Hitotsubashi Journal of Economics 56 (2015), pp.73-91.

ENVIRONMENTAL POLLUTION, INFORMAL SECTOR, PUBLIC EXPENDITURE AND ECONOMIC GROWTH

Manash Ranjan Gupta

Economics Research Unit, Indian Statistical Institute
Kolkata 700108, India
manashgupta@isical.ac.in

and

Trishita Ray Barman*

Economic Research Unit, Indian Statistical Institute
Kolkata 700108, India
trbarman@gmail.com

Received July 2013; Accepted September 2014

Abstract

The impact of environmental pollution on productivity is analyzed in a dynamic two commodity model consisting of a formal sector and an informal sector. Environmental quality and public infrastructural expenditure affect productivity of private inputs in both sectors. Both the sectors pollute environment and receive the benefits of public expenditure on abatement and infrastructure but the burden of tax is imposed only on the formal sector. Properties of the steady-state growth equilibrium and of the second-best optimum fiscal policy are analyzed. The socially optimal relative size of the informal sector is less than its second-best optimal relative size in the decentralized competitive equilibrium.

Keywords: endogenous growth, informal sector, public expenditure, environmental pollution, abatement expenditure
JEL Classification Codes: H2, H4, O4, Q5

I. *Introduction*

There exists a substantial theoretical literature on endogenous economic growth dealing with the role of productive public expenditure; and most of the existing models are one sector aggregative in nature. Models developed by Barro (1990), Futagami, Morita and Shibata (hereafter called FMS) (1993), etc.[1], belong to this set. Another set of one sector dynamic

* Communicating author

models[2] focuses on the interaction between environmental pollution and economic growth. However, one sector framework is not the appropriate one to analyze dynamics of the economy and the optimality of fiscal policy when a substantial part of economic activities remain untaxed. The aggregate of various untaxed economic sectors is known as informal sector or the shadow economy in the literature.

Various empirical works study features of informal sector firms in various countries. De Soto (1989) studies the informal sector in Peru. Chickering and Salahdine (1993) present evidence from selected underdeveloped Asian countries. Tokman (1992) provide evidence from Latin American and Caribbean countries. Nippon (1991) and Alonzo (1991) study the informal sector in Thailand; and Mazumdar's (1976) study on informal sector is based on evidences from Bombay[3]. Huq and Sultan (1991) report evidences from Bangladesh. These empirical studies point out various causes of the growth of informal sector[4]; and these include high corporate income taxes and bureaucratic controls on formal sector firms, existence of labour unions and labour legislation laws in the formal labour market, etc.

There are a few two sector dynamic models incorporating both the formal sector and the informal sector[5]; and only a handful of them analyze the role of productive public expenditure on economic growth. This small set includes the works of Loayza (1996), Penalosa and Turnovsky (2005) and Turnovsky and Basher (2009). Loayza (1996) develops a two sector dynamic model where the production technologies in both the formal and the informal sectors are identical. Production in both the sectors use a public input apart from private inputs; and the public input is financed solely by the proceeds from income taxes imposed on the formal sector. Public input is subject to congestion effect resulting from informal production because the informal sector uses the public input but does not contribute to its financing. The steady-state equilibrium growth rate is maximized and the income tax rate derived from this exercise is found to be lower than that in Barro and Sala-i-Martin (1992) model where there is no informal sector. This is so because an increase in tax rate encourages the expansion of the informal sector; and thus reduces the growth rate through negative congestion effect. In Penalosa and Turnovsky (hereafter called PT) (2005), private capital and labour are perfectly mobile between the formal sector and the informal sector but the public input, whose financing is done taxing the formal sector, is specific to the formal sector only. Their model focuses on the importance of distinction between capital income and labour income in the context of designing an optimal income tax policy. In Turnovsky and Basher (hereafter called TB) (2009), private capital is specific to the formal sector and labour is mobile between the two sectors. The public

[1] See, for example, Aschauer (1989), Chen (2006), Tsoukis and Miller (2003), Chang (1999), Turnovsky (1997, 1996), Hu, Ohdoi and Shimomura (2008), Ohdoi (2007), Greiner and Semmler (2000), Kalaitzidakis and Kalyvitis (2004), Baier and Glomm (2001), Yakita (2004), Shioji (2001), Tamai (2007), Burguet and Fernandez-Ruiz (1998), Ghosh and Mourmouras (2004), Raurich-Puigdevall (2000), Cazzavillan (1996), Zhang (2000), Neill (1996), Mourmouras and Lee (1999), Park and Phillippopoulos (2002), Tanaka (2002), Chen and Lee (2007), etc.

[2] See, for example, Managi (2006), Dinda (2005), Di Vita (2008), Hartman and Kwon (2005), D. Ayong Le Kama (2001), Elbasha and Roe (1996), Oueslati (2002), Bertinelli, Strobl and Zou (2007),Smulders and Gradus (1996), Byrne (1997), Itaya (2008), Bovenberg and Smulders (1995), Benarroch and Weder (2006), Selden and Song (1995).

[3] An industrial city of India presently known as Mumbai.

[4] We do not analyze the causes behind the growth or existence of an informal sector. Rather presume that such a sector already exists whose output is untaxed and then analyze the properties of equilibrium and fiscal policy.

[5] See the works of Sarte (2000), Gibson (2005), Antunes and Cavalcanti (2007), Saracoglu (2008), Loayza (1996), Penalosa and Turnovsky (2005), Turnovsky and Basher (2009), etc.

infrastructure requirement per unit of output is fixed in both the sectors; and the formal sector has a higher per unit infrastructure requirement than the informal sector. This public infrastructure is financed by imposing taxes on the capital and labour incomes of the formal sector. This model also analyzes properties of the long run growth rate maximizing tax policy. However, neither PT (2005) nor TB (2009) uses Barro (1990) type production function in their models in which public expenditure and other inputs are imperfect substitutes.

Moreover, none of these dynamic models deals with the problem of environmental pollution caused by production activities of either the formal sector or of the informal sector. Greiner (2005) and Economides and Philippopoulos (hereafter called EP (2008)) deal with the interaction between economic growth and environmental pollution using the Barro-FMS framework. Greiner (2005) analyze the properties of long run growth rate maximizing fiscal policy but EP (2008) analyze the properties of Ramsey optimal fiscal policy solving a Stackleberg differential game. However, both these models are built on single sector aggregative framework and therefore do not incorporate the problem of the informal sector. Various other studies which deal with pollution and informal sector, do so to the extent that they assume informal sector firms to be adopting low cost and pollution friendly technologies and the benefits of environmental policies of the government to be largely restricted to formal sector firms. These studies include the works of Biller and Quintero (1995), Blackman and Bannister (1998), Blackman (2000), Kolstad (2000), Chaudhuri and Mukhopadhyay (2006), Kathuria (2007), etc.

We develop a two commodity two sector endogenous growth model consisting of both formal sector and informal sector and analyze the role of public infrastructural expenditure and environmental pollution. The two goods produced by two sectors are heterogeneous in nature. The representative household allocates capital between the formal sector and the informal sector. Pollution is generated by production of both the sectors. We assume environmental quality to be an accumulable input that can be improved by abatement activities and is degraded due to pollution. Greiner (2005) and EP (2008) also assume industrial production to be the source of pollution. However, there is no informal sector in their models. In our model, both sectors pollute the environment but the emission-output coefficients in the formal and informal sectors are different. Government imposes proportional income tax only on the formal sector and finances the abatement expenditure as well as public infrastructural expenditure from its tax revenue. Optimal and/or growth rate maximizing fiscal policy design is important in the presence of free-riding of public infrastructural services by informal sector because exclusion of this untaxed sector as a beneficiary of public services may not only be infeasible but undesirable too. For example, services of roads and power infrastructure are important for benefits of improved connectivity and ease of everyday living even when few economic agents cannot be made to pay for these services. In case of environmental service/good, however, the informal sector not only free-rides the use of this input but also degrades or pollutes it[6]. The tax allocation problem assumes greater relevance now because of two things. First, government now has to allocate tax revenue collected from the formal sector alone between public

[6] Although it can be argued that public infrastructure services are also subject to wear and tear through repeated usage and this is in some sense is degradation too. However, for environmental goods and services (eg water, air, etc.), wear and tear does not arise due to repeated usage but due to pollution which is more explicit. Hence, it must be treated in a more explicit manner than the wear and tear of infrastructure while designing policy.

infrastructure and environmental services. So, the interesting question is whether the efficient tax allocation rule should take into account free use of these services by the informal sector. And secondly, since both sectors pollute environment and one sector does not contribute fiscal resource towards mitigation of this pollution, it is worthwhile to determine the efficient fiscal allocation rule to mitigate this damage. Even though informal sector activities are untaxed, intuitively, mitigation of pollution generated by it is important because otherwise such damage would adversely affect tax base by shrinking formal sector output.

We derive following results from this model. First, we prove the existence of a unique steady-state equilibrium growth path in the market economy with simultaneous existence of the formal and the informal sector. Secondly, the long run growth rate maximizing income tax rate is dependent upon the emission-output coefficient of the formal sector only; and this result is independent of whether two sectors have identical production technologies or not. The congestion effect parameter does not affect this income tax rate unlike in Barro and Sala-i-Martin (1992) model with no informal sector. Thirdly, if there is identical production technologies in two sectors, the growth rate maximizing abatement expenditure rate and the growth rate maximizing ratio of productive public expenditure to formal sector's output depend not only on the emission-output coefficient of the formal sector but also on that of the informal sector. Fourthly, in the steady-state growth equilibrium, both the social welfare maximization and the balanced growth rate maximization are achieved by the same values of fiscal policy instruments. Fifthly, with identical production technologies in two sectors, the decentralized steady-state growth equilibrium appears to be saddle-point stable. This result is different from that of Loayza (1996) model that does not show any transitional dynamic property. Lastly, the growth rate maximizing relative size of the informal sector in the steady-state growth equilibrium of the competitive economy exceeds its socially efficient size when this sector pollutes the environment. However, an important limitation of this exercise is that properties of Ramsey optimal policies cannot be analyzed due to technical complication of its working though EP (2008) derive numerical solution of a Ramsey problem in a less complicated model without any informal sector. No model developed so far derives analytical properties of Ramsey optimal policies in the presence of the informal sector.

The paper is organized as follows. Section II describes the basic competitive equilibrium model. Section III shows the existence of unique steady-state growth equilibrium and analyzes the properties of the long run growth rate maximizing fiscal policies. Stability property of the decentralized steady-state equilibrium is analyzed in section IV. Section V deals with the steady state equilibrium in the planned economy. Concluding remarks are made in section VI.

II. *The Model*

There are two production sectors in a small open economy - formal and informal; and they produce two heterogeneous goods expressed in same unit. Both sectors use private capital, public infrastructure and environmental quality as inputs. All markets are competitive and the representative firm maximizes profit. The benevolent government imposes a proportional tax on the income of the representative household earned from the formal sector. The representative household who consumes a part of the post-tax income and invests the rest in private capital formation does not pay any tax on her income earned from the informal sector. No penalty[7] is imposed by the government even if the tax evasion is detected. The representative household maximizes her lifetime utility subject to the budget constraint; and the lifetime utility is defined as the infinite integral of the discounted present value of instantaneous utility derived from consumption of two goods, the rate of discount being a constant. He also makes the capital allocation between the formal sector and the informal sector while maximizing lifetime utility.

Let the subscripts F and I stand for the formal sector and the informal sector respectively. Following equations describe the model.

$$Y_F = (\lambda K)^{\alpha} G^{\eta} E^{1-\alpha-\eta} \text{ with } 0 < \alpha,\ \eta < 1; \tag{1}$$

$$Y_I = \{(1-\lambda)K\}^{\phi} G^{\beta} E^{1-\phi-\beta} \text{ with } 0 < \phi,\ \beta < 1; \tag{2}$$

$$\dot{K} = (1-\tau)Y_F + Y_I - C_F - C_I; \tag{3}$$

$$G = (\tau - T)Y_F; \tag{4}$$

$$\dot{E} = (T - \delta_F)Y_F - \delta_I Y_I \text{ with } 0 < \delta_F,\ \delta_I < 1; \tag{5}$$

$$u(C_F, C_I) = \frac{(C_I^{\theta} C_F^{1-\theta})^{1-\sigma}}{1-\sigma} \text{ with } 0 < \theta,\ \sigma < 1; \tag{6}$$

Equation (1) describes the Cobb-Douglas production function in the formal sector which satisfies constant returns to scale in terms of private capital, public capital and environmental quality. Y_F is the level of output produced in the formal sector. K and E are stocks of private capital and environmental quality respectively. G is the non rival flow of public productive input. λ is the fraction of private capital allocated to the formal sector. Elasticities of output with respect to private capital, public capital and environmental quality are denoted by α, η and $(1-\alpha-\eta)$ respectively.

Equation (2) describes the Cobb-Douglas production function in the informal sector. $(1-\lambda)$ is the fraction of private capital allocated to the informal sector. Elasticities of output of this sector with respect to private capital, public capital and environmental quality are denoted by ϕ, β and $(1-\phi-\beta)$ respectively[8].

The budget constraint of the representative household is given by equation (3). We do not consider depreciation of private capital. Government taxes income of the formal sector only and this proportional income tax rate is denoted by τ. The representative household's income from the informal sector is not taxed. Here C_F and C_I represent the levels of consumption of the formal good and of the informal good respectively. Here $C_F + C_I$ is total consumption expenditure; and $Y_F + Y_I$ is the value of total production of both the sectors[9].

Equation (4) describes the government's budget constraint. The government simultaneously finances public infrastructure expenditure and abatement expenditure using the tax revenue. T is the abatement expenditure rate defined as the ratio of abatement expenditure to formal sector's output.

[7] Introduction of an exogenous penalty rate does not affect the results of this model if the revenue earned from penalty is not used to finance the public expenditure. However, even in this case, results may be different when the penalty rate is made endogenous. Loayza (1996) introduces endogenous penalty rate.

[8] Total private physical capital is typically allocated between formal and informal sectors in countries where there is a substantial presence of the latter. In case of public goods like infrastructure and environment, which are often non-rival, the informal sector does free-ride the services of these goods despite being an agent of wear and tear and pollution.

[9] We consider a small open economy with the terms-of-trade being assumed to be equal to unity.

Equation (5) shows how environmental quality changes over time depending upon the magnitudes of emission and abatement activity. Here emission is assumed to be a flow variable and each of the two sectors generate emission as a by-product of its production. Emission level is proportional to the level of production in each of the two sectors; and δ_F and δ_I are the constant emission-output coefficients in the formal sector and in the informal sector respectively. Abatement activities bring improvements in environmental quality; and there exists a substantial theoretical and empirical literature dealing with the role of abatement activities and effectiveness of abatement policies of the government[10]. TY_F is the total abatement expenditure made by the government in this model.

Many models of environmental pollution assume level of pollution to be a positive function of the level of production[11] of the final good. This is consistent with only one segment of the Environmental Kuznets curve[12], according to which, there exists an inverted U-shaped relationship between the pollution level and the income level.

Instantaneous utility of the representative consumer being a positive and concave function of the consumption level of each of the two heterogeneous goods, it is given by equation (6). $\{\theta(1-\sigma)-1\}$ and $\{(1-\theta)(1-\sigma)-1\}$ represent the constant elasticities of marginal utility with respect to C_I and C_F respectively. Here we assume $Max\{\theta(1-\sigma), (1-\theta)(1-\sigma)\}<1$ to ensure diminishing marginal utility of consumption of each of these two heterogeneous goods.

Stocks of E and K are exogenous at a particular point of time. E is a non rival stock and G is a non rival flow. Given the stocks of capital and environmental quality, and given the fiscal instrument rates, equations (1), (2) and (4) together determine Y_F, Y_I and G at each point of time. Thus equation (5) determines the absolute rate of improvement in the environmental quality, denoted by $\dot{E}$. The household chooses C_I and C_F; and this determines the absolute rate of private capital accumulation, $\dot{K}$.

III. *Dynamic Equilibrium*

The representative household maximizes $\int_0^\infty u(C_I, C_F)e^{-\rho t}dt$ with respect to C_I, C_F and λ subject to equations (1), (2), (3) and (6). The capital allocation between the two sectors in the decentralized competitive economy is given by

$$\lambda^{\frac{\alpha(1-\beta)-(1-\eta)}{1-\eta}}(1-\lambda)^{1-\phi}=\frac{\phi}{\alpha}\frac{(\tau-T)^{\frac{\beta-\eta}{1-\eta}}}{(1-\tau)}\left(\frac{E}{K}\right)^{\frac{\alpha(1-\beta)-(1-\eta)}{1-\eta}}. \tag{7}$$

If we assume $\alpha=\phi$ and $\beta=\eta$, then equation (7) is reduced to

---

10 See the works of Liddle (2001), Managi (2006), Dinda (2005), Di Vita (2008), Smulders and Gradus (1996), Byrne (1997), etc.

11 For example, see the works of Liddle (2001), Oueslati (2002), Hartwick (1991), Smulders and Gradus (1996), Byrne (1997), Gruver (1976), Dinda (2005), etc.

12 Analysis on this curve is available in Managi (2006), Dinda (2005), Di Vita (2008), Hartman and Kwon (2005), Seldon and Song (1995), etc.

$$\left(\frac{1-\lambda}{\lambda}\right)^{1-\alpha}=\frac{1}{(1-\tau)}. \tag{7A}$$

The demand rate of growth[13] of consumption is derived as follows.

$$\frac{\dot{C}_I}{C_I}=\frac{\dot{C}_F}{C_F}=\frac{1}{\sigma}\left[\alpha(1-\tau)(\tau-T)^{\frac{\eta}{1-\eta}}\lambda^{\frac{\alpha+\eta-1}{1-\eta}}\left(\frac{E}{K}\right)^{\frac{1-\alpha-\eta}{1-\eta}}-\rho\right]. \tag{8}$$

We consider a steady-state growth equilibrium where all macroeconomic variables grow at the same rate, g_m. Hence, we have

$$\frac{\dot{C}_F}{C_F}=\frac{\dot{C}_I}{C_I}=\frac{\dot{Y}_F}{Y_F}=\frac{\dot{Y}_I}{Y_I}=\frac{\dot{K}}{K}=\frac{\dot{E}}{E}=\frac{\dot{G}}{G}=g_m. \tag{9}$$

1. Existence of the Steady-state Growth Equilibrium

We now turn to show the existence of a unique steady state equilibrium growth rate in the competitive economy; and so we use equations (1), (2), (3), (4), (5), (8) and (9) to obtain the following equations.

$$\frac{\dot{C}_I}{C_I}=\frac{\dot{C}_F}{C_F}=\frac{1}{\sigma}\left[\alpha\lambda^{\frac{\alpha+\eta-1}{1-\eta}}(1-\tau)(\tau-T)^{\frac{\eta}{1-\eta}}\left(\frac{E}{K}\right)^{\frac{1-\alpha-\eta}{1-\eta}}-\rho\right]=g_m; \tag{10}$$

$$\frac{\dot{K}}{K}=\left(1+\frac{\alpha}{\phi}\frac{1-\lambda}{\lambda}\right)\lambda^{\frac{\alpha}{1-\eta}}(1-\tau)(\tau-T)^{\frac{\eta}{1-\eta}}\left(\frac{E}{K}\right)^{\frac{1-\alpha-\eta}{1-\eta}}-\frac{1}{1-\theta}\frac{C_F}{K}=g_m; \tag{11}$$

and

$$\frac{\dot{E}}{E}=\left[T-\delta_F-\delta_I(1-\tau)\frac{\alpha}{\phi}\frac{1-\lambda}{\lambda}\right]\lambda^{\frac{\alpha}{1-\eta}}(\tau-T)^{\frac{\eta}{1-\eta}}\left(\frac{E}{K}\right)^{-\frac{\alpha}{1-\eta}}=g_m. \tag{12}$$

Using equations (7), (10), (11) and (12) we obtain the following equation[14] to solve for g_m.

$$\begin{aligned}g_m(\sigma g_m+\rho)^{\frac{\alpha}{1-\alpha-\eta}}=&\{\alpha(1-\tau)\}^{\frac{\alpha}{1-\alpha-\eta}}(\tau-T)^{\frac{\eta}{1-\alpha-\eta}}\Big[(T-\delta_F)\\&-\delta_I\phi^{\frac{\phi}{1-\phi}}\{\alpha(1-\tau)\}^{-\frac{\alpha(1-\phi-\beta)}{(1-\phi)(1-\alpha-\eta)}}(\tau-T)^{\frac{\beta(1-\alpha)-\eta(1-\phi)}{(1-\phi)(1-\alpha-\eta)}}(\rho+\sigma g_m)^{\frac{\alpha(1-\beta)-\phi(1-\eta)}{(1-\phi)(1-\alpha-\eta)}}\Big]\end{aligned} \tag{13}$$

The L.H.S. of equation (13) is an increasing function of g_m. Its R.H.S. is a decreasing function of g_m, given the income tax rate, τ, and the abatement expenditure rate, T, if $\alpha(1-\beta)-\phi(1-\eta)>0$. However, this R.H.S. is independent of g_m when $\alpha(1-\beta)=\phi(1-\eta)$. Thus the existence of a unique g_m is guaranteed if $\alpha(1-\beta)-\phi(1-\eta)\geq 0$ and $0<\delta_F<T<\tau$. Equation (B4) in Appendix (B) shows that $\left(\frac{E}{K}\right)$ is a function of g_m; and then equation (B2) shows that $\left(\frac{C_F}{K}\right)$ is a function of g_m. Equation (7) then can be used to show that λ is a function

[13] Equations (7) and (8) are derived in appendix (A).

[14] The derivation of equation (13) is worked out in appendix (B).

of g_m. Also we must have $0<\lambda<1$ because R.H.S. of equation (7) is always non zero. An equilibrium with $0<\lambda<1$ implies the simultaneous existence of the formal sector and the informal sector. We can state the following proposition.

Proposition 1: There exists a unique steady state growth equilibrium in the competitive economy with coexistence of the formal and the informal sector, given the income tax rate and the abatement expenditure rate, if $\alpha(1-\beta)-\phi(1-\eta)\geq 0$ and if $0<\delta_F<T<\tau$.

We assume perfect inter-sectoral mobility of private capital along with the assumption of diminishing marginal productivity of capital in each of these two sectors. So we can explain the coexistence of both the sectors in equilibrium even without assuming endogenous penalty rate on tax evasion in the informal sector. In Loayza (1996), marginal productivity of capital is constant in both the sectors even though capital is perfectly mobile between the two sectors. So the assumption of an endogenous penalty rate on informal sector is necessary in that model to ensure the coexistence of these two sectors.

2. Fiscal Policy

We assume that the government maximizes the steady-state equilibrium growth rate with respect to the fiscal instruments, τ and T, subject to the steady-state equilibrium equation (13). Thus, we obtain the following expressions of the tax rate and the abatement expenditure rate[15] as shown in equations below.

$$\tau^{*}=1-\alpha(1-\delta_F); \tag{14}$$

and

$$\begin{aligned}&\{1-\alpha(1-\delta_F)-T^{*}\}^{\frac{\eta(1-\phi)-\beta(1-\alpha)}{(1-\phi)(1-\alpha-\eta)}}\left[(T^{*}-\delta_F)-(1-\alpha-\eta)(1-\delta_F)\right]\\&\quad=\delta_I\phi^{\frac{\phi}{1-\phi}}\left(\frac{\beta}{1-\phi}\right)\{\alpha^2(1-\delta_F)\}^{-\frac{\alpha(1-\phi-\beta)}{(1-\phi)(1-\alpha-\eta)}}(\rho+\sigma g_m)^{\frac{\alpha(1-\beta)-\phi(1-\eta)}{(1-\phi)(1-\alpha-\eta)}}.\end{aligned} \tag{15}$$

We derive equations (14) and (15) without assuming identical production technologies in the two sectors. The steady-state growth rate maximizing income tax rate is found to be independent of the balanced growth rate, g_m, and of technology parameters of the informal sector because tax is imposed only on the income earned from the formal sector and because capital income as well as labour income are taxed at equal rates. On the contrary, the abatement expenditure rate is found to depend on the balanced growth rate, and the emission-output coefficients of each of the two sectors.

Now, using equation (14) in equation (15) we get,

$$\begin{aligned}&\{\tau^{*}-T^{*}\}^{\frac{\eta(1-\phi)-\beta(1-\alpha)}{(1-\phi)(1-\alpha-\eta)}}\left[\eta(1-\delta_F)-(\tau^{*}-T^{*})\right]\\&\quad=\delta_I\phi^{\frac{\phi}{1-\phi}}\left(\frac{\beta}{1-\phi}\right)\{\alpha^2(1-\delta_F)\}^{-\frac{\alpha(1-\phi-\beta)}{(1-\phi)(1-\alpha-\eta)}}(\rho+\sigma g_m)^{\frac{\alpha(1-\beta)-\phi(1-\eta)}{(1-\phi)(1-\alpha-\eta)}}.\end{aligned} \tag{16}$$

[15] The derivation of equations (14) and (15) is worked out in appendix (C) from the first order conditions of maximization. Second order conditions of maximization are also satisfied.

If, $\delta_I = 0$, i.e., we assume that informal sector does not pollute the environment then we get $\tau^* - T^* = \eta(1-\delta_F)$, since $\tau^* \neq T^*$. This implies that in the absence of informal sector pollution the growth rate maximizing public expenditure share is the formal sector pollution-adjusted competitive output share of the formal sector; it does not depend on the public infrastructure and environmental quality elasticities of informal sector output. Since the tax base in this model comprises of the formal sector output alone the public expenditure share that maximizes steady-state equilibrium growth rate in the absence of informal sector pollution takes only formal sector pollution and productivity parameter of the public infrastructure good in the formal sector into account. This happens because service of public infrastructure is non-rival in nature.

However, the abatement expenditure rate has a complex expression as given by equation (15); and so we assume identical production technologies[16], [17] in the two sectors at this stage. This implies that $\alpha = \phi$ and $\eta = \beta$. However, this assumption is independent of the unit relative price assumption[18]. The importance of distinction between formal and informal sector still remains valid because informal sector income is not taxed even with this simplifying assumption. Then equation (15) is reduced to the following.

$$
\begin{aligned}
T^* &= \delta_F + (1-\delta_F)(1-\alpha-\eta) + (1-\delta_F)\left(\delta_I \frac{Y_I}{Y_F}\right)\left[\frac{\beta}{\phi(1-\phi)\alpha^{\frac{1+\alpha}{1-\phi}}(1-\delta_F)^{!+\frac{1}{1-\phi}}}\right] \\
&= \delta_F + (1-\alpha-\eta)(1-\delta_F) + \delta_I\{\alpha(1-\delta_F)\}^{-\frac{\alpha}{(1-\alpha)}}\left(\frac{\eta}{1-\alpha}\right) \qquad (15.1)
\end{aligned}
$$

Thus, the steady-state equilibrium growth rate maximizing abatement expenditure rate is equal to the sum of formal sector pollution rate (δ_F), formal sector pollution-adjusted competitive output share of environmental quality in the formal sector ($(1-\delta_F)(1-\alpha-\eta)$) and a fraction $\left[\frac{\beta}{\phi(1-\phi)\alpha^{\frac{1+\alpha}{1-\phi}}(1-\delta_F)^{!+\frac{1}{1-\phi}}}\right]$ of the rate of informal sector pollution in terms of the formal sector output $\left(\delta_I \frac{Y_I}{Y_F}\right)$. Note that the growth rate maximizing abatement expenditure rate does not allow adjustment of the competitive output share of environmental quality for pollution from the informal sector. The competitive output share is adjusted only for formal sector pollution; and expenditure on mitigation of pollution from the informal sector is done separately as evident from the third additive term. This is because, the growth rate maximizing fiscal expenditures are made from formal sector tax revenue alone, and therefore, as long as any public good is non-rival it does not matter if informal sector free-rides its benefits. However, environmental quality is degraded by pollution generated by informal sector output too; and therefore, this needs mitigation which takes informal sector pollution parameter into

---

[16] Equations (13) and (15) simultaneously solve for the steady-state equilibrium growth rate and the optimum value of the abatement expenditure rate. Analytically it is extremely difficult to show the existence of a unique value of T lying in the interval (0, 1). The assumption of identical technologies solves this problem.

[17] Identical production technologies in the formal and the informal sectors are assumed by Loayza (1996), Sarte (2000), etc.

[18] Here α, ϕ, η and β are technological parameters but the equilibrium value of relative product price is determined by the supply demand mechanism in the competitive international market and is taken as given by a small open economy. These technological restrictions are not binding on consumer's utility maximizing problem.

account in the abatement expenditure rate.

Using equations (14) and (15.1) we obtain

$$\tau^{\star}-T^{\star}=\eta(1-\delta_F)-\delta_I\{\alpha(1-\delta_F)\}^{-\frac{\alpha}{(1-\alpha)}}\left(\frac{\eta}{1-\alpha}\right). \tag{17}$$

$(\tau^{\star}-T^{\star})$ is the ratio of productive public infrastructural expenditure to formal sector's income that maximizes the steady-state equilibrium growth rate in this model. The R.H.S. of equation (17) is the competitive share of the public input in the unpolluted output of the formal sector less a constant term. This constant term is the fraction of the formal sector's output allocated to nullify the effect of pollution generated by the informal sector. Thus the steady-state equilibrium growth rate maximizing ratio of productive public infrastructural expenditure to taxable income in this model is lower than the competitive output share of the public input in the formal sector. This result is different from those obtained in the models of Barro (1990), FMS (1993), Greiner (2005), etc. This is so because the informal sector uses the public input without paying any tax and causes pollution. The abatement expenditure is also financed from the tax revenue obtained from the formal sector; and the steady-state equilibrium growth rate maximizing abatement expenditure rate varies positively with the emission rate generated by the informal sector.

In a static model, without any productive public expenditure and environmental pollution fiscal policy is distortionary. However, in a dynamic model such as the present one fiscal policy is not necessarily distortionary if it helps in correcting for the dynamic externality effects. In the present model, the aggregate disposable income, $Y=Y_I+(1-\tau^*)Y_F$, can be written as $Y=\left(1-\tau^*+\Delta^{\frac{\alpha}{1-\phi}}\right)Y_F$ where Δ is given by equation (19). Here Y_F also depends on G and E; and the financing of G and $\dot{E}$ depend on fiscal policy rates like τ and T. This model is dynamic with productive public expenditure and accumulation of environmental quality. Both productive public expenditure and abatement expenditure are financed by income tax revenue; and so fiscal policy is not necessarily distortionary when dynamic positive effects are incorporated. The question of optimal fiscal policy arises in this case justifying the purpose of this study.

The model of Loayza (1996) also shows that the ratio of public infrastructural expenditure to income falls short of the competitive output share of the public input. However, none of these two sectors generates emissions in his model. Development of the informal sector there lowers the efficiency of the public input used by the formal sector through congestion effects.

The social welfare function is given by

$$W=\int_0^{\infty} e^{-\rho t}\frac{(C_I^{\theta}C_F^{1-\theta})^{1-\sigma}}{1-\sigma}dt. \tag{18}$$

Using equations (10) and (11) and assuming that the economy is on the steady state equilibrium growth path, it can be shown[19] that

$$C_F=(1-\theta)\left[\left\{\frac{\left(\Delta^{\frac{1}{1-\phi}}+1\right)^{-1}}{\alpha}+\frac{\Delta^{\frac{1}{1-\phi}}\left(\Delta^{\frac{1}{1-\phi}}+1\right)^{-1}}{\phi}\right\}(\rho+\sigma g_m)-g_m\right]K(0)e^{g_m t};$$

[19] The derivation is worked out in appendix (D).

where

$$\Delta=\left[\psi\{\alpha(1-\tau)\}^{\frac{\alpha\beta-(1-\eta)(1-\psi)}{1-\alpha-\eta}}(\tau-T)^{\frac{\beta(1-\alpha)-\eta(1-\psi)}{1-\alpha-\eta}}(\sigma g_m+\rho)^{\frac{\alpha(1-\beta)-\psi(1-\eta)}{(1-\alpha-\eta)}}\right] \tag{19}$$

Using equations (18) and (19) we have

$$W=\frac{[K(0)]^{1-\sigma}}{1-\sigma}\frac{\theta^{\theta(1-\sigma)}}{(1-\theta)^{(1-\theta)(1-\sigma)}}\left[\left\{\frac{\left(\Delta^{\frac{1}{1-\psi}}+1\right)^{-1}}{\alpha}+\frac{\Delta^{\frac{1}{1-\psi}}\left(\Delta^{\frac{1}{1-\psi}}+1\right)^{-1}}{\psi}\right\}(\rho+\sigma g_m)-g_m\right]^{1-\sigma}$$
$$[\rho-(1-\sigma)g_m]^{-1} \tag{20}$$

If we assume $\alpha=\psi$[20] then equation (20) takes the following form.

$$W=\frac{[K(0)]^{1-\sigma}}{1-\sigma}\frac{\theta^{\theta(1-\sigma)}}{(1-\theta)^{(1-\theta)(1-\sigma)}}\left[\frac{\rho-(\alpha-\sigma)g_m}{\rho-(1-\sigma)g_m}\right][\rho-(\alpha-\sigma)g_m]^{-\sigma}.$$

This shows that W varies positively with g_m[21]. Thus the level of social welfare in the decentralized economy is maximized when the steady-state equilibrium growth rate is maximized[22]. Therefore, the fiscal policy which maximizes the steady-state equilibrium growth rate also maximizes social welfare at the steady-state equilibrium. However, the values of fiscal instruments thus obtained are only second-best optima because distortion due to proportional taxation is not removed in the decentralized economy.

We now state the following proposition.

Proposition 2:

(i) When production technologies in the two sectors are identical, the income tax rate and the abatement expenditure rate obtained as solutions to maximization of growth rate in the steady-state equilibrium are given by

$$\tau^{*}=1-\alpha(1-\delta_F),$$

and

$$T^{*}=\delta_F+(1-\alpha-\eta)(1-\delta_F)+\delta_I\{\alpha(1-\delta_F)\}^{-\frac{\alpha}{(1-\alpha)}}\left(\frac{\eta}{1-\alpha}\right).$$

(ii) The growth rate maximizing ratio of productive public infrastructural expenditure to taxable income in the steady-state equilibrium is equal to the competitive share of the public input in the unpolluted output of the formal sector less the share of formal sector's income used

[20] The assumption of identical technologies implies $\alpha=\psi$ and $\eta=\beta$. However, even if $\eta\neq\beta$, W appears to be a positive function of g_m.

[21] The instantaneous social welfare function, in this model, depends only on the levels of consumption of the goods produced by the two sectors. However, it could also depend on environmental quality. In that case, the social welfare maximizing fiscal policies in the steady-state equilibrium may be different from the growth maximizing fiscal policies.

[22] This is not true when the economy is off the steady state growth path at the initial time point. In this case, we should include the welfare in the transitional phase too; and evaluating this analytically is a very hard technical work.

to negate the polluting effect of the informal sector; and hence this ratio varies inversely with the magnitude of the emission-output coefficients of the formal sector as well as of the informal sector.

(iii) The steady-state growth rate maximizing fiscal policy rates are able to achieve second-best optimum in the decentralized competitive economy.

The presence of differential emission-output coefficients in the two production sectors in the economy and their differential role on government's revenue generation make our result different from those found in the existing literature. If $\delta_I = \delta_F = 0$ then we get back the result identical to that of Barro (1990) and FMS (1993) models.

We use equations (13), (14) and (15.1) and obtain

$$g_m(\sigma g_m + \rho)^{\frac{\alpha}{1-\alpha-\eta}} = (1-\alpha)(1-\alpha-\eta)\{\alpha^2(1-\delta_F)\}^{\frac{\alpha}{1-\alpha-\eta}}$$
$$\left[\eta(1-\delta_F) - \delta_I\{\alpha(1-\delta_F)\}^{-\frac{\alpha}{(1-\alpha)}}\left(\frac{\eta}{1-\alpha}\right)\right]^{\frac{\eta}{1-\alpha-\eta}}\left[(1-\alpha)(1-\delta_F) - \delta_I\{\alpha(1-\delta_F)\}^{-\frac{\alpha}{(1-\alpha)}}\right]. \tag{13.1}$$

Equation (13.1) solves for g_m when growth rate maximizing values of fiscal policy variables are chosen. A positive value of g_m is obtained when the right hand side of equation (13) is positive; and thus the condition for long-run endogenous growth is given by

$$\frac{(1-\delta_F)^{\frac{1}{(1-\alpha)}}}{\delta_I} > \frac{\alpha^{-\frac{\alpha}{(1-\alpha)}}}{(1-\alpha)}.$$

Given the value of α this condition is likely to be satisfied when δ_F and δ_I take very low values. So the economy may not grow at all in the long-run when the pollution rates are high in these two sectors.

Again, using equations (14) and (7A) we obtain the inter-sectoral capital allocation ratio which is given by

$$\frac{1-\lambda}{\lambda} = \{\alpha(1-\delta_F)\}^{-\frac{1}{1-\alpha}}. \tag{7B}$$

Equation (7B) clearly shows that this growth rate maximizing inter-sectoral capital allocation ratio in the market economy is independent of the emission-output coefficient in the informal sector. This is so because the income tax rate is independent of this emission-output coefficient in the informal sector and hence the rate of return on capital in either sector is not disturbed by this coefficient.

IV. *Stability Property*

We investigate the stability property of the unique decentralized steady-state equilibrium with given values of policy parameters when production technologies in two sectors are identical[23]. Equations of motion of the dynamic system are given by differential equations[24] showing $\frac{\dot{C}_F}{C_F}$, $\frac{\dot{K}}{K}$ and $\frac{\dot{E}}{E}$.

We define $x=\frac{C_F}{K}$ and $y=\frac{E}{K}$; and then using equations (1), (2), (4) to (8), we have

$$\frac{\dot{x}}{x}=\left(\frac{\alpha}{\sigma}-1\right)\lambda^{\frac{\alpha+\eta-1}{1-\eta}}(1-\tau)(\tau-T)^{\frac{\eta}{1-\eta}}y^{\frac{1-\alpha-\eta}{1-\eta}}-\frac{\rho}{\sigma}+\frac{x}{1-\theta}; \tag{21}$$

and

$$\frac{\dot{y}}{y}=\left[T-\delta_F-\delta_I(1-\tau)\frac{1-\lambda}{\lambda}\right]\lambda^{\frac{\alpha}{1-\eta}}(\tau-T)^{\frac{\eta}{1-\eta}}y^{-\frac{\alpha}{1-\eta}}-\lambda^{\frac{\alpha+\eta-1}{1-\eta}}(1-\tau)(\tau-T)^{\frac{\eta}{1-\eta}}y^{\frac{1-\alpha-\eta}{1-\eta}}+\frac{x}{1-\theta}. \tag{22}$$

We then express λ in terms of τ using equation (7A). The determinant of the Jacobian matrix corresponding to differential equations given by (21) and (22) is given by

$$|J|=-\frac{1}{1-\theta}\left[\left(\frac{\alpha}{1-\eta}\right)\left\{T-\delta_F-\delta_I(1-\tau)^{-\frac{\alpha}{1-\alpha}}\right\}\left\{(1-\tau)^{-\frac{1}{1-\alpha}}+1\right\}^{-\frac{\alpha}{1-\eta}}(\tau-T)^{\frac{\eta}{1-\eta}}y^{-\frac{\alpha}{1-\eta}-1}\right.$$
$$\left.+\frac{\alpha}{\sigma}\left(\frac{1-\alpha-\eta}{1-\eta}\right)\left\{(1-\tau)^{-\frac{1}{1-\alpha}}+1\right\}^{-\frac{\alpha+\eta-1}{1-\eta}}(1-\tau)(\tau-T)^{\frac{\eta}{1-\eta}}y^{\frac{1-\alpha-\eta}{1-\eta}-1}\right].$$

Here $0<\delta_F,\ \delta_I<T<\tau<1$ and $T>\delta_F+\delta_I(1-\tau)^{-\frac{\alpha}{1-\alpha}}$ when values of τ and T are chosen maximizing the growth rate in the steady-state equilibrium. So $|J|<0$ in this case; and hence we can state the following proposition.

Proposition 3: If production technologies of the two sectors are identical, the unique steady-state equilibrium is saddle-point stable with a unique saddle path converging to that equilibrium point when fiscal instruments are chosen to maximize the steady-state growth rate.

In Loayza (1996) model, there exists no transitional dynamic property because it behaves

---

[23] Equation (7A) shows that $\frac{\lambda}{1-\lambda}$ is a linear function of $\frac{E}{K}$ when $\alpha=\psi$ and $\eta=\beta$. So $\frac{\dot{\lambda}}{\lambda}$ is linearly dependent on $\frac{\dot{E}}{E}$ and $\frac{\dot{K}}{K}$ and is independent of λ. Hence we replace the expression of λ from equation (7A) in equations (10), (11) and (12). However, if identical production technology is not assumed then λ can only be expressed as an implicit function of $\frac{E}{K}$ as shown in equation (7); and $\frac{\dot{\lambda}}{\lambda}$ depends on λ. Our dynamic system is a 3×3 differential system in that case. Hence, for the sake of technical simplicity, we analyze the stability property of the steady-state equilibrium assuming identical production technologies in these two sectors.

[24] Equation (7A) shows that $\frac{\lambda}{1-\lambda}$ is a linear function of $\frac{E}{K}$ when $\alpha=\psi$ and $\eta=\beta$. So $\frac{\dot{\lambda}}{\lambda}$ is linearly dependent on $\frac{\dot{E}}{E}$ and $\frac{\dot{K}}{K}$ and is independent of λ. Hence we replace the expression of λ from equation (7A) in equations (10), (11) and (12). However, if identical production technology is not assumed then λ can only be expressed as an implicit function of $\frac{E}{K}$ as shown in equation (7); and $\frac{\dot{\lambda}}{\lambda}$ depends on λ. Our dynamic system is a 3×3 differential system in that case. Hence, for the sake of technical simplicity, we analyze the stability property of the steady-state equilibrium assuming identical production technologies in these two sectors.

like a *AK* model similar to Barro (1990) model with a flow public expenditure. Our model also assumes flow public expenditure. However, we protect our model from being trapped into the *AK* model by assuming environmental quality to be an accumulable input; and obtain the saddle-point stability property of the long run equilibrium even with a flow public expenditure. FMS (1993) brings back transitional dynamic properties in Barro (1990) model introducing durable public input. Greiner (2005) model exhibits transitional dynamic properties treating environmental pollution as a flow variable but treating public input expenditure as a stock variable.

V. *The Problem of The Social Planner*

The social planner can internalize the externalities arising from public infrastructure and environmental quality.

This socially efficient growth rate[25] denoted by g_c and the capital allocation between the two sectors in the steady-state equilibrium are derived from the social planner's optimization problem and are given by the following equations.

$$(\rho+\sigma g_c)^{\beta-\eta}=\frac{[\alpha(1-\delta_F)]^{\beta}}{\{\psi(1-\delta_I)\}^{\eta}}\left(\frac{1-\lambda}{\lambda}\right)^{\eta(1-\psi)}; \tag{23}$$

and

$$(\rho+\sigma g_c)^{\beta-\eta}=\left[(1-\alpha-\eta)+\frac{\alpha}{\psi}(1-\beta-\psi)\left(\frac{1-\lambda}{\lambda}\right)\right]^{\beta-\eta}(1-\delta_F)^{\frac{\psi-\alpha}{\{\alpha(\beta-1)+\psi(1-\eta)\}}}$$
$$\left[\frac{\alpha}{\psi}\left(\frac{1-\delta_F}{1-\delta_I}\right)\right]^{\frac{\alpha}{\{\alpha(\beta-1)+\psi(1-\eta)\}}}\left[\eta+\beta\frac{\alpha}{\psi}\left(\frac{1-\lambda}{\lambda}\right)\right]^{\frac{\eta\psi-\alpha\beta}{\{\alpha(\beta-1)+\psi(1-\eta)\}}}\left(\frac{1-\lambda}{\lambda}\right)^{\frac{\alpha(1-\psi)}{\{\alpha(\beta-1)+\psi(1-\eta)\}}}. \tag{24}$$

Equations (23) and (24) solve for g_c and λ; and unique steady-state equilibrium may exist[26].

If two sectors have identical production technologies, i.e., if $\alpha=\psi$ and $\eta=\beta$, then from equation (22), we have

$$\frac{1-\lambda}{\lambda}=\left(\frac{1-\delta_I}{1-\delta_F}\right)^{\frac{1}{1-\alpha}}. \tag{23A}$$

Equation (23A) shows socially efficient capital allocation between two sectors. Equations (7B) and (23A) are identical if $\delta_I=0$; and equation (23A) solves for a higher value of λ when $\delta_I>0$. So, with identical production technologies, the inter-sectoral capital allocation in the competitive steady-state equilibrium is socially efficient only if the informal sector does not cause environmental pollution. In the presence of environmental pollution caused by informal sector's production, socially efficient capital allocation to the formal sector exceeds the

[25] The working of the planned economy and derivations of equations (23) and (24) are described in the Appendix (F).

[26] The conditions for this existence are also derived in Appendix (E).

competitive equilibrium allocation in the steady-state equilibrium. This leads to the following proposition.

Proposition 4: In the presence (absence) of environmental pollution generated by the informal sector, the relative size of the formal sector in the competitive economy in the decentralized steady-state equilibrium falls short of (is equal to) its socially efficient size when the two sectors have identical production technologies.

However, the socially efficient growth rate, g_c, is indeterminate in this case because

$$(\rho+\sigma g_c)^{\beta-\eta}=1 \text{ for } \eta=\beta.$$

Loayza (1996) neither compares the competitive economy solution to the socially efficient solution nor considers the pollution generating role of the informal sector. However, informal sector activities generate environmental pollution in reality; and it is well known that fiscal policies are not effectively designed to control the informal sector activities and to internalize their negative externalities. Our present exercise indicates the importance of appropriate environmental policies to control the pollution generated by informal sectors.

VI. *Conclusion*

In this paper, we develop a two sector endogenous growth model consisting of a formal and an informal sector, with special reference to the interaction between productive public expenditure and environmental pollution. Production technology in the formal as well as in the informal sector use public infrastructure and environmental quality as inputs. Formal sector's income is taxed and this tax revenue finances government's expenditure on public input and abatement activities. Environmental quality is improved by abatement expenditure and degraded through emissions caused by production activities in the formal as well as by the informal sector. In the decentralized economy, we analyze the properties of second-best optimum income tax policy and abatement expenditure policy in the presence of environmental pollution generated by the informal sector when this sector does not contribute to government's revenue generation.

We derive following interesting results analyzing our model when both the sectors have identical production technologies. First, the second-best optimum income tax rate is less than that in Barro (1990) and FMS (1993) models where there is no informal sector. It varies positively with the emission-output coefficient in the formal sector but is independent of the emission-output coefficient in the informal sector. On the other hand, the second-best optimum abatement expenditure rate and the second-best optimum ratio of productive public infrastructural expenditure to formal sector's output depend on pollution-output coefficients of both the sectors. Secondly, the balanced growth rate maximizing fiscal policy and the social welfare maximizing fiscal policy are found to be identical in the steady-state equilibrium. Thirdly, the steady-state growth equilibrium exhibits saddle-point stability property. This is similar to the transitional dynamic result in TB (2009) model but differs from that in the Loayza (1996) model. Lastly, the inter-sectoral capital allocation in the competitive economy appears to be socially inefficient when informal sector pollutes the environment.

However, our model suffers from various limitations. Our informal sector need not pay any penalty when identified as a defaulter. In reality, the informal sector pays the penalty when tax evasion is detected. Results may be different when the penalty rate varies positively with the relative size of the informal sector. We assume away other realities like population growth, labour institutions, inter-sectoral labour allocation, etc. The assumption of identical technologies helps us to work out analytical solutions in simplified forms but empirically it is not a very tenable assumption. We also ignore the problems of skill accumulation and technological progress in our model. Our future research would take care of these aspects.

Bibliography

Alonzo, R. (1991), "The Informal Sector in the Philippines," in: A. Chickering, & M. Salahdine, *The Silent Revolution*, San Francisco: International Center for Economic Growth.

Antunes, A.R. and T.V. Cavalcanti (2007), "Start Up Costs, Limited Enforcement, and the Hidden Economy," *European Economic Review* 51, pp.203-224.

Aschauer, D.A. (1989), "Is Public Expenditure Productive," *Journal of Monetary Economics* 23, pp.177-200.

Baier, S.L. and G. Glomm (2001), "Long-Run Growth and Welfare Effects of Public Policies with Distortionary Taxation," *Journal of Economic Dynamics and Control* 25, pp.2007-2042.

Barro, R.J. (1990), "Government Spending in a Simple of Endogenous Growth," *Journal of Political Economy* 98, pp.103-125.

Barro, R.J. and X. Sala-i-Martin (1992), "Public Finance in Models of Economic Growth," *Review of Economic Studies* 59, pp.645-61.

Benarroch, M. and R. Weder (2006), "Intra-Industry Trade in Intermediate Products, Pollution and Internationally Increasing Returns," *Journal of Environmental Economics and Management Vol* 52, pp.675-689.

Bertinelli, L., E. Strobl and B. Zou (2008), "Economic Development and Environmental Quality: A Reassessment in Light of Nature's Self-Regeneration Capacity," *Ecological Economics* 66, pp.371-378.

Biller, D. and J.D. Quintero (1995), "*Policy Options to Address Informal Sector Contamination in Urban Latin America: The Case of Leather Tanneries in Bogota, Colombia,"* Washington: The World Bank, Latin America Technical Department, Environment Division.

Blackman, A. (2000), "Informal Sector Pollution Control: What Policy Options Do We Have?," *World Development* 28, pp.2067-2082.

Blackman, A. and G.J. Bannister (1998), "Community Pressure and Clean Technology in the Informal Sector: An Econometric Analysis of the Adoption of Propane by Traditional Mexican Brickmakers," *Journal of Environmental Economics and Management* 35, pp.1-21.

Bovenberg, L. and S. Smulders (1995), "Environmental Quality and Pollution-Augmenting Technological Change in a Two-Setor Endogenous Growth Model," *Journal of Public Economics* 57, pp.369-391A.

Burguet, R. and J. Fernandez-Ruiz (1998), "Growth Through Taxes or Borrowing? A Model of

Development Traps with Public Capital," *European Journal of Political Economy* 14, pp.327-344.

Byrne, M.M. (1997), "Is Growth a Dirty Word? Pollution, Abatement and Endogenous Growth," *Journal of Development Economics* 54, pp.261-281.

Chang, W.-y. (1999), "Government Spending, Endogenous Labour, and Capital Accumulation," *Journal of Economic Dynamics and Control* 23, pp.1225-1242.

Chaudhuri, S. and U. Mukhopadhyay (2006), "Pollution and Informal Sector: A Theoretical Analysis," *Journal of Economic Integration* 21, pp.363-378.

Chen, B.-L. (2006), "Public Capital, Endogenous Growth, and Endogenous Fluctuations," *Journal of Macroeconomics* 28, pp.768-774.

Chen, B.-L. and S.-F. Lee (2007), "Congestible Public Goods and Local Indeterminacy: A Two Sector Endogenous Growth Model," *Journal of Economic Dynamics and Control* 31, pp.2486-2518.

Chickering, A. and M. Salahdine (1991), "Introduction and The Informal Sector Search for Self Governance," in: A. Chickering and M. Salahdine, *The Silent Revolutions,* San Francisco, International Center for Economic Growth.

de Soto, H. (1989), *The Other Path,* New York, Harper & Row.

Di Vita, G. (2008), "Capital Accumulation, Interest Rate and the Income-Pollution Pattern: A Simple Model," *Economic Modelling* 25, pp.225-235.

Dinda, S. (2005), "A Theoretical Basis for the Environmental Kuznets Curve," *Ecological Economics* 53, pp.403-413.

Economides, G. and A. Philippopoulos (2008), "Growth Enhancing Policy is the Means to Sustain the Environment," *Review of Economic Dynamics* 11, pp.207-219.

Elbasha, E.H. and T.L. Roe (1996), "On Endogenous Growth: The Implications of Environmental Externalities," *Journal of Environmental Economics and Management* 31, pp.240-268.

Futagami, K., Y. Morita, and A. Shibata (1993), "Dynamic Analysis of an Endogenous Growth Model with Public Capital," *Scandinavian Journal of Economics* 95, pp.607-625.

Ghosh, S. and I.A. Mourmouras (2004), "Endogenous Growth, Welfare and Budgetary Regimes," *Journal of Macroeconomic* 26, pp.623-635.

Gibson, B. (2005), "The Transition to a Globalized Economy: Poverty, Human Capital and the Informal Sector in a Structuralist CGE Model," *Journal of Development Economics* 78, pp.60-94.

Greiner, A. (2005), "Fiscal Policy in an Endogeneous Growth Model with Public Capital and Pollution," *Japanese Economic Review* 56, pp.67-84.

Greiner, A. and W. Semmler (2000), "Endogenous Growth, Government Debt and Budgetary Regimes," *Journal of Macroeconomics* 22, pp.363-384.

Gruver, G. (1976), "Optimal Investment and Pollution in a Neoclassical Growth Context," *Journal of Environmental Economics and Management* 5, pp.165-177.

Hartman, R. and O.-S. Kwon (2005), "Sustainable Growth and the Environmental Kuznets Curve," *Journal of Economic Dynamics and Control* 29, pp.1701-1736.

Hartwick, J.M. (1991), "Degradation of Environmental Capital and National Accounting Procedures," *European Economic Review* 35, pp.642-649.

Hu, Y., Ohdoi, R. and K. Shimomura (2008), "Indeterminacy in a Two-Sector Endogenous Growth Model with Productive Government Spending," *Journal of Macroeconomics* 30, pp.1104-1123.

Huq, M. and M. Sultan (1991), "Informality in Development: The Poor as Entrepreneurs in Bangladesh," in: A. Chickering and M. Salahdine, *The Silent Revolutions,* San Francisco, International Center for Economic Growth.

Itaya, J.-i. (2008), "Can Environmental Taxation Stimulate Growth? The Role of Indeterminacy in Endogenous Growth Models with Environmental Externalities," *Journal of Economic Dynamics and Control* 32, pp.1156-1180.

Jones, R.W. (1965), "The Structure of Simple General Equilibrium Models," *Journal of Political Economy* 73, pp.557-572.

Jones, R.W. (1971), "A Three Sector Model in Theory, Trade, and History," in: J.N. Bhagwati, R.W. Jones, R.A. Mundell, J. Vanek, eds., *Trade, Balance of Payments and Growth,* Amsterdam, North-Holland.

Kalaitzidakis, P. and S. Kalyvitis (2004), "On the Macroeconomic Implications of Maintenance in Public Capital," *Journal of Public Economics* 88, pp.695-712.

Kathuria, V. (2007), "Informal Regulation of Pollution in a Developing Country: Evidence from India," *Ecological Economics* 63, pp.403-417.

Kolstad, C.D. (2000), *Environmental Economic,* Oxford University Press.

Le Kama, A.D. (2001), "Sustainable Growth, Renewable Resources and Pollution," *Journal of Economic Dynamics and Control* 25, pp.1911-1918.

Liddle, B. (2001), "Free Trade and the Environment-Development System," *Ecological Economics* 39, pp.21-36.

Loayza, N. (1996), "The Economics of the Informal Sector: A Simple Model and Some Evidence from Latin America," *Carnegie-Rochester Conference Series on Public Policy* 45, pp.129-162.

Managi, S. (2006), "Are There Increasing Returns to Pollution Abatement? Empirical Analytics of the Environmental Kuznets Curve in Pesticides," *Ecological Economics* 58, pp.617-636.

Mazumdar, D. (1976), "The Urban Informal Sector," *World Development* 4.

Mourmouras, I.A. and J.E. Lee (1999), "Government Spending on Infrastructure in an Endogenous Growth Model with Finite Horizons," *Journal of Economics and Business* 51, pp.395-407.

Neill, J.R. (1996), "Fuelling the Engine of Growth with Investment in Infrastructure: A Lesson from Neoclassical Growth Theory," *Journal of Macroeconomics* 18, pp.521-529.

Nipon, P. (1991), "The Informal Sector in Thailand," in: A. Chickering and M. Salahdine, *The Silent Revolutions,* San Francisco, International Center for Economic Growth.

Ohdoi, R. (2007), "Productive Government Spending, Patterns of Specialisation and Economic Growth in a Small Open Economy," *The Japanese Economic Review* 58, pp.127-146.

Oueslati, W. (2002), "Environmental Policy in an Endogenous Growth Model with Human Capital and Endogenous Labour Supply," *Economic Modelling* 19, pp.487-507.

Park, H. and A. Philippopoulos (2002), "Dynamics of Taxes, Public Services and Endogenous Growth," *Macroeconomic Dynamics* 6, pp.187-201.

Penalosa, C.G. and Turnovsky, S.J. (2005), "Second-Best Optimal Taxation of Capital and Labour in a Developing Economy," *Journal of Public Economics* 89, pp.1045-1074.

Raurich-Puigdevall, X. (2000), "Global Indeterminacy in an Endogenous Growth Model with Public Capital," *Journal of Economics* 71, pp.255-280.

Saracoglu, D.S. (2008), "The Informal Sector and Tax on Employment: A Dynamic General

Equilibrium Investigation," *Journal of Economic Dynamics and Control* 32, pp.529-549.

Sarte, P.-D.G. (2000), "Informality and Rent-Seeking Bureaucracies in a Model of Long-Run Growth," *Journal of Monetary Economics* 46, pp.173-197.

Selden, T.M. and S. Daqing, (1995), "Neoclassical Growth, the J Curve for Abatement, and the Inverted U Curve for Pollution," *Journal of Environmental Economics and Management* 29, pp.162-168.

Shioji, E. (2001), "Public Capital and Economic Growth: A Convergence Approach," *Journal of Economic Growth* 6, pp.205-227.

Smulders, S. and R. Gradus (1996), "Pollution Abatement and Long-Term Growth," *European Journal of Political Economy* 12, pp.505-532.

Tamai, T. (2007), "Public Intermediate Goods, Endogenous Growth, and Indeterminacy," *Economic Modelling* 24, pp.683-689.

Tanaka, J. (2002), "A Note on Government Spending on Infrastructure in an Endogenous Growth Model with Finite Horizon," *Journal of Economics and Business* 54, pp.651-654.

Tokman, V. (1992), "The Informal Sector in Latin America: From Underground to Legal," in: V. Tokman, *Beyond Regulation: The Informal Economy in Latin America.*

Tsoukis, C. and N.J. Miller (2003), "Public Services and Endogenous Growth," *Journal of Policy Modelling* 25, pp.297-307.

Turnovsky, S.J. (1996), "Fiscal Policy, Adjustment Costs, and Endogenous Growth," *Oxford Economic Papers* 48, pp.361-381.

Turnovsky, S.J. (1997), "Fiscal Policy in a Growing Economy with Public Capital," *Macroeconomic Dynamics* 1, pp.615-639.

Turnovsky, S.J. and M.A. Basher (2009), "Fiscal Policy and the Structure of Production in a Two-Sector Developing Economy," *Journal of Development Economics* 88, pp.205-216.

Yakita, A. (2004), "Elasticity of Substitution in Public Capital Formation and Economic Growth," *Journal of Macroeconomics* 26, pp.391-408.

Zhang, J. (2000), "Public Services, Increasing Returns, and Equilibrium Dynamics," *Journal of Economic Dynamics and Control* 24, pp.227-246.