Public Investment, Taxation, and Growth in Economies with Multi-leveled Governments

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Abstract

This paper examines the dynamic effects of taxation and investment on the growth path of an economy. A simple neoclassical growth model with different tiers of government is developed. The initial focus is on governments that aim to maximise their citizens' welfare and economic performance by providing consumption goods for private consumption and public capital for private production. It is shown that a long-run per capita output maximising tax rate can be derived and that there also exists an optimal degree of fiscal decentralisation. The analysis then extends to the case where governments attempt instead to maximise their own tax revenue to fund expenditures which do not contribute to the utility of their citizens. Three different cases of taxation arrangement are considered: tax competition, tax sharing, and tax coordination. The modeling shows that intensifying tax competition will lead to an increase in the aggregate tax rate as compared to the cases of sharing and coordination amongst governments. These tax rates are both higher than the long-run per capita output maximising rate that was implied under the welfare maximising government scenario.

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1. Introduction

Over the past few decades, the world has witnessed a shift in the institutional structuring of government, including fiscal-federal arrangements, towards greater decentralisation. Authors such as Oates (1999, 2005), Campbell (2003), Eller (2004), Letelier (2005), and Bodman and Hodge (2010) provide a largely empirical analysis of the various factors underlying the differing degrees of decentralisation across countries. However, given that promoting economic growth is one among the very top priorities in any government's economic policy agenda, these changing patterns of fiscal (and other) responsibilities across tiers of government does raise an important question about the effect of such fiscal decentralisation on economic performance.[1]

While empirical studies looking at this issue are numerous,[2] theoretical works are surprisingly few. For example, a recent paper by Sato and Yamashige (2005) provides a model with a complex principal-agent nature within the structure of government to explain the evolution of fiscal decentralisation and economic development. Using a game theoretic approach, Edwards (2005) introduces tax competition and a time consistency issue into an overlapping generation (OLG) growth model with human capital to look at the impact of tax competition on growth. Madies and Ventelou (2005) also model human capital in an OLG setting and investigate the effects of tax on the growth path of an economy where the governments provide education services to enhance human capital. Rauscher (2005) and Koethenbuerger and Lockwood (2010) address the issue of fiscal decentralisation and growth in a model with mobile factors and stochastic shocks to productivity.

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[1] While the study in this paper is mainly concerned with the impact of fiscal decentralisation on economic performance using a growth framework, this paper acknowledges a large literature on fiscal decentralisation using a political economy approach. For example, Persson *et al.* (2000) build a model of public spending under different political institutions: parliamentary regime versus presidential-congressional regime. Besley and Coate (2003) investigate the trade-off between centralised and decentralised provision of local public goods and reach a conclusion that the relative performance of these two systems of government depends on the spillovers and differences in tastes for public spending.

[2] For example, see Bodman (2011), Bodman and Hodge (2010), Thornton (2007), Thiessen (2003), Martinez-Vazquez and McNab (2003), and Xie *et al.* (1999).

While the focus of the paper is on the impacts of decentralisation of fiscal policy across tiers of government within a country, the analysis could equally apply to an institutional framework such as the division of fiscal responsibilities between the European Union and its member States, sometimes referred to as the issue of 'subsidiarity'. Akai *et al.* (2007) provide related research that considers how the structures of intra-regional complementarity and inter-regional complementarity affect the relationship between fiscal decentralisation and economic growth. The results of the studies in this literature are generally inconclusive suggesting either that the growth rate is lower or is higher with decentralisation.

The main purpose of the present paper is to make a theoretical contribution to this literature by formalising a framework in which different structures of government lead to different long-run output levels.[3] In particular, the analysis considers two federal arrangements in a standard neoclassical growth model where physical capital is the key factor to economic growth (while private capital is supplied by private agents in the economy, public capital is provided by either the Federal government or the State government). The main difference between these two federal arrangements lies in their different policy objectives. Whilst in the first scenario, the governments aim at maximising their citizens' welfare and economic performance, in the second scenario, the governments find ways to maximise tax revenues for their own expending purposes.

The assumption of welfare maximising behaviour by governments is closely related to the work of Zou (1996), Davoodi and Zou (1998), and Xie *et al.* (1999) which also assumes two tiers of government which supply public capital for private production activity.[4] However, this paper goes beyond the previous analyses by incorporating a more realistic

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[3] This modeling framework is in line with the discussion in the classic work by Oates (1972) on the optimal form of government: a federal system. This federal system makes full use of the advantages and limits the shortcomings of the two polar forms. While the centralised system helps resolve the stabilisation and distribution problems, it leads to welfare losses and technical waste due to uniformity in provision of public spending for private consumption. By contrast, a decentralised form of government offers increasing economic efficiency as the provision of goods closely matches with local tastes.

[4] Specifically, our simple model consists of one Federal government and only one State government. Hence there is no tax competition amongst different State governments. Consideration of multiple State governments, as well as any potential inefficiencies in public expenditure that may arise due to this tax competition, leading in turn to detrimental effects on economic growth, is beyond the scope of this paper and will be investigated in our next research project.

assumption that these governments also provide private consumption goods which enhance citizens' welfare (through entering the representative's utility function). In doing so, this creates a dynamic general equilibrium framework in which the implications of the tax rate and degree of decentralisation for steady state output levels can be investigated. Similar to Barro (1990), a long-run output maximising tax rate is derived. In addition, it is demonstrated that there exists an analogous optimal degree of fiscal decentralisation that maximises the economy's steady state level of per capita output, and hence its growth rate.[5]

The alternative assumption of tax revenue maximising governments is built on the contribution by Treisman (2006) on public investment. The new contribution of the present paper is to develop a similar setting, but in a dynamic, growth context, to examine how steady state output level responds to various taxes and investment strategies.[6] This paper distinguishes between three distinct cases: (i) when the governments set their tax rates non-cooperatively (tax competition); (ii) when they share the tax revenue collected; and (iii) when they strategically coordinate their taxing and investing behaviors (tax coordination). The main result of this theoretical analysis is the implication that intensifying tax competition will lead to an increase in aggregate tax rate as compared to the case of coordination of governments. These tax rates are both higher than the steady state output maximising rate that would be obtained under the first arrangement of welfare maximising governments.

According to Treisman (2006), tax sharing systems are very popular around the world. In many countries, subnational governments get some fraction of total tax revenue. In other countries, tax sharing takes the form of fiscal transfers from central governments to local governments' budgets. In this current paper, to a certain extent, the first arrangement of welfare maximizing governments can be considered to mimic the developed world while the second arrangement of revenue maximising governments offers a representation of most

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[5] Analysing an economy at its steady state level of per capita output implies that policies leading to the maximisation of its long-run output level are consistent with those that maximise its rate of economic growth.

[6] The issue of tax competition in federations has been examined by many studies, however, in a static setting (e.g. Keen, 1998; Keen and Kotsogiannis, 2002). By contrast, this paper considers the same issue in a dynamic growth framework. Although the central focus of the paper is on the steady state analysis, it is possible to investigate the transitional dynamics if needed. The static setting simply provides a snapshot of the economy.

developing countries. Having said that, it is clearly not the paper's ambition to develop a model that can fully reproduce the world, in all its complexity. Rather, the paper asks the question whether the model is able to help us examine strategic behaviours of governments in different possible situations of tax sharing. It is hoped that with theoretical basis presented, some general expectations and policy recommendations on the fiscal interactions between a central government and a local government can be reached.

The rest of the paper is structured as follows. In Section 2, the basic model of a welfare maximising government is set up. In this model, the production function for the private sector is a general function of private capital and two kinds of public capital (provided by the Federal and State governments). A representative individual's utility is derived from private consumption as well as Federal and State public consumption. Tax is collected by the Federal government and part of its revenue is allocated to the State government. Within this dynamic framework, all parties interact and optimally decide how much to invest and how much to spend on consumption. In Section 3, the equilibrium of this dynamic system is derived. An analysis of the impact of the tax rate and the degree of fiscal decentralisation on the long-run output level is then provided and the optimal levels of these fiscal parameters are derived. Section 4 extends the model to consider non-benevolent governments, differentiating between the three different situations of tax competition, tax base sharing, and tax coordination and comparing the growth and tax results of these alternative situations. The results generated under this scenario are compared with those obtained in the benevolent government case. Section 5 concludes the paper with a summary of the main findings and offers some final remarks.

2. Production and Utility

The aggregate production function of the economy is assumed to be Cobb-Douglas in form with constant returns to scale.[7] There are four inputs: private capital stock K, State public capital stock S, Federal public capital stock F, and labor N:

$$Y = K^\alpha S^\beta F^\gamma N^\sigma$$

where α, β, γ, and σ are positive constants, $\alpha + \beta + \gamma + \sigma = 1$ to give constant returns to scale, and $\alpha + \beta + \gamma < \sigma$ to reflect the empirical observation that labor's share in national product exceeds that of capital. The production function can be expressed in its intensive (per capita) form:

$$y = k^\alpha s^\beta f^\gamma \tag{1}$$

where $y = \dfrac{Y}{N}$, $k = \dfrac{K}{N}$, $s = \dfrac{S}{N}$, and $f = \dfrac{F}{N}$ denote the output, private capital, and public (State or Federal) capital per worker respectively. The three types of capital are assumed to depreciate at different rates ζ, η, and δ and their marginal productivities are given by $\dfrac{\alpha y}{k}$, $\dfrac{\beta y}{s}$, and $\dfrac{\gamma y}{f}$ respectively. The model could be extended to include capital provided by other levels of government, say local (city, town, etc.) government, without changing the qualitative conclusions of the analysis.

In each time period, the State and Federal governments share the same tax base, y, on which an income tax is levied at rate τ. The share of the State government in total tax revenue is $\theta \in (0,1)$ and that of Federal government is $1 - \theta$, where θ represents the degree of fiscal expenditure decentralisation.

In practice, there may exist separate tax bases across, or within, different tiers of government. However, it is not always feasible to separate out completely these different tax

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[7] This choice of Cobb-Douglas form is consistent with a key assumption of the paper: State and Federal capital goods are not perfect substitutes. As a result, there is a trade- off between these two kinds of public goods and it is possible to derive the optimal level of decentralisation later in the paper.

bases. To simplify matters, this paper assumes a common tax base only.[8] An alternative assumption would be that different tax rates are set by different governments so that the extent of decentralisation would implicitly be determined. However, to focus the emphasis on the interrelation between the two tiers of government in making decisions over tax collection and tax revenue allocation, a common tax rate is assumed and each government receives a share of this joint tax. Given that there is only one government at each level (either Federal or State), this assumption over tax revenue collection and allocation precludes any inefficiencies that arise from tax competition as discussed by Keen and Marchand (1997).

Tax revenues are assumed to be transformed into the public supply of consumption or investment goods. Within each level of government, officials choose the level of investment in the per capita public capital stock (e.g. infrastructure investment) which is complementary to the private capital stock in the production of output.[9] They also choose the level of expenditure per capita on State and Federally supplied private consumption goods, represented by e and g (e.g. health care, educational services), which contribute to consumer welfare.

If the Federal government's budget is assumed always to be balanced then:

$$(1-\theta)\tau y = \dot{f} + g + \delta f$$

or

$$\dot{f} = (1-\theta)\tau y - g - \delta f \tag{2}$$

The total revenue of the State government is its share in tax revenue collected while its expenditures are those associated with the supply of consumer and investment goods and maintenance of the capital stock. Hence, the State government's budget constraint is:

$$\theta\tau y = \dot{s} + e + \eta s$$

or

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[8] Investigating the situation of different tax bases for different levels of government is, therefore, left for future research.
[9] An example of the complementarity between public investments and private investment is that better local and interregional roads increase the level of private output, *ceteris paribus*.

$$\dot{s} = \theta \tau y - e - \eta s \tag{3}$$

The budget constraint for the representative agent is characterised by the condition that the after tax income is divided between total spending on private consumption, c, and private investment:

$$(1-\tau) y = \dot{k} + c + \zeta k$$

or

$$\dot{k} = (1-\tau) y - c - \zeta k \tag{4}$$

The representative consumer's utility function is:

$$U = \int_0^\infty [u(c) + v(e) + \omega(g)].e^{-\rho t} dt = \int_0^\infty \left(\frac{c^{1-\mu_c}-1}{1-\mu_c} + \frac{e^{1-\mu_e}-1}{1-\mu_e} + \frac{g^{1-\mu_g}-1}{1-\mu_g} \right).e^{-\rho t} dt \tag{5}$$

where c, e and g are as defined above, and $0 < \rho < 1$ is the rate of time preference. The time subscripts are suppressed for simplicity.[10]

The optimisation problem for the representative consumer is to maximise his utility function given in (5) subject to the budget constraint described in (4), taking the time paths of both kinds of publicly provided consumption goods and public capital stocks as given. The current-value Hamiltonian function for this problem is:

$$H(c, k, \lambda_k) = u(c) + v(e) + \omega(g) + \lambda_k \left[(1-\tau) y - c - \zeta k \right]$$

where λ_k is a co-state variable. The necessary conditions are given by (4) and

$$\frac{\dot{c}}{c} = \frac{1}{\mu_c} \left[(1-\tau)\alpha \frac{y}{k} - \rho - \zeta \right] \tag{6}$$

together with the transversality condition $\lim_{t \to \infty} \lambda_k k e^{-\rho t} = 0$.

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[10] As a matter of convenience, the utility function is assumed to be separable in all of its arguments. This assumption makes the derivation for the optimal steady state output level greatly at ease.

Assuming benevolent State and Federal governments, their optimisation problem is to choose the levels of investment in publicly supplied capital per capita, s and f, and the levels of publicly provided private goods per capita, e and g, to maximise consumer welfare in (5) subject to the budget constraint in (2) for the Federal government, and (3) for the State government while taking the time paths of the other variables as given. This gives the following current-value Hamiltonian function for the State optimisation problem:

$$H(c,k,\lambda_s) = u(c) + v(e) + \omega(g) + \lambda_s[\theta\tau y - e - \eta s]$$

where λ_s is a co-state variable. The necessary conditions are given by (3) and

$$\frac{\dot{e}}{e} = \frac{1}{\mu_e}\left[\theta\tau\beta\frac{y}{s} - \rho - \eta\right] \tag{7}$$

plus the transversality condition $\lim_{t\to\infty}\lambda_s s e^{-\rho t} = 0$. The current value Hamiltonian function for the Federal government's optimisation problem is:

$$H(c,k,\lambda_f) = u(c) + v(e) + \omega(g) + \lambda_f\left[(1-\theta)\tau y - g - \delta f\right]$$

where λ_f is a co-state variable. Hence, the necessary conditions are (2) and

$$\frac{\dot{g}}{g} = \frac{1}{\mu_g}\left[(1-\theta)\tau\gamma\frac{y}{f} - \rho - \delta\right] \tag{8}$$

as well as the transversality condition $\lim_{t\to\infty}\lambda_f f e^{-\rho t} = 0$.

Equations (2) - (4) and (6) – (8) form a dynamic system in the six endogenous variables of the model: per capita consumption of private goods produced by the private, State and Federal sectors, c, e and g, and investment in private, State and Federal per capita capital stocks, k, s and f. The paper will now focus on the steady state equilibrium of this dynamic system at arbitrary levels of the tax and revenue share variables τ and θ.

Proposition 1. *The steady state equilibrium of the economy is uniquely determined by the system of equations (9)-(14).*

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In the steady state, $\dot{c} = \dot{e} = \dot{g} = \dot{k} = \dot{s} = \dot{f} = 0$. The system of dynamic equations (2) – (4), (6) - (8) reduces to:

$$(1-\theta)\tau y - g - \delta f = 0 \tag{9}$$

$$\theta \tau y - e - \eta s = 0 \tag{10}$$

$$(1-\tau) y - c - \zeta k = 0 \tag{11}$$

$$(1-\tau)\alpha \frac{y}{k} - \rho - \zeta = 0 \tag{12}$$

$$\theta \tau \beta \frac{y}{s} - \rho - \eta = 0 \tag{13}$$

$$(1-\theta)\tau\gamma \frac{y}{f} - \rho - \delta = 0 \tag{14}$$

These equations have the standard interpretation. Equations (9) – (11) say that in steady state, total income is exhausted by consumption expenditures and depreciation, leaving zero contribution to the stock of each kind of capital. Equations (12) – (14) indicate that in the steady state the after tax marginal product of each kind of capital is equal to the sum of the discount rate and its depreciation rate. Solving this system gives

$k^* = \left[\dfrac{\theta^\beta (1-\theta)^\gamma \tau^{\beta+\gamma} (1-\tau)^{1-\beta-\gamma} \alpha^{1-\beta-\gamma} \beta^\beta \gamma^\gamma}{(\rho+\eta)^\beta (\rho+\delta)^\gamma (\rho+\zeta)^{1-\beta-\gamma}} \right]^{\frac{1}{\sigma}}$. Other variables can be expressed as functions

of k^*, such as $s^* = \dfrac{\theta \tau \beta (\rho+\zeta)}{(1-\tau)\alpha(\rho+\eta)} .k^*$, $f^* = \dfrac{(1-\theta)\tau\gamma(\rho+\zeta)}{(1-\tau)\alpha(\rho+\delta)} .k^*$, and $y^* = \dfrac{\rho+\zeta}{(1-\tau)\alpha} .k^*$. As

soon as the closed form solution y^* is obtained, the remaining variables can also be derived:

$c^* = (1-\tau) y^* - \zeta k^*$, $e^* = \theta \tau y^* - \eta s^*$, and $g^* = (1-\theta)\tau y^* - \delta f^*$. The steady state output level is:

$$y^* = \left[\dfrac{\theta^\beta (1-\theta)^\gamma \tau^{\beta+\gamma} (1-\tau)^\alpha \alpha^\alpha \beta^\beta \gamma^\gamma}{(\rho+\zeta)^\alpha (\rho+\eta)^\beta (\rho+\delta)^\gamma} \right]^{\frac{1}{\sigma}} \tag{15}$$

3. Optimal Tax Rate and Degree of Fiscal Decentralisation

Since the focus of the paper is on economic growth, the question of whether there is a tax rate and degree of fiscal expenditure decentralisation that maximises the steady state level of per capita output is now considered, noting that any polices that lead to a maximisation of long-run per capita output will raise growth.

Proposition 2. *There exists an optimal income tax rate and an optimal tax revenue share that maximises the long-run per capita output level.*

Proof. The maximisation problem is:

$$\text{Max}_{\tau,\theta} \; y^* = \left[\frac{\theta^\beta (1-\theta)^\gamma \tau^{\beta+\gamma} (1-\tau)^\alpha \alpha^\alpha \beta^\beta \gamma^\gamma}{(\rho+\zeta)^\alpha (\rho+\eta)^\beta (\rho+\delta)^\gamma} \right]^{\frac{1}{\sigma}}$$

Let $y^* = y(\tau,\theta)$, and $h(\tau,\theta) = \ln y(\tau,\theta)$. It can be seen that $h_x = \dfrac{y_x}{y}$ or $y_x = h_x.y$ where y_x and h_x denotes the partial derivatives of y^* with respect to x (here $x = \tau, \theta$).

The first order necessary conditions for a maximum are:

$$y_\tau = h_\tau y = 0 \Leftrightarrow h_\tau = 0$$

$$y_\theta = h_\theta y = 0 \Leftrightarrow h_\theta = 0$$

Now consider the $h(\tau,\theta) = \ln y(\tau,\theta)$ function:

$$h(\tau,\theta) = \frac{1}{\sigma} \left[\beta \ln \theta + \gamma \ln (1-\theta) + (\beta+\gamma) \ln \tau + \alpha \ln (1-\tau) + \ln \left(\frac{\alpha^\alpha \beta^\beta \gamma^\gamma}{\rho^{1-\sigma}} \right) \right]$$

$$h_\tau = \frac{1}{\sigma} \left[\frac{\beta+\gamma}{\tau} - \frac{\alpha}{1-\tau} \right] = 0 \Leftrightarrow \tau^* = \frac{\beta+\gamma}{\alpha+\beta+\gamma}$$

$$h_\theta = \frac{1}{\sigma} \left[\frac{\beta}{\theta} - \frac{\gamma}{1-\theta} \right] = 0 \Leftrightarrow \theta^* = \frac{\beta}{\beta+\gamma}$$

It is shown in the Appendix that a sufficient condition for the second order conditions for a maximum to be satisfied is $\alpha + \beta + \gamma < \sigma$, which corresponds to the empirical observation that labor's share in national product exceeds that of capital.

The first-order conditions for a maximum indicate that the optimal tax rate is given by the ratio of the sum of the output elasticities attributable to State and Federal capital to the total sum of the output elasticities attributable to all kinds of capital, State, Federal, and private. In other words, the public sector share in total capital formation should reflect the relative produtivities of public and private sector capital. Here, an increase in the tax rate has two different effects. On the one hand, it causes a negative effect on private investment. On the other hand, it enhances public investment. At the point where these effects exactly offset each other (the tax rate is equal to the public sector share in total capital formation), per capita output is maximized.

The optimal degree of decentralisation is given by the ratio of the output elasticity attributable to State capital to the sum of the output elasticities attributable to both State and Federal capital. In other words, the degree of fiscal decentralisation should reflect the relative productivities of State and Federal capital.[11] The intuition is that increasing the marginal revenue share of the State government will increase their incentive to invest in business-supporting infrastructure. However, this also causes a disincentive to make public investment for the Federal government. When the revenue share is equal to the relative productivity of State capital, the two opposing effects exactly cancel each other out leading to the optimal share of revenue.

Combining the optimal tax rate and optimal degree of decentralisation it can be seen that, similar to Barro (1990) and generally in line with Davoodi and Zou (1998) and Xie *et al*. (1999), each level of government's share of per capita gross national product is equal to the share it would get if the services of public capital were competitively provided inputs to production.

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[11] The analysis here does not differentiate between State and Federal capital. Either level of government could provide capital goods but at potentially different levels of efficiency. For example, if the Federal government decides to supply goods that are normally supplied by the State governments, e.g. garbage collection, it might do so relatively less efficiently, resulting in a lower value of the output elasticity of its capital input.

4. A model with revenue maximising governments

It may be argued that not all governments care about their citizens' welfare, an argument which mostly, but not exclusively, is applied to developing countries. In this section of the paper, a new model is set up where governments' objective changes from pure welfare to revenue maximisation.[12] Both State and Federal governments no longer care about consumer welfare (no public provision of goods and services), but care only about the present value of their tax receipts which are assumed to be dissipated through various forms of patronage, embezzlement, oppression, or warfare, generating no utility (or, perhaps controversially, disutility) for the representative consumer. In a centralised system the two levels of government set their tax rates so as to maximise their joint tax revenue flow, whereas in a decentralised system each government sets its tax rate so as to maximise its own tax revenue flow.

Because in this model there are no goods or services provided by the governments for their residents to consume the representative agent's utility function collapses to:

$$U = \int_0^\infty u(c).e^{-\rho t}dt = \int_0^\infty \frac{c^{1-\mu_c}-1}{1-\mu_c}.e^{-\rho t}dt , \ 0 < \rho < 1 \tag{16}$$

In other words, the representative agent derives no utility from governments' goods. The agent's utility only comes from consuming his own private consumption goods.

Although the governments do not provide goods which enhance consumer utility, they still provide capital goods such as roads or electricity networks which contribute to the private production process. The production function of the representative agent is assumed to be the same as that specified in equation (1):

$$y = k^\alpha s^\beta f^\gamma,$$

with the same set of restrictions on the values of the coefficients.

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[12] As noted by Besley and Smart (2007), in a democracy, revenue maximising politicians can be voted out at the ballot box. The political circumstances of consumers in the non-democratic countries are more complicated (Collier, 2009).

In each time period, the Federal government taxes output at rate τ_f while the State government taxes output at rate τ_s.[13] The representative agent's budget constraint can now be written as:

$$\dot{k} = \left(1 - \tau_f - \tau_s\right) y - c - \zeta k \qquad (17)$$

Therefore, the necessary conditions for maximising the representative's utility function given in (16) include (17), the transversality condition $\lim_{t \to \infty} \lambda_k k e^{-\rho t} = 0$, and the following:

$$\frac{\dot{c}}{c} = \frac{1}{\mu_c}\left[(1 - \tau_f - \tau_s)\alpha \frac{y}{k} - \rho - \zeta\right] \qquad (18)$$

The two tiers of governments now maximise their net revenue receipts which are equal to the difference between total tax revenues collected and the amounts devoted to new public investments. Assume that the dictator governments invest an amount Ω_i such that $0 \le \Omega_i \le \tau_i y$, $i = f, s$ in infrastructure each period.

The Federal government's lifetime value of net receipts, R_f, is:

$$R_f = \int_0^\infty r_f . e^{-\rho t} dt = \int_0^\infty \left(\tau_f y - \Omega_f\right) . e^{-\rho t} dt \qquad (19)$$

where $r_f = \tau_f y - \Omega_f$ is the flow of net receipt at any point in time. The Federal government's net receipt in each period equals gross revenue from tax on output, $\tau_f y$, less the amount invested in infrastructure. This net receipt is then assumed to be spent on the dictator government's own consumption, Θ_f, so that its budget is always balanced:

$$r_f = \Theta_f$$

The equation of motion for the Federal government's public capital stock is represented by:

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[13] As the governments share the same tax base but set different tax rates, policies of one government will have impact on the fiscal standing of the other. Such externalities occur via the effects of infrastructure investment, regulations, etc.

$$\dot{f} = \Omega_f - \delta f$$

Similarly, the State government's lifetime value of net receipts, R_s, is:

$$R_s = \int_0^\infty r_s . e^{-\rho t} dt = \int_0^\infty (\tau_s y - \Omega_s) . e^{-\rho t} dt \tag{20}$$

where $r_s = \tau_s y - \Omega_s$ is the net cash flow at any point in time. Here, $\tau_s y$ is total income tax revenue allocated to the State government and Ω_s is State government's new investment in infrastructure per unit of time. This net receipt is then also assumed to be spent on the dictator government's own consumption, Θ_s, so that its budget is always balanced.

The equation of motion for the State government's public capital stock is represented by:

$$\dot{s} = \Omega_s - \eta s$$

There are three different situations that are worth examining, one corresponding to a decentralised tax system and the other two to a centralised system. The first situation is the case in which the governments make non-cooperative decisions on investment and tax rate (the *non-cooperative scheme*) to maximise their net cash flows which are available for expenditure on the dictators' goods Θ_i, $i = s, f$. The second scenario is where the governments share their tax revenue collected but make non-cooperative decisions on investment (the *tax sharing scheme*). We call the last scenario the *joint optimum scheme* where the governments coordinate in choosing their investment strategies as well as tax rates.

In the non-cooperative scheme case, the Federal government chooses Ω_f to maximise its net receipts in (19) while the State government chooses Ω_s to maximise its net receipts given in (20). After setting up current-value Hamiltonian functions and solving optimality conditions for these maximisation problems, the following are obtained:

$$\tau_f \gamma \frac{y}{f} - (\delta + \rho) = 0 \tag{21}$$

$$\tau_s \beta \frac{y}{s} - (\eta + \rho) = 0 \tag{22}$$

Under the tax sharing scheme, similar to the previous scenario of benevolent governments, assume that the State government receives a fixed share of $\theta \in (0,1)$ and the Federal government receives a fixed share of $1-\theta$ in total tax revenue. The Federal government chooses Ω_f to maximise its lifetime value of net receipts where the instantaneous amount is given by $(1-\theta)(\tau_f y + \tau_s y) - \Omega_f$ while the State government chooses Ω_s to maximise its net receipts of $\theta(\tau_f y + \tau_s y) - \Omega_s$. The derived optimality conditions for these maximisation problems are:

$$(1-\theta)(\tau_f + \tau_s)\gamma\frac{y}{f} - (\delta + \rho) = 0 \tag{23}$$

$$\theta(\tau_f + \tau_s)\beta\frac{y}{s} - (\eta + \rho) = 0 \tag{24}$$

As for the *joint optimum scheme*, the State and Federal governments strategically choose their investment levels and then the tax rates to maximise their joint net cash flow, $(\tau_f y + \tau_s y) - \Omega_f - \Omega_s$. Therefore, the derived optimality conditions are:

$$(\tau_f + \tau_s)\gamma\frac{y}{f} - (\delta + \rho) = 0 \tag{25}$$

$$(\tau_f + \tau_s)\beta\frac{y}{s} - (\eta + \rho) = 0 \tag{26}$$

It is also necessary to mention the constraint on the tax rates. To make sure that there is enough incentive for private production, the total income tax rate must be less than 100 per cent or $\tau_s + \tau_f < 1$.

In steady state, $\dot{k} = 0$, $\dot{c} = 0$, $\dot{f} = 0$, and $\dot{s} = 0$. Using the two conditions $\dot{k} = 0$ and $\dot{c} = 0$ by setting the right hand side of (17) and (18) equal to zero respectively, and together with a pair

of derived optimality conditions under each scheme described above, the models can be solved to yield equilibrium levels for output. In particular, under the non-cooperative scheme:

$$y_{nc}^* = \left[\frac{\left(1-\tau_f -\tau_s\right)^\alpha \tau_s^\beta \tau_f^\gamma \alpha^\alpha \beta^\beta \gamma^\gamma}{\left(\zeta + \rho\right)^\alpha (\eta + \rho)^\beta (\delta + \rho)^\gamma} \right]^{\frac{1}{\sigma}} \tag{27}$$

Similarly, under the tax sharing scheme:

$$y_{ts}^* = \left[\frac{\left(1-\tau_f -\tau_s\right)^\alpha \left(\tau_s + \tau_f\right)^{\beta+\gamma} \alpha^\alpha \beta^\beta \gamma^\gamma \theta^\beta \left(1-\theta\right)^\gamma}{\left(\zeta . \rho\right)^\alpha (\eta + \rho)^\beta (\delta + \rho)^\gamma} \right]^{\frac{1}{\sigma}} \tag{28}$$

And under the joint optimum scheme:

$$y_{jo}^* = \left[\frac{\left(1-\tau_f -\tau_s\right)^\alpha \left(\tau_s + \tau_f\right)^{\beta+\gamma} \alpha^\alpha \beta^\beta \gamma^\gamma}{\left(\zeta + \rho\right)^\alpha (\eta + \rho)^\beta (\delta + \rho)^\gamma} \right]^{\frac{1}{\sigma}} \tag{29}$$

Proposition 3. *For any given set of tax rates, the joint optimum scheme induces the highest long-run output level. However, it is unclear about the comparison of the long-run output levels of the other two schemes.*

Proof. Since $0 < \theta < 1$ then $0 < \theta^\beta \left(1-\theta\right)^\gamma < 1$ with all values in the range $0 < \beta, \gamma < 1$. It is clear that the output level under the tax sharing scheme is lower than that under the joint optimum scheme. In order to compare the levels of output between the non-cooperative scheme and the joint optimal scheme, it is necessary only to compare $\left(\tau_s + \tau_f\right)^{\beta+\gamma}$ with $\tau_s^\beta \tau_f^\gamma$. There are three possibilities:

If $\tau_f = \tau_s = \tau$ then $\left(\tau_s + \tau_f\right)^{\beta+\gamma} = \left(2\tau\right)^{\beta+\gamma} = 2^{\beta+\gamma} \tau^{\beta+\gamma} > \tau_s^\beta \tau_f^\gamma = \tau^{\beta+\gamma}$ because $2^{\beta+\gamma} > 1$.

If $\tau_f > \tau_s$ then $\left(\tau_s + \tau_f\right)^{\beta+\gamma} > \tau_f^{\beta+\gamma} = \tau_f^\beta . \tau_f^\gamma > \tau_s^\beta \tau_f^\gamma$.

Similarly, if $\tau_s > \tau_f$ then $\left(\tau_s + \tau_f\right)^{\beta+\gamma} > \tau_s^{\beta+\gamma} = \tau_s^\beta . \tau_s^\gamma > \tau_s^\beta \tau_f^\gamma$.

In all cases the result is that $\left(\tau_s + \tau_f\right)^{\beta+\gamma} > \tau_s^\beta \tau_f^\gamma$. This means that long-run output level under joint optimum scheme, y_{jo}^*, is higher than that under the non-cooperative scheme, y_{nc}^*. Therefore, the conclusion is that the output level induced under the joint optimum scheme is the highest.

In terms of comparing output level under the non-cooperative scheme with that under the tax sharing scheme, it is only necessary to compare $\tau_s^\beta \tau_f^\gamma$ with $\left(\tau_s + \tau_f\right)^{\beta+\gamma} \theta^\beta \left(1-\theta\right)^\gamma$. It can be seen that when $\theta = \dfrac{\tau_s}{\tau_s + \tau_f}$ then these are equal. In other words, the non-cooperative scheme is a special situation of the tax sharing scheme when the revenue share of the State government is fixed at $\theta = \dfrac{\tau_s}{\tau_s + \tau_f}$. However, when $\theta \neq \dfrac{\tau_s}{\tau_s + \tau_f}$, it is unclear if the long-run output level under the tax sharing scheme is higher or lower than the long-run output level under the non-cooperative scheme.

The intuition is as follows. As the governments maximise their own tax revenue instead of citizens' welfare, there is tax competition between them. This competition generates a vertical externality which is internalised in joint optimum schemes but not in the other two schemes. Therefore, the joint optimum scheme yields the highest output level as the governments cooperate in setting taxes and making infrastructure investment. In case of tax sharing scheme, both governments have some stake in both revenue sources so they incline to invest more in infrastructure as compared to the non-cooperative scheme. However, each government is only allowed to get a fraction of the outcome from its infrastructure investment, they have less willingness to invest. With these two opposing effects, it is not possible to generalise whether the tax sharing scheme will lead to a higher or lower long-run per capita output level as compared to the non-cooperative scheme.

Proposition 4. *The aggregate revenue maximising tax rate imposed on the economy (the sum of Federal tax rate and State tax rate) is the same under the tax sharing and joint optimum*

schemes. It is lower than the tax rate imposed under the non-cooperative scheme. However, both of these tax rates are higher than in the case of the welfare maximising government.

Proof. Consider the non-cooperative scheme first. The two steady state conditions $\dot{f} = 0$ and $\dot{s} = 0$ imply that $\Omega_f = \delta f$ and $\Omega_s = \eta s$. Using these results together with (21), the instantaneous tax revenue for the Federal government can be derived as follows:

$$r_f = \tau_f y (1 - \gamma) + \rho f$$

As there are no intertemporal elements for the tax rate in the maximisation problem, maximising the present value of net receipts reduces to maximising the net receipt in each period. The first order condition with respect to τ_f gives:

$$\frac{\partial r_f}{\partial \tau_f} = (1 - \gamma)\left(y + \tau_f y_{\tau_f}\right) = 0 \Leftrightarrow y = -\tau_f y_{\tau_f} \tag{30}$$

Similarly, using (22), the tax revenue for the State government is:

$$r_s = \tau_s y (1 - \beta) + \rho s$$

The first order condition with respect to τ_s is:

$$\frac{\partial r_s}{\partial \tau_s} = (1 - \beta)\left(y + \tau_s y_{\tau_s}\right) = 0 \Leftrightarrow y = -\tau_s y_{\tau_s} \tag{31}$$

With output level given in (27) then $y_{\tau_f} = \frac{1}{\sigma}\left[\frac{-\alpha}{1 - \tau_f - \tau_s} + \frac{\gamma}{\tau_f}\right] y$ and

$y_{\tau_s} = \frac{1}{\sigma}\left[\frac{-\alpha}{1 - \tau_f - \tau_s} + \frac{\beta}{\tau_s}\right] y$. Using (30) and (31) together with these two conditions, it can be

solved to get $\tau_s^* = \left(1 - \frac{\alpha}{1+\sigma}\right)\frac{1 - \alpha - \gamma}{2 - 2\alpha - \beta - \gamma}$ and $\tau_f^* = \left(1 - \frac{\alpha}{1+\sigma}\right)\frac{1 - \alpha - \beta}{2 - 2\alpha - \beta - \gamma}$. The

aggregate tax rate imposed on the economy is $\tau^* = \tau_f^* + \tau_s^* = 1 - \frac{\alpha}{1+\sigma}$.

Now consider the tax sharing scheme. Substituting (23) and (24) into the tax revenue functions gives the equilibrium revenue for the Federal government:

$$r_f = (1-\theta)(\tau_s + \tau_f) y (1-\gamma) + \rho f$$

The first order condition with respect to τ_f gives:

$$\frac{\partial r_f}{\partial \tau_f} = (1-\theta)(1-\gamma)\left[y + (\tau_f + \tau_s) y_{\tau_f} \right] = 0 \Leftrightarrow y = -(\tau_f + \tau_s) y_{\tau_f} \qquad (32)$$

Similarly, the equilibrium tax revenue for the State government is:

$$r_s = \theta(\tau_s + \tau_f) y (1-\beta) + \rho s$$

The first order condition with respect to τ_s is:

$$\frac{\partial r_s}{\partial \tau_s} = \theta(1-\beta)\left[y + (\tau_f + \tau_s) y_{\tau_s} \right] = 0 \Leftrightarrow y = -(\tau_f + \tau_s) y_{\tau_s} \qquad (33)$$

Note that, unlike the case of welfare maximising governments, here θ is not a choice variable. The reason is that because the revenue enhancing governments are maximising their tax revenues, if possible, each would wish to set its tax revenue share equal to 1 or 100 percent.

Now turn to the joint optimum scheme. Using (25) and (26), the equilibrium tax revenue functions are respectively:

$$r_f = (\tau_s + \tau_f) y (1-\gamma) + \rho f$$

$$r_s = (\tau_s + \tau_f) y (1-\beta) + \rho s$$

The first order conditions are:

$$\frac{\partial r_f}{\partial \tau_f} = (1-\gamma)\left[y + (\tau_f + \tau_s) y_{\tau_f} \right] = 0 \Leftrightarrow y = -(\tau_f + \tau_s) y_{\tau_f} \qquad (34)$$

$$\frac{\partial r_s}{\tau_s} = (1-\beta)\left[y + (\tau_f + \tau_s) y_{\tau_s} \right] = 0 \Leftrightarrow y = -(\tau_f + \tau_s) y_{\tau_s} \qquad (35)$$

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From (32)-(35), it can be seen that the first order conditions for maximising tax revenues are the same for these two schemes. With outputs given by (28), and (29) then

$$y_{\tau_f} = \frac{1}{\sigma}\left[\frac{-\alpha}{1-\tau_f-\tau_s}+\frac{\beta+\gamma}{\tau_f+\tau_s}\right]y = y_{\tau_s}.$$ Substituting this result into the first order conditions

above and solving gives $\tau^* = 1-\alpha$ where $\tau = \tau_f + \tau_s$.

Under the tax sharing scheme, the optimal tax rates set by each level of government are $\tau_s^* = \theta(1-\alpha)$ and $\tau_f^* = (1-\theta)(1-\alpha)$ respectively. However, under the joint optimum scheme, it is impossible to separate this result into τ_f^* and τ_s^* because the governments maximise their total tax revenue receipts rather than separate tax revenue. The two levels of government are merged and they act very much like one integrated government.

Using the result derived in Section 3 of the paper, the optimal tax rate in the benevolent government case can be expressed as:

$$\tau^* = \frac{\beta+\gamma}{\alpha+\beta+\gamma} = 1 - \frac{\alpha}{\alpha+\beta+\gamma} = 1 - \frac{\alpha}{1-\sigma}$$

It is now possible to compare this tax rate with those under the revenue maximising cases. It can be seen that $1 - \dfrac{\alpha}{1+\sigma} > 1 - \alpha > 1 - \dfrac{\alpha}{1-\sigma}$. This implies that the tax rate under the non-cooperative scheme is the highest, followed by the tax rate under the tax sharing and joint optimum schemes. The welfare maximising governments impose the lowest level of tax rate. These results are generally in line with those of Keen (1998) and Keen and Kotsogiannis (2002) where the general conclusion is that vertical fiscal externalities lead to high tax rates. The intuition is that when the objective of the government is to maximise own tax revenue rather than citizens' welfare, tax rate tends to be higher. In addition, tax competition between the two layers of governments leads to over taxation in the absence of their coordination due to vertical externality.

Proposition 5. *Under all schemes, the aggregate tax rate that maximises the long-run output level is the same as the rate set under the case of welfare maximising governments. In general, this tax rate is lower than the revenue maximising aggregate tax rates found in Proposition 4.*

Proof. Consider the non-cooperative scheme with long-run output level given in (27). The first order conditions of output with respect to the tax rates are:

$$y_{\tau_f} = \frac{1}{\sigma}\left[\frac{-\alpha}{1-\tau_f-\tau_s}+\frac{\gamma}{\tau_f}\right]y=0 \tag{31}$$

$$y_{\tau_s} = \frac{1}{\sigma}\left[\frac{-\alpha}{1-\tau_f-\tau_s}+\frac{\beta}{\tau_s}\right]y=0 \tag{32}$$

Solving these two conditions gives $\tau_f^* = \dfrac{\gamma}{\alpha+\beta+\gamma}$ and $\tau_s^* = \dfrac{\beta}{\alpha+\beta+\gamma}$ or

$\tau^* = \tau_f^* + \tau_s^* = \dfrac{\beta+\gamma}{\alpha+\beta+\gamma} = 1-\dfrac{\alpha}{1-\sigma}$. This tax rate is the same as the optimal tax rate obtained under the case of benevolent governments.

Now turn to the tax sharing and joint optimum schemes. With output levels given in (28) and (29), the first order conditions with respect to tax rates are:

$$y_{\tau_f} = y_{\tau_s} = \frac{1}{\sigma}\left[\frac{-\alpha}{1-\tau_f-\tau_s}+\frac{\beta+\gamma}{\tau_f+\tau_s}\right]y=0 \tag{33}$$

Solving these conditions yields $\tau^* = \dfrac{\beta+\gamma}{\alpha+\beta+\gamma}$ where $\tau = \tau_f + \tau_s$. Here, the aggregate output maximising tax rate is the same as the one obtained under the case of welfare maximising governments and the non-cooperative scheme of revenue maximising governments. Therefore, the rule of thumb for the governments to maximise the per capita output level is to set the aggregate tax rate equal to the share of public capital in the total share of capital in production. As was shown above, this tax rate is lower than the tax rate that maximises the revenue receipts to the governments.

5. Conclusions

Observed increases in the decentralisation of government structure, particularly in regards to fiscal responsibilities across tiers of government, clearly suggest a need for an increased understanding of the causes of such differing degrees of decentralisation but also the consequences of decentralisation for economic performance. A substantial amount of empirical research has taken place into the drivers of decentralisation and into the relationship between decentralisation and economic growth, however it is fair to say that this research is somewhat undermined by a lack of formal theoretical research to underpin the empirical analysis. This paper takes one step toward addressing this issue. A simple growth model with different tiers of government which focuses on steady state analysis is developed and used to examine the dynamic effects of fiscal decentralisation on the long-run output level of an economy.

The focus is first on the case of welfare maximising governments that aim to maximise their citizens' welfare and economic performance by providing consumption goods for private consumption and public capital for private production. The analysis then extends to the case of revenue maximising governments that attempt instead to maximise their own tax revenue. Whether acting out of a motive of welfare maximisation or not, the modeling suggests that governments that wish to maximise the per capita output of their economy will set the combined tax imposed by the various levels of government at a rate equal to the ratio of the output elasticity of public capital relative to that of the total capital stock. As other researchers have noted, this is the share of per capita output that public capital would receive if its services were sold in competitive markets.

Benevolent governments will allocate expenditures among different levels of government according to the relative productivities of the capital stocks that these levels provide. Productivity in this sense should be interpreted in a general way to include the efficiency of the process of transforming private output into public capital as well as the productivity of the capital itself. By this measure the capital provided through bureaucracies

that impose significant transactions costs and make poor investment decisions has low productivity and the level of government responsible should be charged with a correspondingly lower share of public expenditure. On this argument, the effect of fiscal decentralisation of expenditure decisions on economic growth depends on the relative efficiencies of the various levels of government.

When non-benevolent governments choose maximising tax revenue as their objective, the tax rate chosen will be higher than that which maximises output per capita, and will be the same whether the tax system is centralised (cooperative) or decentralised (non-cooperative). However, in a decentralised system in which jurisdictions compete for a share of revenue, per capita output will be lower because of lower public capital stocks. Each level of government attempts to shift the responsibility for provision of public capital goods to others, while benefiting from taxes on output produced using those goods.

The results of the analysis suggest two simple lessons for the design of a fiscal system intended to promote economic performance. A centralised or cooperative tax system will provide the necessary revenues to provide public capital for production and services for consumption without the adverse effects of fiscal externalities. The sharing of these revenues among levels of government should be based on the relative productivities of the infrastructure supplied by these governments. Further empirical research on the relative productivities of the activities of Federal, State, and Local governments is required to establish the optimal degree of government expenditure decentralisation in the economy.

Some important issues have not been addressed in this paper. Most significantly, the paper does not allow the mobility of economic agents and resources and the tax competition amongst State governments. It could be that tax competition amongst non-cooperative State governments would lead to inefficiencies in public expenditure, as pointed out by Keen and Marchand (1997). In turn this could induce a lower long-run output level. The analysis in this paper has not considered the optimal provision of public consumption goods (in addition to the optimal provision of public capital). The paper has also not considered the case where different levels of

government have different tax bases. Further extensions to the analysis and a comprehensive examination of these issues will surely enrich the research agenda in the future and provide a greater theoretical platform from which policymakers can make informed decisions over these important fiscal policy and structure of government issues.

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Appendix

Second order sufficient conditions for a maximum

Applying the chain rule of differentiation to the first order necessary condition for a maximum $y_x = h_x y$, it can be shown that:

$$y_{xx} = h_{xx} y + h_x y_x = h_{xx} y + h_x \left(h_x y \right) = \left(h_{xx} + h_x^2 \right) y$$

Using this result, the second derivatives and the cross partial derivative can be written as follows:

$$y_{\tau\tau} = \left(h_{\tau\tau} + h_\tau^2 \right) y$$

$$y_{\theta\theta} = \left(h_{\theta\theta} + h_\theta^2\right) y$$

$$y_{\tau\theta} = y_{\theta\tau} = h_{\tau\theta}\, y + h_\tau\, y_\theta = h_{\tau\theta}\, y + h_\tau\left(h_\theta\, y\right) = \left(h_{\tau\theta} + h_\tau h_\theta\right) y$$

From the results above, can be derived the following:

$$h_{\tau\tau} = \frac{1}{\sigma}\left[\frac{-(\beta+\gamma)(1-\tau)^2 - \alpha\tau^2}{\tau^2(1-\tau)^2}\right]$$

$$h_\tau^2 = \frac{1}{\sigma^2}\left[\frac{(\beta+\gamma)^2(1-\tau)^2 - 2\alpha(\beta+\gamma)\tau(1-\tau) + \alpha^2\tau^2}{\tau^2(1-\tau)^2}\right]$$

$$h_{\theta\theta} = \frac{1}{\sigma}\left[\frac{-\beta(1-\theta)^2 - \gamma\theta^2}{\theta^2(1-\theta)^2}\right]$$

$$h_\theta^2 = \frac{1}{\sigma^2}\left[\frac{\beta^2(1-\theta)^2 - 2\beta\gamma\theta(1-\theta) + \gamma^2\theta^2}{\theta^2(1-\theta)^2}\right]$$

Hence:

$$y_{\tau\tau} = \left(h_{\tau\tau} + h_\tau^2\right) y = \frac{(\beta+\gamma)(\beta+\gamma-\sigma)(1-\tau)^2 + \alpha\tau^2(\alpha-\sigma) - 2\alpha(\beta+\gamma)\tau(1-\tau)}{\sigma^2\tau^2(1-\tau)^2}\, y$$

$$y_{\theta\theta} = \left(h_{\theta\theta} + h_\theta^2\right) y = \frac{\beta(\beta-\sigma)(1-\theta)^2 + \gamma\theta^2(\gamma-\sigma) - 2\beta\gamma\theta(1-\theta)}{\sigma^2\theta^2(1-\theta)^2}\, y$$

Because $\alpha+\beta+\gamma<\sigma$ by assumption of the production function, $y_{\tau\tau}<0$ and $y_{\theta\theta}<0$ with $\forall(\tau,\ \theta)$. It also necessary to check the sign of $D = y_{\tau\tau}y_{\theta\theta} - \left(y_{\tau\theta}\right)^2$. It can be seen that $h_{\tau\theta}=0$ with $\forall\tau,\ \theta$ while $h_\tau=0$ and $h_\theta=0$ when evaluating at $(\tau^*,\ \theta^*)$. Hence $y_{\tau\theta} = \left(h_{\tau\theta} + h_\tau h_\theta\right) y = 0$ when evaluating at $(\tau^*,\ \theta^*)$. This implies that $D = y_{\tau\tau}y_{\theta\theta} - \left(y_{\tau\theta}\right)^2 > 0$ when evaluating at $(\tau^*,\ \theta^*)$. The second order sufficient conditions are satisfied for a maximum of long-run output level.