The dual nature of public goods and congestion: the role of fiscal policy revisited

Santanu Chatterjee   *Department of Economics, University of Georgia*

Sugata Ghosh   *Department of Economics and Finance, Brunel University*

Abstract. The role of fiscal policy is examined when public goods provide both productive and utility services. In the presence of congestion, the consumption tax is shown to be distortionary. Optimal fiscal policy involves using consumption-based instruments in conjunction with the income tax. An income tax-financed increase in government spending dominates both lump-sum and consumption tax-financing. Replacing the lump-sum tax with an income tax to finance a given level of spending dominates introducing an equivalent consumption tax. These results contrast sharply with the literature, where the consumption tax is generally viewed as the least distortionary source of public finance. JEL classification: E21, E62, H21, H41, H54

La nature duale des biens publics et de la congestion : un ré-examen de la politique fiscale. On ré-examine le rôle de la politique fiscale quand les biens publics fournissent à la fois des services productifs et de bien-être. Quand il y a congestion, on montre que la taxe sur la consommation crée des distorsions. La politique fiscale optimale consiste à faire bon usage des taxes sur la consommation en conjonction avec l'impôt sur le revenu. Une dépense gouvernementale financée par l'impôt sur le revenu est préférable à un financement par un paiement forfaitaire ou une taxe sur la consommation. Remplacer le paiement forfaitaire par un impôt sur le revenu pour financer un niveau donné de dépense vaut mieux qu'introduire une taxe équivalente sur la consommation. Ces résultats contrastent vivement avec ce qu'on trouve dans la littérature spécialisée, où l'on considère généralement la taxe sur la consommation comme la source de finance publique qui crée le moins de distorsion.

1. Introduction

Objectives and motivation. Public goods and associated externalities provide a crucial channel through which government spending and taxation policies affect private resource allocation and social welfare. In analyzing the link between public goods and macroeconomic performance, most of the literature has compartmentalized public goods into two distinct types: (i) those that impinge directly on productivity, thereby entering the production process as a public input complementary to private capital and labour, and (ii) those that are purely welfare-enhancing, thereby interacting with private consumption in the utility function.[1] In this paper, we argue that most public goods, such as infrastructure, education, healthcare services, and law and order, play a *dual* role in influencing private economic activity by simultaneously affecting both private productivity *and* utility (welfare). Consequently, the dichotomy in defining public goods can lead to inaccurate implications for the design and evaluation of fiscal policies. By departing from this standard assumption of dichotomy, we derive a set of new results linking fiscal policy to an economy's structural characteristics and its macroeconomic performance, and thereby synthesize two seemingly independent strands of literature on this issue.

The following examples might help set this discussion in perspective. Consider economic infrastructure, which is, without exception, treated purely as a productivity-enhancing input in the production process. Roads and highways, apart from influencing productivity by facilitating the transportation of goods and services, might also be an important source of utility to consumers, who might get pleasure out of driving or taking road trips.[2] Similar examples can be offered for other aspects of infrastructure as well, such as power and water supply, transport and communication, and so on. Education is another example of a public good whose dual role is often overlooked. Its productivity-enhancing role is underlined by the economy's set of skills, knowledge base, human capital, and, ultimately, a more productive workforce. It can also be argued that altruistic parents derive satisfaction from sending their children to good schools, with the

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1   One strand of literature, starting with Bailey (1971) and with later contributions by Aschauer (1988) and Barro (1989), highlights the welfare-enhancing properties of public goods by focusing on the substitutability between public and private consumption in the utility function. On the other hand, Gramlich (1994) reviews the empirical evidence that suggests that government investment expenditures may have large productivity effects on the economy. A second strand of research therefore focuses on the productivity-enhancing role of public investment goods, such as infrastructure; see Arrow and Kurz (1970) for an early analysis, and Barro (1990), Futagami, Morita, and Shibata (1993), Baxter and King (1993), and Glomm and Ravikumar (1994) for later contributions. Though Turnovsky and Fisher (1995) and Turnovsky (2004) study both public consumption and investment, they are modelled as individually *distinct* goods. Another recent contribution, by Economides, Park, and Philippopoulos (2011), also distinguishes between productivity and utility-enhancing public goods in analyzing second-best optimal policy in a Ramsey model.

2   The *New York Times* reported that about 87% of all vacation travellers in the U.S. (38 million people) used the country's interstate highway system for road trips during the 2006 Memorial Day weekend.

intention of enabling them to be better citizens in the future. Moreover, in developing countries that lack credit markets, investment in a child's education is often seen as a means of providing social insurance for parents in their old age. Further, in many countries (and certainly in the US), school facilities are regularly used for recreational activities such as fairs and sporting events, which provide direct utility benefits to users. This argument holds for traditionally defined public consumption goods as well, such as law and order, national parks, defence. While these goods might directly affect the utility consumers derive from them, they can also have significant productivity benefits (by providing security, protecting property rights, or reducing stress).[3] In essence, most public goods should be viewed as providing a composite bundle of services, rather than targeting some specific aspect of economic activity (such as production or consumption).

The objective of this paper is to study the design and impact of fiscal policy on growth and welfare when (i) the aggregate stock of a composite public good simultaneously provides *both* consumption and productive services, and (ii) these services are subject to *differential* degrees of relative congestion. Therefore, agents in the economy (e.g., consumers and firms) can derive *different* types of services (e.g., utility and productivity) from the accumulated stock of the *same* public good. Further, the degree of rivalry (i.e., congestion) generated may also vary across agents, depending on the underlying usage of the public good. For example, power outages and shortages in water supply during peak 'usage' seasons such as summer are common examples of congestion in many developing countries (World Bank 1994). However, the disutility caused by a power outage for a household may be quite different from the loss in productivity suffered by a firm or worker. Similar examples can be motivated for highway or air-traffic congestion as well. This aspect of the paper clearly distinguishes itself from the existing literature, where the effects of congestion are restricted to either production *or* utility, depending on the type of public good (i.e., consumption or investment) being modelled.[4]

Value-added. Our contributions are threefold. First, we highlight a new mechanism through which a consumption tax might impact growth and welfare.[5] In

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3 Tanzi and Schuknecht (1997, 2000) find that government provision of education, health, public pensions, and social insurance has led to increases in the literacy and life-expectancy rates and reductions in infant mortality rates and unemployment insecurity in the OECD countries over the 1913–1990 period, during which there was a fourfold increase in public spending as a proportion of GDP. In effect, they make the argument that traditionally defined public 'capital' goods contribute as much to social welfare as do public 'consumption' goods.

4 Congestion is often used as a classic example of rivalry associated with public goods, and its effects on growth, welfare, and the design of optimal fiscal policy have been studied by several authors, including Edwards (1990), Barro and Sala-i-Martin (1992), Fisher and Turnovsky (1998), and Eicher and Turnovsky (2000).

5 The consumption tax has a long history in economics, dating back to Hobbes (1651), with Fisher (1937) and Kaldor (1955) providing the early contributions in the 20th century; see Atkinson and Stiglitz (1980) for a review of the early literature and Gentry and Hubbard (1997) for a discussion on the distributional effects of consumption taxes. More recently, the

the context of endogenous growth, the only condition under which a consumption tax is distortionary is when the labour-leisure choice is endogenous (see, e.g., Milesi-Ferretti and Roubini 1998 and Turnovsky 2000 for some recent examples). In contrast, we show that when public goods provide 'dual' services and the utility services are subject to congestion, a consumption tax is indeed *distortionary*, affecting both the economy's dynamic adjustment and its equilibrium resource allocation, even when the labour supply is *exogenous*. The dual nature of the public good plays an important role in this result by linking the marginal utility of consumption and its relative price to the marginal return on private capital.[6]

Second, the above feature enables us to generalize some important results on optimal fiscal policy in the context of public goods and growth. Most of the existing literature relies on the income tax as the sole corrective fiscal instrument for congestion, with the consumption tax playing the role of a *non-distortionary* lump-sum tax, used to balance the government's budget (see Barro and Sala-i-Martin 1992; Turnovsky 1996). However, our analysis assigns an important role to *consumption*-based fiscal instruments as a *complement* to the income tax in correcting for different sources of congestion. This is due to the distortionary role played by the consumption tax (or subsidy) in our set-up. This refinement is possible only when one acknowledges the dual nature of a public good and the differential congestion externalities its usage generates. More important, we demonstrate that most of the standard results in the literature on optimal fiscal policy and congestion can be conveniently derived as *special cases* of our more general model.

Third, given that both income and consumption taxes are distortionary in our set-up, we conduct several policy experiments to compare numerically their relative efficacy as financing tools for government spending. For empirically plausible values of the elasticity of substitution in production, financing an increase in government spending through an increase in the income tax rate dominates lump-sum and consumption tax financing, when the services from the public good are congested. In the presence of congestion, replacing the lump-sum tax with an income tax to finance a given level of government spending improves

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consumption tax has also occupied a significant place in the political debate on tax reform in the United States. See, for example, the 2003 United States Economic Report of the President (chap. 5, 175–212) for a discussion on the pros and cons of a consumption-based tax system relative to an income-based system.

6 The possibility of a dual role played by public investment was first suggested by Arrow and Kurz (1970, chap. 1), though a formal treatment was not provided. In a recent contribution, Agenor (2008) develops a model where, within a Cobb-Douglas production setting, infrastructure services influence the production of goods and the provision of healthcare services. The latter, in turn, affects both individual welfare and productivity. The focus of this paper, however, is very different. While Agenor (2008) focuses on the expenditure side of the government's budget and the potential trade-offs between spending on infrastructure and healthcare, we focus on the revenue side and the differential effects of congestion: using a more general CES production structure, we characterize the appropriate mix of income and consumption-based tax instruments that can be used to correct for the different types of congestion generated by a composite public good.

welfare by reducing congestion. In contrast, the introduction of an equivalent consumption tax actually worsens welfare by increasing congestion. These results also contrast sharply with the existing literature, where the consumption tax is often viewed as the least distortionary source of financing government spending.

The rest of the paper is organized as follows. Section 2 develops the analytical framework using a composite public good. Section 3 characterizes resource allocation in a centrally planned economy, which yields the benchmark first-best optimum. Section 4 derives the macroeconomic equilibrium in a decentralized economy and discusses the design of optimal fiscal policy. In section 5, we conduct a numerical analysis of the model and its dynamic properties, with a particular emphasis on welfare. Section 6 concludes the paper.

2. Analytical framework

We consider a closed economy populated by N infinitely lived identical agents, each of whom maximizes intertemporal utility from the consumption from a private good C, and the services derived from the accumulated economy-wide *stock* of a composite public good, K_g:

$$
U \equiv U(C, K_g) = \int_0^\infty \frac{1}{\gamma} \left[C \left\{ K_g \left(\frac{K}{\bar{K}} \right)^{1-\sigma_c} \right\}^\theta \right]^\gamma e^{-\beta t} dt,
$$

$$
-\infty < \gamma \leq 1, \ 0 \leq \theta \leq 1, \ 0 \leq \sigma_c \leq 1,
$$

(1)

where θ denotes the relative importance of the public good in the utility function. The available stock of the public good is non-excludable, but the services derived from it by an individual agent may be subject to rivalry, in the form of relative congestion. In other words, the 'utility' benefits derived by the agent from the composite public good depend on the usage of its own private capital (K), relative to the aggregate economy-wide usage ($\bar{K}$).[7] σ_c parameterizes the degree of relative congestion associated with the (utility) benefits derived from the public good.

The public good, apart from generating utility benefits for the representative agent, is also available for productive purposes. Each agent produces a private good, whose output is given by Y, using a CES technology, and its individual stock of private capital and the economy-wide stock of the public good serve as factors of production. However, the productive services derived from the public

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7 The use of private capital to characterize congestion from the public good can be motivated by a simple example: suppose that private vehicles are used to transport goods or labour during the week, but for leisure activities during the weekend.

good may also be subject to congestion, in a manner similar to (1):

$$
Y = A \left[\alpha K^{-\rho} + (1 - \alpha) \left\{ K_g \left(\frac{K}{\bar{K}} \right)^{1-\sigma_y} \right\}^{-\rho} \right]^{-\frac{1}{\rho}},
$$
$$
0 < \alpha < 1, \ -1 < \rho < \infty, \ 0 \le \sigma_y \le 1,
$$
(2)

where σ_y measures the degree of relative congestion associated with the productive benefits derived from the composite public good.[8] The elasticity of substitution between private capital and the public good is given by $s = 1/(1 + \rho)$.[9]

The parameterization of θ in (1) provides a convenient tool by which the role of the public good in influencing economic activity can be defined. For example, when $\theta > 0$, the public good plays a *dual* role in the economy, by providing both productive and utility services. On the other hand, when $\theta = 0$, the public good is just a productive input with no direct utility benefits. This case corresponds to the standard public capital-growth model found in the literature, as in Futagami, Morita, and Shibata (1993).

The accumulation of public capital is enabled by the flow of new public investment, given by

$$
\dot{K}_g = G - \delta_g K_g,
$$
(3)

where G represents the flow of expenditures on the public good, which may be undertaken by either a social planner or a government, and δ_g is the rate of depreciation of the stock of public capital. Finally, the economy's aggregate resource constraint is given by

$$
\dot{K} = Y - C - G - \delta_K K,
$$
(4)

where δ_K denotes the depreciation rate for private capital.

The analytical description of the model will proceed sequentially in the following manner. First, we will describe the allocation problem in a centrally planned economy. Given this 'first-best' benchmark equilibrium, we will then derive the equilibrium in a decentralized economy. This sequential analysis will enable us to

8 In our specification, when $\sigma_i = 1 (i = c, y)$, there is no congestion associated with the public good. In that case, the public good is a non-rival good available equally to all agents. On the other hand, $\sigma_i = 0$ represents a situation of proportional congestion, where congestion grows with the size of the economy. The case where $0 < \sigma_i < 1$ represents partial congestion. It is also plausible that the degrees of relative congestion in the utility and production functions are distinct, that is, $\sigma_c \ne \sigma_y$.

9 Assuming flexibility in the production structure by adopting a CES technology is useful for analyzing the efficacy of fiscal policy shocks as the degree of factor substitutability changes. When $s = 1 (\rho = 0)$, we obtain the familiar Cobb-Douglas specification. On the other hand, as $s \to 0 (\rho \to \infty)$, (3) converges to the fixed-proportions production function, and when $s \to \infty$ $(\rho \to -1)$, there is perfect substitutability between private capital and the public good.

characterize the design of optimal fiscal policy in the decentralized economy. The crucial behavioural difference between the centrally planned economy and the decentralized one lies in the way the congestion externalities are internalized. In the centralized economy, the social planner recognizes the relationship between the stocks of individual and aggregate private capital, $\bar{K} = NK$, ex ante. However, in the decentralized economy, the representative agent fails to internalize this relationship, although it holds ex post, in equilibrium. As a result, the resource allocation problem in the decentralized economy is subject to the various sources of congestion described in (1) and (2), and consequently is suboptimal. Optimal fiscal policy in the decentralized economy would then entail deriving the appropriate tax and expenditure rates for the government that would enable a replication of the equilibrium in a centrally planned economy.

3. A centrally planned economy: the first-best equilibrium

Since the planner internalizes the effects of congestion ex ante, we set $\bar{K} = NK$ and normalize $N = 1$. The planner's utility and production functions then take the form

$$U = \int_0^\infty \frac{1}{\gamma} \left(CK_g^\theta\right)^\gamma e^{-\beta t} dt \tag{1a}$$

$$Y = A\left[\alpha K^{-\rho} + (1-\alpha)K_g^{-\rho}\right]^{-\frac{1}{\rho}}. \tag{2a}$$

It is also convenient to begin with the assumption that the planner allocates a fixed fraction, g, of output to investment in the public good, to sustain an equilibrium characterized by endogenous growth. We will relax this assumption in section 3.2 to characterize optimal public investment.

$$\dot{K}_g = G - \delta_g K_g = gY - \delta_g K_g, \quad 0 < g < 1. \tag{5}$$

The planner chooses consumption and the accumulation of private capital and the public good by maximizing (1a) subject to (4) and (5), while taking note of (2a) and (3). The equilibrium relationships will be described in terms of the following stationary variables: $z = K_g/K$, the ratio of the stock of the public good to private capital, $c = C/K$, the ratio of private consumption to private capital, and $y = Y/K$, the output-private capital ratio. Under the assumption that g is arbitrarily fixed, the optimality conditions are given by

$$C^{\gamma-1}K_g^{\theta\gamma} = \lambda \tag{6a}$$

$$\alpha A^{-\rho}\left[(1-g)+qg\right]y^{1+\rho}-\delta_K=\beta-\frac{\dot{\lambda}}{\lambda} \tag{6b}$$

$$\frac{\dot{q}}{q}+\frac{1}{q}(1-\alpha)A^{-\rho}\left[(1-g)+qg\right]\left(\frac{y}{z}\right)^{1+\rho}+\frac{\theta}{q}\left(\frac{c}{z}\right)-\delta_g=\beta-\frac{\dot{\lambda}}{\lambda}, \tag{6c}$$

where λ is the shadow price of private capital, q is the shadow price of the public good relative to that of private capital, and $y=A[\alpha+(1-\alpha)z^{-\rho}]^{-1/\rho}$.

The optimality conditions (6a)–(6c) can be interpreted as follows. The marginal utility of consumption equals the shadow price of private capital in (6a), while (6b) equates the rate of return on private investment to the corresponding return on consumption. An analogous interpretation holds for (6c), which equates the return on public investment to that on consumption. The first term on the left-hand side of (6c) describes the capital gains emanating from the rate of change in its real price q (given that private capital is treated as the numeraire good). Since the public good plays a dual role in this economy, both as a consumption and an investment good, its social return is derived from two sources: (i) the return from production, given by the second term on the left-hand side of (6c), and (ii) the return from utility, given by the term $\theta(c/z)$, which measures the marginal rate of substitution between the private consumption good and the stock of the public good.

3.1. Macroeconomic equilibrium

Given the presence of two capital stocks, the equilibrium will be characterized by transitional dynamics around the steady state. The core dynamics of the centrally planned economy can be expressed by the evolution of the stationary variables z, c, and q, derived from (4), (5), and (6):

$$\frac{\dot{z}}{z}=gA\left[(1-\alpha)+\alpha z^{\rho}\right]^{-\frac{1}{\rho}}-\delta_g-A(1-g)\left[\alpha+(1-\alpha)z^{-\rho}\right]^{-\frac{1}{\rho}}+c+\delta_K \tag{7a}$$

$$\frac{\dot{c}}{c}=\frac{\alpha A^{-\rho}[(1-g)+qg]y^{1+\rho}+\theta\gamma\left\{g(y/z)-\delta_g\right\}-(\beta+\delta_K)}{1-\gamma} \tag{7b}$$
$$-A(1-g)[\alpha+(1-\alpha)z^{-\rho}]^{-\frac{1}{\rho}}+c+\delta_K$$

$$\dot{q}=qA^{-\rho}[(1-g)+qg]\left[\alpha-(1-\alpha)\frac{z^{-(1+\rho)}}{q}\right]y^{1+\rho}-\theta\left(\frac{c}{z}\right)+q(\delta_g-\delta_K). \tag{7c}$$

The steady-state equilibrium is attained when $\dot{z}=\dot{c}=\dot{q}=0$ and is characterized by balanced growth and a constant relative price of the public good. Denoting the steady-state levels by $\tilde{z}$, $\tilde{c}$, and $\tilde{q}$, and given a predetermined policy

g, the behaviour of the dynamic system (7) can be expressed in a linearized form around the steady-state equilibrium:

$$\underline{\dot{X}} = \Delta \left(\underline{X} - \tilde{X} \right), \tag{8}$$

where $\underline{X}' = (z, c, q)$, $\tilde{X}' = (\tilde{z}, \tilde{c}, \tilde{q})$, and Δ represents the 3×3 coefficient matrix of the linearized system.[10]

3.2. Optimal public expenditure
Instead of allocating an arbitrarily fixed fraction of output to expenditure on the public good, the planner can plausibly make an optimal choice with respect to the public spending rate g. Let the optimal share of public expenditure in output be $\hat{g}$, which is to be derived endogenously from equilibrium. Performing this optimization, we find that

$$\hat{q} = 1. \tag{9}$$

In other words, in choosing the optimal quantity of public expenditure, the planner must ensure that the shadow prices of private capital and the public good are equalized along the transition path. Substituting (9) into the steady-state conditions corresponding to (7), we can write the steady-state conditions for the planner as follows ('^' denotes the steady-state value of a variable when g is set optimally):[11]

$$\hat{g}A\left[(1-\alpha) + \alpha\hat{z}^{\rho}\right]^{-\frac{1}{\rho}} = A(1-\hat{g})\left[\alpha + (1-\alpha)\hat{z}^{-\rho}\right]^{-\frac{1}{\rho}} - \hat{c} \tag{10a}$$

$$\frac{\alpha A^{-\rho}\hat{y}^{1+\rho} + \theta\gamma\hat{g}\left(\hat{y}/\hat{z}\right) - \beta}{1-\gamma} = A(1-\hat{g})\left[\alpha + (1-\alpha)\hat{z}^{-\rho}\right]^{-\frac{1}{\rho}} - \hat{c} \tag{10b}$$

$$A^{-\rho}\left[\alpha - (1-\alpha)\hat{z}^{-(1+\rho)}\right]\hat{y}^{1+\rho} = \theta\left(\frac{\hat{c}}{\hat{z}}\right). \tag{10c}$$

Given (9), we can solve (10a)–(10c) for the optimal steady-state values of $\hat{z}$, $\hat{c}$, and $\hat{g}$.

An interesting point to note here is that (9) implies $\dot{q} = 0$ at all points of time. Therefore, the core dynamics are *independent* of the (unitary) real shadow price of the public good. Substituting (9) into (7b) and noting (7a), we can easily verify that when g is set at its socially optimal level, the dynamics are reduced to a

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10 Details regarding the linearized dynamics are available upon request. We have numerically verified that the linearized dynamic system (8) is characterized by one stable (negative) and two unstable (positive) eigenvalues, which generates saddle-point behaviour.

11 We set $\delta_K = \delta_g = 0$ in this section, without any loss of generality.

second-order system and can be expressed solely in terms of z and c.[12] When the planner optimally allocates output to investment in the public good, the resource costs appearing in (6b) and (6c) are no longer relevant. However, in evaluating the marginal costs and benefits of the private and public expenditure decisions, the planner must consider the fact that allocating an extra unit of output to the public good provides not only a productivity return, but also a utility return. This aspect of the model represents a significant departure from earlier work regarding the optimality of public investment in endogenous growth models. For example, Turnovsky (1997) finds that when g is chosen optimally, the economy is *always* on a balanced growth path and devoid of transitional dynamics. However, in this more generalized set-up, once the social planner chooses the optimal allocation of g, the stationary variables z and c are not constant, but evolve gradually along the transition path, while the social planner ensures that the shadow prices of private capital and the public good are always equalized. The key point here is that since the social return from the public good is derived from both utility and production, the corresponding investment in private capital must track this return along the transition path for (9) to hold. As a result, z and c must adjust accordingly at each point in time, until the steady-state equilibrium is attained.

It is easy to demonstrate that the relative importance of the public good in the utility function (θ) plays a crucial role in this result. To see this, assume that $\theta = 0$ in (10). Given that $\hat{q} = 1$, it is immediately evident from (10c) that $\hat{z} = [(1-\alpha)/\alpha]^{\frac{1}{1+\rho}}$. This implies that $\dot{z} = 0$ at all points of time. Consequently, from (10b), it turns out that $\dot{c} = 0$ must hold if the transversality conditions are to be satisfied. Therefore, in the special case where $\theta = 0$, the economy is always on its balanced growth path and there is no dynamic adjustment. This is essentially the result obtained in Turnovsky (1997). On the other hand, once the dual nature of the public good is internalized, that is, $\theta > 0$, the equilibrium is characterized by a transitional adjustment path. We can then conclude that the utility function (1) represents a general specification, from which earlier results in the literature can be derived as special cases, depending on the magnitude of θ.

4. A decentralized economy

We now consider the case of a decentralized economy where the government plays a passive role, while the representative agent makes its own resource allocation decisions. There are two differences between this regime and the centrally planned economy described in section 3. First, the government now provides the entire stock of the public good using the financial and policy instruments at its disposal, while the representative agent takes this stock as exogenously given in making its private allocation decisions. Second, the representative agent does not internalize

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12 In this case, the core dynamics reduce to a second-order system given by $\dot{X} = \bar{\Delta}(X - \tilde{X})$, where $X' = (z, c)$, $\tilde{X}' = (\tilde{z}, \tilde{c})$, and $\bar{\Delta}$ represents the 2×2 coefficient matrix of the linearized system.

the effects of the two sources of congestion externality, σ_c and σ_y. The utility function for the representative agent in this regime is therefore given by (1), while the production function is given by (2). The agent accumulates wealth in the form of private capital and holdings of government bonds, subject to the constraint

$$\dot{K} + \dot{B} = (1 - \tau_y)(Y + rB) - (1 + \tau_c)C - T - \delta_K K, \tag{11}$$

where r is the interest earnings on government bonds, τ_y is the income tax rate, τ_c is the consumption tax rate, and T is a lump-sum tax. Taking the stock of K_g as given, the agent chooses its flow of consumption, private investment, and holdings of government bonds to maximize (1), subject to the flow budget constraint (11) and the accumulation rule for private capital in (3), while taking note of (2). It is important to note here that in performing its optimization, the representative agent fails to internalize the relationship $\bar{K} = NK$, although it will hold ex post in equilibrium. As before, we will express the equilibrium in terms of the stationary variables z and c, and normalize $N = 1$, without loss of generality. Since the agent does not make an allocation decision with respect to the public good, its shadow price, q, is not relevant. The optimality conditions for the agent are

$$C^{\gamma - 1} K_g^{\theta \gamma} = \lambda(1 + \tau_c) \tag{12a}$$

$$(1 - \tau_y)A^{-\rho}[\alpha + (1 - \alpha)(1 - \sigma_y)z^{-\rho}]y^{1+\rho} + \theta(1 - \sigma_c)(1 + \tau_c)c - \delta_K = \beta - \frac{\dot{\lambda}}{\lambda} \tag{12b}$$

$$\beta - \frac{\dot{\lambda}}{\lambda} = (1 - \tau_y)r. \tag{12c}$$

The interpretation of the optimality conditions (12a)–(12b) is analogous to that of the centrally planned economy, except that in (12b), the rate of return on private capital is subject to the sources of congestion in production and utility. The presence of congestion raises the total market return on private capital when K increases, by increasing the productive and utility services derived from the stock of the public good. The last term on the left-hand side of (12b), $\theta(1 - \sigma_c)(1 + \tau_c)c$, represents the marginal rate of substitution between consumption and private capital generated by congestion in the utility function. In other words, it reflects the price of consumption relative to private capital. This is the crucial channel through which a consumption tax affects the agent's resource allocation decisions along the equilibrium path. Equation (12c) equates the rate of return on consumption to the return on government bond holdings and represents the no-arbitrage condition that equalizes the returns from consumption, private capital, and government bonds.

The government provides the necessary expenditure for the provision of the public good, which accumulates according to (5), and g now represents the (exogenous) fraction of output allocated by the government to the accumulation of the public good. Public investment is financed by tax revenues and issuing government debt:

$$\dot{B} = r(1 - \tau_y)B + G - \left(\tau_y Y + \tau_c C + T\right). \tag{13}$$

Combining (13) with (11) yields the aggregate resource constraint for the economy, given by (4). The steady-state equilibrium in the decentralized economy is given by

$$gA\left[(1 - \alpha) + \alpha\tilde{z}^\rho\right]^{-\frac{1}{\rho}} - \delta_g = A(1 - g)\left[\alpha + (1 - \alpha)\tilde{z}^{-\rho}\right]^{-\frac{1}{\rho}} - \tilde{c} - \delta_K \tag{14a}$$

$$\frac{(1 - \tau_y)A^{-\rho}\left[\alpha + (1 - \alpha)(1 - \sigma_y)\tilde{z}^{-\rho}\right]\tilde{y}^{1+\rho} + \theta\left[(1 - \sigma_c)(1 + \tau_c)\tilde{c} + \gamma\left\{g\left(\tilde{y}/\tilde{z}\right) - \delta_g\right\}\right] - (\beta + \delta_K)}{1 - \gamma}$$
$$= A(1 - g)\left[\alpha + (1 - \alpha)\tilde{z}^{-\rho}\right]^{-\frac{1}{\rho}} - \tilde{c} - \delta_K. \tag{14b}$$

Equations (14a) and (14b) can be solved for the steady-state values of $\tilde{z}$ and $\tilde{c}$. The dynamic evolution of the economy and the steady-state equilibrium are independent of the shadow price of the public good, q. This happens because the representative agent treats the government-provided stock of the public good as exogenous to its private decisions. As a result, the agent does not internalize the effect of its private investment decisions on the evolution of the public good.

4.1. Income versus consumption taxes in the presence of congestion

The macroeconomic equilibrium for the decentralized economy in (14) provides some new insights on the interaction between private resource allocation decisions and the government's fiscal instruments. Interestingly, the consumption tax, τ_c, can be *distortionary* in this set-up, affecting *both* the dynamic evolution and the steady-state equilibrium of the economy. This is a significant result, since our framework does not assume an endogenous labour-leisure choice which, in the literature, has been a crucial channel for a consumption tax to be distortionary. However, two conditions must be simultaneously satisfied for the consumption tax to have distortionary effects in our framework: (i) the public good plays a dual role by providing both utility and productive services ($\theta > 0$), and (ii) the utility services derived from the public good are subject to congestion ($0 < \sigma_c < 1$). As discussed in the introduction, both these conditions are plausible in the context of most public goods. Intuitively, a change in the consumption tax rate will increase the marginal rate of substitution between private consumption and private capital through the utility services derived from the public good, which in turn affects the market return from private capital, given by (12b). Therefore, the

dual nature of the composite public good and congestion generated by its utility services provide an alternative transmission mechanism for the consumption tax in affecting private economic decisions.

The steady-state equilibrium in (14a) and (14b) also throws some light on the way an income and a consumption tax might impact the economy in the presence of congestion externalities. Since both the utility and productive services from the public good are congested by private usage, the market return on private capital in a decentralized economy is above its socially optimal level, given by (6b). Therefore, the decentralized equilibrium is characterized by 'too much' private investment and 'too little' private consumption, relative to the social optimum. In this scenario, the goal of public policy would be to reduce the market return on private capital. From (12b) and (14), it is clear that an increase in income tax will help alleviate congestion by reducing the after-tax marginal return on private capital. On the other hand, an increase in the consumption tax works exactly in the opposite direction, by *increasing* the after-tax return on capital. This happens because, in the presence of congestion in utility services, a consumption tax will increase the relative price of consumption and lower that of private capital; see (12b). However, the impact of these tax rates on intertemporal welfare will depend crucially on the private allocation of resources between consumption and private investment. This allocation in turn will depend on (i) the elasticity of substitution in production and (ii) the relative importance of the public good in the utility function. These insights give us an important basis for comparing the dynamic effects of the two competing fiscal instruments, that is, the income and consumption tax rates, which we will consider in section 5 by undertaking a numerical analysis of the model.

4.2. Optimal fiscal policy

Given that income and consumption taxes impact the economy in very different ways, what tax and expenditure rates in the decentralized economy will replicate the social planner's optimum? Let these choices be represented by the vector $\underline{\Lambda}' = (\hat{g}, \hat{\tau}_y, \hat{\tau}_c)$. Then, by definition, $\underline{\Lambda}$ is a description of optimal fiscal policy in the decentralized economy. To determine these optimal choices, we will compare the equilibrium outcome in the decentralized and centrally planned economies. Since our focus is on the two distortionary tax rates, we will assume that g is set optimally at $\hat{g}$, given by the solution to (10), and is appropriately financed by some combination of non-distortionary lump-sum taxes and government debt. Given $\hat{g}$, a comparison of (10b) and (14b) yields the following long-run optimal relationship between the income and consumption tax rates:[13]

$$\tau_y = \frac{A^{-\rho}(1-\alpha)(1-\sigma_y)(y/z)^\rho + \theta(1-\sigma_c)(1+\tau_c)(c/y)}{A^{-\rho}[\alpha + (1-\alpha)(1-\sigma_y)z^{-\rho}]y^\rho}. \tag{15}$$

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13 Again, without any loss of generality, we set $\delta_K = \delta_g = 0$.

From (15), we see that in the presence of congestion in both production and utility, only *one* tax rate can be chosen independently to attain the first-best equilibrium.[14] This implies that the government has a choice in the 'mix' between the income and consumption tax rates: if one is set arbitrarily, the other automatically adjusts to satisfy (15) to replicate the first-best allocation. But what kind of a policy 'mix' must the government choose? Given (15), a unique combination of τ_y and τ_c is unattainable. However, even if one individual tax instrument is at its non-optimal level, (15) suggests that the government can still adjust the other appropriately to attain the social optimum.

To see this flexibility in designing optimal fiscal policy, note that, in (15), the income and consumption tax rates are positively related. A useful benchmark, then, is to derive the tax on income, say, $\hat{\tau}_y$, when $\tau_c = 0$. Given this benchmark rate, we can evaluate the role of the consumption-based tax when the actual income tax rate, τ_y, differs from its benchmark rate, $\hat{\tau}_y$. When consumption taxes are absent, that is, $\tau_c = 0$, the appropriate tax on income is given by

$$\hat{\tau}_y = \frac{A^{-\rho}(1-\alpha)(1-\sigma_y)(y/z)^\rho + \theta(1-\sigma_c)(c/y)}{A^{-\rho}[\alpha + (1-\alpha)(1-\sigma_y)z^{-\rho}]y^\rho} > 0. \tag{15a}$$

Therefore, the income tax rate required to attain the first-best optimum must correct for *both* sources of externalities, σ_y and σ_c, taking into account the impact of the public good on utility, θ. Even if the production externality is absent, that is, $\sigma_y = 1$, but the consumption externality is present, that is, $0 < \sigma_c < 1$, the optimal income tax must be positive, to correct the distortions in utility caused by private investment. Also, note that when public capital provides direct utility benefits ($\theta > 0$), the optimal income tax rate is higher than those derived in the previous literature, namely, Barro (1990), Futagami, Morita, and Shibata (1993), and Turnovsky (1997).

Now suppose that the actual income tax rate is different from its benchmark rate derived in (15a). The government has a choice to use the consumption tax to correct for this deviation, yet attain the first-best optimum without altering the income tax rate. To see this, subtract (15a) from (15):

$$\tau_c = \frac{A^{-\rho}[\alpha + (1-\alpha)(1-\sigma_y)z^{-\rho}]y^\rho}{\theta(1-\sigma_c)(c/y)} (\tau_y - \hat{\tau}_y). \tag{16}$$

Therefore, when $\tau_y > \hat{\tau}_y$, the government must introduce a positive consumption tax ($\tau_c > 0$) to attain the first-best equilibrium. On the other hand, if $\tau_y < \hat{\tau}_y$, a consumption subsidy ($\tau_c < 0$) is the appropriate corrective fiscal instrument. In

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14 Note that (15) holds only at the steady state and should therefore be viewed as a long-run relationship. In general, in models with multiple state variables (such as this), the transitional paths of the decentralized and the centrally planned economy will differ, requiring time-varying tax rates in the decentralized economy in order to replicate the social planner's transition path. Owing to space constraints, we refer the reader to expositions in Turnovsky (1997), Benhabib, Qinglai, and Nishimura (2000), and Mino (2001).

the case where $\tau_y = \hat{\tau}_y$, as in (16), the consumption tax must be zero ($\tau_c = 0$). The intuition behind this result can be explained as follows. When the income tax rate is above its benchmark rate given in (15a), the private return on capital falls below its socially optimal return. In this case, a positive tax on consumption helps offset this deviation by raising the private return to capital relative to consumption. Conversely, if the income tax rate is below its benchmark rate, then the private return on capital exceeds its social return and a consumption subsidy corrects this deviation by lowering the private return on capital relative to consumption. Of course, when there is no congestion in utility ($\sigma_c = 1$) or when the public good is purely a productive input ($\theta = 0$), this margin of adjustment is non-existent and the consumption tax has no bearing on the equilibrium allocation. In this case, the optimal tax on income is the only corrective fiscal instrument and is similar to that obtained in the public-capital growth literature:[15]

$$\hat{\tau}_y = \frac{(1 - \alpha)(1 - \sigma_y)}{[\alpha z^\rho + (1 - \alpha)(1 - \sigma_y)]}.$$

Our discussion of optimal fiscal policy can be evaluated by relating it to the corresponding literature on congestion, taxation, and growth. A useful benchmark in this literature is a paper by Turnovsky (1996). In that paper, a consumption tax is non-distortionary and works like a lump-sum tax, and it must be reduced to zero as the degree of congestion increases, while the income tax emerges as the sole policy instrument when there is proportional congestion. When there is no congestion in production, the optimal income tax rate is zero and government expenditure must be financed by the *non-distortionary* consumption tax. Our results can be viewed as both a refinement and a generalization of these results. First, we show that under certain very plausible conditions, the consumption tax is distortionary, both in transition as well as in steady state. Second, we show that a consumption-based fiscal instrument (in the form of a tax or subsidy) can be used jointly with an income tax to correct for different sources of congestion in an economy. Third, when there is no congestion in production ($\sigma_y = 1$), the income tax rate must still be positive, with or without a consumption tax or subsidy, to correct for distortions in utility. Finally, when there is no congestion in utility ($\sigma_c = 1$), the consumption tax is non-distortionary and our results are comparable to those in Turnovsky (1996) as well as most of the literature.

5. Fiscal policy and economic welfare: a numerical analysis

We begin our analysis of the framework laid out in sections 3 and 4 with a numerical characterization of both the centrally planned and decentralized equilibria. In particular, we are interested in (i) analyzing the role played by the relative

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15 For an example with the Cobb-Douglas specification, see Turnovsky (1997).

importance of the public good in utility (θ) in the propagation of fiscal policy shocks and (ii) the sensitivity of the welfare responses to various fiscal shocks to (a) the elasticity of substitution in production, (b) the congestion parameters, and (c) the relative importance of the public good in the utility function.

5.1. The first-best equilibrium

Our starting point is the steady-state equilibrium in the centrally planned economy. The following table describes the choices of the structural and policy parameters we use to calibrate this equilibrium:[16]

Preference parameters: $\gamma = -1.5$, $\beta = 0.04$, $\theta \in [0, 0.3]$
Production parameters: $A = 0.4$, $\alpha = 0.8$, $s \in [0.5, \infty]$, $\delta_K = \delta_g = 0.08$

The preference parameters β and γ are chosen to yield an intertemporal elasticity of substitution in consumption of 0.4, which is consistent with Guvenen (2006). Since there is no known estimate of θ, the relative weight of the public good in the utility function, we consider a range between 0 and 0.3, where $\theta = 0$ corresponds to the standard public capital-growth framework, where the public good is only a productive input and $\theta = 0.3$ corresponds to the estimate of the ratio of public consumption to private consumption used by Turnovsky (2004).[17] The output elasticity of private capital is set at 0.8, which is reasonable if we consider private capital to be an amalgam of physical and human capital, as in Romer (1986). This of course implies that the corresponding output elasticity for the public good is 0.2, which is consistent with the empirical evidence reviewed by Gramlich (1994). Given the paucity of empirical evidence on the elasticity of substitution between private capital and public goods in production (s), we choose a range between 0.5, indicating low substitutability between K and K_g, and infinity, indicating perfect factor substitutability.[18] The case where $s = 1$ ($\rho = 0$) represents the familiar Cobb-Douglas technology and will serve as a useful benchmark. Finally, the depreciation rates on the two capital stocks are set to equal 8% each, and this serves as a plausible benchmark.

Table 1 characterizes the first-best optimum for different values of θ. When $\theta = 0$, the equilibrium outcome corresponds to the case where the public good is only a

16 The calibration of the model is purely for *illustrative* purposes, rather than approximating a real economy. The introduction of adjustment cost functions for private and public investment would enable the calibration of a real economy, as in Turnovsky (2004). However, the central results of our analysis would remain qualitatively unaffected by these changes.

17 It should be noted here that Turnovsky (2004) treats the public good in the utility function as a pure consumption good, with no productive effects, as does most of the literature, where public consumption and investment goods are clearly distinguishable. Moreover, treatments of public consumption goods typically consider a flow of services, whereas in our case it is the accumulated stock that is relevant.

18 The only exception is Lynde and Richmond (1993), who estimate the elasticity of substitution between public and private capital in the context of a more general translog production function for the manufacturing sector in the U.K.

TABLE 1
Benchmark equilibrium in the centrally planned economy The Cobb-Douglas case ($s = 1$)

	$\hat{z}$	$\hat{c}$	$\hat{g}$	$\hat{C}/Y$	$\hat{K}/Y$	$\hat{\Psi}$ (%)
$\theta = 0$	0.25	0.143	**0.106**	0.468	3.299	4.90
$\theta = 0.1$	0.308	0.146	**0.127**	0.462	3.170	5.01
$\theta = 0.3$	0.419	0.151	**0.163**	0.449	2.976	5.05

TABLE 2
Optimal public investment in the centrally planned economy ($\hat{g} = G/Y$)

	$\theta = 0$	$\theta = 0.1$	$\theta = 0.3$
$s = 0.5$	**0.181**	0.192	0.204
$s = 1$	**0.106**	0.127	0.163
$s \to \infty$	**0.001**	0.040	0.099

productive input. Therefore, considering the outcomes when $\theta > 0$ provides useful insights into its role in resource allocation. For example, when $\theta = 0$, the optimal ratio of the public good to private capital ($\hat{z}$) is 0.25, while the corresponding value for the consumption-capital ratio ($\hat{c}$) is about 0.14. Optimal public expenditure ($\hat{g}$) is about 10.6% of aggregate output. The consumption-output and capital-output ratios are 0.47 and 3.3, respectively, while the steady state is characterized by a balanced growth rate of 4.9%. As θ increases, the utility return from public expenditure increases, thereby augmenting its total return, causing the central planner to allocate a larger fraction of output to the public good relative to private investment. This is reflected by an increase in the equilibrium levels of $\hat{z}$ and $\hat{g}$. A larger stock of the public good, being complementary to private consumption, facilitates the consumption of the private good, leading to an increase in $\hat{c}$. The consumption-output and capital-output ratios are lower for higher values of θ, indicating that the higher $\hat{g}$ expands output proportionately more than consumption and private capital. As θ increases, the larger fraction of output allocated to public spending increases the productivity of private capital, leading to higher equilibrium growth relative to the case when $\theta = 0$.

Table 2 illustrates the optimal rates of public expenditure for variations in both θ and the elasticity of substitution, s. As in table 1, we see that for any given s, an increase in θ will lead the planner to allocate a higher fraction of output to investment in the public good. On the other hand, for any given θ, an increase in the elasticity of substitution lowers the optimal allocation of $\hat{g}$. This happens because a larger s increases the return on private capital relative to the public good, leading the planner to allocate fewer resources to the public good and more to private capital on the margin. An interesting feature of table 2 is the relationship between the rate of optimal public expenditure, the relative weight of the public good in utility, and its output elasticity. For example, in

the flow model of Barro (1990), the optimal rate of public investment is given by, say, $g^* = 1 - \alpha = 0.2$ (since $\alpha = 0.8$ in our calibration), that is, by setting the rate of public investment equal to its output elasticity. Turnovsky (1997) shows that when public investment is treated as a stock rather than a flow, $g^* < 1 - \alpha$. In table 2, this corresponds to the case where $\theta = 0$, and let us denote this rate by $\hat{g}_{\theta=0}$. Our numerical results show that when the *dual* benefits of the public good are internalized by the planner ($\theta > 0$), the optimal rate of public expenditure, say, $\hat{g}_{\theta>0}$, is still lower than $(1 - \alpha)$, but is higher than $\hat{g}_{\theta=0}$, that is, $\hat{g}_{\theta=0} < \hat{g}_{\theta>0} < g^* = 1 - \alpha$. For example, when $s = 1$, and $\theta = 0$, $\hat{g}_{\theta=0} = 0.106$. But when $\theta = 0.3$, $\hat{g}_{\theta>0} = 0.163$. Therefore, internalizing the dual nature of the public good generates an optimal expenditure rate that is less than in Barro (1990) but larger than in Turnovsky (1997).

5.2. Equilibrium in a decentralized economy

Table 3A characterizes the benchmark equilibrium and long-run effects of fiscal policy shocks in a decentralized economy for the Cobb-Douglas production function ($s = 1$) and for different values of θ. As a benchmark specification, we consider the case of partial congestion, where $\sigma_y = \sigma_c = 0.5$.[19] The pre-shock value for g is set arbitrarily at 5% of GDP, and is financed entirely through a non-distortionary lump-sum tax (equivalent to government debt), so that $\tau_y = \tau_c = 0$. For example, with $\theta = 0$, the ratio of the public good to private capital is about 0.1, while the consumption-capital ratio is 0.12. The agent devotes about 46% of output to consumption, while the capital-output ratio is 3.94. Finally, these allocations lead to a long-run balanced growth rate of about 4.34%.

5.2.1. Long-run effects of fiscal policy shocks

The panels of table 3B report the long-run impact of five fiscal policy shocks on the equilibrium allocation in the decentralized economy for different values of θ. The first three (labelled I–III) pertain to an increase in g from 5% to 8% of GDP, financed by (I) an increase in lump-sum taxes, (II) an increase in the income tax rate, τ_y, and (III) an increase in the consumption tax rate, τ_c. In each case, the tax increase finances only the *increment* in government spending, the pre-shock rate of spending being financed by lump-sum taxes. The last two policy shocks relate to the replacement of the lump-sum tax as a means of financing the benchmark rate of government spending by introducing (IV) an income tax and (V) a consumption tax. In experiments IV and V, the lump-sum tax is reduced to zero as it is replaced by an income or consumption tax to finance the benchmark rate of government spending. In our discussion below, we will focus on two sets of comparisons, between policy changes I–III and IV and V.[20]

19 Even though we set the two congestion parameters to be equal, we will consider the sensitivity of the results to their variation in table 4B.

20 While our analysis here is focused on comparisons across steady states, we have also analyzed the transitional dynamics for the policy shocks described above. In the interest of space, we will make the results available only upon request.

TABLE 3
Equilibrium in a decentralized economy with congestion
Structural parameters: $A = 0.4$, $\beta = 0.04$, $\gamma = -1.5$, $\alpha = 0.8$, $s = 1$, $\delta_K = \delta_g = 0.08$, $\sigma_c = \sigma_y = 0.5$
Base (pre-shock) policy parameters: $g = 0.05$, $\tau_y = 0$, $\tau_c = 0$

A. Benchmark equilibrium

	$\tilde{z}$	$\tilde{c}$	$\tilde{C}/Y$	$\tilde{K}/Y$	$\tilde{\psi}(\%)$
$\theta = 0$	0.1029	0.1177	0.4639	3.9401	4.337
$\theta = 0.1$	0.1031	0.1180	0.4649	3.9390	4.317
$\theta = 0.3$	0.1034	0.1185	0.4664	3.9360	4.286

B. Long-run effects of fiscal policy shocks

	$\theta = 0$					$\theta = 0.1$					$\theta = 0.3$				
Policy $\rightarrow$	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
$d\tilde{z}$	0.066	0.070	0.066	0.004	0	0.066	0.069	0.065	0.004	−0.0002	0.066	0.069	0.064	0.004	−0.001
$d\tilde{c}$	0.007	0.011	0.007	0.006	0	0.007	0.011	0.007	0.006	−0.0003	0.007	0.010	0.005	0.005	−0.001
$d(\tilde{C}/Y)$	−0.018	−0.007	−0.018	0.019	0	−0.019	−0.008	−0.020	0.019	−0.001	−0.020	−0.009	−0.025	0.018	−0.003
$d(\tilde{K}/Y)$	−0.371	−0.389	−0.371	−0.031	0	−0.370	−0.387	−0.368	−0.031	0.002	−0.368	−0.384	−0.361	−0.029	0.005
$d\tilde{\psi}$	0.951	0.695	0.951	−0.387	0	0.962	0.714	0.999	−0.378	0.021	0.984	0.747	1.089	−0.360	0.060
$d\tilde{W}(\%)$	7.013	7.496	7.013	0.239	0	9.039	9.522	8.956	0.226	−0.023	11.875	12.363	11.624	0.224	−0.065

Description of policy shocks:
I. A lump-sum tax-financed increase in government spending, $g = 0.05$ to 0.08; $dg = 0.03$
II. An income tax-financed increase in government spending, $dg = d\tau_y$
III. A consumption tax-financed increase in government spending, $dg = d\tau_c$
IV. The income tax replaces lump-sum tax/government debt to finance the benchmark rate of government spending, $dg = (\tilde{c}/\tilde{y})d\tau_c + \tau_c d(\tilde{c}/\tilde{y})$
V. The consumption tax replaces lump-sum tax/government debt to finance the benchmark rate of government spending, $g = \tau_y$
The consumption tax replaces lump-sum tax/government debt to finance the benchmark rate of government spending, $g = (\tilde{c}/\tilde{y})\tau_c$

An increase in government spending. In general, an increase in government spending leads to a higher flow of investment in the public good, thereby increasing its long-run stock relative to private capital. The larger stock of the public good increases the long-run productivity of private capital, thereby encouraging an increase in private investment. As the flow of output increases because of the shift towards (public and private) investment, private consumption also increases. However, given the higher stocks of private capital and the public good, output increases more than in proportion to both consumption and private capital, leading to declines in their respective proportions in total output. The investment boom also increases the long-run equilibrium growth rate and welfare. The increase in welfare can be attributed to two factors: (a) an indirect effect, operating through the investment channel which, by increasing the flow of output, generates a higher flow of consumption, and (b) a direct effect, since the increase in the stock of the public good lowers relative congestion and leads to an increase in the proportion of utility services derived from its stock.[21]

As the relative importance, θ, of the public good in the utility function increases (i.e., its 'dual' role is recognized), the growth effect of an increase in government spending becomes smaller, while the welfare effect becomes larger. This is because, when $\theta > 0$, an increase in the stock of the public good raises the marginal valuation of consumption (through the public good's utility services), which has a dampening effect on growth and a magnifying effect on welfare. Comparing policies I–III in table 3B, we see that an increase in spending financed by increasing the income tax leads to the highest welfare gain among the three financing policies. This can be attributed to two reinforcing factors: (a) the greater substitution towards consumption due to the lower after-tax return on capital, and (b) the smaller increase in the stock of private capital, which in turn generates higher services from the public good in the utility function by reducing congestion. This result is robust to variations in θ. The consumption tax is identical to a lump-sum tax when $\theta = 0$, but for positive values of θ the consumption tax is indeed distortionary and, interestingly, is the most distortionary of the three financing policies. In fact, the consumption tax-financed increase in government spending leads to the smallest improvements in long-run welfare when compared with the cases of lump-sum and income tax-financing. This can be attributed to (a) the relative fall in private consumption due to a decrease in its after-tax return and (b) the increase in the after-tax return on private capital when $\theta > 0$ (see equation 12b), which worsens the distortions created by congestion from the use of the public good in the utility function.

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21 Changes in welfare levels are computed by an equivalent variation in output across steady-states; that is, we determine the percentage change required in the initial output level, $Y(0)$ (and therefore in the output flow over the entire base path), such that the agent is indifferent between the initial welfare level and the welfare following the policy change, as in Turnovsky (2004). The details of this derivation are available upon request.

Tax policies to finance the benchmark rate of government spending. In policy experiments IV and V in table 3B, the lump-sum tax is replaced by an income tax or a consumption tax to finance the benchmark rate of government spending (5% of GDP), respectively. In each case, the lump-sum tax is reduced to zero to maintain the government's balanced budget. In effect, these represent two types of tax policy changes for a given level of government spending. The introduction of an income tax reduces the after-tax return to private capital and leads to a decline in its stock. By reducing the stock of capital, the income tax reduces congestion in the production function. As a result of this policy shock, both $\tilde{z}$ and $\tilde{c}$ rise. The substitution away from capital (and towards consumption) leads to a decline in the long-run growth rate. However, this shift in favour of consumption is good from a welfare perspective, as welfare increases with an increase in θ. A policy implication is that the more the public good generates utility services (i.e., the higher is θ), the more effective is the income tax as an instrument for reducing congestion from a given level of government spending.

When $\theta = 0$, the consumption tax is completely non-distortionary and does not change the equilibrium resource allocation. However, as θ increases, the effects of replacing the lump-sum tax with a consumption tax contrast sharply with those from the introduction of an income tax. The higher consumption tax, by raising the after-tax return on private capital, draws more resources away from consumption, reducing the services derived from the public good in the utility function. The consequent increase in private investment reduces both $\tilde{z}$ and $\tilde{c}$ and increases the long-run growth rate. However, such a policy is socially undesirable, a consumption tax makes the economy worse off by drawing resources away from consumption into capital, which aggravates the distortions from congestion. Therefore, in sharp contrast to the existing literature, our experiments indicate that introducing a consumption tax to finance a given level of government spending is actually more distortionary than an equivalent increase in the income tax rate.

5.3. Welfare analysis

Our analysis in the previous section established the following key results related to the welfare effects of fiscal policy changes:

(i) The welfare increases resulting from higher government spending rise with θ, the relative importance of the underlying public good in utility,

(ii) The welfare increase from an increase in government spending is the highest when it is financed by raising the income tax and the lowest when financed by a consumption tax. This result is robust to changes in θ.

(iii) As a means of financing a given level of government spending, an increase in the income tax has sharply contrasting welfare effects compared with an equivalent increase in the consumption tax. While an income tax increase

improves welfare by mitigating congestion, a consumption tax increase worsens the distortions from congestion.

However, the above results were derived for the benchmark specification of a Cobb-Douglas production function and a given level of (equal) relative congestion in the utility and production. It is instructive at this point to examine whether these results are robust to variations in (i) the elasticity of substitution in production and (ii) differential relative congestion in utility and production. Tables 4A and 4B report the results of these sensitivity tests, respectively, for changes in long-run welfare.

Table 4A reports the sensitivity of welfare changes to the various fiscal shocks discussed above for different values of the elasticity of substitution in production, s. In general, for any given θ, an increase in s lowers the welfare impact of an increase in public spending. This happens because the larger s is, the higher is the return from private investment relative to a given level of public investment. Therefore, as s increases, higher public spending causes the agent to allocate more resources to private investment by substituting away from consumption, which has an adverse effect on welfare. Therefore, for higher values of elasticity of substitution, an increase in government spending can be welfare reducing. However, as θ increases, the negative effects of a larger s are more than offset (or partially alleviated) as the higher dual benefits of public expenditure affect both productivity and private consumption. Comparing the welfare changes from policies I–III and IV and V in table 4A, we see that our previous results remain robust to variations in the elasticity of substitution in production within an empirically plausible range. In other words, an income tax-financed increase in government spending yields the highest welfare gains, while the consumption tax-financed increase yields the lowest gains.

Table 4B reports the welfare sensitivity to fiscal shocks for variations in the relative congestion parameters, σ_y and σ_c. As before, our central results remain robust to variations in these parameters: the income tax continues to yield the highest welfare gains, while the consumption tax yields the lowest. When we consider tax policy changes, the consumption tax worsens the distortions from congestion, while the income tax alleviates these distortions. Note that when $\sigma_c = 1$, the public good does not congest the utility function and the consumption tax essentially behaves like a lump-sum tax. Therefore, only in the case where there is no congestion in utility or production, that is, $\sigma_c = \sigma_y = 1$, the income tax is more distortionary than the lump-sum and consumption taxes.

6. Conclusions

This paper analyzes the impact of fiscal policy in a growing economy, where the accumulated stock of a composite public good generates dual services for

TABLE 4
Welfare sensitivity of fiscal policy shocks to structural parameters and congestion

A. Welfare sensitivity to the elasticity of substitution (s) and the relative importance of public capital in utility (θ)
($\sigma_y = \sigma_c = 0.5$)

	$\theta = 0$					$\theta = 0.1$					$\theta = 0.3$				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
$s = 0.5$	122.08	125.95	122.08	3.10	0	124.67	128.51	123.88	2.91	−0.22	126.53	130.24	124.35	2.59	−0.56
$s = 0.75$	24.11	25.07	24.11	0.68	0	25.34	26.29	25.17	0.65	−0.05	26.68	27.63	26.20	0.61	−0.13
$s = 1$	7.01	7.50	7.01	0.24	0	9.04	9.52	8.96	0.23	−0.02	11.88	12.36	11.62	0.22	−0.07
$s = 1.25$	1.20	1.52	1.20	0.11	0	3.52	3.84	3.46	0.10	−0.02	6.89	7.21	6.71	0.10	−0.05
$s = 1.75$	−2.92	−2.71	−2.92	0.05	0	−0.38	−0.18	−0.42	0.03	−0.01	3.35	3.54	3.23	0.03	−0.04
$s \to \infty$	−6.97	−6.84	−6.97	0.06	0	−4.22	−4.13	−4.25	0.03	−0.01	−0.15	−0.09	−0.22	0.02	−0.03

B. Welfare sensitivity to congestion parameters (σ_y and σ_c)
($s = 1$, $\theta = 0.3$)

	$\sigma_y = 0$					$\sigma_y = 0.5$					$\sigma_y = 1$				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
$\sigma_c = 0$	11.51	12.59	10.66	1.17	−0.35	11.75	12.42	11.09	0.58	−0.23	11.99	12.31	11.56	0.06	−0.08
$\sigma_c = 0.5$	11.60	12.52	11.21	0.86	−0.15	11.87	12.36	11.61	0.22	−0.07	12.16	12.27	12.06	0.05	−0.04
$\sigma_c = 1$	11.73	12.44	11.73	0.45	0	12.06	12.29	12.06	−0.26	0	12.44	12.23	12.44	−0.93	0

Description of policy shocks:
I.   A lump-sum tax-financed increase in government spending, $g = 0.05$ to 0.08; $dg = 0.03$
II. An income tax-financed increase in government spending, $dg = d\tau_y$
III. A consumption tax-financed increase in government spending, $dg = (\tilde{c}/\tilde{y})d\tau_c + \tau_c d(\tilde{c}/\tilde{y})$
IV. The income tax replaces lump-sum tax/government debt to finance the benchmark rate of government spending, $g = \tau_y$
V.   The consumption tax replaces lump-sum tax/government debt to finance the benchmark rate of government spending, $g = (\tilde{c}/\tilde{y})\tau_c$

the private sector by simultaneously enhancing both productivity *and* welfare. We motivate this idea by discussing examples of common public goods, such as infrastructure, education, law and order, that can generate both productivity and utility benefits for the private sector. This represents a departure from the conventional modelling strategy in the public goods-growth literature, wherein the role of such goods are generally compartmentalized to being either productivity *or* utility enhancing. Modelling for the differential effects of congestion in the utility and productive services derived from such public goods, we show that a consumption tax can be distortionary, with a transmission mechanism that is qualitatively opposite to that of an income tax. This structure enables us to generalize existing results in the literature on optimal fiscal policy by demonstrating the possibilities of using both income- and consumption-based tax or subsidy policies as corrective instruments for congestion. The optimal fiscal policy rules we derive indicate greater flexibility in the choice of corrective policy instruments relative to the sole reliance on the income tax that is prevalent in the literature.

We also conduct several policy experiments to numerically examine the efficacy of different taxes as financing tools for government spending on public goods. Our results indicate that financing an increase in government spending through an increase in the income tax rate dominates lump-sum and consumption tax-financing policies when the services from the public good are congested. In the presence of congestion, replacing the lump-sum tax with an income tax to finance a given level of government spending improves welfare by reducing congestion. In contrast, the introduction of an equivalent consumption tax actually worsens welfare by increasing the distortions from congestion. These results also contrast sharply with the existing literature, where the consumption tax is often viewed as the least distortionary source of financing government spending. Our results therefore contribute to the fiscal policy-growth literature by highlighting a new channel through which consumption taxes (or subsidies) might impact an economy's equilibrium and welfare, even in the absence of an endogenous labour-leisure choice.

Given the recent policy shift in many developing countries towards market provision of many public goods such as power generation, water and sewerage, irrigation, highway construction, communications, one fruitful extension of this framework might be to analyze the role of consumption and income taxes when a public good is privately provided. In that case, the consumption-based financing policies might be an important determinant of the market price of the public good by affecting the marginal rate of substitution between private consumption and the privately provided public good. Another area of interest might be to examine the implications of consumption taxation in models with an endogenous labour-leisure choice, but in the presence of utility and productivity enhancing public goods. Therefore, we hope that our results will provide the foundations for future research in the complex domain of public goods and economic growth.

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