FINANCING PUBLIC EXPENDITURES THROUGH PROGRESSIVE TAXATION: EFFECTS ON GROWTH, WELFARE AND INEQUALITY

ALPER ÜNSAL

BOĞAZİÇİ UNIVERSITY

2016

FINANCING PUBLIC EXPENDITURES THROUGH PROGRESSIVE TAXATION: EFFECTS ON GROWTH, WELFARE AND INEQUALITY

Thesis submitted to the

Institute for Graduate Studies in the Social Sciences

in partial fulfillment of the requirements for the degree of

Master of Arts

in

Economics

by

Alper Ünsal

Boğaziçi University

2016

DECLARATION OF ORIGINALITY

I, Alper Ünsal, certify that

- I am the sole author of this thesis and that I have fully acknowledged and documented in my thesis all sources of ideas and words, including digital resources, which have been produced or published by another person or institution;
- this thesis contains no material that has been submitted or accepted for a degree or diploma in any other educational institution;
- this is a true copy of the thesis approved by my advisor and thesis committee at Boğaziçi University, including final revisions required by them.

Signature..

Date 15.08.2016

ABSTRACT

Financing Public Expenditures through Progressive Taxation:
Effects on Growth, Welfare and Inequality

Theoretical and empirical studies have revealed that there is a positive impact of public investments, i.e. infrastructure investments, on economic growth. Noting that the growth literature containing productive public capital often neglects distributional effects and the relevant studies rely on financing methods using flat taxation, the implications of having a progressive tax schedule on economic growth and distributional measures are explored in this study. More specifically, an endogenous growth model is used in which public investment is a direct factor in both production and utility functions while labor-elastic agents are taxed progressively according to their relative capital income and labor income levels. After forming the theoretical model, numerical analyses are also conducted to find the effects of increases in public expenditures on both economy-wide parameters, i.e. GDP growth rate, and on income, wealth and welfare dispersions. This study shows that, without harming economic growth, it is possible to alleviate inequalities in an economy through increases in public expenditure financed by progressive taxes. Among the discussed tax methods, most influential one on all dimensions is found to be capital income taxes. Its progressivity level has to be assigned to be lower than a threshold level above which it begins to harm economic growth.

ÖZET

Kamu Harcamalarının Artan Oranlı Vergilerle Finanse Edilişi: Büyüme, Refah ve Eşitsizlik Üzerindeki Etkiler

Hem teorik hem empirik çalışmalar, altyapı yatırımları gibi kamu yatırımlarının iktisadi büyüme üzerinde pozitif etkileri olduğunu göstermektedir. Bu çalışmada, üretken kamu sermayesini içeren büyüme literatürünün dağılımsal etkileri genellikle yok saydığı ve ilgili çalışmaların sabit vergi oranlarına dayandığı dikkate alınarak, artan oranlı vergilendirme yöntemine sahip olmanın iktisadi büyüme ve dağılımsal ölçütler üzerindeki olası etkileri araştırılmıştır. Daha spesifik olarak, kamu yatırımının hem üretim hem fayda fonksiyonlarında bir girdi olarak yer aldığı ve elastik olarak işgücü arz eden bireylerin sermaye gelirleri ve maaş gelirleri üzerinden artan oranlı olarak vergilendirildikleri bir endojen büyüme modeli kullanılmaktadır. Teorik modelin oluşturulmasından sonra kamu harcamalarındaki artışların hem GSYH büyüme oranı gibi ekonomi genelindeki parametreler; hem de gelir, servet ve refah dağılımları üzerindeki etkilerini bulmak için nümerik analizler de ayrıca icra edilmiştir. Bu çalışma göstermektedir ki, artan oranlı vergilerle finanse edilen kamu harcaması artışları aracılığıyla bir ekonomideki eşitsizlikleri hafifletmek iktisadi büyümeye zarar vermeden mümkündür. Sermaye gelirine konulan verginin, üzerinde tartışılan vergi metodları arasında, bütün sonuçlar üzerinde en yüksek etkiye sahip olan olduğu bulunmuştur. Bu vergilerin artan oranlılık seviyesi de, kendisini aştığında iktisadi büyümeye zarar vermeye başlayacağı bir eşik değerinin altında kalacak şekilde tayin edilmelidir.

TABLE OF CONTENTS

CHAPTER 1 : INTRODUCTION 1

CHAPTER 2 : LITERATURE REVIEW 4

CHAPTER 3 : THE MODEL 13

3.1 Firms and technology 13

3.2 Consumers 14

3.3 Progressivity in taxation 15

3.4 Individuals' utility maximization 16

3.5 Government 17

CHAPTER 4: MACROECONOMIC EQUILIBRIUM 19

4.1 Balanced growth path characterization 21

4.2 Transition path dynamics 21

4.3 Distributional dynamics 23

CHAPTER 5: NUMERICAL ANALYSIS 24

5.1 An increase in the rate of public expenditures 26

CHAPTER 6: CONCLUSION 32

APPENDIX A: EQUATIONS 34

APPENDIX B: FIGURES 36

REFERENCES 45

LIST OF TABLES

Table 1. Parameter Values for the Benchmark Economy 25

Table 2. Benchmark Calibrations 25

Table 3. Steady State Values for the Benchmark Economies 25

Table 4. Effects of Public Expenditure Shocks under Fixed Tax Progressivity . 26

Table 5. Steady State Growth Rates (%) after Each Shock 27

Table 6. Steady State Output-Private Capital Ratios after Each Shock ... 28

Table 7. Steady State Public-Private Capital Ratios after Each Shock 28

Table 8. Steady State Normalized Average Welfare after Each Shock 29

Table 9. Steady State Wealth Distributions (%) after Each Shock 30

Table 10. Steady State Income Distributions (%) after Each Shock 30

Table 11. Steady State Welfare Distributions (%) after Each Shock 30

LIST OF FIGURES

Figure 1. Financing through a Combined Income Tax Increase 36

Figure 2. Financing through a Consumption Tax Increase 37

Figure 3. Financing through a Lump-sum Tax Increase 38

Figure 4. Financing through a Capital Income Tax Increase 39

Figure 5. Financing through a Labor Income Tax Increase 40

Figure 6. Transition Paths for Wealth Distribution 41

Figure 7. Transition Paths for Income Distribution 42

Figure 8. Transition Paths for Welfare Distribution 42

Figure 9. Transition Paths for Public-Private Capital Ratio 43

Figure 10. Transition Paths for Growth Rate (%) 43

Figure 11. Transition Paths for Average Welfare 44

Figure 12. Transition Paths for Output-Capital Ratio 44

CHAPTER 1
INTRODUCTION

In the last three decades, the role of and public expenditures on economic growth has been widely investigated. On the empirical side, Aschauer (1989) laid the foundations of this discussion finding a positive correlation between non-military public capital stock and economic growth in the U.S. data. On the theoretical side, a milestone study is Barro (1990). In this paper, the production function is expressed directly in terms of public-private capital ratio for the first time. Following these studies, many scholars analyzed this relationship, but the role of public expenditures on income, wealth and welfare distributions stayed as a matter that had not been investigated sufficiently.

Among the small number of studies on public expenditures and inequality, Calderon and Serven (2004) finds that stock of infrastructure assets positively affects growth and alleviates inequality. Lopez (2004) discusses that improving infrastructure and education has similar effects found in Calderon and Serven (2004). In Benos (2009), because of the growth depressing effects of distortionary taxes, it is suggested that these expenditures should be financed by non-distortionary taxes. Chatterjee and Turnovsky (2012) yields a well-specified analytical model in this issue. Public capital affects both production and the quality of time devoted to leisure. In this model, financing modes of public capital are distortionary flat taxes and a non-distortionary lump-sum tax. As a result, their results on growth are compatible with prior studies, but at the distributional side positive impacts on income, wealth and welfare distributions are found.

In this paper, I aim to form a comprehensive model in order to capture the empirical findings in which public capital is found to have growth and equality benefits. The elements of the model in this paper are as follows. Firstly, the labor-elastic agents in the economy are heterogeneous in terms of their time preferences. Thus; income, wealth and welfare distributions are determined endogenously. Secondly, the production and utility functions in Chatterjee and Turnovsky (2012) are used only with the difference of heterogeneity in individuals' time preferences. In these functions, composite externalities of public capital and aggregate private capital interact with aggregate labor used for production to yield effective units of labor and individuals' time devoted to leisure to denote the quality of leisure. In order to finance its expenditures, the government uses progressive taxes on capital income and labor income, together with a flat consumption tax and a lump-sum tax. Then, the implications of an increase in the government expenditure rate are explored. This increase is financed by an increase in (i) the base capital income tax rate, (ii) the base labor income tax rate, (iii) a composition of the previous two, (iv) the consumption tax rate and (v) the lump-sum tax rate. As a result; the public-private capital ratio, productivity of private capital, relative wealth and labor-supply choices of the agents are endogenously determined both at the equilibrium and through the transition paths caused by government expenditure shocks. Income, welfare and wealth distributions, expressed in terms of the aforementioned parameters, are also determined.

After setting the model, it is analyzed numerically due to its complex nature. Some of the results obtained by imposing a government expenditure shock by using the aforementioned fiscal policies are as below:

(i) The effects of a government expenditure increase are ambiguous only in the case of financing through capital income taxes. In other cases, an increase in growth rate and alleviations in distributional measures are captured within plausible intervals of labor income tax progressivity.

(ii) Progressive income tax is by far the most effective one on changes in growth and distributional measures. Its progressivity level is negatively correlated with the growth rate of the economy and income, welfare and wealth inequalities. Thus, a low income tax progressivity level imply positive effects on all measures and after a threshold point it begins to harm the growth rate. As a result, it is the most important candidate to occupy the top of the agenda of an equality-favoring government, because this goal can be achieved without harming the growth rate of the economy through an increase in government expenditures.

(iii) A government expenditure shock causes instantaneous jumps in income and welfare inequalities when it is imposed. These are because the initial changes in labor supply decisions of the agents. Income inequality initially increases as richer (poorer) agents tend to work more (less) due to this shock. Then, this increase in income dispersion dampens and falls below its pre-shock level. Welfare dispersion decreases in the short-run because of the changes in leisure decisions, since consumption decisions of the agents are affected marginally. Then, it stabilizes at its new equilibrium level which is higher than the short-run level but lower than the before-shock level. Because private capital is an accumulable factor, its dispersion does not have initial jumps and tend to decrease over time in all financing scenarios.

The rest of the paper is as follows. Section 2 presents a review on the existing literature. The model is defined in Ssection 3. In Section 4, the steady-growth equilibrium and the transition path dynamics of the economy are derived together with the definitions of distributional measures. In Section 5 numerical analyses of the model are performed and their results are discussed. Section 6 concludes before the transition paths occurred after some of the financing methods are presented in the Appendix Section.

CHAPTER 2
LITERATURE REVIEW

Aschauer's seminal paper in 1989 has sparked attention for investigation of the relationship between expenditures on public services and economic growth. He finds that non-military public capital stock is positively correlated with economic growth with an elasticity of 0.39 using U.S. data. Furthermore, the 'core' infrastructure of streets, highways, airports, mass transit, sewers, water systems are found to be the most important factors affecting total factor productivity. In total, the elasticity of this set of 'core' infrastructure is estimated to be 0.24. A comprehensive analysis on this area of the studies is found in Bom and Lightart (2010). By taking into account the findings of studies between 1983 and 2008, it is found that the effect of public capital on growth is much lower in the short run, with an elasticity approximation of 0.085, while the approximate elasticity is 0.268 in the long run, similar to the results in Aschauer (1989). Throughout the literature, the output elasticity of infrastructure was estimated as low as a range between 0.07 and 0.10 [Calderon et al. (2015)], but is always positive and significant. Upon the analyses on long run effects, Arslanalp et al. (2010) investigates also short run effects. An increase in public services accelerates growth at a higher rate in OECD countries in the short run, while in the others the growth impact is higher once longer time intervals are considered.

Barro (1990) develops a milestone endogenous growth model, deeming government expenditure as a direct factor affecting productivity. According to that model, maximizations of social welfare and growth rate need equal amount of output devoted to public investments, which is objected by Futagami et al. (1993). Futagami et al. (1993) includes public expenditure as a stock variable in their model, a deviation from incorporating it as a flow variable like in Barro (1990). With this inclusion; optimal tax rate for financing public expenditures seems to be greater for growth maximization than for social welfare maximization. In both papers, growth maximizing tax rate is found to be equal to the elasticity of public expenditure on growth. In Futagami et al. (1993) model, transition paths can also be obtained because of regarding public capital as a stock variable. Furthermore; under certain conditions, a unique steady growth equilibrium and a unique stable transition path exist. Devarajan et al. (1996) uses an endogenous growth model comprising two kinds of public capital with different productivity levels. In this model not only physical productivities of components of government expenditure but also shares of government expenditure allocated to them can lead to higher steady-state growth rate for the economy. This model suggests that seemingly productive public expenditures could become unproductive if there is an excessive amount of them, a case encountered in developing economies misallocating their resources used for public expenditures. Balducci (2005) proposes a model relating optimal government size with the intertemporal discount rate, which means that if the economy is optimistic about the future –coincides with a low discount rate- then it prefers a lower government intervention. For the pessimistic economies, size of the government would be higher which in return leads to lowered growth rates. Turnovsky and Fisher (1995) employ a model to compare the effects of government consumption expenditure and government infrastructure expenditure on macroeconomic performance. Government expenditure on both forms lead to a resource withdrawal effect lowering overall wealth. This results in encourage to work and capital accumulation. Among the two forms, government infrastructure expenditure is more likely to offset the resource withdrawal effect leading to a higher growth rate. Rioja (1999)'s findings are compatible with Futagami et al. (1993)'s. It is found that devoting more resources to infrastructure investments results in a higher

GDP growth, but this does not always mean a welfare gain. Additionally, a %4 increase in infrastructure investments to output ratio is proposed for Latin American countries. In Pintea and Turnovsky (2006), public capital is provided also by private firms beside public firms in their two-sector model. Upon their benchmark level, %4, of government investment, an unanticipated shock is imposed to raise it to %8. The corresponding results are an increase in private output between %32 and %42 and an increase in public to private capital ratio between %158 to over %200.

The relationship between public capital and growth has been further investigated by analyzing the effects of components of public capital. It is shown that, in developed economies, a positive causal link exists between growth and public investments in technologically advanced services, while the investments on basic services do not have an effect on growth. A reverse relationship is applicable in underdeveloped economies. Candelon et al.'s (2009) work is a descriptive example on this issue. By looking at developing economies, they lay down a model to test the threshold effects of infrastructure types on growth. They find that, below a specific level of a certain type of infrastructure stock, new investments on this type do not have an effect on growth and after a higher threshold is exceeded the positive link disappears because of over-investment. A paper supporting this result is Röller and Waverman (2001). The analysis made on OECD countries in this paper shows that provided that a critical mass of telecommunication services exist, the positive effect of new investments on this infrastructure type on growth is pretty much stronger than poorer non-OECD countries. Czernich et al. (2011) supports these findings and states that in developed countries annual growth of per-capita GDP can be raised by 0.9 to 1.5 percentage points if a %10 percentage point increase in the broadband penetration rate is achieved. Also, Egert et al. (2009) gives a result compatible with the aforementioned over-investment effect. In OECD countries telecommunication and electricity services affect growth positively, while new investments on roads and railways are ineffective. Estache et al. (2008) performs an analysis on infrastructure in Africa and expresses that, besides economic development level, legal origin of a country, i.e. having a British dominion heritage, is another determinant on elasticity variations of components of infrastructure stock.

Public capital affects growth not only because of its quantity, but also because of its quality, obviously. Reinikka and Svensson (2002) investigate the reasons for different results for responses to public investment and show that poor quality of public infrastructure services reduces the productivity of private investments. But, this effect is far from being as effective as the quantity of public capital. Calderon (2009) yields the result that, in African countries, the contribution of increases in public capital stocks is about nine times more effective than improvements in their quality. The importance of investments in public services is also reflected in this paper. For instance, if the African countries were to catch up the infrastructure stock and quality of the region's leader, Mauritius, their rate of economic growth would be enhanced for 2.2 percent on the average and 3.5 percent in maximum case. Gupta et al. (2014) is another example where the quality of public investments is found to be statistically significant for explaining variations in the rate of economic growth.

On the theoretical side; Kalaitzidakis and Kalyvitis (2004), Agenor (2009), Dioikitopoulos and Kalyvitis (2008) theorizes the role of maintenance as a mean of measuring physical quality of infrastructure services. In these models, a fraction of resources devoted to public infrastructure is invested in maintenance efforts. Maintenance enters into the equations via an efficiency parameter or via depreciating infrastructure. Maintenance appears to be robustly correlated with growth but its effect is relatively small, a result that coincides with empirical studies. In Agenor (2009), it is also found that optimal tax rate for growth does not depend on maintenance.

An indirect effect of public capital on growth is realized through its effects on human capital. Baldacci et al. (2008) finds that education and health expenditures have a significant direct effect on accumulation of health and education capital, which in return fosters growth. Bose et al. (2007) states that government investment on education is significantly associated with economic growth. Bloom et al. (2004) estimate that good health, given in terms of life expectancy, augments growth positively, even after its impact on work experience as a proxy is tested. Similarly, in their analyses for the poorest countries, Bhargava et al. (2001) show that one percent increase in adult survival rate is associated with 0.05% increase in growth rate, which is relatively small but much larger than the effect of one percent increase in investment/GDP ratio, 0.014%. Their results also support the aforementioned threshold effect and express that the effect of adult survival rate disappears after a threshold point.

Theoretical models also find a positive but small effect of human capital on growth and welfare. Ashraf et al. (2008) allows for a direct effect of health on worker productivity and an indirect effect of health on schooling. Compatible with empirical literature, it is found that growth gains of health and education are surprisingly small. Optimal tax rates for financing public investments are also found irrelevant of composition of them when their compositions are they are used for augmenting human capital in Monteiro and Turnovsky (2008). In some other studies like Agenor (2010), Agenor and Neanidis (2015), Agenor and Neanidis (2011), Agenor (2011); indirect effects of human capital on growth are also theorized. In Agenor (2010), level of human capital affects time preference of individuals. In Agenor and Neanidis (2015), infrastructure investments affect growth indirectly through their enhancing impact on innovation. In Agenor (2011) and Agenor and Neanidis (2011), higher infrastructure quality enhances schooling which in return augments growth. In all of these models, the effect of human capital, expressed in terms of education and health, on growth is found to be minor.

There are also studies that analyze the role of governance quality as a factor affecting the impact of public capital. Esfahani and Ramirez (2003) argue that having good institutional and organizational quality of a country is more influential than simply having more infrastructure assets on growth. Rajkumar and Swaroop (2008) finds that public spending on health and education has no impact on health and education outcomes in poorly governed countries, while it seems to be significantly important on growth in well-governed countries.

Blackburn et al. (2011) presents a dynamic general equilibrium model of public sector corruption and economic growth. Their results are that in a low (high) development regime, a unique equilibrium exists with high (low) corruption and low (high) growth; while in an intermediate development regime, equilibria of both types –either with a low or with a high corruption level- can occur. Bohn (2007) proposes a model to analyze the effects of political polarization and instability on public underinvestment. In their model, below a threshold stability level, due to heavy discounting, underinvestment or even no investment on public services may be optimal; a case more relevant with low income countries. Cadot et al. (2006) finds little correlation between infrastructure spending and maximization of economic returns, even after controlling for pork-barrel. For politicians, the main factor fostering investment in roads and railways is actually to gain advantage in elections, not to improve transportation means. Thus, pork-barrel matters but its growth effects appear to be small. Chakraborty and Dabla-Norris (2010) analysis suggests that weak institutions imply a high inefficiency of public spending if it is chosen to simply increase it, a case encountered with in low-income countries. This paper suggests that quality of monitoring and bureaucratic oversight, thus efficiency of public capital is critical for the correlation between growth and public investment. In Ghosh and Gregoriou (2010); for OECD countries, effect of corruption on growth is small.

To sum up, the link between growth and public capital is investigated in numerous studies in this literature. But, the effects of tax schemes as an input and inequality levels as an output of public capital are seldom considered. One of these seldom works is Calderon and Serven (2004). Not surprisingly, their estimates support the fact that growth is positively affected by the stock of infrastructure assets. Furthermore, they find that infrastructure quantity and quality have a robust negative impact on income inequality, a fact which is again rarely engaged in the theoretical side of this literature. Thus, infrastructure development, which fosters growth and alleviates income inequality, is considered to stand at the top of the poverty reduction agenda. On the taxation side, Benos (2009) discusses that distortionary taxation depresses the positive growth impact exerted by public expenditures and property rights protection. He concludes that higher levels of these expenditures will have their full growth benefits for EU economies only if they are financed by increases in non-distortionary taxes.

Barro and Sala-i-Martin (1992) states that in reality, public goods are rival but non-excludable to varying degrees due to the effect of congestion. In such cases, income taxation is found to be superior to lump-sum taxation to finance public spending in their model. Turnovsky (2000a) uses elastic labor supply which is generally left inelastic throughout the literature. Having elastic labor supply raises potential problems related with existence of an equilibrium balanced growth regime. But, it is found that under plausible conditions a unique balanced growth path exists. With labor supply elasticity introduced; taxes on capital income, labor income and consumption has adverse effects on growth. A tax on capital income is the least harming one among these. Chatterjee and Turnovsky (2012) is an example of the studies that incorporate welfare and income inequality with public investments. Level of public investment is found to be resulting in a more unequal environment in terms of welfare distribution. Income distribution is sensitive to how new investments financed, but even at the most inequality-reducing case there is a small reduction in income inequality. These results obtained by an endogenous growth model under flat taxation are different than Calderon and Serven (2004) in which a reverse relationship between inequality and public investment is found empirically. Chatterjee and Turnovsky (2012) model is a comprehensive one that incorporates labor supply elasticity, agent heterogeneity, an infinite-time horizon, public capital affecting both individuals‘ utility and firms‘ production functions. Thus, their model is used as a base model in this thesis. The positive correlation between inequality and public investment, which could not be obtained in Chatterjee and Turnovsky (2012), is captured by using a progressive tax scheme in Angyridis (2014). In this discrete-time model, total income of individuals are taxed progressively and government expenditures include public consumption which is regarded to be inferior of government investment if public services.

The approach of combining progressive taxation and public capital seems to be a very plausible one since it is seen that increasing the level of public investment alone is found to be a growth-enhancing policy throughout all aforementioned studies but is also a policy that harms income and welfare distribution when financed by flat taxes. In many studies including Li and Sarte (2004), Padovano and Galli (2002), Koyuncu and Turnovksy (2016); tax progressivity is shown to be correlated negatively with growth and income inequality. As a result, financing public investments through progressive taxes may offset the inequalizing effects of flat taxes without causing a decline in growth rate. In Lloyd-Braga et al. (2008), consistent with the results in this thesis, progressive taxation is also found to be a potential source of indeterminacy when it is imposed on labor income; thus, controlling the economy for determinacy is also an issue that should not be ignored.

CHAPTER 3

THE MODEL

3.1 Firms and technology

The economy consists of representative firms which utilize labor supplied by the agents, L_j, and rent private capital, K_j. The corresponding output function of each firm, indexed by j, is the constant elasticity of substitution function below:

$$Y_j = A[\alpha(X_P L_j)^{-\rho} + (1-\alpha)K_j^{-\rho}]^{-\frac{1}{\rho}} \tag{1a}$$

where $s \equiv 1/(1+\rho)$ represents the elasticity of substitution in production between capital and effective units of labor. To obtain the efficiency units of labor, a composite production externality, X_P, which is the weighted average of the aggregate levels of public capital, K_G, and private capital, K, is used:

$$X_P = K^{\varepsilon} K_G^{1-\varepsilon},\ 0 \leq \varepsilon \leq 1 \tag{1b}$$

Due to the identicality of production conditions, all firms utilize the same amounts of private capital and employment of labor, such that $K_j = K$ and $L_j = L\ \forall j$. Here, K and L are the average economy-wide levels of private capital and employment of labor. By using the ratio of the economy-wide levels of public capital to private capital, $z \equiv \frac{K_G}{K}$, the average product of aggregate private capital is found to be:

$$y \equiv y(z,\ell) = A[(1-\alpha) + \alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}]^{-\frac{1}{\rho}} \tag{2}$$

with average leisure time denoted by $\ell = 1 - L$.

By using the average product of aggregate private capital, the marginal returns to capital and labor can be found as:

$$r = r(z,\ell) \equiv (1-\alpha)A^{-\rho}y(z,\ell)^{1+\rho} \tag{3a}$$

$$w = \omega(z,\ell)K;\ \omega(z,\ell) \equiv \alpha A^{-\rho}y(z,\ell)^{1+\rho}z^{-\rho(1-\varepsilon)}(1-\ell)^{-(1+\rho)} \tag{3b}$$

3.2 Consumers

In the economy, there is a unit mass of a continuum of infinitely-lived consumers, indexed by i, heterogeneous in their initial private capital levels, $K_{i,0}$, and rates of time preference, β_i.[1] Consumers can decide on the allocation of their one-unit time to leisure or work and maximize their constant elasticity of substitution utility functions given below, by choosing their flows of consumption C_i and time devoted to leisure, $\ell_i = 1 - L_i$:

$$U_i = \int_0^\infty \frac{1}{\gamma}[C_i^{-\nu} + \theta(X_U\ell_i)^{-\nu}]^{-\frac{\gamma}{\nu}} e^{-\beta_i t}\,\mathrm{d}t \tag{4a}$$

with $q \equiv 1/(1+\nu)$ denoting the intra-temporal elasticity of substitution between consumption and leisure in the utility function and $e \equiv 1/(1-\gamma)$ denoting the inter-temporal elesticity of substitution.

Consumers' utility functions are affected by a composite externality similar to the one in the production function:

$$X_U = K^\varphi K_G^{1-\varphi},\ 0 \le \varphi \le 1 \tag{4b}$$

The utility benefits are further weighted by θ in yielding overall utility.

[1] Heterogeneity of rates of time preference is different than the model in Chatterjee and Turnovsky (2012).

3.3 Progressivity in taxation

After having reviewed a heterogenized version of the model in Chatterjee and Turnovsky (2012), a modification on the model is made by introducing progressive tax rates on capital income and labor income of the consumers. Due to the implausibility of imposing taxes regarding the ratios of the agents' consumption levels to the economy-wide average level of consumption in reality, the consumption tax is left flat.

The progressivity levels of the tax rates are introduced in a similar way in Koyuncu and Turnovsky (2016):

$$\tau_{k,i} = \zeta_k \left(\frac{rK_i}{rK} \right)^{\phi_k} = \zeta_k \left(\frac{K_i}{K} \right)^{\phi_k} \tag{5a}$$

The tax rate on wages:

$$\tau_{w,i} = \zeta_w \left(\frac{w(1-\ell_i)}{w(1-\ell)} \right)^{\phi_w} = \zeta_w \left(\frac{1-\ell_i}{1-\ell} \right)^{\phi_w} \tag{5b}$$

Here, ϕ_k and ϕ_w specify the levels of progressivity of taxes on the relative capital income and the relative labor income, respectively. ζ_k and ζ_w determine the levels of the tax schedules.[2]

Additionally, τ_c represents the flat tax rate level imposed on consumption and T represents the lump-sum tax collected from each agent.

After describing the tax rates, it is important to note the marginal tax rates which denote the changes in tax rates. As Li and Sarte (2004) states, the marginal tax rates, $\tau_{k,i}^m$ and $\tau_{w,i}^m$, imply that the degree of progressivity of a tax schedule is expressed in terms of the ratio of the marginal tax rate to the imposed tax rate. If this ratio, in this case $1+\phi_k$ or $1+\phi_w$, exceeds 1, the tax schedule is regarded to be progressive:

$$\tau_{k,i}^m = \frac{\partial \tau_{k,i} K_i}{\partial K_i} = (1+\phi_k)\tau_{k,i} \tag{5a'}$$

[2]With $\phi_k = 0$ and $\phi_w = 0$, the agent-specific tax rates simplify to the flat tax rate case.

$$\tau_{w,i}^{m}=\frac{\partial \tau_{w,i}(1-\ell_i)}{\partial(1-\ell_i)}=(1+\phi_w)\tau_{w,i} \tag{5b'}$$

Imposing the tax schedule in (5) to consumers' income, the capital accumulation constraint of the individual i becomes:

$$\dot{K}_i=(1-\tau_{k,i})rK_i+(1-\tau_{w,i})w(1-\ell_i)-(1+\tau_c)C_i-T \tag{6}$$

3.4 Individuals' utility maximization

Maximization of the consumer's utility function with respect to the rate of consumption, leisure and rate of capital accumulation subject to the equation (6) yields the first-order conditions:

$$[C_i^{-\nu}+\theta(X_U\ell_i)^{-\nu}]^{-(\frac{\gamma}{\nu}+1)}C_i^{-(\nu+1)}=\lambda_i(1+\tau_c) \tag{7a}$$

$$\left[C_i^{-\nu}+\theta(X_U\ell_i)^{-\nu}\right]^{-(\frac{\gamma}{\nu}+1)}\frac{\theta(X_U\ell_i)^{-\nu}}{\ell_i}=\lambda_i\omega K\left(1-\tau_{w,i}^{m}\right) \tag{7b}$$

$$r\left(1-\tau_{k,i}^{m}\right)=\beta_i-\frac{\dot{\lambda}_i}{\lambda_i} \tag{7c}$$

where λ_i is the shadow value of private capital and the transversality condition is as below:

$$\lim_{t\to\infty}\lambda_i K_i e^{-\beta_i t}=0 \tag{7d}$$

Then, the TVC implies that the growth rate of the individual's private capital is constrained by:

$$\frac{\dot{K}_i}{K_i}<r(1-\tau_{k,i}^{m}) \tag{7d'}$$

In order to find the ratio of agent i's consumption level to her allocated time to leisure, which is the marginal rate of substitution between consumption and leisure, equation (7b) is divided by equation (7a):

$$\frac{C_i}{\ell_i} = \left[\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}\right]^{\frac{1}{1+\nu}} K\left(1-\tau_{w,i}^m\right)^{\frac{1}{1+\nu}} \tag{8}$$

which can be summarized as: [3]

$$C_i = \ell_i \Omega_i(\ell_i, \ell, z)K;\ \Omega_i(\ell_i, \ell, z) \equiv \left[\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}\right]^{\frac{1}{1+\nu}} \left(1-\tau_{w,i}^m\right)^{\frac{1}{1+\nu}} \tag{8'}$$

3.5 Government

The government finances its investments, G, according to the flow equation below:

$$\dot{K}_G = gY = G \tag{9}$$

Here, g is the share of output assigned to public investment. Since the rates of tax revenues fluctuate in accordance with the changes in capital and labor income distributions, the government also imposes a lump-sum tax (or a lump-sum subsidy), T, to maintain the same g. Thus, the flow equation of new investment is:

$$G = r\int[\tau_{k,i}K_i]\mathrm{d}i + w\int[\tau_{w,i}(1-\ell_i)]\mathrm{d}i + \tau_c C + T \tag{10}$$

where C indicates the aggregate level of consumption.

In order to simplify the complication in this equation, weighted average equations are defined as below:

$$\bar{\tau}_k \equiv \int \tau_{k,i}\frac{K_i}{K}\mathrm{d}i \tag{11a}$$

[3] Agent-specific tax rates obviously lead to different rates of substitution between consumption and leisure, Ω_i, for each agent. This rate is the same for each agent in Chatterjee and Turnovsky (2012) and is equated to the rate of substitution of each others' and to the economy-wide average.

$$\bar{\tau}_w \equiv \int \tau_{w,i} \frac{1-\ell_i}{1-\ell} \mathrm{d}i \tag{11b}$$

$$\bar{\Omega} \equiv \int \left(1-\tau_{w,i}^m\right)^{\frac{1}{1+\nu}} \left[\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}\right]^{\frac{1}{1+\nu}} \frac{\ell_i}{\ell} \mathrm{d}i \tag{11c}$$

Dividing the combination of the equations (8), (10) and (11) by K concludes that:

$$gy = \frac{\dot{K}_G}{K} = r\bar{\tau}_k + \omega\bar{\tau}_w(1-\ell) + \tau_c\bar{\Omega}\ell + \tau y \tag{12}$$

with $T = \tau y$. [4]

[4] $0 < \tau < 1$.

CHAPTER 4

MACROECONOMIC EQUILIBRIUM

Taking the time derivative of the equation (8) yields: [5]

$$\frac{\dot{C}_i}{C_i} = \frac{\dot{\ell}_i}{\ell_i} + \frac{\dot{K}}{K} + \frac{1}{1+\nu}\frac{\phi_w \tau^m_{w,i}}{1-\tau^m_{w,i}}\left(\frac{\dot{\ell}_i}{\ell_i}\frac{\ell_i}{1-\ell_i} - \frac{\dot{\ell}}{\ell}\frac{\ell}{1-\ell}\right) + \frac{1}{1+\nu}\frac{\dot{\omega}}{\omega} + \frac{\nu(1-\varphi)}{1+\nu}\frac{\dot{z}}{z} \quad (13)$$

Then, combination of the equation (7c) and the time derivative of the equation (7a) follow as:

$$\begin{aligned}\beta_i - r\left[1-\tau^m_{k,i}\right] =& \frac{(\gamma+\nu)C_i^{-\nu}}{C_i^{-\nu} + \theta\left(Kz^{1-\varphi}\ell_i\right)^{-\nu}}\frac{\dot{C}_i}{C_i} - (\nu+1)\frac{\dot{C}_i}{C_i} \\ &+ \frac{(\gamma+\nu)\theta(Kz^{1-\varphi}\ell_i)^{-\nu}}{C_i^{-\nu} + \theta\left(Kz^{1-\varphi}\ell_i\right)^{-\nu}}\left(\frac{\dot{\ell}_i}{\ell_i} + \frac{\dot{K}}{K} + (1-\varphi)\frac{\dot{z}}{z}\right)\end{aligned} \quad (14)$$

The agent's capital accumulation constraint can be rewritten by noting (8'):

$$\dot{K}_i = (1-\tau_{k,i})rK_i + (1-\tau_{w,i})w(1-\ell_i) - (1+\tau_c)\ell_i\left[\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}\right]^{\frac{1}{1+\nu}} K\left(1-\tau^m_{w,i}\right)^{\frac{1}{1+\nu}} - T \quad (6')$$

And the combination of (6) and (11) yields the aggregate private capital accumulation constraint in terms of aggregate and weighted terms:

$$\frac{\dot{K}}{K} = (1-\bar{\tau}_k)r + (1-\bar{\tau}_w)\omega(1-\ell) - (1+\tau_c)\bar{\Omega}\ell - \tau y \quad (15)$$

$$\frac{\dot{K}}{K} = (1-g)y(z,l) - \bar{\Omega}(z,\ell,\ell_1)\ell \quad (15')$$

[5]The equation for $\frac{\dot{\omega}}{\omega}$ is given in the Appendix A1.

So, the next three equations can characterize the macroeconomic equilibrium.

If the relative capital of an agent is defined as $k_i \equiv \frac{K_i}{K}$, [6] then its evolution can be described as the combination of (6') and (15):

$$\begin{aligned} \dot{k}_i =& \Big[(1-\tau_{w,i})\omega(1-\ell_i) - (1+\tau_c)\ell_i\Omega_i - \tau y\Big] \\ & - \Big[(\tau_{k,i} - \bar{\tau}_k)r + (1-\bar{\tau}_w)\omega(1-\ell) - (1+\tau_c)\bar{\Omega}\ell - \tau y\Big]k_i \end{aligned} \tag{16}$$

Evolution of the public to private capital ratio in the economy is implied by (12) and (6):

$$\frac{\dot{z}}{z} = \frac{gy(z,l)}{z} - [(1-g)y(z,l) - \bar{\Omega}(z,\ell,\ell_1,\ldots,\ell_N)\ell] \tag{17}$$

Substituting (8) and (13) into (14) results in the evolution of each agent's allocation of time to leisure:[7]

$$\frac{\dot{\ell}_i}{\ell_i} = \frac{\beta_i - r(1-\tau^m_{k,i}) - (\gamma-1)\frac{\dot{K}}{K} - \Gamma_{N,i}(\ell_i,\ell,z)\frac{\dot{\ell}}{\ell} - \Gamma_{O,i}(\ell_i,\ell,z)\frac{\dot{z}}{z}}{\Gamma_{M,i}(\ell_i,\ell,z)} \tag{18}$$

And the evolution of the economy-wide average amount of time devoted to leisure:[8]

$$\frac{\dot{\ell}}{\ell} = \frac{\int \frac{\ell_i E_i}{\Gamma_{M,i}}\mathrm{d}i}{\ell + \int \frac{\ell_i \Gamma_{N,i}}{\Gamma_{M,i}}\mathrm{d}i} \tag{19}$$

[6] $\dot{k}_i = \frac{K_i}{K}\left(\frac{\dot{K}_i}{K_i} - \frac{\dot{K}}{K}\right)$.

[7] The functions denoted by Γ are given in the Appendix A2, A3 and A4

[8]
$$E_i = \beta_i - r(1-\tau^m_{k,i}) - (\gamma-1)\frac{\dot{K}}{K} - \Gamma_{O,i}\frac{\dot{z}}{z}$$

4.1 Balanced growth path characterization

A balanced growth path of the economy can be characterized by setting $\dot{\ell}_i = \dot{\ell} = \dot{z} = \dot{k}_i = 0$ in the equations (16), (17) and (18).

Equations (17) and (18) yield that the steady state growth rates of the aggregate and individuals' private capital levels, ψ, equals:

$$\tilde{\psi} = \frac{\beta_i - r(1 - \tau_{k,i}^m)}{\gamma - 1} = \frac{gy(\tilde{z}, \tilde{\ell})}{\tilde{z}} \tag{20}$$

and conclude that the private capital of an individual i is:

$$\tilde{k}_i = \left[\frac{(\gamma - 1)gy(\tilde{z}, \tilde{\ell})/\tilde{z} + r(\tilde{z}, \tilde{\ell}) - \beta_i}{r(\tilde{z}, \tilde{\ell})(1 + \phi_k)\zeta_k} \right]^{\frac{1}{\phi_k}} \tag{21}$$

Hence, the only individual-specific parameters having effects on the private capital distribution are the individuals' rates of time preference.

Furthermore, equating the equation (16) to zero yields positive correlation between the steady-state levels of private capital and the amount of time devoted to leisure.

$$\begin{aligned} &\left[\frac{\dot{K}}{K} - r(1 - \tau_{k,i}) \right] (k_i - 1) + r(\tau_{k,i} - \bar{\tau}_k) \\ &= \omega \left[(\ell - \ell_i) + (1 - \ell)\bar{\tau}_w - (1 - \ell_i)\tau_{w,i} \right] + (1 + \tau_c)(\bar{\Omega}\ell - \Omega_i \ell_i) \end{aligned} \tag{22}$$

The transversality condition implies the minimum amount of consumption to private capital ratio, $c \equiv \frac{C}{K}$, that must be assigned to obtain a steady growth:

$$\tilde{c}_i > \frac{r(\tilde{z}, \tilde{\ell})\tilde{k}_i \tau_{k,i}(\tilde{k}_i) + \omega(\tilde{z}, \tilde{\ell})(1 - \tau_{w,i}(\tilde{\ell}_i, \tilde{\ell}))(1 - \tilde{\ell}_i) - \tau y(\tilde{z}, \tilde{\ell})}{1 + \tau_c} \tag{23}$$

4.2 Transition path dynamics

Since, c_i's are written in terms of (z, ℓ, ℓ_i) and linearization of the equations of (21) imply that $(z, \ell, \ell_1, \ldots, \ell_N)$(t) determine $k_i(t)$'s; the transition path of the economy can be obtained by linearizing the equations (17) and (18) around the steady-state for an economy consisting of N discrete agents. The linearized equations are described as:

$$\begin{aligned} z(t) &= \tilde{z} + [z(0) - \tilde{z}]e^{\mu t} \\ \ell_i(t) &= \tilde{\ell}_i + \nu_i[z(t) - \tilde{z}] \end{aligned} \tag{24}$$

where μ is the stable root (negative eigenvalue) of the linearized dynamic system given below

$$\begin{bmatrix} \dot{z} \\ \dot{\ell}_1 \\ \vdots \\ \dot{\ell}_N \end{bmatrix} = \begin{bmatrix} \frac{\partial \dot{z}}{\partial z} & \frac{\partial \dot{z}}{\partial \ell_1} & \cdots & \frac{\partial \dot{z}}{\partial \ell_N} \\ \frac{\partial \dot{\ell}_1}{\partial z} & \frac{\partial \dot{\ell}_1}{\partial \ell_1} & \cdots & \frac{\partial \dot{\ell}_1}{\partial \ell_N} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial \dot{\ell}_N}{\partial z} & \frac{\partial \dot{\ell}_N}{\partial \ell_1} & \cdots & \frac{\partial \dot{\ell}_N}{\partial \ell_N} \end{bmatrix} \begin{bmatrix} z(t) - \tilde{z} \\ \ell_1(t) - \tilde{\ell}_1 \\ \vdots \\ \ell_N(t) - \tilde{\ell}_N \end{bmatrix} \tag{25}$$

and ν_i's are the components of the normalized eigenvector corresponding to the negative eigenvalue:

$$\begin{bmatrix} \frac{\partial \dot{z}}{\partial z} & \frac{\partial \dot{z}}{\partial \ell_1} & \cdots & \frac{\partial \dot{z}}{\partial \ell_N} \\ \frac{\partial \dot{\ell}_1}{\partial z} & \frac{\partial \dot{\ell}_1}{\partial \ell_1} & \cdots & \frac{\partial \dot{\ell}_1}{\partial \ell_N} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial \dot{\ell}_N}{\partial z} & \frac{\partial \dot{\ell}_N}{\partial \ell_1} & \cdots & \frac{\partial \dot{\ell}_N}{\partial \ell_N} \end{bmatrix} \begin{bmatrix} 1 \\ \nu_1 \\ \vdots \\ \nu_N \end{bmatrix} = \mu \begin{bmatrix} 1 \\ \nu_1 \\ \vdots \\ \nu_N \end{bmatrix} \tag{26}$$

Recalling the equation (8'), an individual's consumption level per aggregate capital, $c_i = C_i/K$, is:

$$c_i(t) = \ell_i(t) \left[\frac{\omega(t) z(t)^{\nu(1-\varphi)}}{\theta(1+\tau_c)} \right]^{\frac{1}{1+\nu}} \left(1 - \tau^m_{w,i}(t) \right)^{\frac{1}{1+\nu}} \tag{27}$$

Linearization of the equation (21):

$$k_i(t) = \tilde{k}_i(t) + (1 + \sum \nu_j)[z(0) - \tilde{z}]e^{\mu t} \tag{28}$$

The before-tax relative income of the individual i is defined as:

$$y_i^b(t) = \frac{r(t)k_i(t) + \omega(t)(1-\ell_i(t))}{r(t) + \omega(t)(1-\ell(t))} \tag{29}$$

The after-tax relative income of the individual i is defined as:

$$y_i(t) = \frac{r(t)(1-\tau_{k,i}(t))k_i(t) + \omega(t)(1-\tau_{w,i}(t))(1-\ell_i(t)) - \tau(t)y(t)}{r(t)(1-\bar{\tau}_k(t) + \omega(t)(1-\bar{\tau}_w(t))(1-\ell(t)) - \tau(t)y(t)} \tag{30}$$

By using the individual's utility equation, her instantaneous levels of welfare and relative welfare, $W_i^r(t) = W_i(t)/W(t)$, are indicated as:

$$\begin{aligned} W_i(t) &= \frac{1}{\gamma}(\ell_i(t)K(t))^{\gamma}[\Omega_i(t)^{-\nu} + \theta z(t)^{-\nu(1-\varphi)}]^{-\gamma/\nu} \\ W_i^r(t) = \frac{W_i(t)}{W(t)} &= \left(\frac{\Omega_i(t)^{-\nu} + \theta z(t)^{-\nu(1-\varphi)}}{\bar{\Omega}(t)^{-\nu} + \theta z(t)^{-\nu(1-\varphi)}}\right)^{-\gamma/\nu}\left(\frac{\ell_i(t)}{\ell(t)}\right)^{\gamma} \end{aligned} \tag{31}$$

4.3 Distributional dynamics

Distributions of the individual-specific variables are defined in terms of coefficients of variation:

$$\sigma_\xi(t) = \frac{s_\xi(t)}{\eta_\xi(t)} \tag{32}$$

where s_ξ and η_ξ stand for respectively standard deviations and means of parameters $\xi \in \{k, \ell, c, W, y^b, y\}$. If the economy has a transition path, i.e. there is a unique negative eigenvalue in the equation (25), all ξ_i(t)'s, thus σ_ξ(t)'s are obtainable.

CHAPTER 5
NUMERICAL ANALYSIS

Numerical analyses of the model are done to trace the effects of a government expenditure increase on GDP growth and distributional means. The benchmark parameterization of the model is done by imposing progressive taxes on capital income and labor income to finance public expenditures, a deviation from Chatterjee and Turnovsky (2012) in which a lump-sum tax is used in doing so. Then, for the benchmark tax progressivity level, a government expenditure shock is given to the economy financed by alternative tax schemes; namely through (a) a combination of capital income tax (τ_k) and labor income tax (τ_w), (b) a flat consumption tax (τ_c), (c) a flat lump-sum tax (τ), (d) a capital income tax (τ_k) and (e) a labor income tax (τ_w). Subsequently, responses of the economy under different tax progressivity levels are analyzed.

Table 1 gives the paramater values used for the calibration. Many parameter values in the utility and production functions are chosen as they were done in Chatterjee and Turnovsky (2012), since they yield results consistent with empirical literature. Another reason for these choices is to capture the effects of tax progressivity by making a comparison with their model that uses flat tax rates to finance public expenditures. In this model, the agents are decomposed into five classes which can be regarded as quintiles of the economy in terms of wealth. Their rates of time preference are chosen around the standard $\beta = 0.04$. [9]

[9]Rates of time preference are not calibrated to mimic the aspects of real economies, since the scope of this study is to construct a model to express that it is possible to alleviate income (and welfare) inequality without harming GDP growth through public expenditures, an evidence captured in the empirical literature. Making such a calibration may be useful for a further policy oriented study.

Table 1: Parameter Values for the benchmark economy

Parameter	Description	Value(s)
$e = 1/(1-\gamma)$	Inter-temporal elasticity of substitution	0.4
θ	The relative weight of leisure in utility	1.75
$q = 1/(1+\nu)$	Intra-temporal elasticity of substitution between consumption and leisure in the utility function	1
A	Technology shift parameter	0.6
α	Share of efficiency units of labor	0.6
$s = 1/(1+\rho)$	Elasticity of substitution in production between capital and effective units of labor	1
ε,φ	Geometric weight of the aggregate private capital in the aggregate composite externalities	0.6
β_i	Rates of time preference	0.036, 0.038, 0.040, 0.042, 0.044

Table 2 and Table 3 yield the effects of changing financing policy from flat lump-sum taxes to progressive capital income and labor income taxes. Here, levels of tax progressivity are chosen to be equal to conventional 0.75. The model in this thesis matches the findings in previous studies on progressive taxation; such as having more average time devoted to leisure, a diminished growth rate and a higher steady-state output-private capital ratio. Additionally, it is found that the steady state public-private capital ratio has to be larger in case of progressive taxes.

Table 2: Benchmark Calibrations

	g	Level of tax schedule	Tax progressivity
This paper	0.05	$\zeta_k = 0.05$; $\zeta_w = 0.05$	$\phi_k = 0.75$; $\phi_w = -0.75$
CT2012	0.05	$\tau = 0.05$	n/a

Table 3: Steady State Values for the Benchmark Economies

Policy	$\tilde{z}$	$\tilde{\ell}$	$\tilde{y}$	$\tilde{\psi}(\%)$
This paper	0.611	0.719	0.249	2.04
CT2012	0.531	0.714	0.243	2.29

A shortcoming of the model is having same wage rate per unit labor supply, a phenomena observed in most of the growth literature. Expectedly, this leads to an unrealistic result, optimality of regressive labor income taxes.

Adding variables affecting human capital, i.e. skill-heterogeneity, may overcome this drawback and make the model closer to the reality but since empirical studies revealed that human capital has little to do with public capital productivity this drawback seems not to be a big one.

5.1 An increase in the rate of public expenditures

Upon the five percent benchmark rate of public expenditures, consistent with corresponding rates in OECD countries, an instantaneous shock of an additional three percentage points is given to the economy through aforementioned tax schemes.

Table 4 summarizes the effects of a three percentage points government expenditure shock on all aggregate and distributional parameters in all tax schemes for the benchmark tax progressivity level. As it can be seen in the table, a change in the level of the capital income tax schedule has the strongest effects for all aggregate and distributional parameters. Thus, it should be regarded as the most effective tool, in terms of the tendency of being growth-favoring or equality-favoring, for financing public expenditures.

Table 4: Effects of Public Expenditure Shocks under Fixed Tax Progressivity

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
$(\phi_k = 0.75)$	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
$(\phi_w = -0.75)$	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
$\tilde{z}$	0.611	0.987	0.910	0.901	1.141	0.905
$\tilde{W}$	1.250	1.481	1.439	1.421	1.567	1.430
$\tilde{y}$	0.249	0.282	0.274	0.279	0.292	0.277
$\tilde{\ell}$	0.719	0.714	0.718	0.710	0.715	0.713
$\tilde{\psi}$ (%)	2.036	2.289	2.414	2.475	2.044	2.447
$\tilde{\sigma}_k$	47.85	26.64	43.51	42.84	16.47	43.01
$\tilde{\sigma}_W$	5.72	3.07	5.12	5.24	1.72	5.31
$\tilde{\sigma}_y$	7.82	2.49	7.11	7.26	1.19	6.25
$\tilde{\sigma}_\ell$	5.70	3.05	5.10	5.22	1.72	5.26

5.1.1 Aggregate Effects

A comparison of the steady state effects of the shock on the rate of government expenditures is given in Table 5. The shock leads to a higher growth rate when it is not financed solely by an increase in the capital income tax rate, the most influent tax type on hampering economic growth. Alleviating inequality levels by increasing public expenditures through capital income tax increases comes with a cost. A more egalitarian policy results in a higher reduction in economic growth. The level of capital income tax progressivity has the key role for such policies. Due to the negative effect of progressive taxes on the aggregate labor supply, growth rate of the economy instantaneously decreases. Then, as public capital increases, growth rate recovers alongside the transition path. If the capital income tax progressivity level is low enough, after-shock growth rate of the economy exceeds its pre-shock level. But, above a threshold progressivity level, positive effects of the public policy will not be sufficient to offset the initial reduction.

Table 5: Steady State Growth Rates (%) after Each Shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	2.06	2.33	2.44	2.50	2.13	2.46
(0.75,-0.75)	2.04	2.29	2.41	2.48	2.04	2.45
(1.125,-1.125)	2.00	2.23	2.38	2.43	1.92	2.44

Table 6 presents the after-shock output-capital ratios. The output-capital ratio increases after the shock in all cases. This is mainly driven by productivity enhancing effect of new public capital. Level of tax progressivity has also an augmenting effect on private capital productivity. Among the given tax schemes, financing through capital income tax has also the highest effect on private capital productivity when tax progressivity is left constant.

Table 6: Steady State Output-Private Capital Ratios after Each Shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	0.246	0.278	0.272	0.275	0.286	0.273
(0.75,-0.75)	0.249	0.282	0.274	0.279	0.292	0.277
(1.125,-1.125)	0.252	0.289	0.278	0.282	0.300	0.283

Table 7 presents after-shock steady state public-private capital ratios. When a three percentage point public expenditure shock is imposed, in all cases, a higher tax progressivity level generates a faster increase in public-private capital ratio in the short run and a higher equilibrium rate at the steady state.

Table 7: Steady State Public-Private Capital Ratios after Each Shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	0.596	0.956	0.890	0.883	1.075	0.888
(0.75,-0.75)	0.611	0.987	0.910	0.901	1.141	0.905
(1.125,-1.125)	0.629	1.036	0.937	0.928	1.251	0.926

Table 8 summarizes the long run levels of normalized average welfare. Here, averages of welfare levels of individuals, defined in the equations (31), are divided by the amount of aggregate capital in the economy and normalized by equating its pre-shock level in the benchmark parameterizationto 1. The government expenditure increase has a positive impact on average welfare in the economy in all cases, with capital income tax being the most influential policy. A higher level of tax progressivity is also seen as an instrument to enhance average welfare. Welfare gain is also seen to be mostly driven by increases in quality of leisure time due to higher public-private capital ratio.

Table 8: Steady State Normalized Average Welfare after Each Shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	0.994	1.174	1.144	1.133	1.227	1.142
(0.75,-0.75)	1.000	1.185	1.152	1.138	1.254	1.144
(1.125,-1.125)	1.001	1.202	1.161	1.150	1.297	1.148

5.1.2 Distributional Effects

With the introduction of progressive taxes in financing new public expenditures; an increase in the growth rate of economy and alleviations in income, wealth and welfare inequalities can be achieved at the same time. In other words, negative effects of distortionary taxes, used to finance public expenditures, on distributional measures can be reversed when they are collected at progressive rates instead of flat rates. Also, only capital income tax has significant effects on all distributional measures.

As a result of this, new public expenditures should be financed by progressive capital taxes if inequality mitigation is aimed. This is feasible as far as the progressivity level is lower than a threshold level above which an undesired growth lowering effect is expected to be the result of this policy. Also, a huge amount of public-private capital ratio, i.e. size of the government, increase has to get along with this policy.

Imposing new progressive taxes increases the incentive to work more for the richer agents. And due to its nature, unlike weak variables like labor supply choice and consumption choice, an individual's private capital, which is an accumulable variable, can not have instantaneous jumps. Thus, any of the aforementioned policies causes income inequality to instantaneously rise when the policy is implemented due to the jumps in the labor supply decisions of the individuals. Then; as the dispersion of wealth gradually decreases, together with a decline in the dispersion of capital income, income dispersion decreases along the transition path. At the steady-state it falls down below its pre-shock level in all cases. In Table 9 and in Table 10, steady state wealth and income inequality levels are given:

Table 9: Steady State Wealth Distributions (%) after Each Shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	80.3	46.6	73.6	72.7	29.2	73.5
(0.75,-0.75)	47.8	26.6	43.5	42.8	16.4	43.0
(1.125,-1.125)	26.2	14.3	23.8	23.5	8.81	23.5

Table 10: Steady State Income Distributions (%) after Each Shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	14.3	6.60	13.4	13.7	2.73	12.6
(0.75,-0.75)	7.82	2.49	7.11	7.26	1.19	6.25
(1.125,-1.125)	3.51	1.09	3.12	3.18	0.48	2.18

When the government expenditure shock is imposed, dispersion of welfare instantaneously declines due to the declines in the distributions of both consumption and leisure choices. Then, as the dispersion of wealth decreases, it augments leisure choice dispersion. Thus, the dispersion of welfare increases along the transition path, but in all cases its final level is found to be lower than its benchmark level. Table 11 represents the steady state welfare distributions:

Table 11: Steady State Welfare Distributions (%) after Each Shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	9.69	5.48	8.77	8.95	3.17	9.12
(0.75,-0.75)	5.70	3.05	5.10	5.22	1.72	5.26
(1.125,-1.125)	3.04	1.56	2.71	2.77	0.86	2.75

Appendix B of this thesis is reserved for the figures depicting the short run effects of the public expenditure rate shocks and the responses of the economy alongside the transition paths. Figures 1-5 correspond to the responses of the economy until it reaches its balanced growth phase, summarized in Table 4, in case of a shock under fixed tax progressivity. Figures 6-12 represent the effects of financing new public expenditures through a capital income tax rate increase on aggregate and distributional parameters at the instant of a shock and alongside the transition paths for three different capital income tax progressivity levels. The directions of the responses in these figures are expected to be consistent with reality but since calibrating the agents' rates of time preferences to match the real economies are left beyond the scope of this thesis, one should expect exaggerated quantities in the responses.

CHAPTER 6

CONCLUSION

In this thesis; two branches of the growth literature, productive government expenditures and progressive taxation, are combined to lay down a model to analyze the growth and inequality effects of public expenditures. Short-run and long-run effects of government expenditure shocks and tax progressivity on aggregate parameters (public-private capital ratio, average welfare, private capital productivity and growth rate of the economy) and distributional measures (income dispersion, wealth dispersion and welfare dispersion) are analyzed.

The model used in this paper is a continuous-time endogenous growth model consisting of agents heterogeneous in their time preferences and supplying labor elastically. It is found that the most influential financing method on both aggregate and distributional measures is the capital income tax. Following an increase in the public expenditures, income inequality instantaneously increases due to changes in labor-supply decisions of the agents and then decreases below the before-shock levels in all cases. An increase in public expenditures also decreases welfare and wealth inequality while affecting average welfare positively both in the short-run and in the long-run. Its effects are ambiguous on the growth rate of the economy. When it is financed by highly progressive capital income taxes, the growth rate of the economy may be diminished together with respectable amounts of alleviations in distributional measures. Thus; through government expenditure increases, important alleviations in income, wealth and welfare distributions can be achieved without harming economic growth, below a threshold level of capital income tax progressivity. These effects are found to be accompanied by doubling the public-private capital ratio.

The model employed in this thesis is mainly applicable to advanced economies. It can be further improved to include decomposition of public capital, since it is found in the empirical studies that different components of public goods have different effects depending on the level of development of an economy. Institutional quality is another aspect causing differences in the outcomes of such policies depending on the development level. Thus, institutional quality can be integrated into this model in order such a generalization to be obtained. Although it is found to be ineffective on growth-public capital relationship, introducing human capital heterogeneity among agents can overcome the deficiency of having constant wage rate per unit of labor supply. Finally and most importantly, calibrating the model to match the behaviors of real economies would yield beneficiary outcomes for policy orientations.

APPENDIX A

EQUATIONS

The evolution of the wage rate per aggregate private capital:

$$
\begin{aligned}
\frac{\dot{\omega}}{\omega} =&(1+\rho)\left\{\frac{\alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}}{(1-\alpha)+\alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}}\right\}\left[(1-\varepsilon)\frac{\dot{z}}{z}-\frac{\dot{\ell}}{\ell}\frac{\ell}{1-\ell}\right] \\
&-\rho(1-\varepsilon)\frac{\dot{z}}{z}+(1+\rho)\frac{\dot{\ell}}{\ell}\frac{\ell}{1-\ell}
\end{aligned}
\tag{A1}
$$

The coefficients in the equation (18):

$$
\begin{aligned}
\Gamma_{M,i} =&\Big[M_{1,i}(\ell_i,\ell)\Xi_i(\ell_i,\ell,z)+M_{2,i}(\ell_i,\ell)\Lambda_i(\ell_i,\ell,z)\Big] \\
\Gamma_{N,i} =&\Big[N_{1,i}(\ell_i,\ell,z)\Xi_i(\ell_i,\ell,z)+N_{2,i}(\ell_i,\ell,z)\Lambda_i(\ell_i,\ell,z)\Big] \\
\Gamma_{O,i} =&\Big[O_1(\ell,z)\Xi_i(\ell_i,\ell,z)+O_2(\ell,z)\Lambda_i(\ell_i,\ell,z)\Big]
\end{aligned}
\tag{A2}
$$

$$
\begin{aligned}
\Xi_i(\ell_i,\ell,z) =&\frac{\left\{\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}(1-\tau^m_{w,i})\right\}^{\frac{-\nu}{1+\nu}}}{\left\{\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}(1-\tau^m_{w,i})\right\}^{\frac{-\nu}{1+\nu}}+\theta z^{-\nu(1-\varphi)}} \\
\Lambda_i(\ell_i,\ell,z) =&\frac{\theta z^{-\nu(1-\varphi)}}{\left\{\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}(1-\tau^m_{w,i})\right\}^{\frac{-\nu}{1+\nu}}+\theta z^{-\nu(1-\varphi)}}
\end{aligned}
\tag{A3}
$$

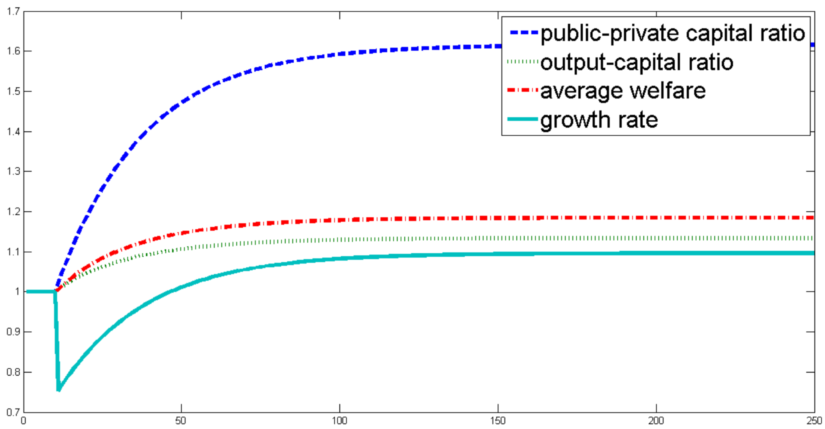
$$
\begin{aligned}
M_{1,i}(\ell_i,\ell) =& \left[(\gamma-1)+\frac{\gamma-1}{\nu+1}\frac{\phi_w\tau^m_{w,i}}{1-\tau^m_{w,i}}\frac{\ell_i}{1-\ell_i}\right]\\
M_{2,i}(\ell_i,\ell) =& \left[(\gamma-1)-\frac{\phi_w\tau^m_{w,i}}{1-\tau^m_{w,i}}\frac{\ell_i}{1-\ell_i}\right]\\
N_{1,i}(\ell_i,\ell,z) =& -\frac{\gamma-1}{1+\nu}\left[\frac{\phi_w\tau^m_{w,i}}{1-\tau^m_{w,i}}-\frac{(1+\rho)(1-\alpha)}{(1-\alpha)+\alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}}\right]\frac{\ell}{1-\ell}\\
N_{2,i}(\ell_i,\ell,z) =& \left[\frac{\phi_w\tau^m_{w,i}}{1-\tau^m_{w,i}}-\frac{(1+\rho)(1-\alpha)}{(1-\alpha)+\alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}}\right]\frac{\ell}{1-\ell}\\
O_1(\ell,z) =& \frac{\gamma-1}{\nu+1}\left[\nu(1-\varphi)+(1-\varepsilon)-\frac{(1-\varepsilon)(1+\rho)(1-\alpha)}{(1-\alpha)+\alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}}\right]\\
O_2(\ell,z) =& -\left[\nu(1-\varphi)+(1-\varepsilon)-\frac{(1-\varepsilon)(1+\rho)(1-\alpha)}{(1-\alpha)+\alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}}\right]
\end{aligned}
\tag{A4}
$$

APPENDIX B

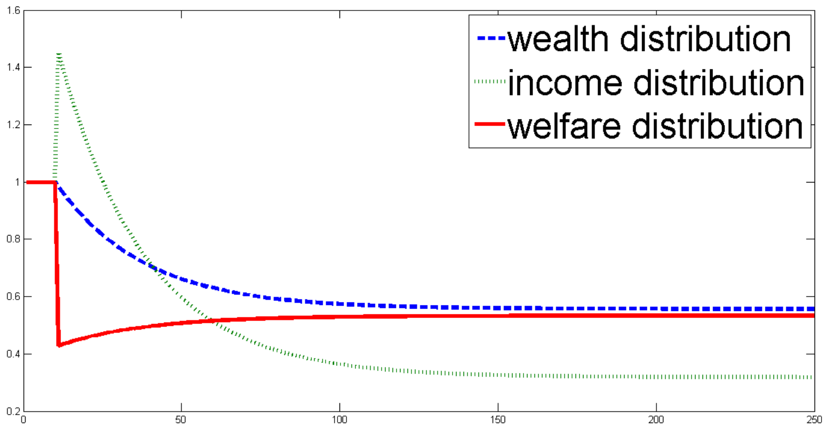
FIGURES

Transition Paths under Fixed Tax Progressivity:

In this part, transition paths for the government expenditure shocks imposed on $(g, \zeta_k, \zeta_w, \phi_k, \phi_w) = (0.05, 0.05, 0.05, 0.75, -0.75)$ according to the taxation methods in Table 4 are given.

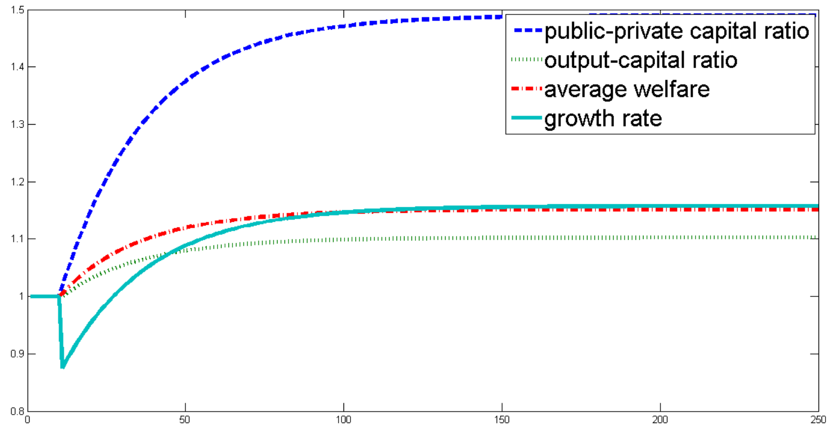


(a) Aggregate effects

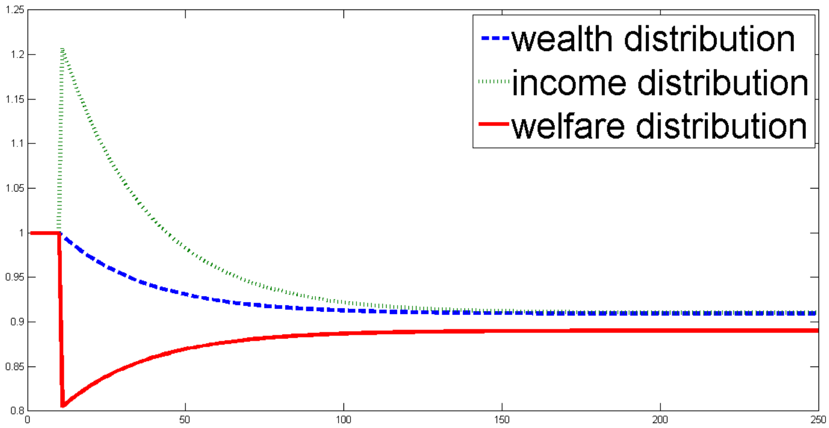


(b) Distributional effects

Figure 1: Financing through a Combined Income Tax Increase

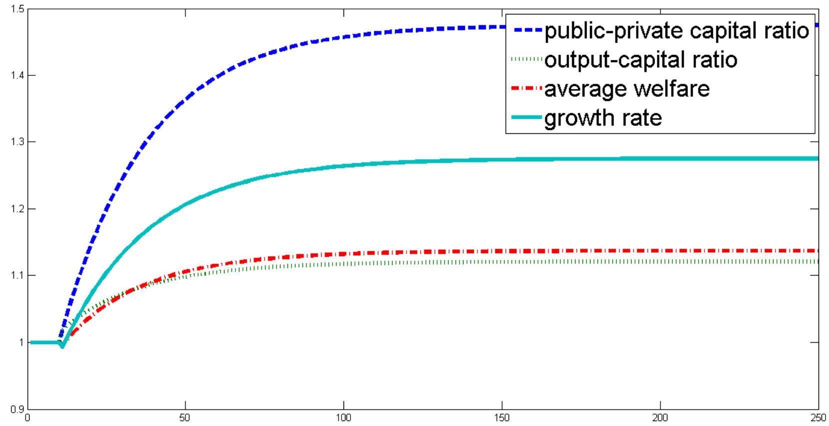


(a) Aggregate effects

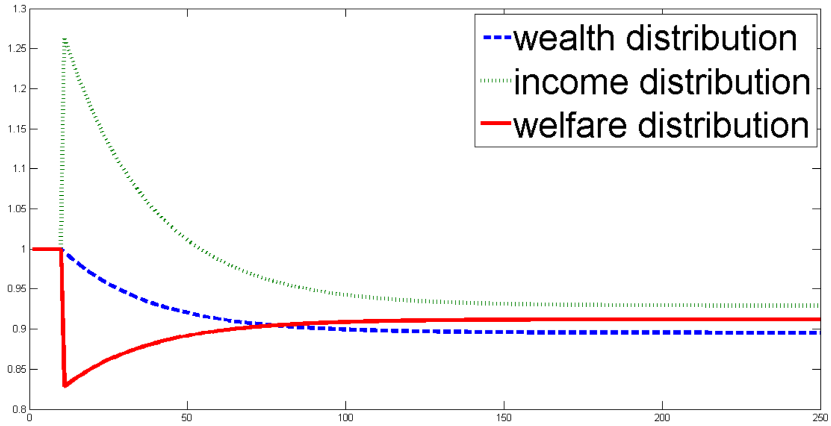


(b) Distributional effects

Figure 2: Financing through a Consumption Tax Increase

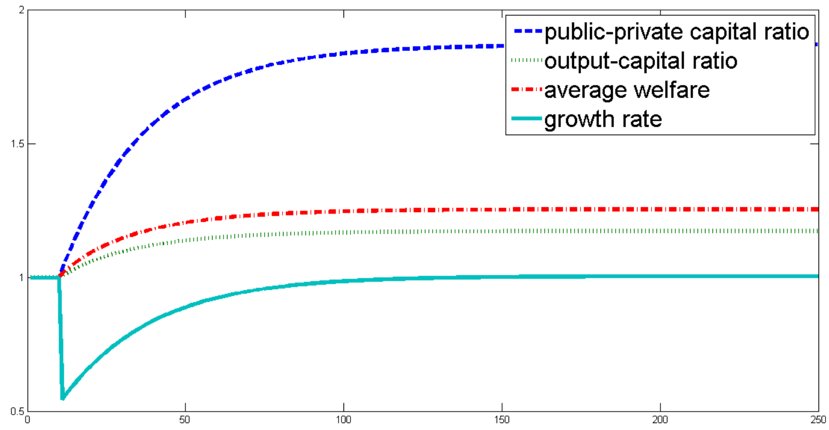


(a) Aggregate effects

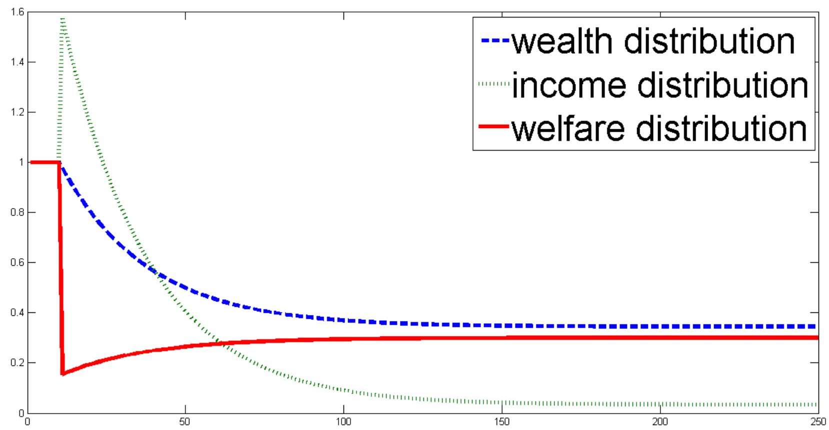


(b) Distributional effects

Figure 3: Financing through a Lump-sum Tax Increase

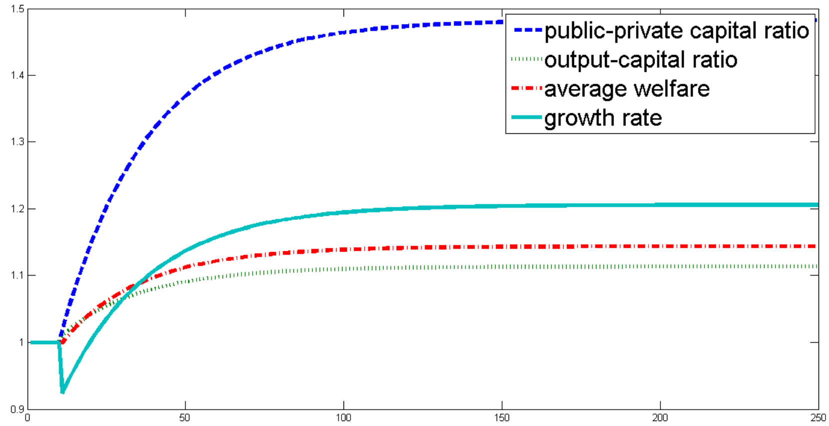


(a) Aggregate effects

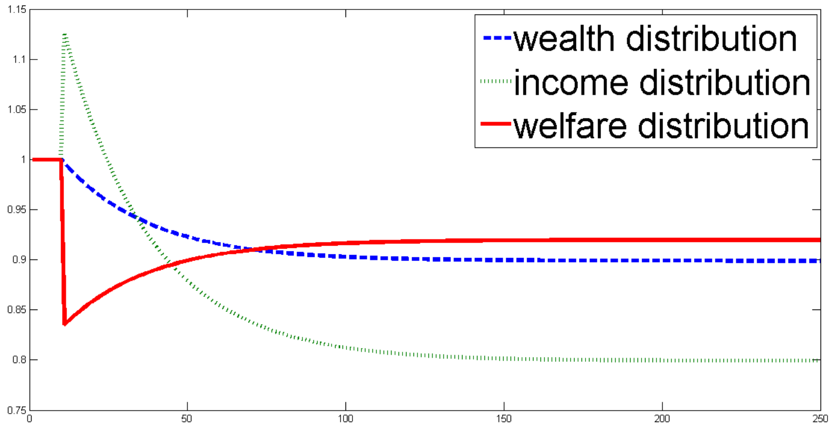


(b) Distributional effects

Figure 4: Financing through a Capital Income Tax Increase



(a) Aggregate effects



(b) Distributional effects

Figure 5: Financing through a Labor Income Tax Increase

Transition Paths for the $\zeta_k = 0.125$ Shocks:

In this part, transition paths for the government expenditure shocks financed by capital income tax increases are given. The shocks are from $(g, \zeta_k, \phi_k) = (0.05, 0.05, 0.5)$ to $(g, \zeta_k, \phi_k) = (0.08, 0.125, 0.5)$, from $(g, \zeta_k, \phi_k) = (0.05, 0.05, 0.75)$ to $(g, \zeta_k, \phi_k) = (0.08, 0.125, 0.75)$ and from $(g, \zeta_k, \phi_k) = (0.05, 0.05, 1.125)$ to $(g, \zeta_k, \phi_k) = (0.08, 0.125, 1.125)$

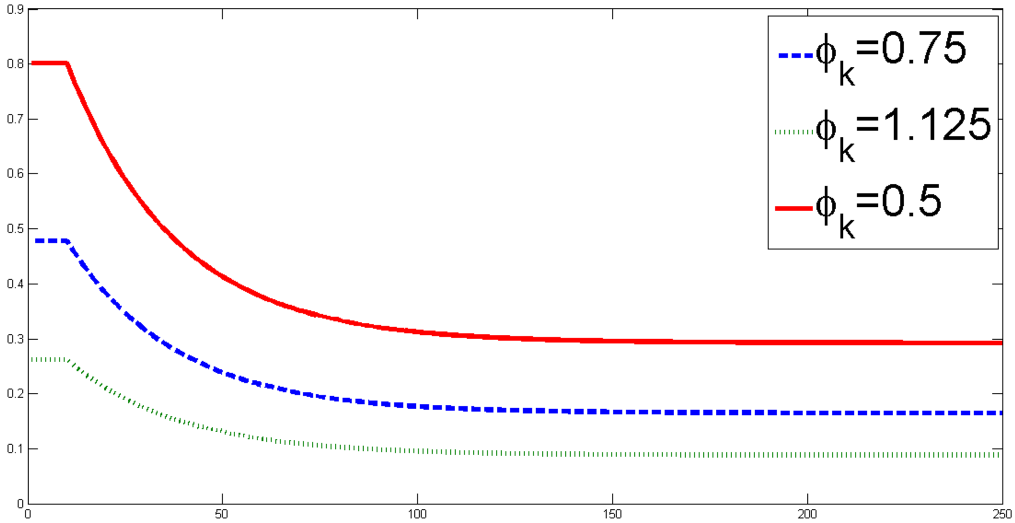


Figure 6: Transition Paths for Wealth Distribution

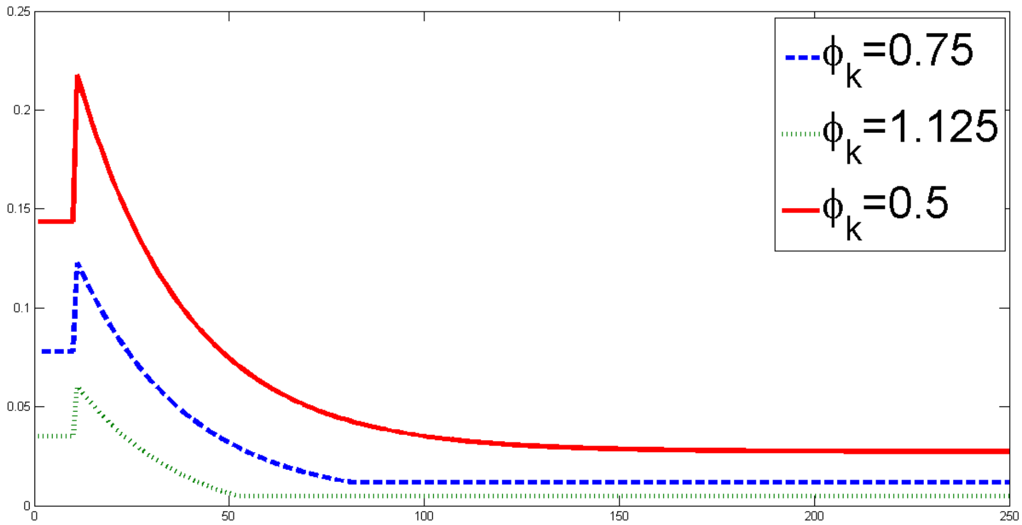


Figure 7: Transition Paths for Income Distribution

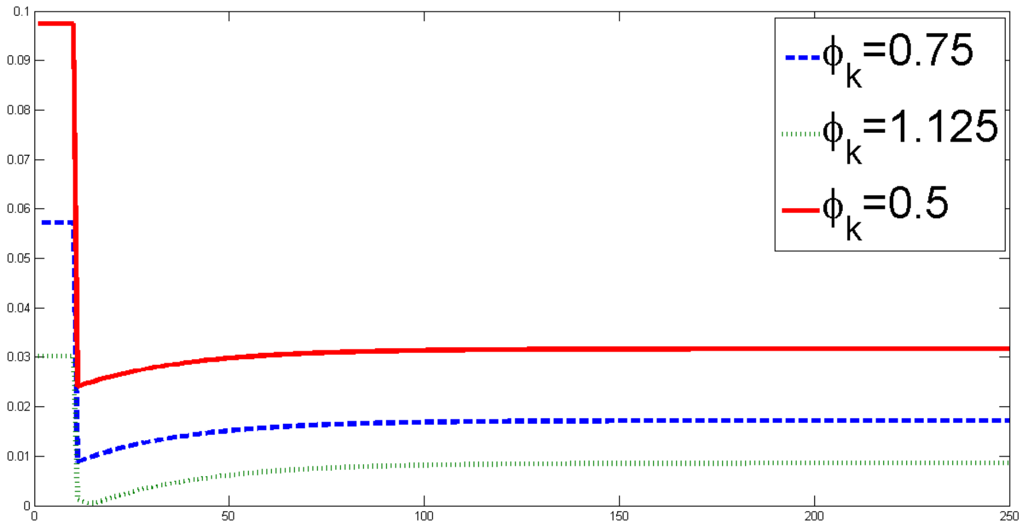


Figure 8: Transition Paths for Welfare Distribution

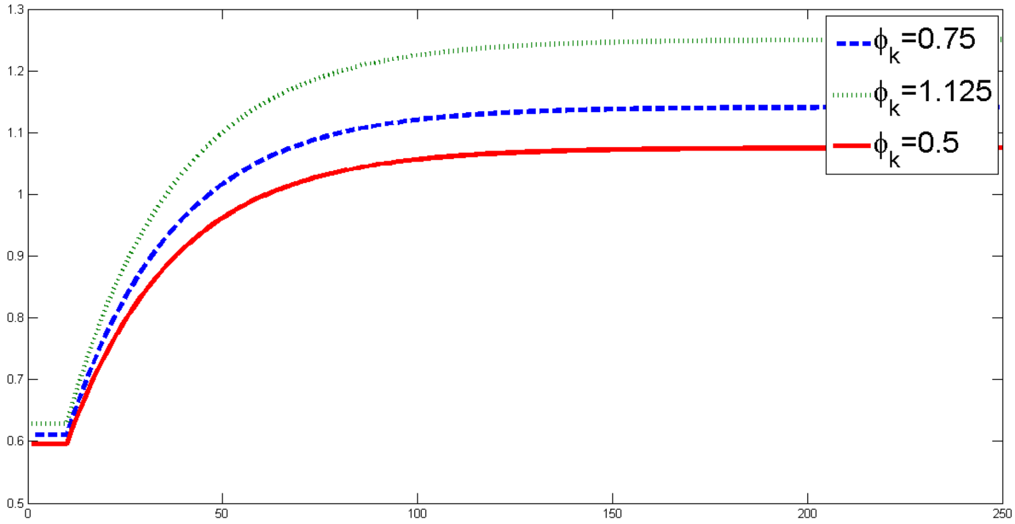


Figure 9: Transition Paths for Public-Private Capital Ratio

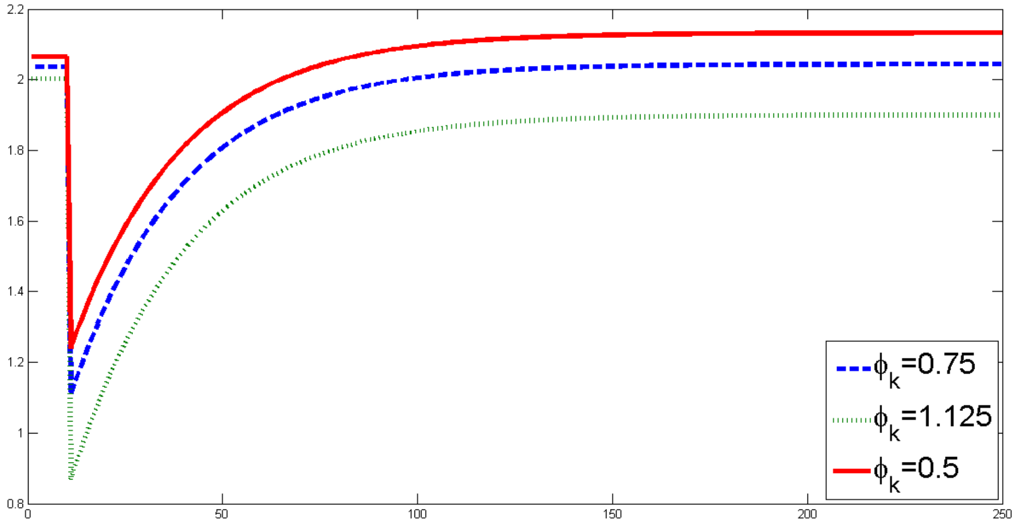


Figure 10: Transition Paths for Growth Rate (%)

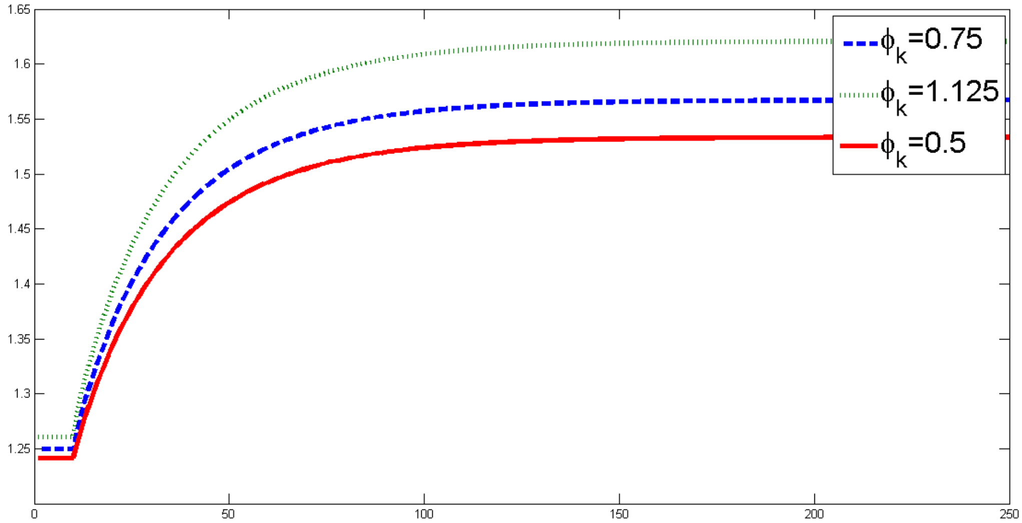


Figure 11: Transition Paths for Average Welfare

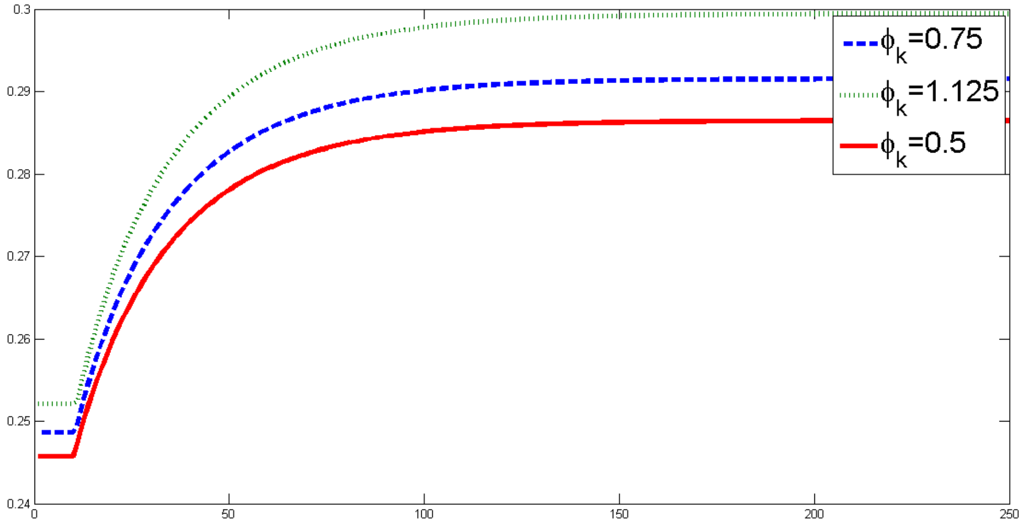


Figure 12: Transition Paths for Output-Capital Ratio

REFERENCES

Agénor, P.-R. (2009). Infrastructure investment and maintenance expenditure: Optimal allocation rules in a growing economy. *Journal of Public Economic Theory*, 11, pp. 233–50.

Agénor, P.-R. (2010). A theory of infrastructure-led development. *Journal of Economic Dynamics and Control*, 34, pp. 932–50.

Agénor, P.-R. (2011). Schooling and public capital in a model of endogenous growth. *ECCA Economica*, 78(309), 108-132.

Agénor, P.-R., Neanidis, K. C. (2015). Innovation, public capital and growth. *Journal of Macroeconomics*, 44, 252-275.

Agénor, P.-R., Neanidis, K. C. (2011). The allocation of public expenditure and economic growth. *The Manchester School*, 79(4), 899-931.

Angyridis, C. (2014). Endogenous growth with public capital and progressive taxation. *Macroeconomic Dynamics*, 19(06), 1220-1239.

Arslanalp, S., Bonhorst, F., Gupta, S., Sze, E. (2010). Public capital and growth. *IMF Working Paper 10/175.*

Aschauer, D. (1989). Is government spending productive?. *Journal of Monetary Economics*, 23, pp. 177–200.

Ashraf, Q., Lester, A., Weil, D. N. (2008). When does improving health raise GDP?. *Cambridge, MA: National Bureau of Economic Research*

Baldacci, E., et al. (2008). Social spending, human capital and growth in developing countries. *World Development*, 36(8): 1317-1341.

Balducci, R. (2005). Public expenditure and economic growth : a critical extension of Barro's (1990) model.

Barro, R. J. (1990). Government spending in a simple model of exogenous growth. *Journal of Political Economy*, 98, pp. 103-125.

Barro, R. J., Sala-í-Martin, X. (1992). Public finance in models of economic growth. *Review of Economic Studies*, 59(4), 645-661.

Benos, N. (2009). Fiscal policy and economic growth : Empirical evidence from EU countries. *MPRA Paper No. 19174.*

Bhargava, A., et al. (2001). Modeling the effects of health on economic growth. *Journal of Health Economics*, 20(3): 423-440.

Blackburn, K., Bose, N. and Haque, M. E. (2011). Public expenditures, bureaucratic corruption and economic development. *The Manchester School*, 79(3).

Bloom, D. E., Canning, D., Sevilla, J. (2004). The effect of health on economic growth: A production function approach. *World Development*, 32 (1), pp. 1-13.

Bohn, F. (2007). Polarisation, uncertainty and public investment failure. *European Journal of Political Economy*, 23(4), 1077-1087.

Bom, P., Ligthart, J. E. (2010). What have we learned from three decades of research on the productivity of public capital? *CESifo Working Paper Series No. 2206*

Bose, N., et al. (2007). Public expenditure and economic growth: A disaggregated analysis for developing countries. *The Manchester School*, 75(5): 533-556.

Cadot, O., Röller, L. H., Stephan A. (2006). Contribution to productivity or pork-barrel? The two faces of infrastructure investment. *Journal of Public Economics*, 90(6-7), pp. 1133–1153.

Calderón, C. (2009). Infrastructure and growth in Africa. *Policy Research Working Paper No. 4914.*

Calderon, C., Serven, L., (2004). The effects of infrastructure development on growth and income distribution. *World Bank Policy Research Paper No. 3400.*

Calderón, C., Moral-Benito, E. and Servén, L. (2015). Is infrastructure capital productive? A dynamic heterogeneous approach. *Journal of Applied Econometrics*, 30(2), 177-198.

Candelon, B., Colletaz, G. and Hurlin, C. (2013). Network effects and infrastructure productivity in developing countries. *Oxford Bulletin of Economics and Statistics*, 75(6), 887-913.

Chakraborty, S., Dabla-Norris, E. (2009). The quality of public investment.

Chatterjee, S., Turnovsky, S. J. Infrastructure and inequality. (2012). *European Economic Review*, 56, Issue 8, November, pp. 1730-1745.

Czernich, N., Falck, O., Kretschmer, T., Woessmann, L. (2011). Broadband infrastructure and economic growth. *The Economic Journal*, 121(552), 505-532.

Devarajan, S., Swaroop, V., Zou, H. F. (1996). The composition of public expenditure and economic growth. *Journal of Monetary Economics*, 37, 313–144.

Dioikitopoulos, E. and Kalyvitis, S. (2008). Public capital maintenance and congestion: Long-run growth and fiscal policies. *Journal of Economic Dynamics and Control*, 32(12), 3760-3779.

Égert, B., Kozluk, T. and Sutherland, D. (2009). Infrastructure and growth: Empirical evidence. *OECD Economics Department Working Paper No. 685*

Esfahani, H., Ramírez, M. (2003). Institutions, infrastructure and economic growth. *Journal of Development Economics*, 70 (2), pp. 443-477.

Estache, A., Speciale, B., Veredas, D. (2008). How much does infrastructure matter to growth in Sub-Saharan Africa?

Fisher, W. H., Turnovsky, S. J. (1995). The Composition of government expenditure and its consequences for macroeconomic performance. *Journal of Economic Dynamics and Control*, 19(4), 747-786.

Futagami, K., Morita, Y., Shibata, A. (1993). Dynamic analysis of an endogenous growth model with public capital. *Scandinavian Journal of Economics*, 95, pp. 607-625.

Ghosh, S., Gregoriou, A. (2010). Can corruption favour growth via the composition of government spending?. *Economics Bulletin*, 30(3), 1-8.

Gupta, S., et al. (2014). Efficiency-adjusted public capital and growth. *World Development*, 57: 164-178.

Kalaitzidakis, P., Kalyvitis, S. (2004). On the macroeconomic implications of maintenance in public capital. *Journal of Public Economics*, 88(3-4), 695-712.

Koyuncu, M., Turnovsky, S. J. (2016). The dynamics of growth and income inequality under progressive taxation. *Journal of Public Economic Theory*, 18(4), 560-588.

Li, W., Sarte, P.-D. (2004). Progressive taxation and long-run growth. *American Economic Review*, 94(5), pp. 1705-1716.

Lloyd-Braga, T., Modesto, L. and Seegmuller, T. (2008). Tax rate variability and public spending as sources of indeterminacy. *Journal of Public Economic Theory*, 10(3), 399-421.

Lopez, H., (2004). Macroeconomics and inequality: Macroeconomic challenges in low income countries. *The World Bank Research*

Workshop.

Monteiro, G. and Turnovsky, S. J. (2008). The composition of productive government expenditure: Consequences for economic growth and welfare. *Indian Growth and Development Review*, 1(1), 57-83.

Padovano F., Galli, E. (2002). Comparing the growth effects of marginal vs. average tax rates and progressivity. *European Journal of Political Economy*, 18, 529–544

Pintea, M., Turnovsky, S. J. (2006). Congestion and fiscal policy in a two-sector economy with public capital: A quantitative assessment. *Computational Economics*, 28, 177-209.

Rajkumar, A. S., Swaroop, V. (2008). Public spending and outcomes: Does governance matter? *Journal of Development Economics Journal of Development Economics*, 86(1), 96-111.

Reinikka, R., Svensson, J. (2002). Coping with poor public capital. *Journal of Development Economics*, 69(1), 51-69.

Rioja, F. K. (1999). Productiveness and welfare implications of public infrastructure: A dynamic two-sector general equilibrium analysis. *Journal of Development Economics*, 58(2), 387-404.

Röller, L.-H., Waverman, L. (2001). Telecommunications infrastructure and economic development: A simultaneous approach. *American Economic Review*, 91 (4), 909-923.

Turnovsky, S. J. (2000a). Fiscal Policy, elastic labor supply, and endogenous growth. *Journal of Monetary Economics*, 45(1), 185-210.