Sectoral Infrastructure Investment In An Unbalanced Growing Economy: The Case Of India*

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November 1, 2011

Abstract

We construct a two sector dynamic general equilibrium model to study the sectoral allocation of public infrastructure investments in the agriculture and manufacturing sectors in India. In addition to the changing employment and output shares of these two sectors, the capital output ratio in agriculture in India has fallen while it has risen in manufacturing. To match these observations we construct a model that deviates from the usual Cobb-Douglas assumption in technologies and allows for a CES production function. We conduct several policy experiments on the fraction of GDP allocated to public infrastructure investment and on its sectoral allocation across agriculture and manufacturing. While the model is able to explain the pattern of structural transformation in India qualitatively, we find that the ability of the model to match the data depends crucially on the income elasticities for the two goods generated by the underlying utility functions.

*We are grateful to the Policy and Planning Research Unit (PPRU) Committee for financial assistance related to this project. Gerhard Glomm gratefully acknowledges very generous hospitality from the ISI during his visit in December 2008.

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1 Introduction

This paper studies the effects of public infrastructure investment in an unbalanced growing economy that is undergoing fundamental changes in the structure of production and employment. There is a large literature on how the process of development is characterized by fundamental changes in the structure of production and employment. In advanced capitalist economies for instance, the magnitude of structural change is impressive. For instance, Madison (1987) finds that, in 1870, the employment share in agriculture amounted to 50% in the US, to 67.5% in Japan, and 49.2% in France. In 1984, employment shares in agriculture fell to 3.3% in the US, 8.9% in Japan, and 7.6% in France. During the same period employment share in the service sector increased from 25.6% to 68.7% in the US, from 18.7% to 56.3% in Japan, and from 23% to 60.4% in France.

While there is a large literature that studies how structural change and growth are related in the development process (see for example Caselli and Colman (2001), Glomm (1992), Gollin, Parente and Rogerson (2002), Laitner (2000), Lucas (2004)) there has been relatively little work focusing on India in particular and similar developing countries in general. In the context of the developing process, India stands out for several reasons. First, India's service sector has grown rapidly in the last three decades, constituting 51% of GDP in 2006 (Banga, 2005). This large size of the service sector growth in India is comparable to the size of the service sector in developed economies where services often provide more than 60% of total output and an even larger share of employment. Since many components of services (such as financial services, business services, hotels and restaurants) are income related and increase only after a certain stage of development, it is the fact that India's service sector is very large relative to its level development that is puzzling. In general, there are relatively few explanations in the literature for the rise of in India's service sector. Moreover little is known on the effect of particular explicit sectoral policies and how they affect structural change. Some examples include Casella (2005) and Suedekum (2005).

Second, the entire decline in the share of agriculture in GDP in the last two decades has been picked up by the service sector with manufacturing sector's share almost remaining the same. In general, such a trend is experienced by high-income countries and not by developing countries such as India. In developing countries the typical pattern is for the manufacturing sector to replace the agricultural sector at first. Only at higher levels of aggregate income does the service sector play an increasingly large role. In addition, in spite of the rising share of services in GDP and trade, there has not been a corresponding rise in the share of services in total employment.

Third, unlike the case of aggregate data where capital-output ratios are often constant over time, the sectoral capital-output ratios in India exhibit large changes over time (see Verma (2008)). This is illustrated in Table 1. While agriculture's capital-output ratio has fallen from 3.3 to 1.2 between 1970-2000, the manufacturing sector's capital-output ratio has risen steadily from 0.6 to 4.2, and the service sector capital-output ratio has fallen from 11 to 2. India's overall capital-output ratio has fallen from 2.83 in 1970 to 2.63 in 2000 thus exhibiting a relatively small decline over time. The sectoral observation is clearly inconsistent with a standard neo-classical model with a Cobb-Douglas technology. This would predict constant capital-output ratios along a balanced growth path in the aggregate economy. One possible reason for increasing capital-output ratios in India's manufacturing sector is the role played by sector specific policies and other institutional features. For instance, a bulk of the capital in the manufacturing sector is owned by the public sector, which makes it immobile (see Marathe, 1986). Also, if there are restrictive labour laws, private and public firms cannot fire their employees, and so inefficient labour continues to be employed (see Bhattacharjea, 2006). This may reduce output and potentially induce the capital-output ratio to increase over time. As in the manufacturing sector, public policies in agriculture may be crucial to understanding why employment shares have exhibited a relatively small decline. Because of the minimum prices support system, agriculture prices stay high. This would keep employment in agriculture and prevent movement to other sectors. However, higher prices would also induce farmers to raise agriculture production, which would in turn tend to reduce prices, suggesting important general equilibrium effects. As Table 1 indicates, both the service and agriculture share of employment hardly move over the 1970-2000 period.

There is a large literature by now studying the effects of infrastructure investment on economic growth. Usually these types of analyses are carried out in a one sector growth model with an aggregate production function, often of the Cobb-Douglas kind. Examples in this school of literature include Barro (1990), Turnovsky and Fischer (1995) Turnovsky (1996), Glomm and Ravikumar (1994, 1997), Eicher (2000), Agenor and Morena-Dodson (2006), Agenor (2008), Ott and Turnnovsky(2006), Angelopoulus, Economides and Kammas (2007) and many others. There are many empirical studies to go along with the above theoretical investigations. Examples of such empirical papers include papers by Barro (1990), Ai and Cassou (1995), Holtz-Eakin (1994), and Lynde and Richmond(1992). The subset of these empirical papers which use time series analysis with aggregate data often find large growth effects, while cross section or panel data studies reveal very small and often negligible effects.

There is a much smaller literature that analyses the effects of infrastructure investment in economies undergoing structural changes such as large shifts or productive activity across from agriculture to manufacturing and then to services. Examples include Arcalean, Glomm, and Schiopu (2007), Carrera, Freire-Seren, and Manzano (2008), de la Fuente, Vives, Dolado and Faini (1995), Carminal (2004), and Ott and Soretz (2010).

In this paper we address the following question: What is the effect of the allocation of infrastructure investment on economic growth in a dynamic general equilibrium model where one sector, say agriculture, shrinks over time, and another sector, manufacturing or services, rises over time. The model we employ for our purposes is an overlapping generations model where all individuals live for two periods. There are two sectors in the model. We refer to these sectors as "agriculture" and "manufacturing", although this identification is not strictly necessary. We just need two sectors whose output and employment shares in the total economy rise and fall and whose capital-output ratios are not constant over relatively long time horizons. In order to be able to match these observations at least qualitatively we deviate from the typical assumption of Cobb-Douglas production functions in both sectors , by allowing one production technology, the technology in the "manufacturing" sector to be of the CES variety. Initially, we assume that the utility function of all individuals is of the semi-linear variety so that the income elasticity for the agricultural good, food, is small. In the later part of the paper check the robustness of our results by allowing Stone-Geary type utility functions. In each production technology the stock of public infrastructure is a productive input. We assume perfect mobility of both private factors of production, labor and capital, between the two sectors.

The economy of India has undergone substantial structural changes with large shifts of resources across the three sectors, agriculture, manufacturing and services and with very large changes in the capital-output ratios in the three sectors. These structural shifts are documented in Verma (2008). We thus calibrate the model to India. We use the calibrated version of the model to conduct policy experiments on the sectoral allocation of public infrastructure investment.

2 The benchmark model without public infrastructure capital

2.1 The set-up

The economy is populated by a large number of individuals in an overlapping generations set up. Each individual lives for two periods, works when young and is retired when old. In order to simplify the analysis, consumption only takes place in the second period of life. There is no population growth and within each generation all individuals are identical ex-ante.

There are two production sectors in this model, agriculture and manufacturing. For now, we abstract from the third important factor services. We will incorporate a third sector into the model in the future. For now we will work with a two sector model and we will call these two sectors "agriculture" and "manufacturing", even though there are just two sectors which differ in their production technology more precisely in the elasticity of substitution between capital and labor. In agriculture the production function is given by

$$Y_{a,t} = A_a K_{a,t}^{\alpha} L_{a,t}^{1-\alpha}, \tag{2.1}$$

where $Y_{a,t}$ denotes agricultural output, $A_{m,t}$ represents total factor productivity, and $K_{m,t}$ and $L_{m,t}$ are physical capital and labor input in agriculture. In manufacturing, the production function is given by

$$Y_{m,t} = A_m((1-\theta)K_{m,t}^{\rho} + \theta L_{m,t}^{\rho})^{1/\rho}, \quad \rho \leq 1, \tag{2.2}$$

where $Y_{m,t}, A_m, K_{m,t}, L_{m,t}$ are, agricultural output, total factor productivity, capital and labor input. We allow for the elasticity of substitution between capital and labor to be different from unity so that we can account for the non-balanced growth feature of the Indian economy.

Throughout this paper we assume that there are competitive factor markets, implying that labor and private capital are paid their respective value marginal products. We also assume that both factors are freely mobile across the two sectors so that the marginal products and factor payments across the sectors are equated.

It is widely observed that income elasticity for food, the agricultural good, are small and often close to zero. This is true even in poor economies. In order to capture this low income elasticity we posit the following utility function.

$$u(c_{m,t+1}, c_{a,t+1}) = c_{m,t+1} + \phi ln c_{a,t+1}, \quad \phi > 0, \tag{2.3}$$

where $c_{m,t+1}$ and $c_{a,t+1}$ denote the amount of the manufacturing good and of the agricultural good. This kind of similar utility functions have been employed in growth models by Glomm (1992), Lucas (2004), and others to model the benchmark case of a zero income elasticity of the demand for food.

Towards the end of the paper we will conduct robustness checks on the particular assumption of semi-linear utility by allowing for Stone-Geary type utility functions. Recall that all consumption takes place only in the second period of life. This all first period income is saved. This assumption eases exposition but does not influence any of our major results.

2.2 Solving the model

A household employed in agriculture solves the following problem:

$$
\begin{aligned}
\max_{c_m, c_a} \quad & c_{m,t+1} + \phi ln c_{a,t+1}, \\
s.t. \quad & c_{m,t+1} + p_{t+1} c_{a,t+1} = p_t w_{a,t}(1 + r_{t+1}) \equiv I_{a,t}
\end{aligned}
\tag{2.4}
$$

where $w_{a,t}$ is the real wage in terms of the agricultural good, p_t is the price of the agricultural good relative to the manufacturing good and r_{t+1} is the real interest rate.

It is easy to obtain demand from a household in the agricultural sector for the two goods as

$$c^a_{m,t+1} = p_t w_{a,t}(1 + r_{t+1}) - \phi \tag{2.5}$$

$$c^a_{a,t+1} = \frac{\phi}{p_{t+1}} \tag{2.6}$$

Of course the problem faced by a household in the manufacturing sector is analogous and the demand from the household is

$$c^m_{m,t+1} = w_{m,t}(1 + r_{t+1}) - \phi \tag{2.7}$$

$$c_{a,t+1} = \frac{\phi}{p_{t+1}} \tag{2.8}$$

Profit maximizing firms hire inputs to so that the value of the marginal products equal factor prices. Setting the marginal product for labor in agriculture equal to the real wage we obtain:

$$w_{a,t} = (1 - \alpha) A_a K^{\alpha}_{a,t} L^{-\alpha}_{a,t} \tag{2.9}$$

In manufacturing this condition becomes

$$w_{m,t} = \theta \frac{y_{m,t}}{L_{m,t}} \Big[(1 - \theta)\big(\frac{K_{m,t}}{L_{m,t}}\big)^{\rho} + \theta\Big]^{-1} \tag{2.10}$$

The equivalent conditions for capital become

$$q_{a,t} = \alpha A_a K^{\alpha-1}_{a,t} L^{1-\alpha}_{a,t} \tag{2.11}$$

$$q_{m,t} = (1 - \theta) \frac{y_{m,t}}{K_{m,t}} \Big[(1 - \theta) + \theta\big(\frac{L_{m,t}}{K_{m,t}}\big)^{\rho}\Big]^{-1} \tag{2.12}$$

Since both factors of production are freely mobile between sectors, marginal products and factor prices are equalized. Thus we obtain the following conditions.

$$p_t(1-\alpha)A_a K_{a,t}^{\alpha} L_{a,t}^{-\alpha} = \theta \frac{y_{m,t}}{L_{m,t}} \Big[(1-\theta)\big(\frac{K_{m,t}}{L_{m,t}}\big)^{\rho} + \theta\Big]^{-1} \tag{2.13}$$

and

$$p_t \alpha A_a K_{a,t}^{\alpha-1} L_{a,t}^{1-\alpha} = (1-\theta) \frac{y_{m,t}}{K_{m,t}} \Big[(1-\theta) + \theta\big(\frac{L_{m,t}}{K_{m,t}}\big)^{\rho}\Big]^{-1} \tag{2.14}$$

Equations (2.13) and (2.14) determine the allocation of inputs across the two sectors and this allocation in turn determines sectoral output. This is a purely static problem. The dynamics enter purely through the savings decision. Since households value consumption only when old all income is saved and turned into capital. We thus have

$$\begin{aligned} K_{t+1} &= L_{a,t} s_{a,t} + L_{m,t} s_{m,t} \\ &= L_{a,t} p_t w_{a,t} + L_{m,t} w_{m,t} \end{aligned} \tag{2.15}$$

If we divide Equation (2.13) by Equation (2.14), we will get:

$$\frac{K_{a,t}}{L_{a,t}} = \frac{\alpha\theta}{(1-\alpha)(1-\theta)} \big(\frac{K_{m,t}}{L_{m,t}}\big)^{(1-\rho)} \tag{2.16}$$

Notice that $\frac{\alpha\theta}{(1-\alpha)(1-\theta)} < 1$ if $(\alpha+\theta) < 1$. Since α is capital's share in agricultural production and θ is related to capital's share in manufacturing, the condition that $(\alpha+\theta) < 1$ seems reasonable.

Market clearing condition for the agricultural good is:

$$L_{a,t-1} \frac{\phi}{p_t} + L_{m,t-1} \frac{\phi}{p_t} = A_a K_{a,t}^{\alpha} L_{a,t}^{1-\alpha}, \tag{2.17}$$

which determines the relative agricultural price:

$$p_t = \frac{\phi}{A_a K_{a,t}^{\alpha} L_{a,t}^{1-\alpha}}. \tag{2.18}$$

The wage in agriculture is given by Equation (2.9), so that we can obtain:

$$L_{a,t} p_t w_{a,t} = \phi(1-\alpha) \tag{2.19}$$

The capital accumulation is governed by:

$$K_{t+1} = \phi(1-\alpha) + \theta A_m((1-\theta)K_{m,t}^{\rho} + \theta L_{m,t}^{\rho})^{\frac{1}{\rho}-1} L_{m,t}^{\rho} \tag{2.20}$$

Notice that an increase in labor income $w_{a,t}l_{a,t}$ in agriculture is exactly offset by a decrease in the relative price p_t so that investment in capital originating in agriculture is independent of income, i.e., the stage of development of the economy.

We simulate the model for reasonable parameter values, which can be found in Table 2. We use two benchmark models in our simulations. These benchmark models differ basically in the level of total factor productivity in the two sectors and in the marginal productivity of labor in the manufacturing CES technology. In benchmark one and two, we change parameter ρ, which captures the intra-temporal elasticity of substitution between capital and labor. In this set of experiments there are differences in the level of total factor productivity between manufacturing and agriculture, but the growth rates of these total factor productivities are zero. The results of allowing ρ to vary from -2 to 0.6 are illustrated in Figures 1- 8. It is apparent that as ρ increases from -2 to 0.6, i.e. the elasticity of substitution increases, the following results obtain: (i) In both benchmark one and two, capital in both agricultural and manufacturing sectors is accumulated. The labor allocation in manufacturing increases over time while the labor allocation in agriculture declines. (ii) As ρ increases, the rate at which capital in agriculture accumulates declines in benchmark one but increases in benchmark two. (iii) As ρ increases, employment in agriculture declines at a lower rate and employment in manufacturing rises at a lower rate. (iv) In all of these experiments the capital-output ratios in both sectors are increasing over time. Varying the elasticity of substitution can thus not account for the observed changes in sectoral composition and the rising/declining capital-output ratio in manufacturing/agriculture. (v) The relative price of the agricultural good rises over time in the first benchmark case where the manufacturing TFP exceeds the agricultural TFP. In the second benchmark case where TFP in agriculture is larger than that in manufacturing, the agricultural price declines over time.

The above results (i) through (iii) on the dependency of the sectoral allocation of capital and labor over time all depend on the degree of complementarity between capital and labor and the particular utility function. Given the utility function that generates zero income elasticity for the demand for food, as capital accumulates and incomes grow, resources are shifted systematically out of agriculture into manufacturing. The relative rates rate at which labor and capital are pulled out of agriculture will of course depend upon the degree of complementarity/subsitutabilty of the two factors of production.

We are interested in matching employment shares, GDP shares and capital-output ratios to the real data. In Figures 9 and 10, we impose no productivity growth in both sectors while fixing ρ at 0.6. Even though we are able to match the observed decreasing agricultural employment share and increasing agricultural GDP share, the observed capital-output ratios are not matched.

3 The benchmark model with sectoral infrastructure policies

3.1 Solving the model with infrastructure

In this section we consider the effects of a policy that (i) invests in infrastructure projects in both sectors and (ii) raises taxes from labor income in the manufacturing (urban) sector only. In this case we make a slight modification of the two production functions. Following Barro (1990) and many others we write the two production functions as

$$A_{a,t} G_{a,t}^{\psi_a} K_{a,t}^{\alpha} L_{a,t}^{1-\alpha} \tag{3.1}$$

$$A_{m,t} G_{m,t}^{\psi_m} \left[(1-\theta) K_{m,t}^{\rho} + \theta L_{m,t}^{\rho} \right]^{1/\rho}, \tag{3.2}$$

where $G_{a,t}$ and $G_{m,t}$ are the stocks of infrastructure in the two sectors. We assume that in both production functions there are constant returns to scale in the two private factors of production so that their factor payments exhaust output. For reasonable estimates of ψ_a and ψ_m it will typically be the case that there are decreasing returns to scale in the augmentable factors so that the growth rate will converge to zero. We assume 100% depreciation. Investment in infrastructure is financed by a tax on labor income in the manufacturing sector only.

The government budget constraint can be written as

$$G_{a,t} + G_{m,t} = \tau w_{m,t} L_{m,t} \tag{3.3}$$

Letting δ_a denote the fraction of government revenue which is allocated to agricultural infrastructure. We can write

$$G_{a,t} = \delta_a \tau w_{m,t} L_{m,t} \tag{3.4}$$

$$G_{m,t} = (1-\delta_a) \tau w_{m,t} L_{m,t} \tag{3.5}$$

With these modifications equations (2.13) and (2.14) become

$$p_t (1-\alpha) A_a G_{a,t}^{\psi_a} \left(\frac{K_{a,t}}{L_{a,t}} \right)^{\alpha} = \theta \frac{y_{m,t}}{L_{m,t}} \left[(1-\theta) \left(\frac{K_{m,t}}{L_{m,t}} \right)^{\rho} + \theta \right]^{-1} \tag{3.6}$$

and

$$p_t \alpha A_a G_{a,t}^{\psi_a} \left(\frac{K_{a,t}}{L_{a,t}} \right)^{\alpha-1} = (1-\theta) \frac{y_{m,t}}{K_{m,t}} \left[(1-\theta) + \theta \left(\frac{L_{m,t}}{K_{m,t}} \right)^{\rho} \right]^{-1} \tag{3.7}$$

Using the government budget constraint and equating the wage rate to the marginal product in manufacturing yields

$$G_{a,t} = \delta_a \tau \theta A_m G_{m,t}^{\psi_m} \Big[(1-\theta) \big(\frac{K_{m,t}}{L_{m,t}} \big)^{\rho} + \theta \Big]^{-1}, \tag{3.8}$$

$$G_{m,t} = (1-\delta_a) \tau \theta A_m G_{m,t}^{\psi_m} \Big[(1-\theta) \big(\frac{K_{m,t}}{L_{m,t}} \big)^{\rho} + \theta \Big]^{-1}, \tag{3.9}$$

and, as before the equilibrium law of motion for physical capital is determined by aggregate savings. The only difference between equations (2.20) and (3.10) is that the latter reflects the income tax rate in the urban sector.

$$K_{t+1} = \phi(1-\alpha) + (1-\tau)\theta A_m G_{m,t}^{\psi_m} ((1-\theta)K_{m,t}^{\rho} + \theta L_{m,t}^{\rho})^{\frac{1}{\rho}-1} L_{m,t}^{\rho} \tag{3.10}$$

Market clearing condition for agricultural goods:

$$l_{a,t-1} c_{a,t}^{a} + l_{m,t-1} c_{a,t}^{a} = A_a K_{a,t}^{\alpha} L_{a,t}^{1-\alpha} G_{a,t}^{\psi_a} \tag{3.11}$$

Therefore, we can get the relative price of agricultural goods in unit of manufacturing goods:

$$p_t = \frac{\phi}{Y_{a,t}} \tag{3.12}$$

We relax the assumption of no productivity growth and allow both agricultural and manufacturing sectors to grow at the same annual rate of 2%. The simulation result is shown in Figure 11, where we broadly match the employment patterns in both sectors, the shares of both sectors as a fraction of GDP, and the capital-output ratios in both sectors.

We are now ready to study the effects of fiscal policy. In particular we consider two fiscal policy reforms. First: Holding the fraction of the total investment going to one sector fixed we change the tax rate and study the effects of this policy on the economic transition paths. In the next two sets of experiments we vary the fiscal policy parameters. First, we study the effect on the transitions of an increase in the tax rate holding constant the allocation of the tax revenue between the two sectors. The results illustrated in Figures 12 through 16 indicate the following results: (i) The shares of labor allocated to the two sectors is remarkably robust to changes in the overall tax rate from 0.1 to 0.5. This five-fold increase in the tax rate generates a negligible change in these employment shares over the entire 30 period trajectory. (ii) As the tax rate is increased the agricultural share of GDP drops faster, although quantitatively this effect as rather small. In period 30 the agricultural share of GDP drops from 0.48 when the tax rate is 0.1 to 0.45 when the tax rate is 0.5. 3. The most pronounced change brought about by an increase in the tax rate is the drop in the agricultural capital/output ration from about 0.55 in period 30 to 0.40 as the tax rate is increased from 0.1 to 0.5.

In the next experiment we keep the tax rate constant at 0.3 and we vary δ_a, the fraction of government revenue allocated to rural infrastructure investment. This share we raise from 0.1 to 0.9. The results of this experiment are illustrated in Figures 17 through 21. We would expect that the agricultural employment and GDP share rise as agricultural infrastructure investment relative to manufacturing investment rises. This expectation is not born out by these experiments. As agricultural infrastructure investment rises, the agricultural supply shifts to the right, but as preferences are semi-linear, the income elasticity for agricultural goods is zero. This preference effect causes the infrastructure investment effect on labors share of income employed in agriculture to be negligible. The same is true for agriculture's share of GDP. Finally as the share of government revenue invested in the agricultural technology rises the capital-output ratio in agriculture falls. This is to be expected as the infrastructure input rises relative to physical capital.

After studying how changes in the tax rate and in the infrastructure allocation influence the dynamic transition path we now study the cross section implications of such changes in fiscal policy. Typically such cross-sections implications are computed in the steady state. In our model, in order to match the data in Table 1, we imposed differential exogenous growth of total factor productivity in the two sectors. This differential TFP growth together with the semi-linear utility function persistently pulls labor and capital out of the agricultural sector so that agricultural labor allocation declines persistently. We therefore arbitrarily use period 5 in the model to check the cross sectional implications of fiscal policy reforms. The results of these experiments are illustrated in Figure 24 and Figure 25. It is apparent from these figures that the effect of fiscal policy reforms, changes in the tax rate and in the sectoral allocation, on GDP comes entirely from the manufacturing sector. The reason is simple: All supply side effects from increased infrastructure in agriculture are completely undone by the zero income elasticity for food induced by the semi-linear utility function.

4 Stone-Geary utility functions with infrastructure

The previous analysis has relied exclusively on semi-linear utility functions. With differential TFP growth in the two sectors this type of utility function allowed the model to qualitatively match the Verma (2008) observations on agriculture and manufacturing. However the zero income elasticity on food demand implications of this utility function are very stark and we therefore relax this particular assumption in this section. The utility functions we use are:

$$U_t = ln[c_{m,t+1} + \mu] + \phi ln[c_{a,t+1} - \gamma] \tag{4.1}$$

The households in agricultural sector then solve the problem:

$$\begin{aligned} \max \qquad & ln[c_{m,t+1} + \mu] + \phi ln[c_{a,t+1} - \gamma] \\ & s.t. c_{m,t+1} + p_{t+1} c_{a,t+1} = (1 - \tau_a) p_t w_{a,t} \end{aligned} \tag{4.2}$$

First order condition:

$$\frac{p_{t+1}}{(1 - \tau_a) p_t w_{a,t} - p_{t+1} c_{a,t+1} + mu} = \frac{\phi}{c_{a,t+1} - \gamma} \tag{4.3}$$

Consumption of households working in agricultural sector:

$$\begin{aligned} c^a_{a,t+1} &= \frac{\phi}{(1+\phi) p_{t+1}} [(1 - \tau_a p_{a,t} w_{a,t} + \mu] + \frac{1}{1+\phi} \gamma \\ c^a_{m,t+1} &= \frac{1}{1+\phi} (1 - \tau_a) p_t w_{a,t} - \frac{\phi}{1+\phi} \mu - \frac{p_{t+1}}{1+\phi} \gamma \end{aligned} \tag{4.4}$$

The households in manufacturing sector solve the problem:

$$\begin{aligned} \max \qquad & ln[c_{m,t+1} + \mu] + \phi ln[c_{a,t+1} - \gamma] \\ & s.t. c_{m,t+1} + p_{t+1} c_{a,t+1} = (1 - \tau_m) w_{m,t} \end{aligned} \tag{4.5}$$

Solving for the optimal consumption of people working in manufacture yields:

$$\begin{aligned} c^m_{a,t+1} &= \frac{\phi}{(1+\phi) p_{t+1}} [(1 - \tau_m w_{m,t} + \mu] + \frac{1}{1+\phi} \gamma \\ c^m_{m,t+1} &= \frac{1}{1+\phi} (1 - \tau_m) w_{m,t} - \frac{\phi}{1+\phi} \mu - \frac{p_{t+1}}{1+\phi} \gamma \end{aligned} \tag{4.6}$$

Factor prices remain the same as in (2.9, 2.10, 2.11, 2.12) and the market clearing condition for the agricultural goods are:

$$L_{a,t-1} c^a_{a,t} + L_{m,t-1} c^m_{a,t} = Y_{a,t} \tag{4.7}$$

Using $(1 - \tau_a) p_t w_{a,t} = (1 - \tau_m) w_{m,t}$, we have

$$\frac{\phi}{p_t} (1 - \tau_a) p_{t-1} w_{a,t-1} + \frac{\phi}{p_t} \mu + \gamma = (1 + \phi) Y_{a,t} \tag{4.8}$$

Market clearing condition for manufacturing good:

$$\frac{(1-\tau_a)p_{t-1}w_{a,t-1}}{p_t} - \frac{\phi\mu}{p_t} - \gamma = \frac{(1+\phi)Y_{m,t}}{p_t} \tag{4.9}$$

The production function with infrastructure and the government budget constraint carry over from the previous analysis (see equations (3.1,3.2,3.3, 3.4, 3.5) and the non-arbitrage conditions are as before.

$$(1-\tau_a)p_t(1-\alpha)A_a G_{a,t}^{\psi_a}\Big(\frac{K_{a,t}}{L_{a,t}}\Big)^{\alpha} = (1-\tau_m)\theta\frac{y_{m,t}}{L_{m,t}}\Big[(1-\theta)\big(\frac{K_{m,t}}{L_{m,t}}\big)^{\rho}+\theta\Big]^{-1} \tag{4.10}$$

and

$$(1-\tau_a)p_t\alpha A_a G_{a,t}^{\psi_a}\Big(\frac{K_{a,t}}{L_{a,t}}\Big)^{\alpha-1} = (1-\tau_m)(1-\theta)\frac{y_{m,t}}{K_{m,t}}\Big[(1-\theta)+\theta\big(\frac{L_{m,t}}{K_{m,t}}\big)^{\rho}\Big]^{-1} \tag{4.11}$$

Using the government budget constraint and equating the wage rate to the marginal product in manufacturing yields:

$$G_{a,t} = \delta_a\tau\theta A_m G_{m,t}^{\psi_m}\Big[(1-\theta)\big(\frac{K_{m,t}}{L_{m,t}}\big)^{\rho}+\theta\Big]^{-1}, \tag{4.12}$$

$$G_{m,t} = (1-\delta_a)\tau\theta A_m G_{m,t}^{\psi_m}\Big[(1-\theta)\big(\frac{K_{m,t}}{L_{m,t}}\big)^{\rho}+\theta\Big]^{-1}, \tag{4.13}$$

Thus the law of motion for physical capital becomes:

$$\begin{aligned} K_t &= L_{a,t-1}(1-\tau_a)p_{t-1}w_{a,t-1} + L_{m,t-1}(1-\tau_m)w_{m,t-1} \\ &= L(1-\tau_m)w_{m,t-1} \end{aligned} \tag{4.14}$$

In the case of the Stone-Geary utility functions, we perform similar policy analysis as in the case of the semi-linear utility functions. We explore the cross section policy implications of changing the policy variables and calculate how the equilibrium values in the fifth period adjust to policy changes. These results are illustrated in Figures 27 and 28. As the tax rates is raised, output in manufacturing rises but output in agriculture falls. The overall effect of increasing the tax rate on overall GDP is positive in the range of tax rates considered, despite the resulting decline in agriculture. Following our intuition, increasing the share of public infrastructure investment going to manufacturing increases manufacturing output and decreases agricultural output.

5 Conclusion

We have constructed a dynamic general equilibrium model that is at least qualitatively consistent with the sectoral growth observations for India. The model is not able to match the changing capital-output ratios even in the presence of CES production technologies, unless productive infrastructure capital is introduced. In that model we introduced publicly provided infrastructure which can be allocated to enhance productivity either in manufacturing or in agriculture. We show that the impact of changing the public provision of infrastructure across the two sectors depends crucially on the relative income elasticities for the two goods implied by the underlying utility function.

There are many other policies and distortions that could be studied in this framework. Examples include explicit subsidies to the farm sector or various labor market distortions, especially in the manufacturing sector. We leave the analysis of such distortions to future research.

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Table 1: Data

	Agriculture		Manufacturing		Services	
	1970	2000	1970	2000	1970	2000
Employment Shares$^{(a)}$	77%	62%	12%	19%	12%	20%
GDP Shares	48%	25%	23%	27%	29%	48%
K/Y Ratios	3.3	0.85	0.6	4.33	11	1.82
Gross Capital Formation	18%	9%	33%	30%	49%	61%

Source: Verma(2008)

(a): the employment share data are for 1970 and 1997.

Table 2: Calibration Values

	Definition	model 1	model 2	model 3
	Utility function	Semilinear	Semilinear	Stone-Gary
	TFP growth	no	yes	yes
	taxation	no	tax manuf	tax both
A_a	initial TFP in agriculture	2	2	2
A_m	initial TFP in manufacturing	1	1	1
g_a	raw growth rate of agri TFP (20 years)	-	1.2	1.2
g_m	raw growth rate of manuf TFP (20 years)	-	1.05	1.05
α	income share of K in agri	0.33	0.33	0.33
θ	income share of L in manuf	0.75	0.75	0.75
ρ	power parameter in CES in manuf	0.6	0.6	0.6
ϕ	parameter in consumption func	5.0	5.0	0.5
ψ_a	power param of G in agri prod.	-	0.1	0.1
ψ_m	power param of G in manuf prod.	-	0.1	0.1
δ_a	gov funding share for agri	-	0.2	0.2
τ_a	tax rate of agricultural income	-	-	0.3
τ_m	tax rate of manufacturing income	-	0.3	0.3
μ_a	subsistent consumption of agri goods	-	0.3	0.3
μ_m	subsistent consumption of manu goods	-	0.3	0.3

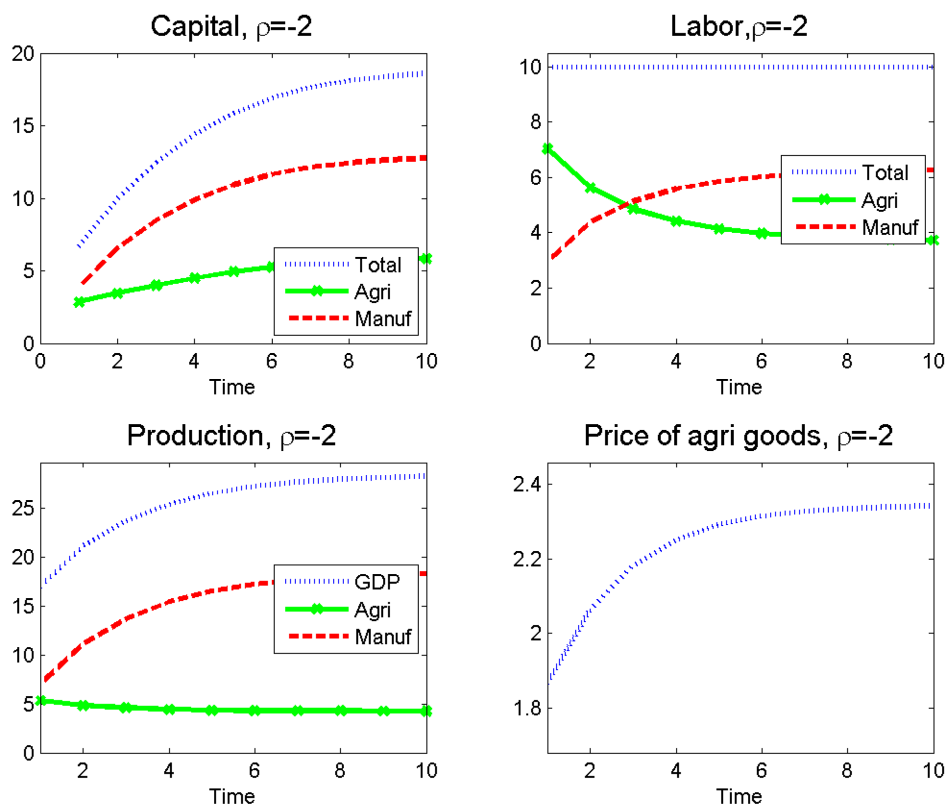

Figure 1: Benchmark 1 (1): no taxes, no productivity growth

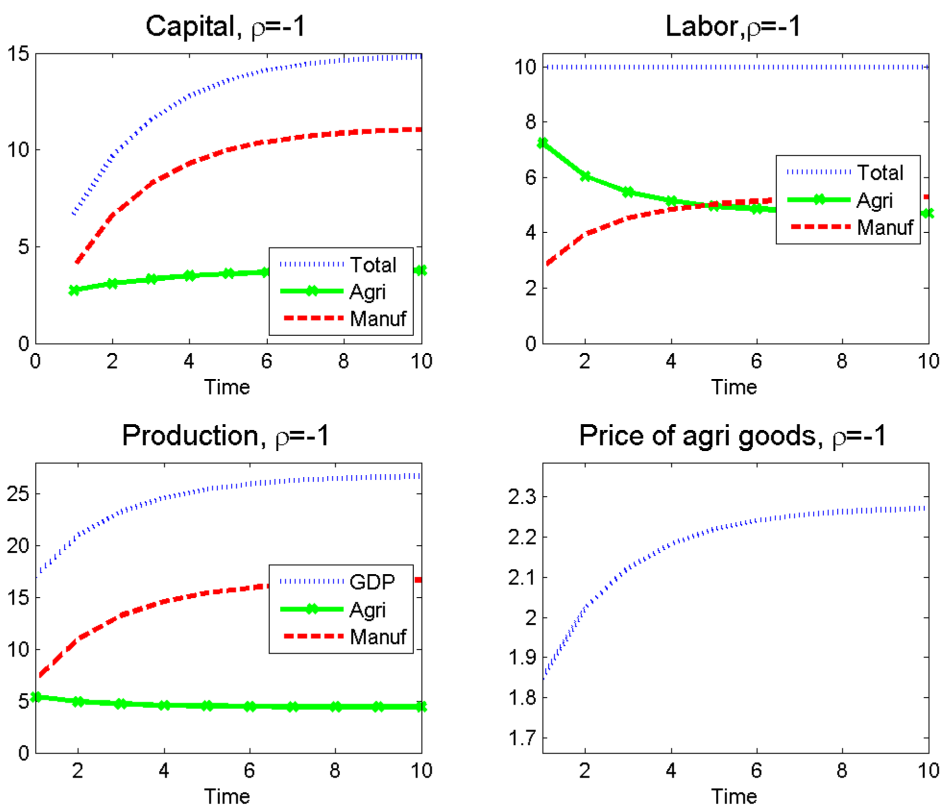

Figure 2: Benchmark 1 (2): no taxes, no productivity growth

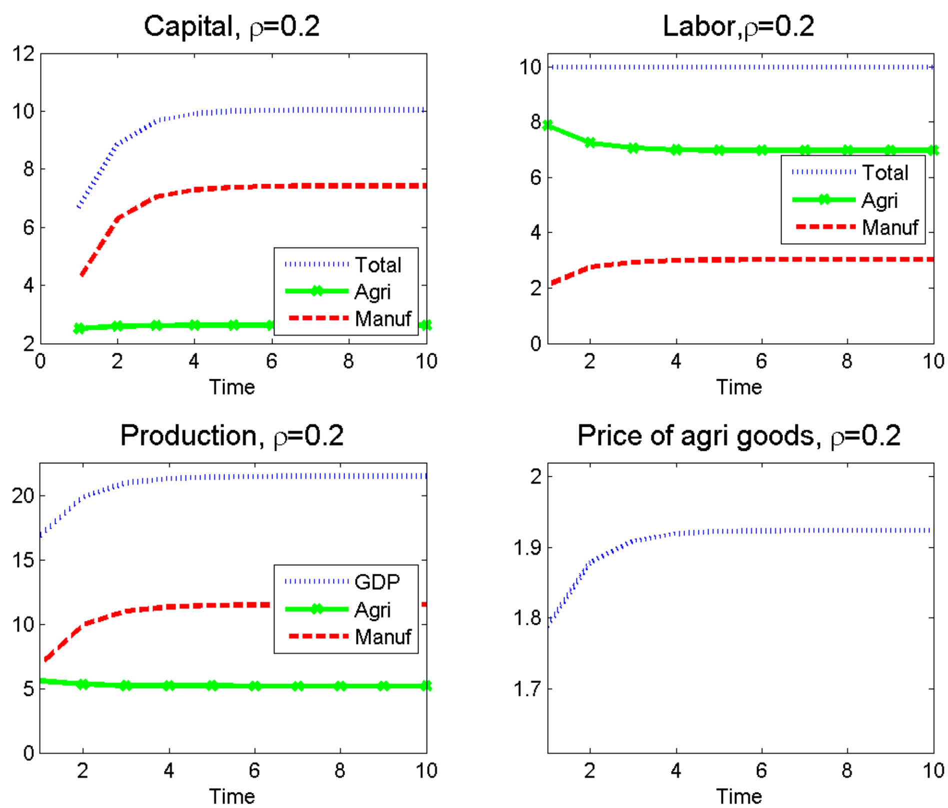

Figure 3: Benchmark 1 (3): no taxes, no productivity growth

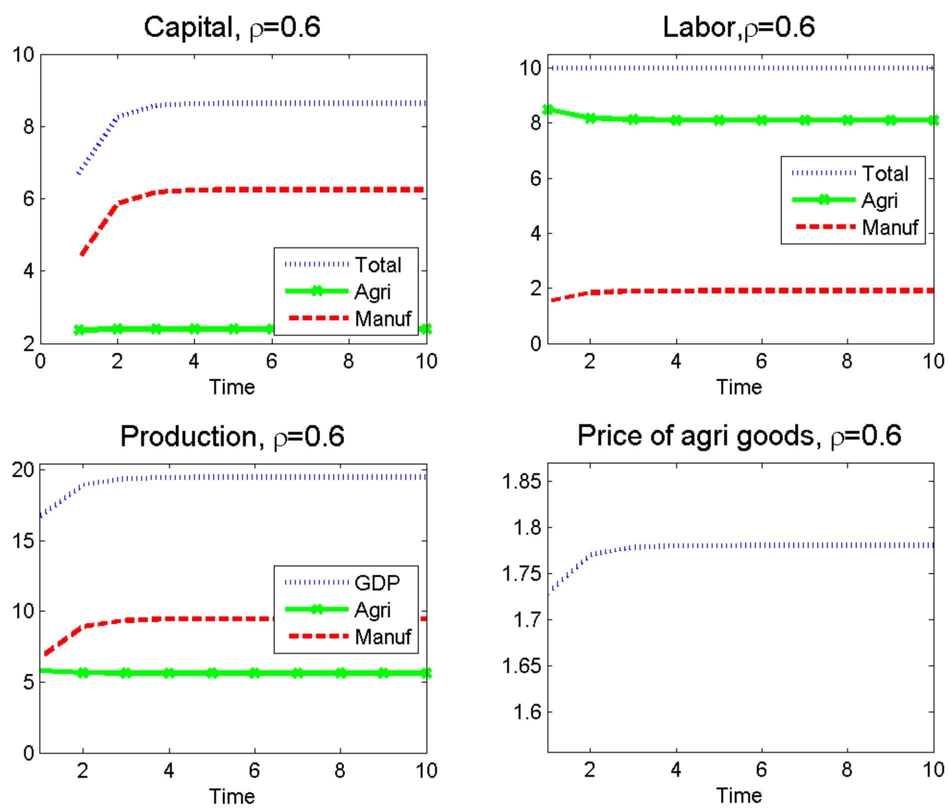

Figure 4: Benchmark 1 (4): no taxes, no productivity growth

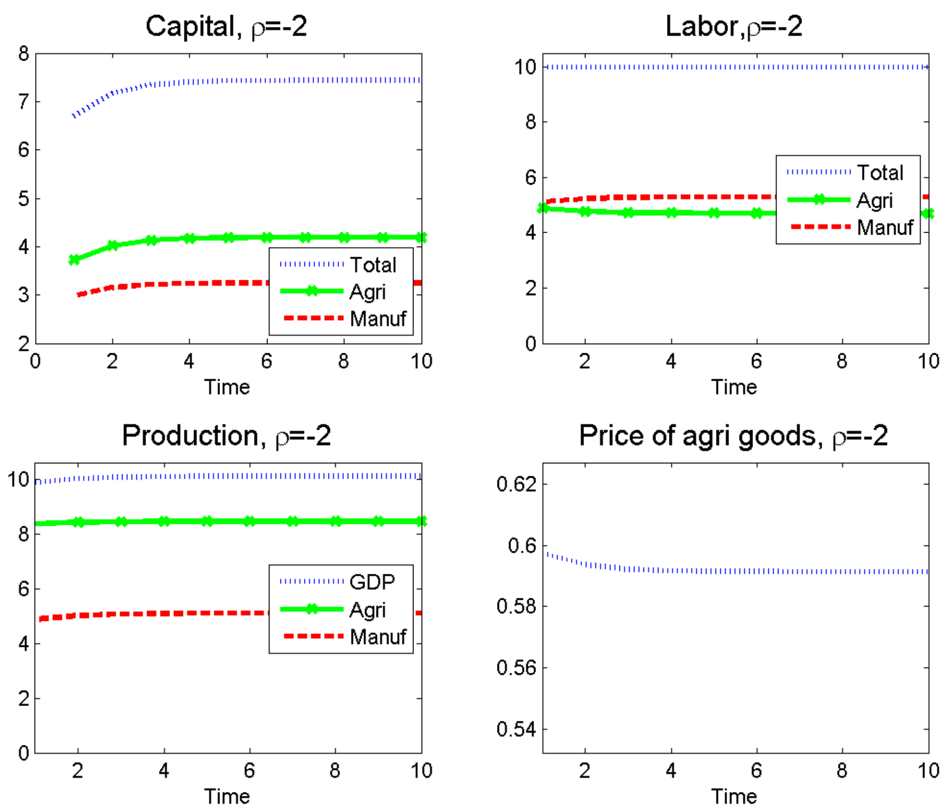

Figure 5: Benchmark 2 (1): no taxes, no productivity growth

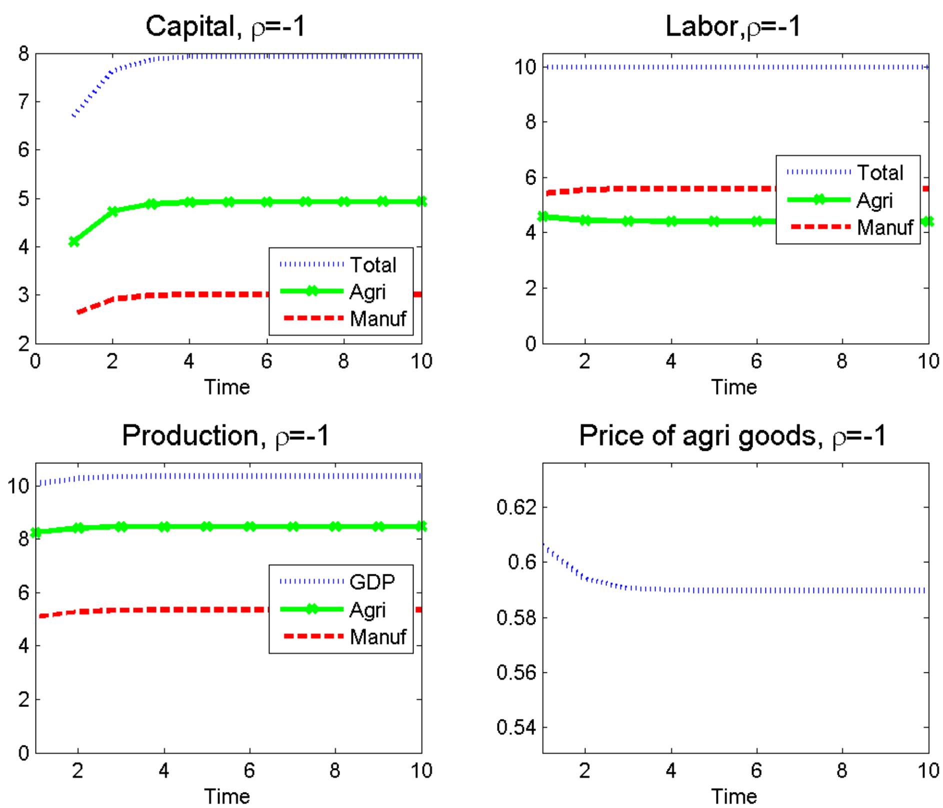

Figure 6: Benchmark 2 (2): no taxes, no productivity growth

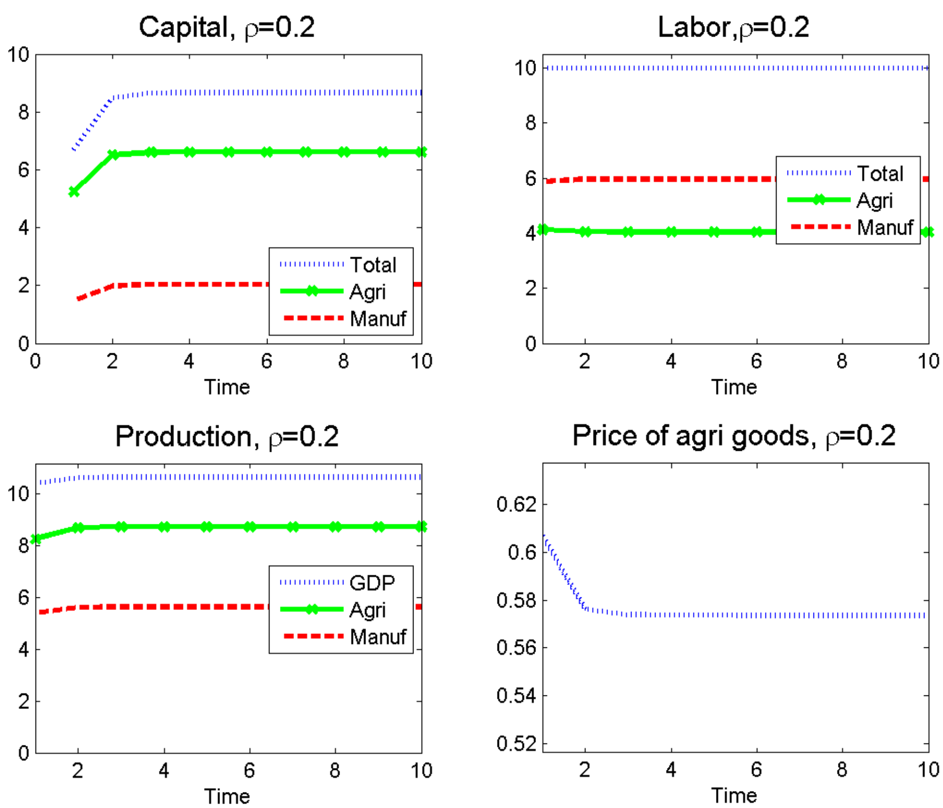

Figure 7: Benchmark 2 (3): no taxes, no productivity growth

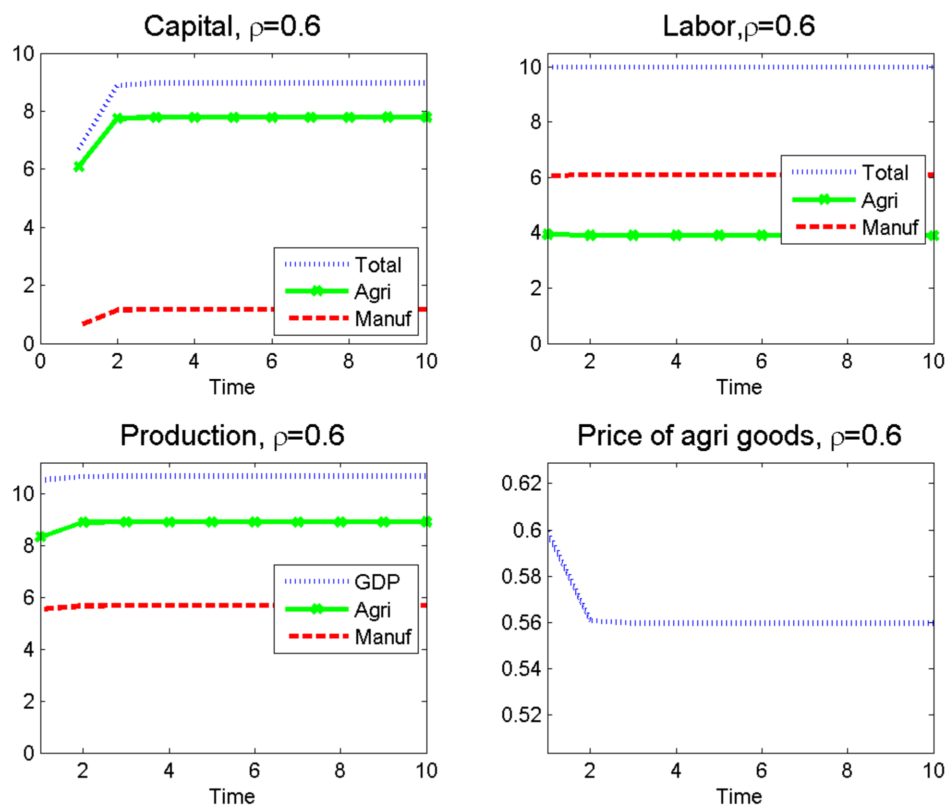

Figure 8: Benchmark 2 (4): no taxes, no productivity growth

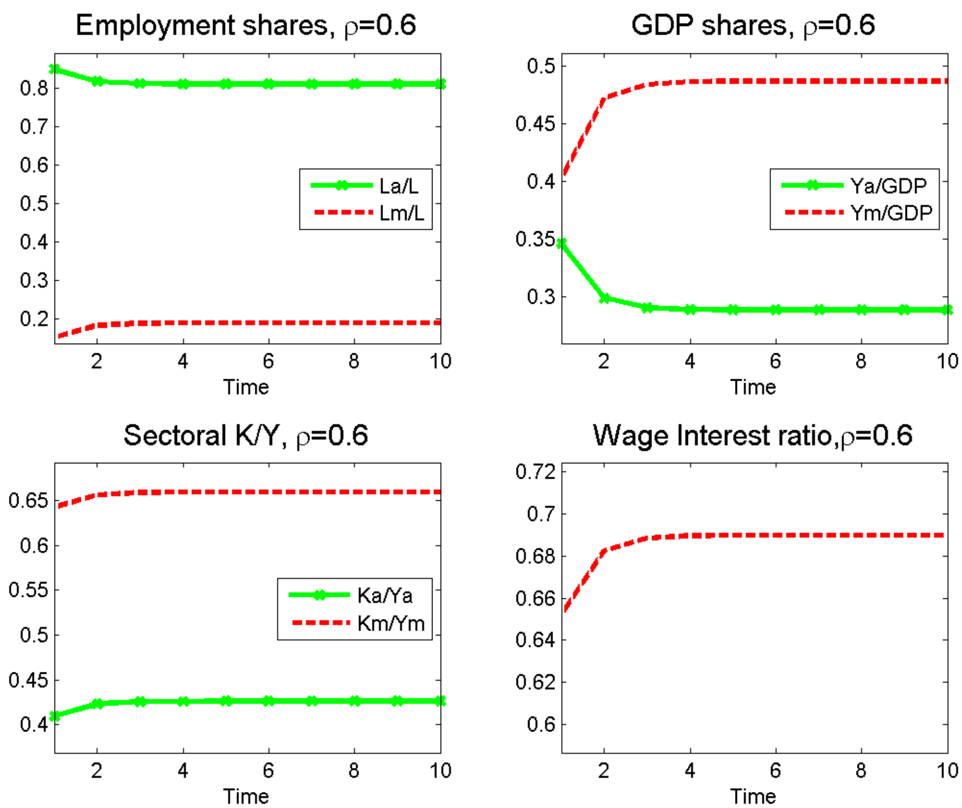

Figure 9: Benchmark 1 (5): no taxes, no productivity growth

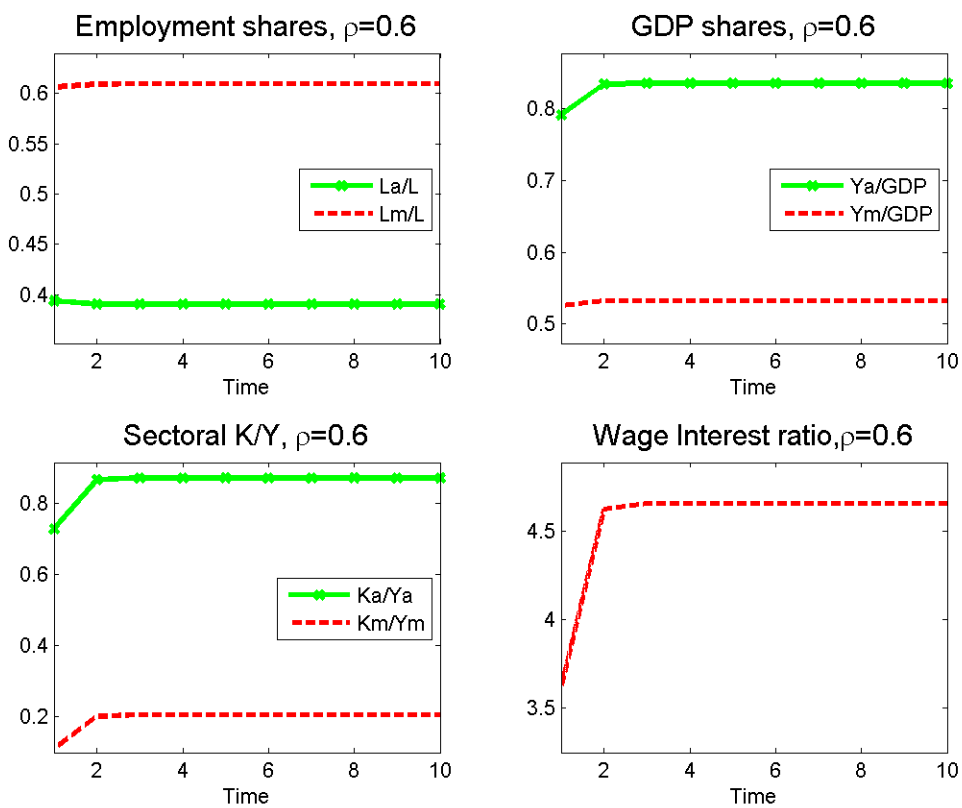

Figure 10: Benchmark 2 (5): no taxes, no productivity growth

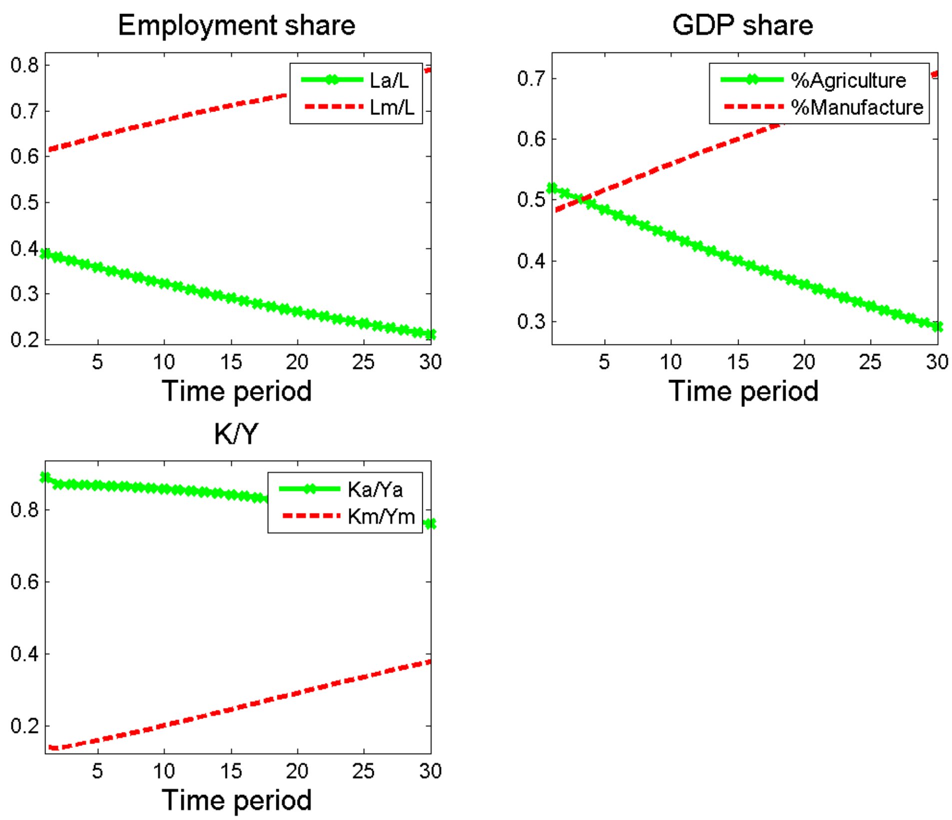

Figure 11: Experiment 1: Manufacturing taxes, same productivity growth

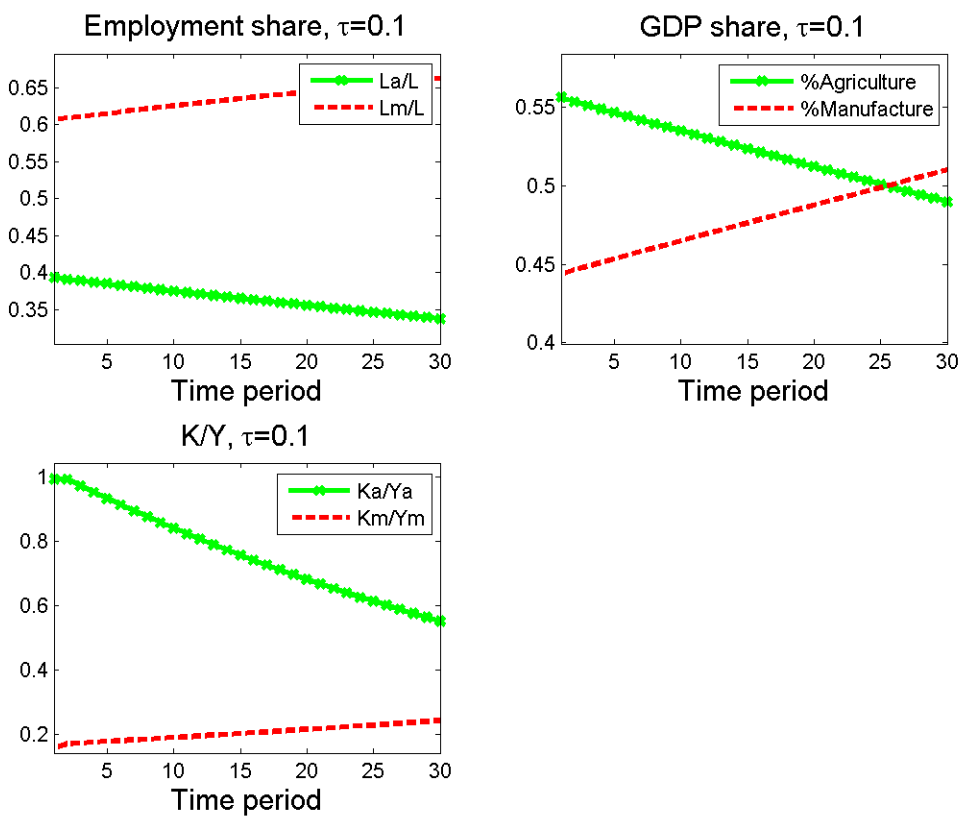

Figure 12: Experiment 2 (1): Varying Manufacturing taxes, different productivity growth

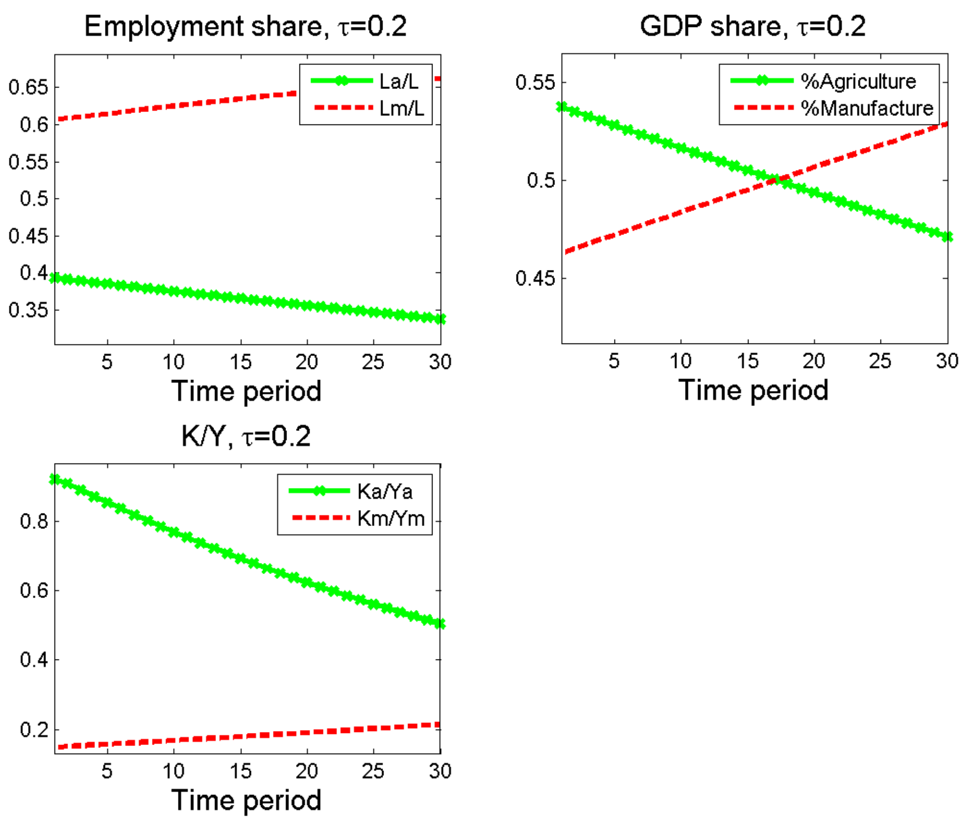

Figure 13: Experiment 2 (2): Varying Manufacturing taxes, different productivity growth

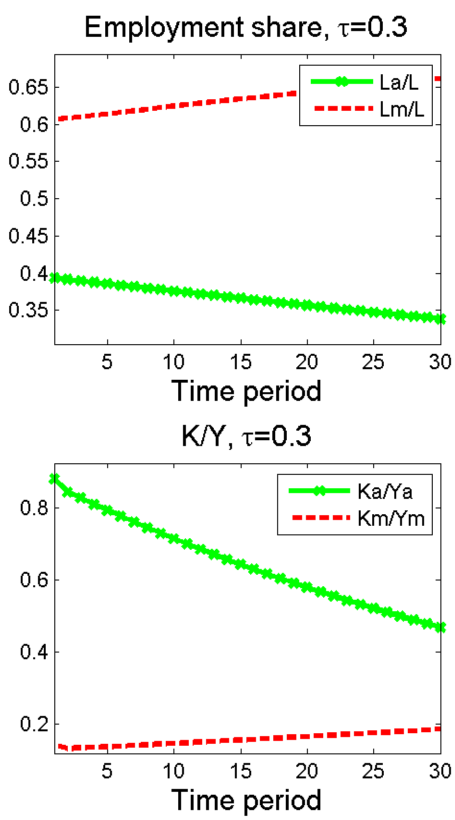

Figure 14: Experiment 2 (3): Varying Manufacturing taxes, different productivity growth

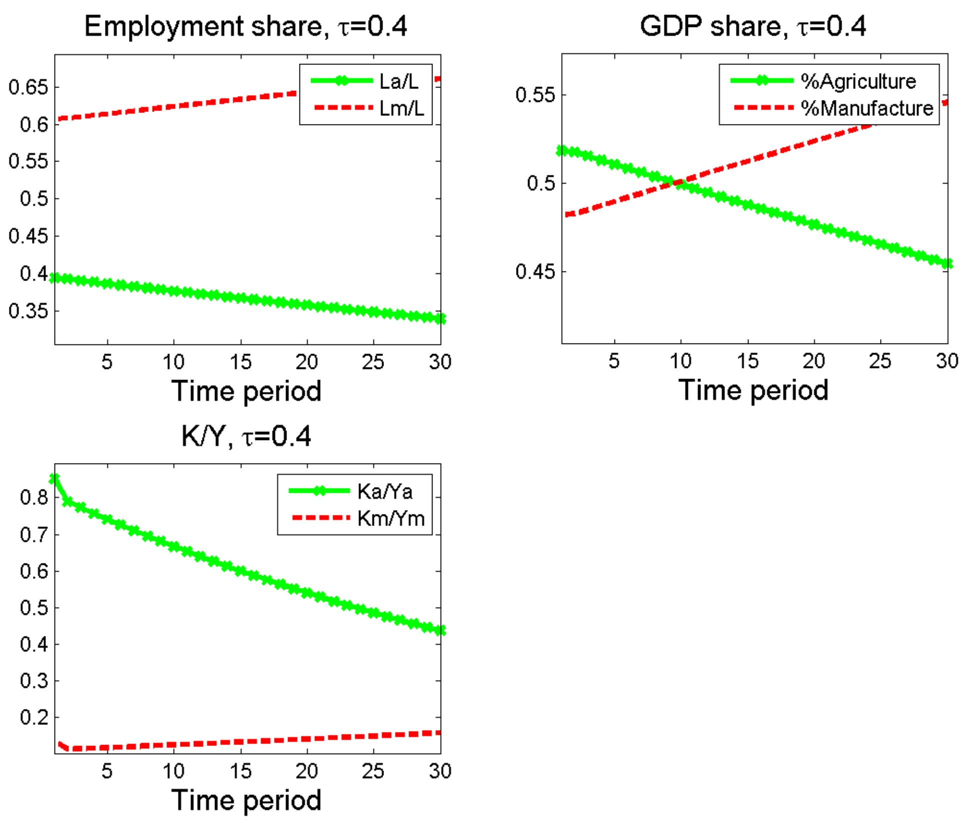

Figure 15: Experiment 2 (4): Varying Manufacturing taxes, different productivity growth

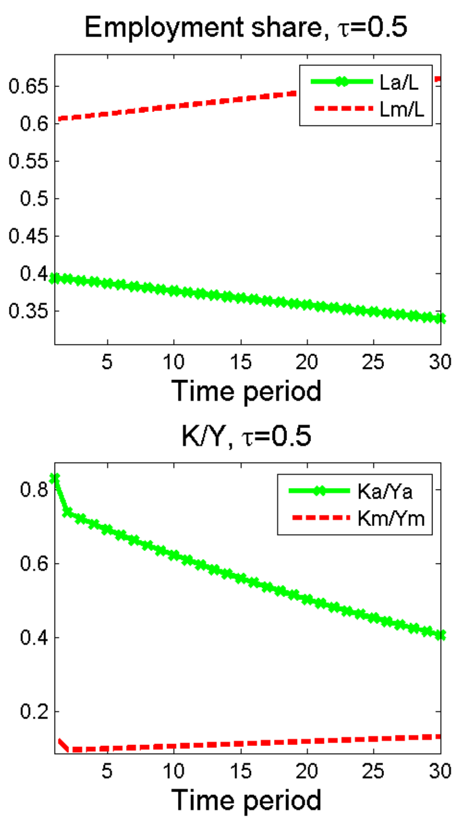

Figure 16: Experiment 2 (5): Varying Manufacturing taxes, different productivity growth

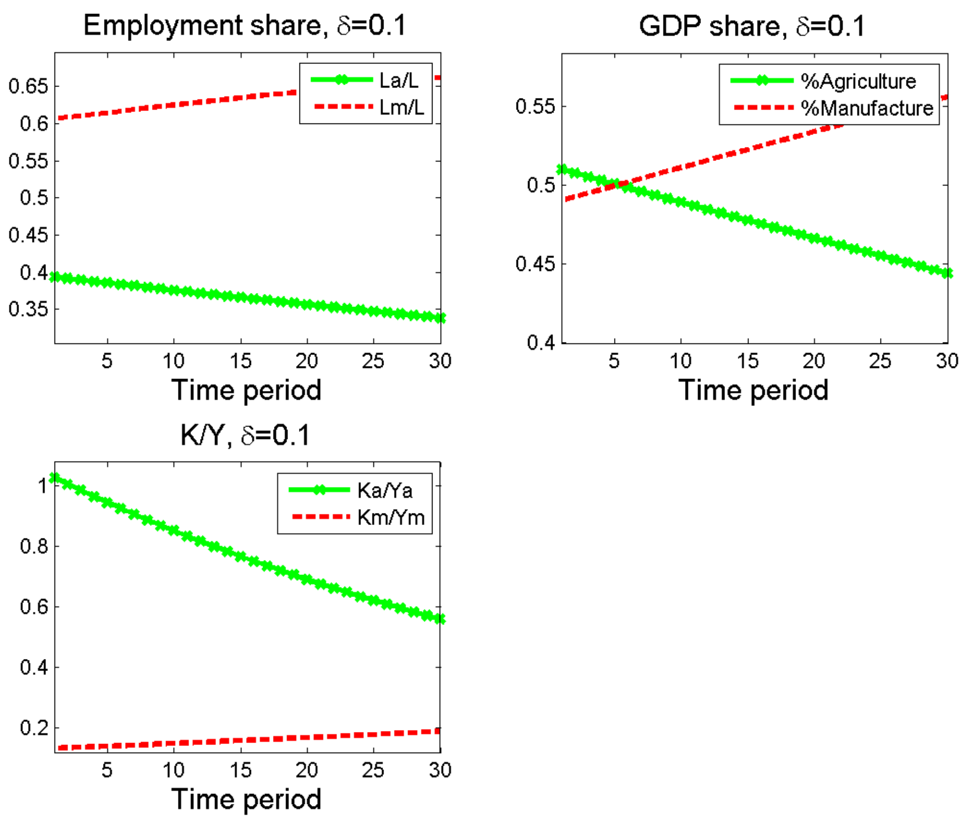

Figure 17: Experiment 3 (1): Varying redistribution, different productivity growth

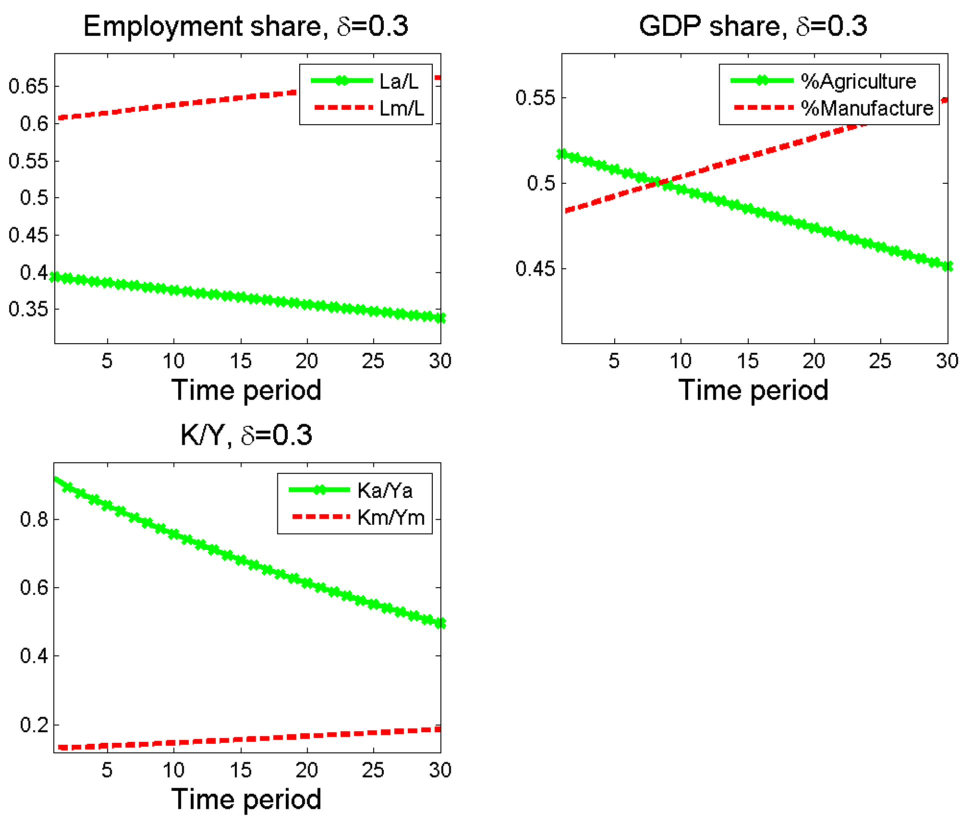

Figure 18: Experiment 3 (2): Varying redistribution, different productivity growth

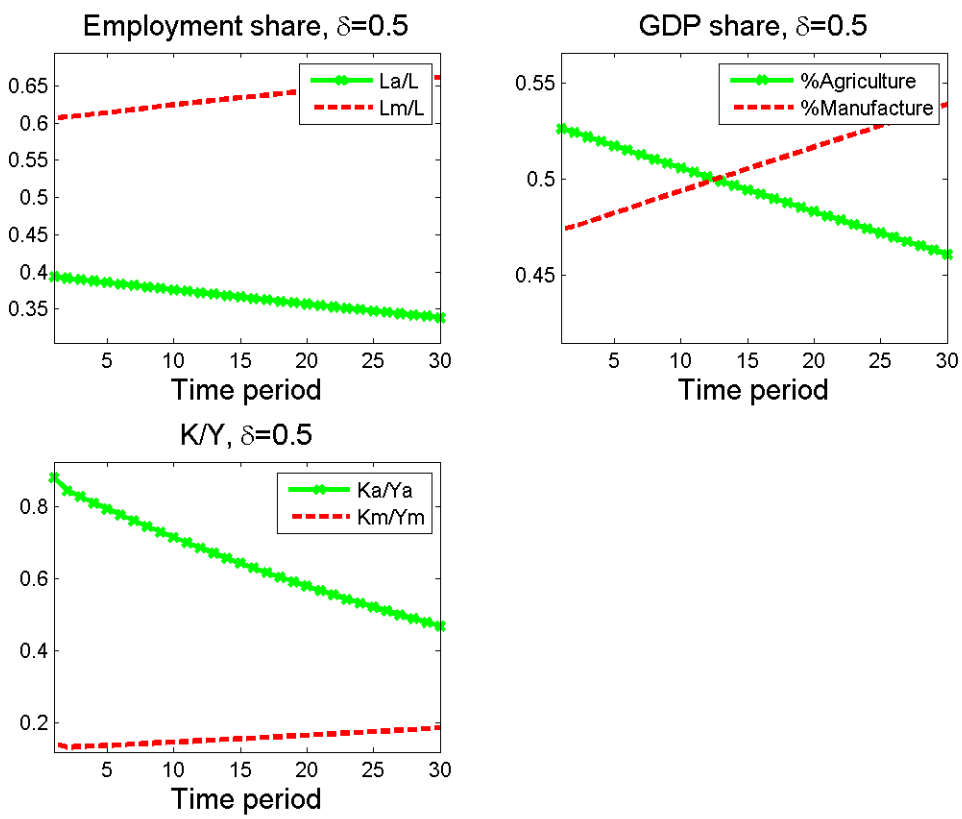

Figure 19: Experiment 3 (3): Varying redistribution, different productivity growth

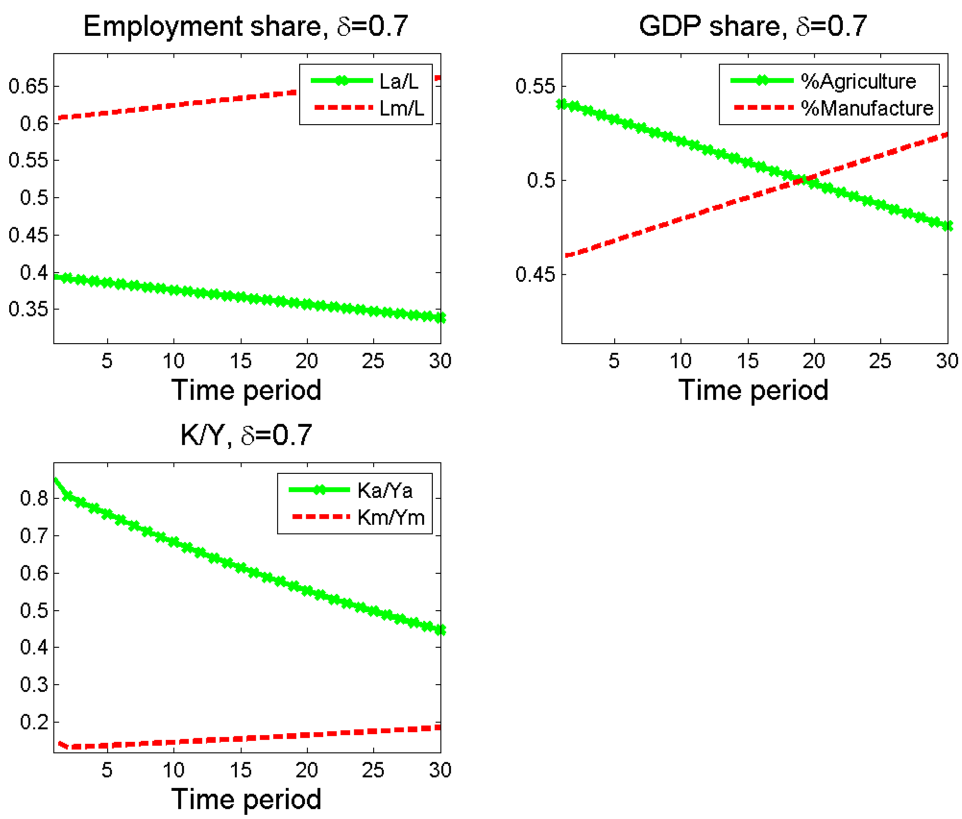

Figure 20: Experiment 3 (4): Varying redistribution, different productivity growth

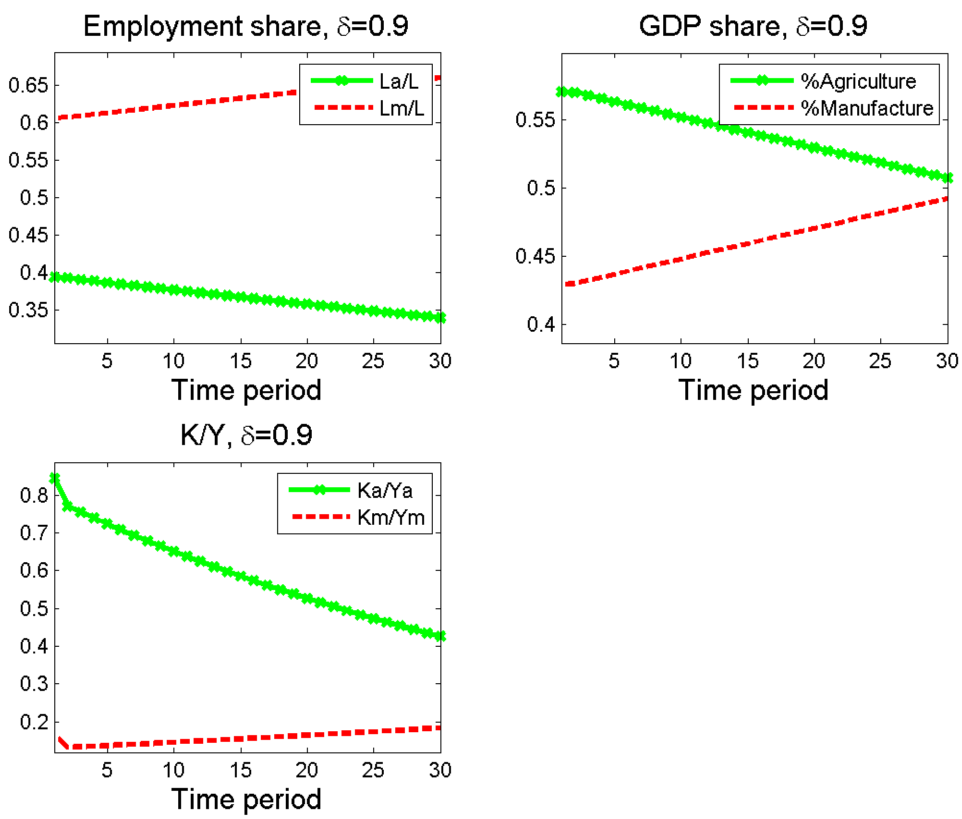

Figure 21: Experiment 3 (5): Varying redistribution, different productivity growth

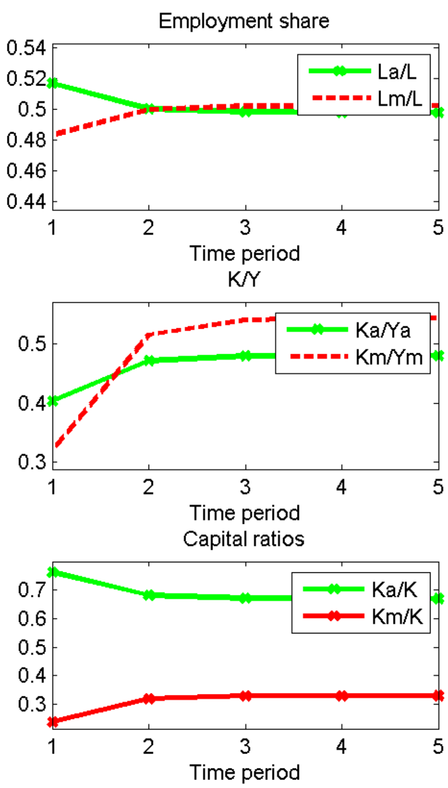

Figure 22: Model 1- Semi-linear utility function

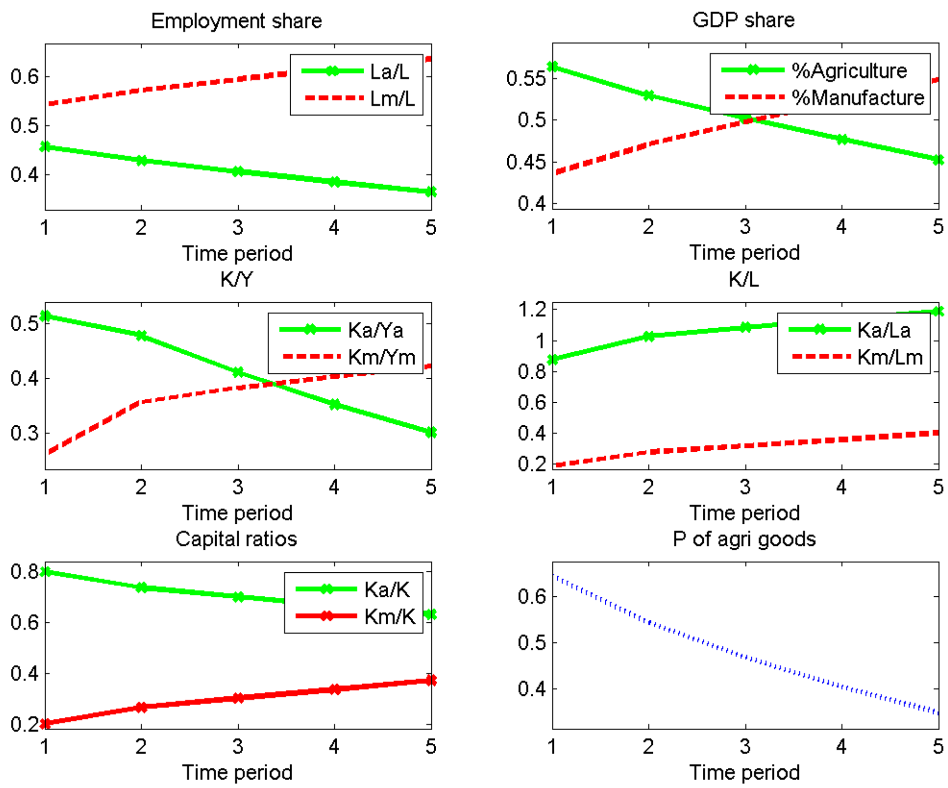

Figure 23: Model 2 - Semi-linear utility function with infrastructure

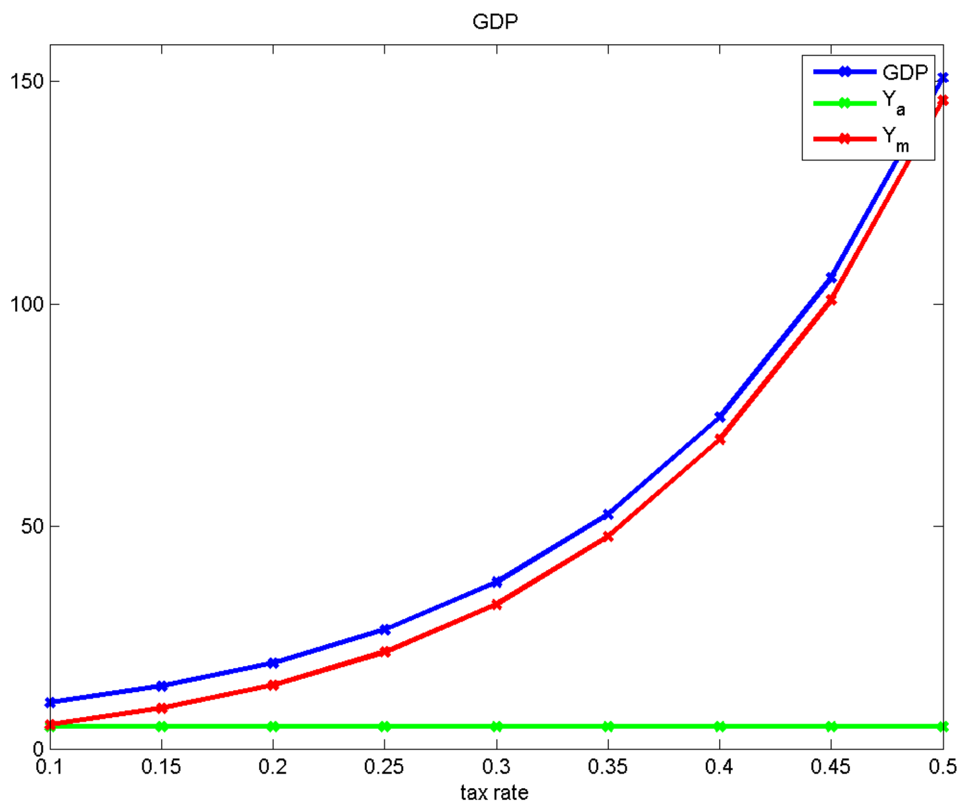

Figure 24: Model 2- Semi-linear utility with infrastructure, changing tax rates

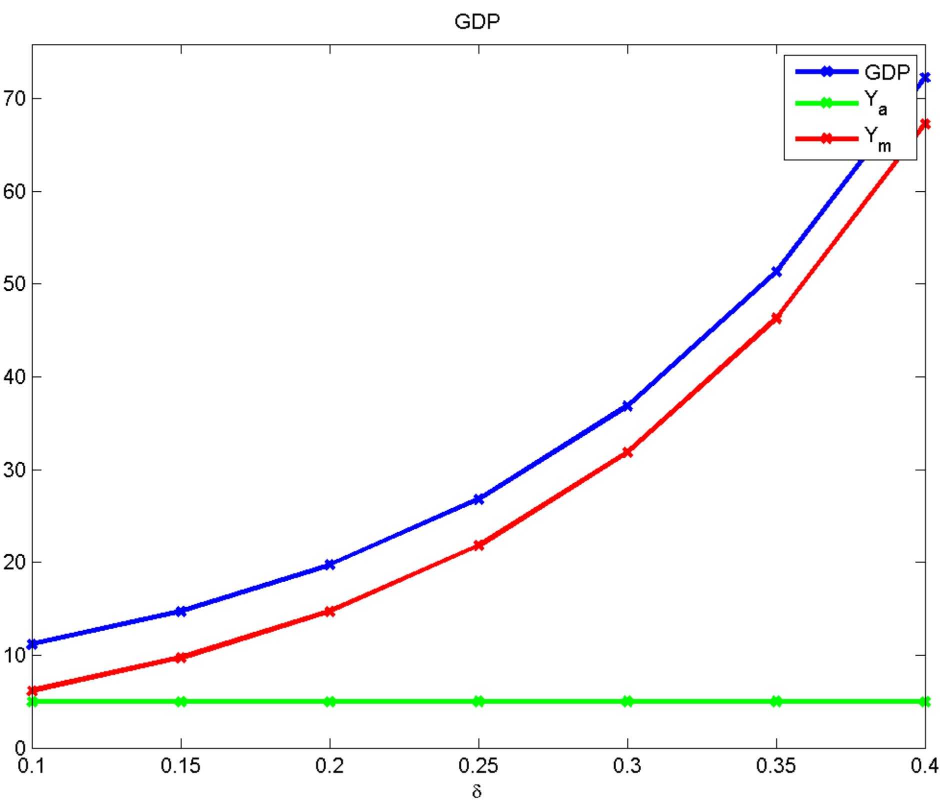

Figure 25: Model 2-Semi-linear utility with infrastructure, changing δ

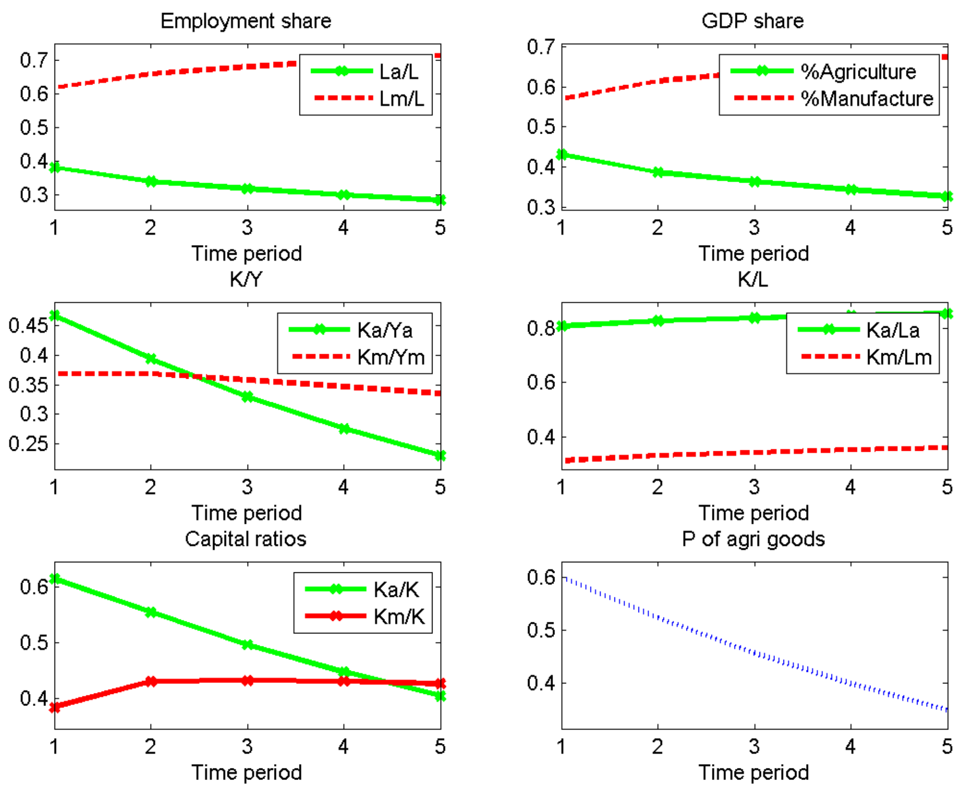

Figure 26: Model 3 - Stone-Gary utility with infrastructure

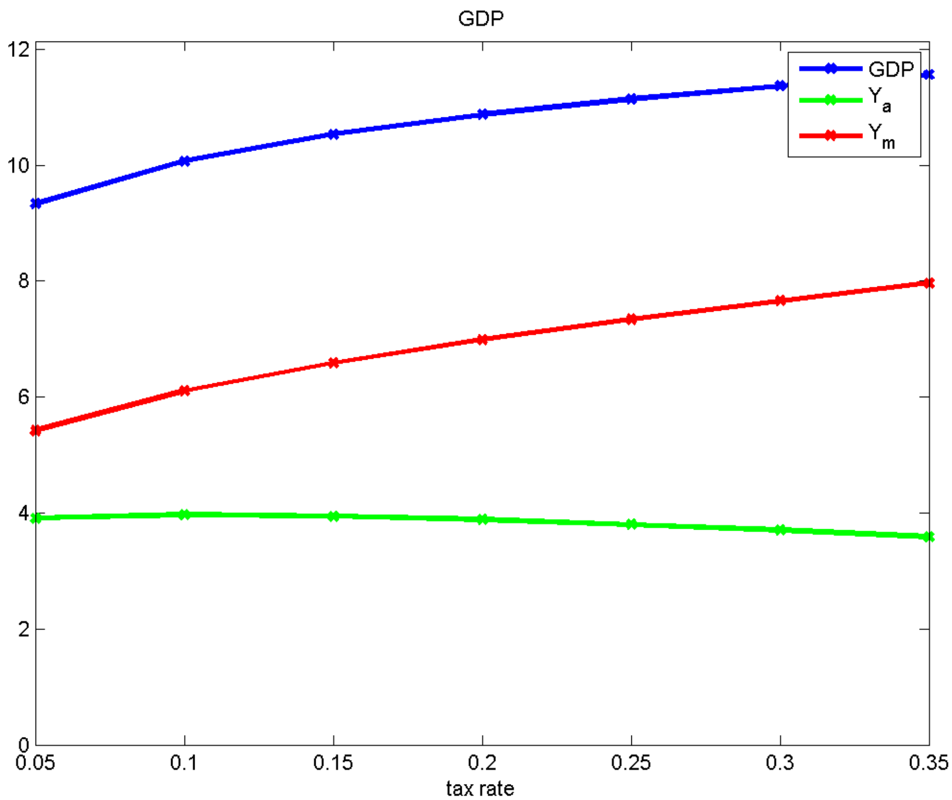

Figure 27: Model 3-Stone-Gary utility with infrastructure, changing tax rate

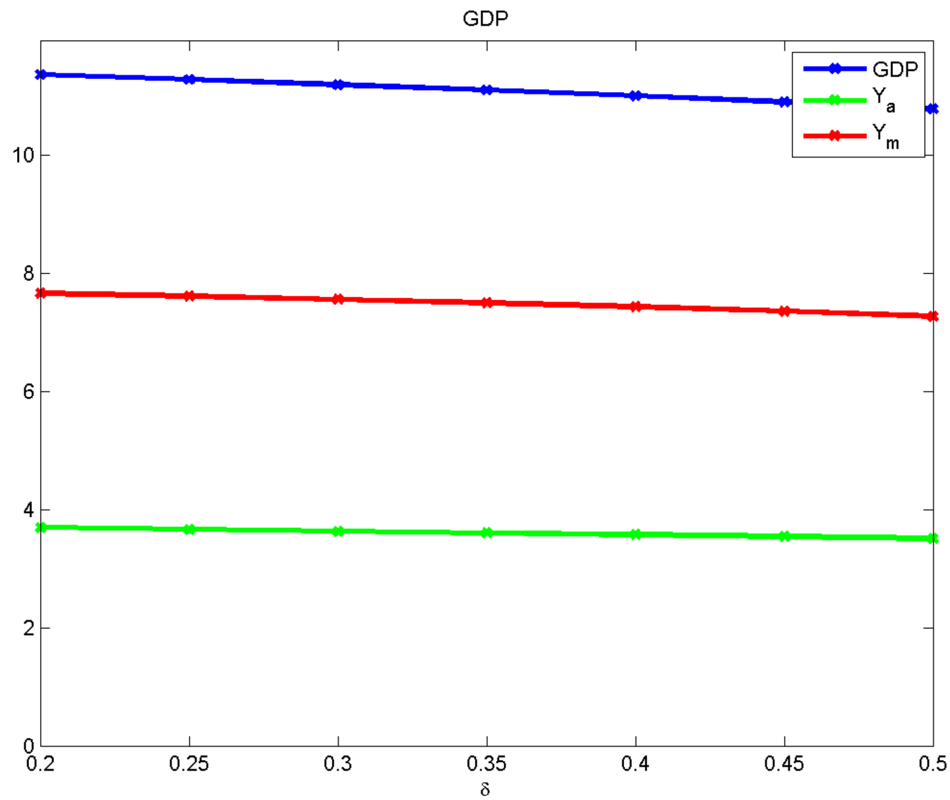

Figure 28: Model 3-Stone-Gary utility with infrastructure, changing delta