (33), and (34), the objective function of corruptible bureaucrat j is rewritten as follows:

$$U(\sigma_{jt}, \sigma_t, k_t) = \sigma_{jt} EU^{CB(dishonest)}(\sigma_t, k_t) + (1-\sigma_{jt}) EU^{CB(honest)}(\sigma_t, k_t). \tag{35}$$

Bureaucrat j chooses his or her probability of engaging in corruption, σ_{jt}, by maximizing $U(\sigma_{jt}, \sigma_t, k_t)$, given the other corruptible bureaucrats' choices, σ_t. In this study, σ_{jt} constitutes his or her strategy. Then, the model has a game-theoretic structure among corruptible bureaucrats. Therefore, we consider a Nash equilibrium.

Definition 1.
σ_{jt}^* is a Nash equilibrium if σ_{jt}^* is the best response to σ_t^* under the given k_t, for all $j \in N^{CB}$. That is, $U(\sigma_{jt}^*, \sigma_t^*, k_t) \geq U(\sigma_{jt}', \sigma_t^*, k_t)$ for all $\sigma_{jt}' \in [0,1]$ and all $j \in N^{CB}$.

In the Nash equilibrium, $\sigma_{jt}^* = \sigma_{-jt}^*$ so that $\sigma_{jt}^* = \sigma_t^*$.

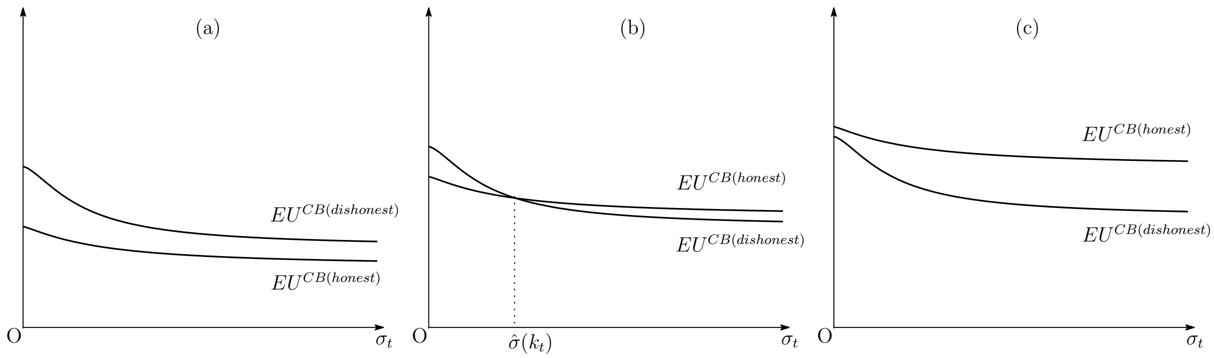

Figure 1: Expected utilities and bureaucrats' strategy.

Firstly, we derive an interval of k_t that satisfies $\partial U(\sigma_{jt}, \sigma_t, k_t)/\partial \sigma_{jt} > 0$. When this inequality holds, $\sigma_{jt} = 1$ becomes optimal. From equations (25), (27), and (33) – (35),

$$\begin{aligned} & \frac{\partial}{\partial \sigma_{jt}} U(\sigma_{jt}, \sigma_t, k_t) > 0 \\ \Leftrightarrow \quad & EU^{CB(dishonest)}(\sigma_t, k_t) > EU^{CB(honest)}(\sigma_t, k_t) \\ \Leftrightarrow \quad & k_t < \frac{V_1(\sigma_t)}{V_2(\sigma_t)} \equiv \tilde{k}(\sigma_t), \end{aligned} \tag{36}$$

where $V_1(\sigma_t) = \{[\beta(1+\beta\pi(\sigma_t))^{-1}+(1-\delta)\rho\theta l(\lambda(1-\tau)(1-\alpha))^{-1}]/[\beta(1+\beta\pi(\sigma_t))^{-1}]\}^{\frac{(1-\eta)\beta\pi(\sigma_t)}{\alpha\eta\chi}}$ and $V_2(\sigma_t) = [(1-\tau)(1-\alpha)Al^{-\alpha}/(1+\beta\pi(\sigma_t))]^{\frac{1}{\alpha}}$. Note that $dV_1(\sigma_t)/d\sigma_t < 0$ and $dV_2(\sigma_t)/d\sigma_t > 0$ so that $d\tilde{k}(\sigma_t)/d\sigma_t < 0$. If $k_t < \tilde{k}(\sigma_t)$, the corruptible bureaucrat takes $\sigma_{jt} = 1$, and then $\sigma_t = 1$ is realized since all the other corruptible bureaucrats choose the same strategy. The condition is rewritten as $k_t < \tilde{k}(1)$. In this case, all corruptible bureaucrats engage in corruption. Then, the strategy $\sigma_{jt} = 1$ if $k_t < \tilde{k}(1)$ is the Nash equilibrium. This case is represented in Figure 1-(a): given $k_t < \tilde{k}(1)$, $EU^{CB(dishonest)}(\sigma_t, k_t)$ is higher than $EU^{CB(honest)}(\sigma_t, k_t)$ for all σ_t.

Secondly, in the case of $\partial U(\sigma_{jt}, \sigma_t, k_t)/\partial \sigma_{jt} < 0$, we obtain $k_t > \tilde{k}(\sigma_t)$. Choosing $\sigma_{jt} = 0$ is optimal if $k_t > \tilde{k}(\sigma_t)$ holds. In addition, the strategy $\sigma_{jt} = 0$ is optimal for all corruptible bureaucrats. This results in $\sigma_t = 0$. Thus, the strategy $\sigma_{jt} = 0$ if $k_t > \tilde{k}(0)$ is the Nash equilibrium. This case is represented in Figure 1-(c): given $k_t > \tilde{k}(0)$, $EU^{CB(honest)}(\sigma_t, k_t)$ is higher than $EU^{CB(dishonest)}(\sigma_t, k_t)$ for all σ_t. We note that $\tilde{k}(1) < \tilde{k}(0)$ holds since $d\tilde{k}(\sigma_t)/d\sigma_t < 0$.

Thirdly, a similar discussion can be applied to the case of $\partial U(\sigma_{jt}, \sigma_t, k_t)/\partial \sigma_{jt} = 0$. $\partial U(\sigma_{jt}, \sigma_t, k_t)/\partial \sigma_{jt} = 0$ yields $k_t = \tilde{k}(\sigma_t)$. In this case, the strategy $\sigma_{jt} \in [0, 1]$ becomes optimal given the other corruptible bureaucrats' strategy and stock of per capita capital. Furthermore, there is a unique σ_{jt} that satisfies $\sigma_{jt} = \hat{\sigma}_t$ and $k_t = \tilde{k}(\hat{\sigma}_t)$ in the interval $\tilde{k}(1) \leq k_t \leq \tilde{k}(0)$ since $\tilde{k}(\sigma_t)$ is a decreasing function of its argument. Its inverse function $\hat{\sigma}_j(k_t)$ becomes the unique strategy depending on k_t. In addition, because $\tilde{k}(\sigma_t)$ is a decreasing function, as capital accumulation progresses, $\hat{\sigma}_j(k_t)$ must decrease; that is, $d\hat{\sigma}_j(k_t)/dk_t < 0$. Thus, the strategy $\hat{\sigma}_j(k_t)$ if $\tilde{k}(1) \leq k_t \leq \tilde{k}(0)$ is the Nash equilibrium. This case is represented in Figure 2-(b): given $\tilde{k}(1) \leq k_t \leq \tilde{k}(0)$, the degree of corruption is determined to hold $EU^{CB(honest)}(\sigma_t, k_t) = EU^{CB(dishonest)}(\sigma_t, k_t)$.

Finally, we obtain the strategy of the corruptible bureaucrat j that constitutes the Nash equilibrium. In our model, all corruptible bureaucrats take the same strategy depending on the level of capital stock. Hence, we omit the subscript j and then denote a corruptible bureaucrat's strategy by $\sigma(k_t)$. The strategy is summarized in the following proposition.

Proposition 1.
A strategy of a corruptible bureaucrat is as follows:

$$\sigma(k_t) = \begin{cases} 1 & \text{if} \quad k_t < \tilde{k}(1), \\ \hat{\sigma}(k_t) & \text{if} \quad \tilde{k}(1) \leq k_t \leq \tilde{k}(0), \\ 0 & \text{if} \quad \tilde{k}(0) < k_t. \end{cases} \tag{37}$$

A corruptible bureaucrat chooses the probability of engaging in corruption, $\sigma(k_t)$, corresponding to the stages of development; that is, the degree of corruption depends on development. Corruptible bureaucrats are unlikely to engage in corruption as capital accumulates.

Figure 2 shows the strategy graphically.

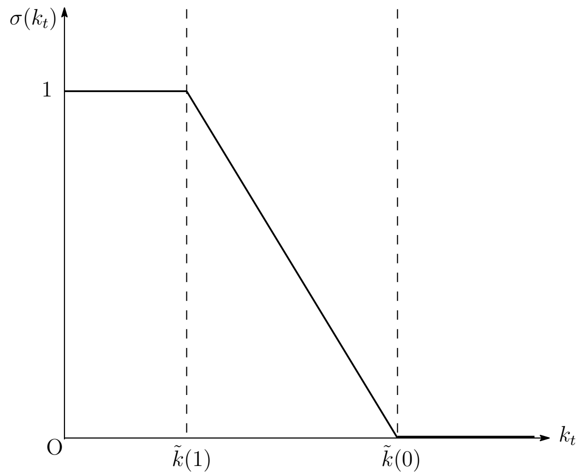

Figure 2: Nash equilibrium strategy of corruptible bureaucrats.

Capital accumulation decreases the degree of corruption through two effects. One is the effect of labor income. Because corruption is punished, dishonest bureaucrats who are detected lose a proportion of their utility. This loss of utility increases with labor income. Thus, high income implies high costs of engaging in corruption. The other is the effect of the mortality rate. When the mortality rate is low, the probability of deriving utility from illegal income is high. Thus, a low mortality rate makes engaging in corruption fascinating. In the early stage of development, $k_t < \tilde{k}(1)$, and late stage, $\tilde{k}(0) < k_t$, the effect of the mortality rate is weaker. In the early (late) stage, labor income is sufficiently low (high) that all (no) corruptible bureaucrats engage in corruption regardless of whether the mortality rate is high or low. On the contrary, in the middle stage, $\tilde{k}(1) \leq k_t \leq \tilde{k}(0)$, such a pure strategy does not become the Nash equilibrium. A corruptible bureaucrat becomes dishonest (honest) if the others become honest (dishonest). This is because, as the next subsection explains in detail, a low (high) degree of corruption results in a high (low) survival rate, implying a high (low) probability of enjoying illegal income. Hence, because of the mortality rate, bureaucrats' decisions to engage in corruption are strategic substitutes. Thus, in the middle stage, the mixed strategy is the Nash equilibrium. These effects lead to a declining degree of corruption as capital accumulates.

3.3 Effects of corruption

This subsection derives public services, public health, and the mortality rate and fertility rates in the Nash equilibrium. Firstly, from (6), (28), and (37), public services are as follows:

$$f(k_t) = \phi(k_t)y(k_t) = \begin{cases} \underline{\phi}y(k_t) & \text{if} \quad k_t < \tilde{k}(1), \\ \phi(\hat{\sigma}(k_t))y(k_t) & \text{if} \quad \tilde{k}(1) \leq k_t \leq \tilde{k}(0), \\ \bar{\phi}y(k_t) & \text{if} \quad k_t > \tilde{k}(0), \end{cases} \tag{38}$$

where $\bar{\phi} = [p\xi + (1-p)\gamma]\theta$, $\underline{\phi} = \{[p\xi + (1-p)\gamma] - bp(\xi - \gamma)\}\theta$, and $\phi(\hat{\sigma}(k_t)) = \{[p\xi + (1-p)\gamma] - \hat{\sigma}(k_t)bp(\xi - \gamma)\}\theta$. $\bar{\phi}$, $\underline{\phi}$, and $\phi(\hat{\sigma}(k_t))$ satisfy $\underline{\phi} < \bar{\phi}$ and $\underline{\phi} \leq \phi(\hat{\sigma}(k_t)) \leq \bar{\phi}$ for all $k_t \in [\tilde{k}(1), \tilde{k}(0)]$. In the early stage of development, $k_t < \tilde{k}(1)$, all corrupt bureaucrats behave dishonestly. They take a proportion of public funds as illegal income, so that the level of public services supplied by bureaucrats is low. As capital accumulates, some corruptible bureaucrats stop the corrupt practice, while others continue to engage in corruption. In this stage, public services increase along with capital accumulation. After the stock of per capita capital exceeds the threshold $\tilde{k}(0)$, corruption does not occur. Thus, all public funds are devoted to public services.

Secondly, from (29) and (38), the quality of public health is represented by

$$h(k_t) = \begin{cases} \underline{\phi} & \text{if} \quad k_t < \tilde{k}(1), \\ \phi(\hat{\sigma}(k_t)) & \text{if} \quad \tilde{k}(1) \leq k_t \leq \tilde{k}(0), \\ \bar{\phi} & \text{if} \quad k_t > \tilde{k}(0). \end{cases} \tag{39}$$

Similarly to public services, the quality of public health depends on corruption. When the stock of per capita capital is sufficiently small, the quality worsens because insufficient public services are supplied to dilute pollution from production. Public health improves and reaches high quality $\bar{\phi}$ in the late stages of development.

Thirdly, the survival rate, or the mortality rate, is also a function of k_t; that is, from (30) and (39), we obtain

$$\pi(k_t) = \begin{cases} \underline{\pi} & \text{if} \quad k_t < \tilde{k}(1), \\ \pi(\hat{\sigma}(k_t)) & \text{if} \quad \tilde{k}(1) \leq k_t \leq \tilde{k}(0), \\ \bar{\pi} & \text{if} \quad k_t > \tilde{k}(0), \end{cases} \tag{40}$$

where $\bar{\pi} = \Pi(\bar{\phi})$, $\underline{\pi} = \Pi(\underline{\phi})$, and $\pi(\hat{\sigma}(k_t)) = \Pi(\phi(\sigma(k_t)))$. $\bar{\pi}$, $\underline{\pi}$, and $\pi(\hat{\sigma}(k_t))$ satisfy $\underline{\pi} < \bar{\pi}$ and $\underline{\pi} \leq \pi(\hat{\sigma}(k_t)) \leq \bar{\pi}$ for all $k_t \in [\tilde{k}(1), \tilde{k}(0)]$. The survival rate in period t is influenced by corruption through public services and public health. In the early stage of development, a highly corrupted bureaucracy induces a small amount of public services. Therefore, the quality of public health is low, yielding a high mortality rate. In the middle stage, the mortality rate remains severe because some corruptible bureaucrats engage in corrupt practices. However, it improves as capital accumulates and the number of dishonest bureaucrats decreases. Finally, in the late stage, the mortality rate sufficiently decreases; that is, the survival rate takes the maximum level $\bar{\pi}$.

Lastly, from (31) and (40), the fertility rate is given by

$$n(k_t) = \begin{cases} \bar{n} & \text{if} \quad k_t < \tilde{k}(1), \\ n(\hat{\sigma}(k_t)) & \text{if} \quad \tilde{k}(1) \leq k_t \leq \tilde{k}(0), \\ \underline{n} & \text{if} \quad k_t > \tilde{k}(0), \end{cases} \tag{41}$$

where $\bar{n} = a/\{e[1 + (1-a)\beta\underline{\pi}]\}$, $\underline{n} = a/\{e[1 + (1-a)\beta\bar{\pi}]\}$, and $n(\hat{\sigma}(k_t)) = a/\{e[1 + (1-a)\beta\pi(\hat{\sigma}(k_t))]\}$. $\bar{n}$, $\underline{n}$, and $n(\hat{\sigma}(k_t))$ satisfy $\underline{n} < \bar{n}$ and $\underline{n} \leq n(\hat{\sigma}(k_t)) \leq \bar{n}$ for all $k_t \in [\tilde{k}(1), \tilde{k}(0)]$.

The preceding results can be summarized in the following proposition.

Proposition 2.
The Nash equilibrium is described as follows.

1. *For early stages in $k_t < \tilde{k}(1)$, all corruptible bureaucrats engage in corruption and then mortality and fertility rates are high.*

2. *For middle stages in $\tilde{k}(1) \leq k_t \leq \tilde{k}(0)$, some proportion of corruptible bureaucrats engage in corruption and the proportion and mortality and fertility rates decrease as capital accumulates.*

3. *For late stages in $k_t > \tilde{k}(0)$, no corruptible bureaucrats engage in corruption and then mortality and fertility rates are low.*

These results concur with most empirical findings. For example, they are consistent with Gupta, Davoodi, and Tiongson (2000) on the positive relationship between corruption and mortality and fertility rates; Bloom, Canning, and Sevilla (2004) and Galor (2005) on the negative relationship between mortality and fertility rates and development; and the literature noted in the Introduction on the negative relationship between corruption and development. In particular, we emphasize that changes in the mortality rate are caused by corruption, concurring with the empirical finding of Rajkumar and Swaroop (2008).

3.4 Dynamics of the economy

This subsection derives the dynamics of per capita capital and transition of an economy. From (32), (40), and (41), the right hand side of the dynamic equation becomes

$$S(k_t) = \frac{\beta w(k_t)}{n(k_t)(1-\lambda)} \left[\frac{(1-a)(1-\lambda)\pi(k_t)}{1+(1-a)\beta\pi(k_t)} + \frac{\lambda\pi(k_t)}{1+\beta\pi(k_t)} \right].$$

Substituting (27) into this equation yields the dynamic equation:

$$k_{t+1} = \frac{\beta(1-\tau)(1-\alpha)Ak_t^{\alpha}}{n(k_t)(1-\lambda)l^{\alpha}} \left[\frac{(1-a)(1-\lambda)\pi(k_t)}{1+(1-a)\beta\pi(k_t)} + \frac{\lambda\pi(k_t)}{1+\beta\pi(k_t)} \right]. \tag{42}$$

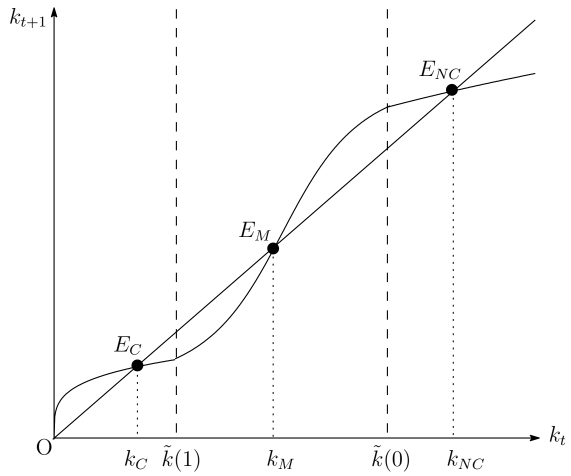

Figure 3: Multiple steady states.
The steady states E_C and E_{NC} are stable, while the steady state E_M is unstable.

Subsequently, from equations (40)−(42), the following three dynamic equations describe the dynamics of the economy:

$$k_{t+1}^{C} = \frac{\tilde{A}k_t^{\alpha}}{\bar{n}}\left[\frac{(1-a)(1-\lambda)\underline{\pi}}{1+(1-a)\beta\underline{\pi}} + \frac{\lambda\underline{\pi}}{1+\beta\underline{\pi}}\right] \quad \text{if} \quad k_t < \tilde{k}(1), \tag{43}$$

$$k_{t+1}^{M} = \frac{\tilde{A}k_t^{\alpha}}{n(\hat{\sigma}(k_t))}\left[\frac{(1-a)(1-\lambda)\pi(\hat{\sigma}(k_t))}{1+(1-a)\beta\pi(\hat{\sigma}(k_t))} + \frac{\lambda\pi(\hat{\sigma}(k_t))}{1+\beta\pi(\hat{\sigma}(k_t))}\right] \quad \text{if} \quad \tilde{k}(1) \leq k_t \leq \tilde{k}(0), \tag{44}$$

$$k_{t+1}^{NC} = \frac{\tilde{A}k_t^{\alpha}}{\underline{n}}\left[\frac{(1-a)(1-\lambda)\bar{\pi}}{1+(1-a)\beta\bar{\pi}} + \frac{\lambda\bar{\pi}}{1+\beta\bar{\pi}}\right] \quad \text{if} \quad \tilde{k}(0) < k_t, \tag{45}$$

where $\tilde{A} = \beta(1-\tau)(1-\alpha)A[(1-\lambda)l^{\alpha}]^{-1}$. k_{t+1}^{C}, k_{t+1}^{M}, and k_{t+1}^{NC} increase in k_t. In addition, these three dynamic equations satisfy the following relations: $k_{t+1}^{NC} > k_{t+1}^{C}$ holds for all $k_t > 0$; $k_{t+1}^{M} = k_{t+1}^{C}$ at $k_t = \tilde{k}(1)$; and $k_{t+1}^{M} = k_{t+1}^{NC}$ at $k_t = \tilde{k}(0)$.

Drawing the three dynamics in the k_t-k_{t+1} plane shows the transition of this economy and steady states, as depicted in Figure 3. Three steady states can exist. We denote the points at which the 45-degree line intersects with the dynamics k_{t+1}^{C}, k_{t+1}^{M}, and k_{t+1}^{NC} as E_C, E_M, and E_{NC}, and then we define the level of k_t at each steady state as k_C, k_M, and k_{NC}, respectively. E_C and E_{NC} are stable, whereas E_M is unstable. Therefore, the economy will converge to E_C (E_{NC}) if its initial stock of per capita capital is less (higher) than k_M. The stable steady states are characterized as follows: E_C has corruption, low quality public health, and high mortality and fertility rates, whereas E_{NC} has no corruption, high quality public health, and low mortality and fertility rates.

Multiple steady states are derived from the two-way causal relationship between corruption and economic development. On the one hand, lower level of capital stock induces bureaucrats to engage in corruption, raising mortality and fertility rates and hampering capital accumulation. On the other hand, in a well-developed economy with no corruption and low mortality and fertility rates, capital accumulation accelerates. The existence of multiple steady states can thus explain the differences in corruption and mortality and fertility rates between poor and rich countries as well as the persistence of poverty and bad governance in some countries[6].

4 Discussion

4.1 Policy of increasing public spending

This subsection discusses the effect of increasing public spending on public health by a government (i.e., increased θ). We examine the changes in the thresholds $\tilde{k}(1)$ and $\tilde{k}(0)$ derived from (36) and the dynamic equation derived from (42).

Firstly, we consider the effect of θ on these thresholds. Increases in θ raise $\tilde{k}(1)$ and $\tilde{k}(0)$ through three channels. The first channel is illegal income. Corruptible bureaucrats obtain higher illegal income. The second is the tax rate. To maintain a balanced budget, the government needs to increase the tax rate. The third is the mortality rate. Increased public spending improves the quality of public health, which reduces the mortality rate. High illegal income, a high tax rate, and a low mortality

[6]Multiple steady states (equilibria) are discussed by other macroeconomic theoretical studies of corruption such as Ehrlich and Lui (1999), Alesina and Angeletos (2005), Blackburn, Bose, and Haque (2006, 2011), Blackburn and Forgues-Puccio (2007), Blackburn and Sarmah (2008), Eicher, García-Peñalosa, and Van Ypersele (2009), Blackburn (2012), Varvarigos and Arsenis (2015), and Akimoto (2018).

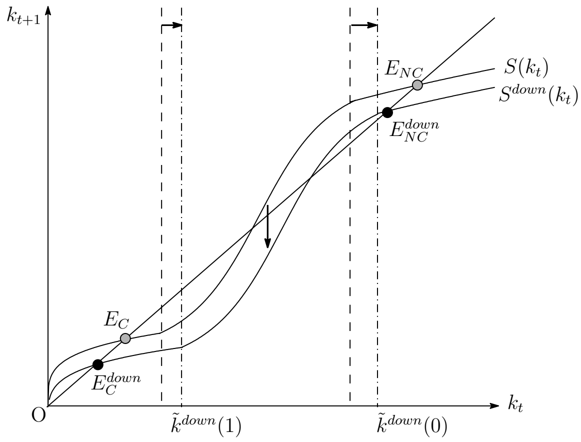

Figure 4: A downward shift in $S(k_t)$.

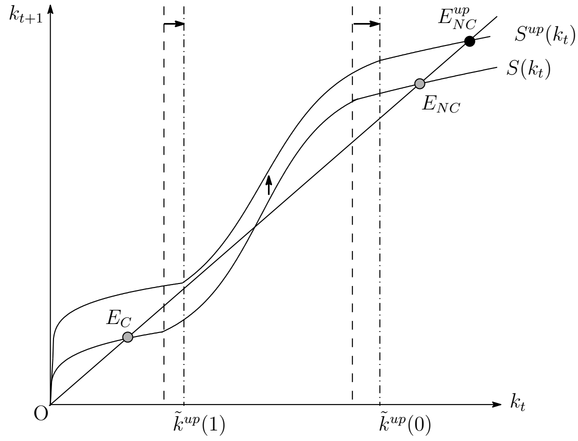

Figure 5: An upward shift in $S(k_t)$.

rate make corruption attractive. Thus, two thresholds rise.

Secondly, we examine whether the dynamic equation shifts upward or downward. The increases in θ have a negative effect on capital accumulation through the tax rate and a positive effect through mortality and fertility rates[7]. The high tax rate decreases the amount of savings because of a declining wage rate. This moves the dynamics downward. On the contrary, the low mortality rate is accompanied by a low fertility rate. These low mortality and fertility rates move the dynamics upward. When the effect of the high tax rate is larger, the dynamics shift downward (see Figure 4). When the effect of low mortality and fertility rates is larger, the dynamics shift upward (see Figure 5). As mentioned above, the thresholds move to the right in both cases.

We consider the former case and an economy at the steady state E_C in Figure 4. When the government increases the funds devoted to public health, the economy converges to the new steady state E_C^{down}. Hence, the economy is worse off because the steady-state level of per capita capital decreases. In addition, corrupt behavior remains rampant. On the contrary, in the latter case, an economy can get out of the steady state characterized by a high level of corruption and high mortality and fertility rates. An

[7]For the dynamics in the middle stage of development, k_{t+1}^M, there exists another negative effect since the changes in the two thresholds affect $\hat{\sigma}(k_t)$ and k_{t+1}^M. If $\tilde{k}(1)$ and $\tilde{k}(0)$ increase, $\hat{\sigma}(k_t)$ must increase for all $k_t \in [\tilde{k}(1), \tilde{k}(0)]$. The high $\hat{\sigma}(k_t)$ hampers capital accumulation in the middle stages through high mortality and fertility rates.

economy at the steady state E_C in Figure 5 can finally converge to the unique steady state E_{NC}^{up} characterized by no corruption and low mortality and fertility rates.

The outcomes of increases in public spending depend on the effects of a high tax rate and low mortality and fertility rates. We can prove that the dynamics shift downward if $\epsilon(k_t) \leq 1$ and upward if $\epsilon(k_t) \geq 1/(1-a)$, where $\epsilon(k_t) \equiv -[d\pi(k_t)/\pi(k_t)]/[d(1-\tau)/(1-\tau)]$. See Appendix C. This finding indicates that the policy of increasing public spending has negative effects on an economy when the policy cannot improve the survival rate effectively. Taking account of the inefficiency of public spending in developing countries suggested by World Bank (2003), k_{t+1}^C and k_{t+1}^M may move downward and k_{t+1}^{NC} upward. In this case, developing countries at E_C are worse off by converging to E_C^{down}, while developed countries at E_{NC} are better off by converging to E_{NC}^{up}.

4.2 Existence of steady states

We next derive the conditions for the existence of steady states, especially stable ones, namely E_C and E_{NC}. To obtain the conditions explicitly, we provide numerical examples.

The existence conditions of E_C and E_{NC} are given by $k_C^* \leq \tilde{k}(1)$ and $\tilde{k}(0) \leq k_{NC}^*$, respectively. k_C^*, the level of per capita capital at steady state E_C, is derived from (43):

$$k_C^* = \left\{ \frac{\tilde{A}}{\bar{n}} \left[\frac{(1-a)(1-\lambda)\underline{\pi}}{1+(1-a)\beta\underline{\pi}} + \frac{\lambda\underline{\pi}}{1+\beta\underline{\pi}} \right] \right\}^{\frac{1}{1-\alpha}}. \tag{46}$$

k_{NC}^*, the level of per capita capital at steady state E_{NC}, is derived from (45):

$$k_{NC}^* = \left\{ \frac{\tilde{A}}{\underline{n}} \left[\frac{(1-a)(1-\lambda)\bar{\pi}}{1+(1-a)\beta\bar{\pi}} + \frac{\lambda\bar{\pi}}{1+\beta\bar{\pi}} \right] \right\}^{\frac{1}{1-\alpha}}. \tag{47}$$

$\tilde{k}(1)$ and $\tilde{k}(0)$ are given by (36).

The conditions depend on the following parameters: α and A for the production technology; a, β, and e for the utility function; λ for the share of bureaucrats; θ for

α	β	$\bar{\pi}$	$\underline{\pi}$	θ	a	e	λ	A	δ	η	ρ
1/3	0.545	0.95	0.3	0.06	0.6	0.2	0.2	6.2	0.5	0.5	0.65

Table 1: The parameter set.

public spending; $\bar{\pi}$ and $\underline{\pi}$ for the survival rates; and δ, η, χ, and ρ for corruption. The values of $(\alpha, \beta, \bar{\pi}, \underline{\pi})$ are set to follow the standard values of the literature. We set $\alpha = 1/3$ and $\beta = (0.98)^{30}$. The value of the discount factor indicates that each period lasts 30 years and that the period discount factor is 0.98. Following Blackburn and Cipriani (2002) and Fanti and Gori (2014)[8], we fix the survival rate in E_{NC} at $\bar{\pi} = 0.95$ and the rate in E_C at $\underline{\pi} = 0.3$. The value of θ is set to 0.06 to fit the ratio of public health expenditure to GDP[9]. We assume that $a = 0.6$, $e = 0.2$, and $\lambda = 0.2$ to obtain the population growth rate calibrated from the model close to the data[10]. Then, from the remaining parameters, $(A, \delta, \eta, \chi, \rho)$, the existence conditions of the steady states are described. The next subsection determines the values of these parameters. Table 1 summarizes the set of parameters[11].

By setting the parameters $(\alpha, \beta, \bar{\pi}, \underline{\pi}, \theta, a, e, \lambda)$ at the values provided in Table 1, the condition $k_C^* \leq \tilde{k}(1)$ becomes

$$A \leq \frac{[1 + 0.953(1-\delta)\rho]^{0.109\frac{1-\eta}{\eta\chi}}}{0.169}. \tag{48}$$

Similarly, the condition $\tilde{k}(0) \leq k_{NC}^*$ becomes

$$A \geq \frac{[1 + 1.243(1-\delta)\rho]^{0.345\frac{1-\eta}{\eta\chi}}}{0.205}. \tag{49}$$

[8] In Blackburn and Cipriani (2002) and Fanti and Gori (2014), the maximum survival rate is 0.95 and the minimum rate is 0.3.

[9] The average ratio for the world is 6% in 2014; see http://apps.who.int/nha/database/Home/Index/en.

[10] The average population growth rate for low income countries is 2.7% in 2016. This fact implies that, in this model, the population growth rate of a low developed economy at E_C is $(1.027)^{30}$ since each period lasts 30 years. For the population growth data, see https://data.worldbank.org/data-catalog/world-development-indicators.

[11] The values are rounded to three decimal places.

Hence, three possible cases exist. Multiple steady states are realized if both (48) and (49) hold at the same time. The unique steady state E_C is realized if only (48) holds. The unique steady state E_{NC} is realized if only (49) holds. The set of parameters, $(A, \delta, \eta, \chi, \rho)$, affects the existence conditions as follows. If A, δ, η, or χ is high, only E_{NC} is likely to exist. On the contrary, if ρ is sufficiently high, only E_C is likely to exist. The increases in the set of parameters, (A, δ, η, χ), decrease the incentive to engage in corruption, while the increase in ρ makes engaging in corruption more attractive.

4.3 The role of cultural norms

We focus on the parameter $\chi \in (0, 1]$. χ represents the psychological costs of dishonest bureaucrats being detected. In other words, it captures how strongly dishonest bureaucrats feel distressed when their corrupt behavior is exposed to the public. In this sense, we can interpret χ as the degree of the severity of corruption in a society (i.e., cultural norms against corruption). If χ is low, implying that the public tolerates corruption, psychological distress is low. This idea is incorporated into the macro-dynamic model of Varvarigos (2017) to examine the relationship between tax evasion and cultural norms. In his model, dishonest behavior and cultural norms are determined endogenously. This subsection analyzes the effects of cultural norms on the existence of the steady states and transition path numerically.

By changing χ from 0.1 to 1, we obtain values of k_C^*, k_{NC}^*, $\tilde{k}(1)$, and $\tilde{k}(0)$ under the given values of the parameters in Table 1. χ does not affect the steady-state levels of per capita capital. That is, k_C^* and k_{NC}^* take constant values: $k_C^* = 0.043$ and $k_{NC}^* = 0.226$. Comparing $k_C^*(k_{NC}^*)$ with $\tilde{k}(1)(\tilde{k}(0))$ reveals whether the steady state $E_C(E_{NC})$. Table 2 summarizes the results.

We consider an economy having the initial level of per capita capital k_0 that is lower than k_C^* to examine a role of cultural norms and their effects on the transition path. For $\chi \in [0.1, 0.4]$, implying that the public is tolerant of corruption, the economy will converge to the unique steady state E_C. For $\chi \in [0.5, 0.6]$, multiple steady states are realized. However, the economy will converge to E_C rather than E_{NC}, as depicted in

χ	0.1	0.2	0.3	0.4	0.5
k_C^*	0.043	0.043	0.043	0.043	0.043
$\tilde{k}(1)$	0.128	0.066	0.053	0.048	0.044
k_{NC}^*	0.226	0.226	0.226	0.226	0.226
$\tilde{k}(0)$	14.840	1.061	0.440	0.284	0.218
Steady State	E_C	E_C	E_C	E_C	E_C & E_{NC}

χ	0.6	0.7	0.8	0.9	1
k_C^*	0.043	0.043	0.043	0.043	0.043
$\tilde{k}(1)$	0.043	0.041	0.040	0.040	0.039
k_{NC}^*	0.226	0.226	0.226	0.226	0.226
$\tilde{k}(0)$	0.183	0.161	0.147	0.136	0.128
Steady State	E_C & E_{NC}	E_{NC}	E_{NC}	E_{NC}	E_{NC}

Table 2: Effects of cultural norms on the existence of the steady states.

Figure 3. For $\chi \in [0.7, 1]$, implying that the public is intolerant of corruption, the economy will converge to the unique steady state E_{NC}. These results indicate that two countries having the same level of per capita capital, $k_0 < k_C^*$, can take different paths depending on the social norms in each country. In addition, our numerical results are concur with those of Varvarigos (2017).

5 Conclusion

This study considers the relationships among corruption, mortality and fertility rates, and capital accumulation and their effects on economic development. In the three-period overlapping generations model, these four factors are determined endogenously and affect each other. The results of this study indicate that an incidence of corruption increases mortality and fertility rates and that this change hampers the capital accumulation process. Corruptible bureaucrats decide whether to engage in corruption based on the level of capital stock. That is, the degree of corruption depends on the stage of development. Thus, a two-way causal relationship between corruption and development exists, which can yield multiple steady states. In the early stage, the steady state is characterized by high corruption and high mortality and fertility rates. In the late stage, the steady state is characterized by no corruption and low mortality and fertility rates. These steady states are stable, while the steady state in the middle stage is unstable; that is, corruptible bureaucrats pursue a mixed strategy. In the relationship between corruption and development, the effects of labor income and the mortality rate play important roles because of the endogenous mortality rate and the setting that not only households but also bureaucrats face the mortality rate during their lifetime.

Appendix

A. Investment behavior of dishonest bureaucrats

There are four possible cases. The first case is that dishonest bureaucrats invest both labor income and illegal income in the domestic market. The second case is that they invest both labor income and illegal income in the foreign market. The third case is that they invest labor income in the domestic market and illegal income in the foreign market. The fourth case is that they invest labor income in the foreign market and illegal income in the domestic market. We prove that expected utility in the third case is higher than that in the other three cases.

Suppose that $R^F_{t+1} = \rho R_{t+1}$ where $\rho \in (0, 1)$ is satisfied. In addition, assume that dishonest bureaucrats will be caught by the government with probability 1 if they invest their illegal income in the domestic market. The probability of being caught is η if they invest illegal income in the foreign market.

The expected utility of the first case U^{dd}_t is

$$U^{dd}_t = (1 - \chi) \ln \frac{\omega_t}{1 + \beta\pi_t} + \beta\pi_t \ln \frac{R_{t+1}\beta\omega_t}{1 + \beta\pi_t}.$$

The expected utility of the second case U_t^{ff} is

$$U_t^{ff} = (1-\eta\chi)\ln\frac{\omega_t}{1+\beta\pi_t} + (1-\eta)\beta\pi_t\ln\left[\frac{R^F_{t+1}\beta\omega_t}{1+\beta\pi_t} + \frac{R^F_{t+1}(1-\delta)G_t}{N_t^B}\right] + \eta\beta\pi_t\ln\frac{\beta R^F_{t+1}\omega_t}{1+\beta\pi_t}.$$

The expected utility of the third case U_t^{df} is

$$U_t^{df} = (1-\eta\chi)\ln\frac{\omega_t}{1+\beta\pi_t} + (1-\eta)\beta\pi_t\ln\left[\frac{R_{t+1}\beta\omega_t}{1+\beta\pi_t} + \frac{R^F_{t+1}(1-\delta)G_t}{N_t^B}\right] + \eta\beta\pi_t\ln\frac{\beta R_{t+1}\omega_t}{1+\beta\pi_t}.$$

The expected utility of the fourth case U_t^{fd} is

$$U_t^{fd} = (1-\chi)\ln\frac{\omega_t}{1+\beta\pi_t} + \beta\pi_t\ln\frac{R^F_{t+1}\beta\omega_t}{1+\beta\pi_t}.$$

Since $R_{t+1} > R^F_{t+1}$, $U_t^{dd} > U_t^{fd}$ and $U_t^{df} > U_t^{ff}$ hold. Subsequently, $U_t^{dd} - U_t^{df}$ becomes

$$U_t^{dd} - U_t^{df} = (1-\chi)\ln\frac{\omega_t}{1+\beta\pi_t} + (1-\eta)\beta\pi_t\ln\frac{R_{t+1}\beta\omega_t}{1+\beta\pi_t} - (1-\eta\chi)\ln\frac{\omega_t}{1+\beta\pi_t} - (1-\eta)\beta\pi_t\ln\left[\frac{R_{t+1}\beta\omega_t}{1+\beta\pi_t} + \frac{R^F_{t+1}(1-\delta)G_t}{N_t^B}\right].$$

Since $\eta \in (0,1)$ and illegal income takes a positive value, $U_t^{dd} - U_t^{df} < 0$. This finding indicates that the expected utility of the third case U_t^{df} is higher than that of the other three cases. When $\rho \geq 1$ and corruptible bureaucrats invest all their income in the foreign market, no equilibrium would exist since $K_{t+1} = 0$. Then, it is optimal that corrupt bureaucrats invest labor income in the domestic market and illegal income in the foreign market.

B. Expected utilities

We prove that $\partial EU^{CB(honest)}(\sigma_t, k_t)/\partial \sigma_t < 0$, $\partial EU^{CB(dishonest)}(\sigma_t, k_t)/\partial \sigma_t < 0$, and $\partial EU^{CB(honest)}(\sigma_t, k_t)/\partial \sigma_t > \partial EU^{CB(dishonest)}(\sigma_t, k_t)/\partial \sigma_t$. By differentiating $EU^{CB(honest)}(\sigma_t, k_t)$ provided by (33) with respect to σ_t, we obtain

$$\frac{\partial EU^{CB(honest)}}{\partial \sigma_t}(\sigma_t, k_t) = \beta \frac{d\pi(\sigma_t)}{d\sigma_t}[\ln W(\sigma_t, k_t) - 1]$$
$$\text{where} \quad W(\sigma_t, k_t) \equiv \frac{\beta R(k_t) w(k_t)}{1 + \beta \pi(\sigma_t)}.$$

$d\pi(\sigma_t)/d\sigma_t < 0$ and $\ln W(\sigma_t, k_t) > 1$ so that $\partial EU^{CB(honest)}(\sigma_t, k_t)/\partial \sigma_t < 0$. Next, differentiating (34) with respect to σ_t yields

$$\frac{\partial EU^{CB(dishonest)}}{\partial \sigma_t}(\sigma_t, k_t) = \beta \frac{d\pi(\sigma_t)}{d\sigma_t}[T_1(\sigma_t, k_t) - T_2(\sigma_t, k_t)]$$
$$\text{where} \quad T_1(\sigma_t, k_t) \equiv (1-\eta)\ln[W(\sigma_t, k_t) + W^{(illegal)}(k_t)] + \eta \ln W(\sigma_t, k_t),$$
$$T_2(\sigma_t, k_t) \equiv \frac{1 - \eta\chi}{1 + \beta\pi(\sigma_t)} + \frac{\eta\beta\pi(\sigma_t)}{1 + \beta\pi(\sigma_t)} + \frac{\frac{(1-\eta)\beta\pi(\sigma_t)}{1+\beta\pi(\sigma_t)} W(\sigma_t, k_t)}{W(\sigma_t, k_t) + W^{(illegal)}(k_t)},$$
$$W^{(illegal)}(k_t) \equiv \frac{(1-\delta)\rho\theta R(k_t) y(k_t)}{\lambda}.$$

If $T_1(\sigma_t, k_t) > \ln W(\sigma_t, k_t)$ and $T_2(\sigma_t, k_t) < 1$, $T_1(\sigma_t, k_t) - T_2(\sigma_t, k_t) > \ln W(\sigma_t, k_t) - 1 > 0$. Then, we can obtain $\partial EU^{CB(dishonest)}(\sigma_t, k_t)/\partial \sigma_t < 0$ and $\partial EU^{CB(honest)}(\sigma_t, k_t)/\partial \sigma_t > \partial EU^{CB(dishonest)}(\sigma_t, k_t)/\partial \sigma_t$.

Firstly, $T_1(\sigma_t, k_t) - \ln W(\sigma_t, k_t)$ becomes

$$\begin{aligned}&(1-\eta)\ln[W(\sigma_t, k_t) + W^{(illegal)}(k_t)] + \eta \ln W(\sigma_t, k_t) - \ln W(\sigma_t, k_t)\\ =&(1-\eta)\left\{\ln[W(\sigma_t, k_t) + W^{(illegal)}(k_t)] - \ln W(\sigma_t, k_t)\right\}.\end{aligned}$$

Then, we prove that $T_1(\sigma_t, k_t) > \ln W(\sigma_t, k_t)$ since $W^{(illegal)}(k_t) > 0$.

Secondly, we calculate $T_2(\sigma_t, k_t) - 1$ as follows:

$$\frac{1-\eta\chi}{1+\beta\pi(\sigma_t)} + \frac{\eta\beta\pi(\sigma_t)}{1+\beta\pi(\sigma_t)} + \frac{\frac{(1-\eta)\beta\pi(\sigma_t)}{1+\beta\pi(\sigma_t)}W(\sigma_t, k_t)}{W(\sigma_t, k_t) + W^{(illegal)}(\sigma_t, k_t)} - 1$$
$$= -\frac{\eta\chi W(\sigma_t, k_t) + [\eta\chi + (1-\eta)\beta\pi(\sigma_t)]W^{(illegal)}(k_t)}{[1+\beta\pi(\sigma_t)][W(\sigma_t, k_t) + W^{(illegal)}(k_t)]} < 0.$$

Then, $T_2(\sigma_t, k_t) < 1$. Therefore, we obtain $T_1(\sigma_t, k_t) - T_2(\sigma_t, k_t) > \ln W(\sigma_t, k_t) - 1 > 0$. This finding indicates that $0 > \partial EU^{CB(honest)}(\sigma_t, k_t)/\partial\sigma_t > \partial EU^{CB(dishonest)}(\sigma_t, k_t)/\partial\sigma_t$ since $d\pi(\sigma_t)/d\sigma_t < 0$ holds.

C. Downward or upward shift in the dynamics

We consider the change in k_{t+1} when an increase in θ raises τ and $\pi(k_t)$ under the given k_t. dk_{t+1}, $d\tau$, and $d\pi(k_t)$ denote the change in k_{t+1}, the increment in τ, and the increment in $\pi(k_t)$, respectively. By using (42), dk_{t+1} is derived as follows:

$$dk_{t+1} = \frac{\tilde{A}k_t^\alpha}{n(k_t)} \frac{T_\tau(k_t)d\tau + T_\pi(k_t)\pi(k_t)}{[1+(1-a)\beta\pi(k_t)][1+\beta\pi(k_t)]^2} \quad \text{where} \tag{A.1}$$

$$T_\tau(k_t) \equiv \left(-\frac{\pi}{1-\tau}\right)\left\{(1-a)(1-\lambda)[1+\beta\pi(k_t)]^2 + \lambda[1+(1-a)\beta\pi(k_t)][1+\beta\pi(k_t)]\right\},$$

$$T_\pi(k_t) \equiv (1-a)(1-\lambda)[1+\beta\pi(k_t)]^2 + \lambda(1-a)\beta\pi(k_t)[1+\beta\pi(k_t)] + \lambda[1+(1-a)\beta\pi(k_t)].$$

Since we consider the effect of increasing θ, we know that $d\tau > 0$, $d\pi(k_t) > 0$, $T_\tau(k_t) < 0$, and $T_\pi(k_t) > 0$. $T_\tau(k_t)d\tau + T_\pi(k_t)d\pi(k_t)$ can be divided into two terms:

$$\{(1-a)[1+\beta\pi(k_t)][1+\beta\pi(k_t) - \lambda] + \lambda\}\left[d\pi(k_t) - \frac{\pi(k_t)}{1-\tau}d\tau\right] \tag{A.2}$$

and

$$\lambda\beta\pi(k_t)\left[(1-a)d\pi(k_t) - \frac{\pi(k_t)}{1-\tau}d\tau\right]. \tag{A.3}$$

If $d\pi(k_t) - \pi(k_t)/(1-\tau)d\tau \leq 0$, (A.2) and (A.3) take negative values. This finding implies $dk_{t+1} < 0$. On the contrary, if $(1-a)d\pi(k_t) - \pi(k_t)/(1-\tau)d\tau \geq 0$, (A.2) and (A.3) take positive values. This finding implies $dk_{t+1} > 0$. By rearranging these conditions, therefore, we can prove that the dynamics of the economy move downward if $\epsilon(k_t) \leq 1$ and upward if $\epsilon(k_t) \geq 1/(1-a)$, where $\epsilon(k_t) \equiv -[d\pi(k_t)/\pi(k_t)]/[d(1-\tau)/(1-\tau)]$.

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