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Fiscal policy reforms in a general equilibrium model with imperfections

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Abstract: The debate on the way of stabilizing the economy, through cuts in public spending or rises in taxes, has been intensified after the crisis in 2008. This holds primarily for the Eurozone periphery countries. In view of high public debts, these countries have been urged to adopt restrictive fiscal policies which have further dampened demand and have worsened the recession, at least in the short term. It is known that within a dynamic general equilibrium (DGE) model with a representative agent a reduction of capital tax rates and the move of the tax burden to labour taxes produces social welfare benefits. However, one should not neglect the resulting distributional implications, which may favour some social groups vis-à-vis others. Such distributional implications are significantly influenced by imperfections in product and labour markets. Thus, this paper employs a DGE model that incorporates heterogeneous agents (entrepreneurs and workers) and imperfectly competitive product and labour markets, augmented with a relatively rich public sector, to quantify the macroeconomic and distributional implications of fiscal reforms like the above in the euro area.
Our main results are as follows: First, the most effective policy for the government to boost output is to reduce the capital tax rate, regardless the policy instrument that adjusts. In addition, if the goal of tax-spending policy is to promote welfare, then it should decrease the tax rate on labour and increase the consumption tax rate. Finally, a reduction in any of the tax rates, financed by an increase in capital tax rate, leads to a fall of inequality between the two social groups.

Keywords: trade unions, market structure, structural reforms
JEL classification: J5, I1.

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1 Introduction

Fiscal policy reforms have been well researched and there is a long tradition in searching the ways of stabilizing the economy with the use of a mix of public spending and tax policy. This debate has been intensified after the emergence of the crisis in 2008, with most of Eurozone periphery countries experience a serious debt crisis. In view of this fact these countries have been urged to adopt restrictive fiscal policies dampening demand and leading to severe recession. So, issues that deal with the mix of taxes with the reduction of public debt and stimulation of the economy, take on great importance in Europe. It is known that within a dynamic general equilibrium (DGE) model with a representative agent a reduction of a constant capital tax rate and the move of the burden to labour tax produces output benefits for the society. However, one should not neglect important distributional implications which favour some groups vis a vis the others. These gains and distributional implications are influenced from the imperfections in product and labour markets.

In light of the above, this paper employs a DGE model that incorporates heterogeneous agents (entrepreneurs and workers) and imperfectly competitive product and labour markets, augmented with a relatively rich public sector, to examine the quantitative macroeconomic and welfare implications of fiscal reforms in Euro Area. It contributes to the literature on the effects of tax-spending policy reforms.[1] In particular, it analyses the effects of: (i) changes in the composition of tax rates; and (ii) changes in public investment met by adjustment in one of the distorting tax rate. It is explored how these reforms affect the economy both in long –run and along the transition path to a new post-reform steady state. A qualitative assessment of the welfare effects associated with the alternative policy reform is also provided.

Our main results are as follows: First, the most effective policy for the government to boost output is to reduce the capital tax rate, regardless the policy instrument that adjusts. In addition, if the goal of tax-spending policy is to promote welfare, then it should decrease the tax rate on labour and increase the consumption tax rate. Finally, a reduction in any of the tax rates, financed by an increase in capital tax rate, leads to a fall of inequality between the two social groups. We notice that the results qualitatively are intuitively and quantitatively are small.

The rest of the paper is organised as follows: section 2 presents the theoretical model, section 3 includes baseline parameterization, section 4 studies the tax-spending reforms and finally, the last section concludes the results. An Appendix includes technical details.

2 Model

This section sets up a dynamic general equilibrium model with imperfect competition in product and labour markets. We start with an informal description of the model.

2.1 Informal description of the model

The economy consists of households, firms, trade unions and a government. There are two distinct types of households, called entrepreneurs and workers, who differ in capital ownership.[2] Entrepreneurs save in the form of physical capital and government bonds. They also own the firms and receive their profits. Workers, on the other hand, are assumed to face

[1] For the effects of tax-spending reforms in general equilibrium models with imperfections, see among others Ardagna (2007), Angelopoulos et al. (2013).

[2] The distinction between capitalists and workers follows a long tradition in the literature on economic policy and social conflict that dates back to e.g. Judd (1985). See Lansing (2011) for a review of general equilibrium models with concentrated ownership of capital as a type of agent heterogeneity.

transactions costs for saving or borrowing which prohibit their participation in financial markets; they thus consume all their disposable income in each time period. Workers may be unemployed; in this case, they receive unemployment benefits from the government. Workers (employed and unemployed) are represented by a trade union which bargains with firms over the wage rate in a right-to-manage union fashion. On the production side, there are final and intermediate good firms. Final good firms act competitively and make zero profits. By contrast, intermediate good firms, being owned by entrepreneurs, enjoy monopoly power in their own product market and make profits. Finally, the government issues bonds and taxes consumption, labour income and capital income in order to finance public spending. The latter includes a uniform lump-sum transfer to all households, public investment that augments public infrastructure benefiting private firms, public consumption that provides direct utility to all households and unemployment benefits received by unemployed workers. The time horizon is infinite and the time is discrete. For simplicity, there is no uncertainty.

2.2 Population

Total population, N, is exogenous and constant over time. There are $k=1,2,...,N^k$ identical entrepreneurs and $w=1,2,...,N^w$ identical workers, where $N^w=N-N^k$. It is convenient to define their population shares, $N^k/N\equiv n^k$ and $n^w=1-n^k$. For notational simplicity, we assume that each entrepreneur owns one of the profit-making intermediate good firms, N^i; thus, the number of these firms equals the number of entrepreneurs, $N^i=N^k$.

2.3 Households

As said, there are two types of households, entrepreneurs and workers. The lifetime utility of each type of household, denoted by superscript $j=k,w$, is:

$$\sum_{t=0}^{\infty}\beta^t\, u\left(C_t^j+\psi\bar{G}_t^c\right) \tag{1}$$

where the parameter $\beta\in(0,1)$ is the time preference rate, C_t^j is j's consumption and $\bar{G}_t^c$ is average (per household) government spending on utility-enhancing public goods and services. Thus, as in e.g. Christiano and Eichenbaum (1992), government consumption spending influences private utility through the value of the parameter $\psi\in[-1,1]$.[3]

In our numerical solutions, we will use for the instantaneous utility function:

$$u\left(C_t^j+\psi\bar{G}_t^c\right)=\frac{\left(C_t^j+\psi\bar{G}_t^c\right)^{1-\sigma}}{1-\sigma} \tag{2}$$

where $\sigma>1$ is a parameter.

2.3.1 Households as entrepreneurs

[3] Following the related literature (see e.g. Ardagna, 2007, and Angelopoulos *et al.,* 2013), and for simplicity, we do not allow for endogenous leisure in the utility function. All agents supply inelastically one unit of time when at work.

Each entrepreneur, k, saves in the form of physical capital, I_t^k, and government bonds, D_t^k. He receives gross income from one unit labour services supplied inelastically at a wage rate w_t^k, capital holdings, $r_t^k K_t^k$, and government bonds, $r_t^b B_t^k$. Thus, r_t^k denotes the gross return to the beginning-of-period capital, K_t^k, and r_t^b denotes the gross return to the beginning-of-period government bonds, B_t^k. Two additional sources of income are dividends paid by firms, π_t^k, and average (per household) lump-sum government transfers, $\bar{G}_t^t$. Thus, the budget constraint of each entrepreneur at time t is:

$$\begin{aligned}&(1+\tau_t^c)C_t^k + I_t^k + D_t^k = \\ &= \left(1-\tau_t^w\right) w_t^i e_t^i + \bar{G}_t^u \left(1-e_t^i\right) + r_t^k K_t^k - \tau_t^k \left(r_t^k - \delta^p\right) K_t^k + r_t^b B_t^k + \left(1-\tau_t^k\right)\pi_t^k + \bar{G}_t^t\end{aligned} \tag{3}$$

where $0 \leq \tau_t^c < 1$ is the tax rate on consumption, $0 \leq \tau_t^w < 1$ is the tax rate on labour income, $0 \leq \tau_t^k < 1$ is the tax rate on income from capital and dividends and the parameter $\delta^p \in (0,1)$ is the depreciation rate of capital.[4]

The laws of motion of physical capital and government bonds are:

$$K_{t+1}^k = (1-\delta^p)K_t^k + I_t^k,\ K_0^k > 0 \text{ given} \tag{4}$$

$$B_{t+1}^k = B_t^k + D_t^k,\ B_0^k > 0 \text{ given} \tag{5}$$

Therefore, the entrepreneur's problem is to choose $\left\{C_t^k, K_{t+1}^k, B_{t+1}^k\right\}_{t=0}^{\infty}$ to maximize (1) and (2) subject to the budget constraint, (3), and the law of motion of capital and bonds, (4) and (5), taking market prices $\left\{r_t^b, r_t^k, w_t^i\right\}_{t=0}^{\infty}$, the employment rate $\left\{e_t^i\right\}_{t=0}^{\infty}$, profits $\left\{\pi_t^k\right\}_{t=0}^{\infty}$, policy variables $\left\{\tau_t^c, \tau_t^k, \tau_t^w, \bar{G}_t^t, \bar{G}_t^u\right\}_{t=0}^{\infty}$, and initial condition for K_0^k and B_0^k as given.

The first order conditions include the constraints, (3)-(5), and:

$$\frac{1}{(1+\tau_t^c)}\frac{\partial u_t(.)}{\partial C_t^k} = \beta\left[\frac{1}{(1+\tau_{t+1}^c)}\frac{\partial u_{t+1}(.)}{\partial C_{t+1}^k}\left(\left(1-\tau_{t+1}^k\right)\left(r_{t+1}^k - \delta^p\right)+1\right)\right] \tag{6a}$$

$$\frac{1}{(1+\tau_t^c)}\frac{\partial u_t(.)}{\partial C_t^k} = \beta\left[\frac{1}{(1+\tau_{t+1}^c)}\frac{\partial u_{t+1}(.)}{\partial C_{t+1}^k}\left(1+r_{t+1}^b\right)\right] \tag{6b}$$

which are the Euler equations for K_{t+1}^k and B_{t+1}^k respectively. The optimality conditions are completed with the terminal conditions, $\lim_{t\to\infty} \beta^t \frac{\partial u_t(.)}{\partial C_t^k} K_{t+1}^k = 0$ and $\lim_{t\to\infty} \beta^t \frac{\partial u_t(.)}{\partial C_t^k} B_{t+1}^k = 0$.

[4] We assume that capital taxes are net of depreciation and that the fiscal authorities cannot impose separate tax rates on profits and capital income. We also assume that returns to government bonds are untaxed. These assumptions are not important to our results.

2.3.2 Households as workers

Since workers are excluded from financial markets, the within-period budget constraint of each worker, w, is:

$$\left(1+\tau_t^c\right)C_t^w = \left(1-\tau_t^w\right)w_t^i e_t^i + \bar{G}_t^u\left(1-e_t^i\right)+\bar{G}_t^t \qquad (7)$$

Individual workers do not make any choices. Given w_t^i, which is determined by the firm-union bargaining and the associated employment level, e_t^i, determined by firms (see below), their consumption follows residually from their budget constraint (7).

2.4 Firms and the production structure

The production environment consists of two sectors: the intermediate good sector and the final good sector. Following Guo and Lansing (1999) and many others in the literature on imperfect competition in product markets, we assume that the final good sector is perfectly competitive, while each intermediate good firm acts as a monopolist in its own market.

2.4.1 Final good firms

Assume, for simplicity, that the single final good is produced by one firm. The output of this firm, Y_t, is produced by a Dixit-Stiglitz type constant returns to scale technology:

$$Y_t = \left[\sum_{i=1}^{N^i} \lambda^i \left(Y_t^i\right)^{\theta}\right]^{\frac{1}{\theta}} \qquad (8)$$

where λ^i denotes the weight attached to each input i (we assume $\sum_{i=1}^{N^i} \lambda^i = 1$ to avoid scale effects, in equilibrium) and $\theta \in (0,1]$ is a measure of the monopoly power enjoyed by intermediate good producers.[5]

The profit of the final good producer is defined as:

$$\Pi_t = Y_t - \sum_{i=1}^{N^i} \lambda^i P_t^i Y_t^i \qquad (9)$$

where P_t^i is the price of each intermediate good i relative to the price of the single final good.

The final good producer behaves competitively by choosing intermediate inputs, Y_t^i, to maximize profits, Π_t. The first-order condition yields the well-known function:

$$P_t^i = \left(\frac{Y_t}{Y_t^i}\right)^{1-\theta} \qquad (10)$$

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[5] When $\theta = 1$, intermediate goods are perfect substitutes to each other in the production of the final goods so that intermediate good producers have no market power.

which gives the demand function for each intermediate good, Y_t^i, used in the next step.

2.4.2 Intermediate good firms

Each intermediate firm produces a homogeneous product, Y_t^i, by choosing two private inputs, capital, K_t^i, and workers, L_t^i, and by using average (per firm) public capital, $\frac{K_t^g}{N^i}$. Its production function is:[6]

$$Y_t^i = \mathrm{A}\left(K_t^i\right)^{\alpha_1}\left(L_t^i\right)^{\alpha_2}\left(\frac{K_t^g}{N^i}\right)^{\alpha_3} \tag{11}$$

where A is total productivity and $\alpha_1, \alpha_2, \alpha_3 \in (0,1)$ denote the output elasticity of private capital, labour and public capital, respectively. We assume constant returns to all three inputs and specifically $\alpha_1 + \alpha_2 + \alpha_3 = 1$.

The profit earned by the intermediate good producer at time t is:

$$\pi_t^i = P_t^i Y_t^i - r_t^k K_t^i - w_t^i L_t^i \tag{12}$$

Taking factor prices, r_t^k and w_t^i, final output, Y_t, and average public capital, $\frac{K_t^g}{N^i}$, as given, the intermediate good firm chooses K_t^i and L_t^i to maximize profits, (12), subject to its production function, (11), and the demand function for its output, (10) (see Appendix C for more details).

The first order conditions are:

$$\theta\alpha_1 \frac{\left(Y_t\right)^{1-\theta}\left(Y_t^i\right)^{\theta}}{K_t^i} = r_t^k \tag{13a}$$

$$\theta\alpha_2 \frac{\left(Y_t\right)^{1-\theta}\left(Y_t^i\right)^{\theta}}{L_t^i} = w_t^i \tag{13b}$$

the above conditions equate factor returns to marginal products. In turn, the profit of each intermediate good firm is:

$$\pi_t^i = \left(1 - \theta\alpha_1 - \theta\alpha_2\right)\left(Y_t\right)^{1-\theta}\left(Y_t^i\right)^{\theta} \tag{14}$$

2.5 Trade union and wage bargaining

We employ a right-to-manage setup where trade unions (representing workers) and firm federations (representing monopolistic intermediate good firms) bargain over workers' wage

[6] We include public investment, and hence public capital, because we wish to have as many fiscal policy instruments as possible and to be close to the data. See e.g. Lansing (1998), for a similar production function.

rate, w_t^w. Thus, w_t^w is chosen so as to maximize a weighted average of the representative worker's labour income and the representative intermediate good firm's profit:

$$U_t^N = \left[\left(1-\tau_t^w\right) w_t^i n^k L_t^i + \bar{G}_t^u \left(1-n^k L_t^i\right) - \bar{G}_t^u\right]^{\phi} \left[\pi_t^i + r_t^k K_t^i\right]^{1-\phi} \tag{15}$$

subject to the labour demand function (13b), and the intermediate firm's product demand function, (10), taking the capital stock, K_t^i, final output, Y_t, and the fiscal policy variables, $\left\{\tau_t^c, \tau_t^k, \tau_t^w, \bar{G}_t^u, \bar{G}_t^t\right\}$, as given.

In the above setup, $n^k L_t^i \equiv e_t^i$ is the average employment rate, so that $\left(1-n^k L_t^i\right)$ is the unemployment rate and $\phi \in [0,1]$ describes the relative bargaining power of the union, with $\phi = 1$ representing the monopoly union case. The outside option for the union is the unemployment benefit, $\bar{G}_t^u$, while for the firm it is the sunk cost of capital, $-r_t^k K_t^i$, which is a consequence of the assumption that the representative firm takes the average capital accumulation as given (see Appendix D for more details).

The first order condition is:

$$\left(1-\tau_t^w\right)\theta\alpha_2 \left(Y_t\right)^{1-\theta}\left(Y_t^i\right)^{\theta} = \frac{\left[\phi + (1-\phi)\alpha_2\theta\right]}{\theta\alpha_2}\bar{G}_t^u L_t^i \tag{16}$$

2.6 Government

On the revenue side, the government issues new bonds, B_{t+1}, and taxes consumption, labour income and capital income at the rates $0 \le \tau_t^c < 1$, $0 \le \tau_t^w < 1$ and $0 \le \tau_t^k < 1$ respectively. On the spending side, the government spends on total unemployment benefits, $N\bar{G}_t^u\left(1-e_t\right)$, total lump-sum transfers, $N\bar{G}_t^t$, total public investment, $N\bar{G}_t^i$ (we define $\bar{G}_t^i$ as the per capita public investment) and total public consumption, $N\bar{G}_t^c$. Thus, the within-period government budget constraint is:

$$\begin{aligned} &N\bar{G}_t^c + N\bar{G}_t^t + N\bar{G}_t^i + N\bar{G}_t^u\left(1-e_t^i\right) + \left(1+r_t^b\right)B_t = \\ &= N^k\tau_t^k\left(r_t^k - \delta^p\right)K_t^k + N^k\tau_t^k\pi_t^k + N\tau_t^w w_t^i e_t^i + N^w\tau_t^c C_t^w + N^k\tau_t^c C_t^k + B_{t+1} \end{aligned} \tag{17}$$

Public investment spending is used to augment public capital used by firms. If we define the per capita public capital as $\bar{k}_t^g \equiv \dfrac{K_t^g}{N}$, the law of motion is:

$$\bar{k}_{t+1}^g = (1-\delta^g)\bar{k}_t^g + \bar{G}_t^i \tag{18}$$

where the parameter $\delta^g \in (0,1)$ is the depreciation rate of public capital.
If we divide the above aggregate constraint by total population, we have in per capita terms:

$$\bar{G}_t^c + \bar{G}_t^t + \bar{G}_t^i + \bar{G}_t^u\left(1-e_t\right) + \left(1+r_t^b\right)\frac{B_t}{N} =$$
$$= n^k\tau_t^k\left(r_t^k - \delta^p\right)K_t^k + n^k\tau_t^k\pi_t^k + \tau_t^w w_t e_t + n^w\tau_t^c C_t^w + n^k\tau_t^c C_t^k + \frac{B_{t+1}}{N} \tag{19}$$

Thus, in each period, there are eight policy instruments $\left(\tau_t^c, \tau_t^k, \tau_t^w, \bar{G}_t^u, \bar{G}_t^t, \bar{G}_t^c, \bar{G}_t^i, B_{t+1}\right)$ out of which only seven can be set independently, with the eighth following residually to satisfy the government budget constraint. Following most of the related literature, we assume that, along the transition path, the adjusting instrument is the end-of-period public debt, B_{t+1}, so that the rest can be set exogenously by the government. At the steady state, we will, instead, set the debt-to-output ratio as in the data and allow government transfers to be the residually determined public financing instrument.

For convenience, concerning the spending policy instruments, we work in terms of their GDP shares:

$s_t^c \equiv \frac{N\bar{G}_t^c}{N^k Y_t^i} = \frac{\bar{G}_t^c}{n^k Y_t^i}$, $s_t^i \equiv \frac{N\bar{G}_t^i}{N^k Y_t^i} = \frac{\bar{G}_t^i}{n^k Y_t^i}$, $s_t^u \equiv \frac{\bar{G}_t^u(N - N^k L_t^i)}{N^k Y_t^i} = \frac{\bar{G}_t^u(1 - n^k L_t^i)}{n^k Y_t^i} = \frac{\bar{G}_t^u(1-e_t)}{n^k Y_t^i}$ and $s_t^t \equiv \frac{N\bar{G}_t^t}{N^k Y_t^i} = \frac{\bar{G}_t^t}{n^k Y_t^i}$.

2.7 Decentralized disequilibrium (DD) of the status quo economy

We solve for a symmetric decentralized disequilibrium (DD). Symmetricity implies $Y_t^i = Y_t$ and $P_t^i = 1$ (see also e.g. Guo and Lansing, 1999). Given the exogenously set policy instruments $\left\{\tau_t^w, \tau_t^c, \tau_t^k, s_t^u, s_t^t, s_t^c, s_t^i\right\}_{t=0}^{\infty}$, and initial conditions for the state variables, K_0^k and B_0^k, a symmetric DD is defined to be an allocation $\left\{Y_t^i, C_t^k, K_{t+1}^k, C_t^w, e_t, \pi_t^k, \bar{k}_{t+1}^g, r_t^b, r_t^k, w_t, B_{t+1}^k\right\}_{t=0}^{\infty}$ such that (i) households, firms and unions undertake their respective optimization problems; (ii) all budget constraints are satisfied; and (iii) all markets clear except in the labour market where we can have deviation from full employment (full employment means $e_t = 1$). Details are in Appendix 1. This is for any feasible policy. The dynamic system summarizing this symmetric DD and the resulting system in the steady state are presented in Appendices 2 and 3 respectively. The next section solves this model numerically.

3 Parameterization and solution of the above model

This section solves the above model numerically.

3.1 Parameter values and policy instruments

Table 1 reports the baseline parameter values for technology and preference, as well as the values of exogenous policy variables, used to solve the above model economy. The time unit is meant to be a year. Regarding parameters for technology and preference, we use relatively standard values often employed by the business cycle literature. Public spending and tax rate values are those of data averages of the European economy over 1990-2008. The data are obtained from OECD, Economic Outlook No. 90.

Table 1: Baseline parameter values and policy instruments		
Parameters and policy instruments	**Definition**	**Value**
$0 \leq \beta \leq 1$	Rate of time preference	0.97
$0 \leq \alpha_1 \leq 1$	Private capital share in production	0.33
$0 \leq \alpha_2 \leq 1$	Labour share in production	0.65
$0 \leq \alpha_3 \leq 1$	Public capital share in production	0.02
$0 \leq \delta^p \leq 1$	Depreciation rate on private capital	0.10
$0 \leq \delta^g \leq 1$	Depreciation rate on public capital	0.10
$0 \leq n^k \leq 1$	Population share of entrepreneurs	0.30
$\sigma > 1$	Relative risk aversion coefficient	2
A	TFP level	1
$-1 \leq \psi \leq 1$	Substitutability between private and public consumption in utility	0
$0 \leq \phi \leq 1$	Union power	0.50
$0 \leq \theta \leq 1$	Product market power	0.90
$0 \leq \tau^c \leq 1$	Consumption tax rate	0.1936
$0 \leq \tau^k \leq 1$	Tax rate on capital income	0.3209
$0 \leq \tau^w \leq 1$	Tax rate on labour income	0.3667
s_t^u	Unemployment benefits to output ratio	0.024
$\frac{B^k}{Y^i}$	Public debt to output ratio	0.60
s_t^c	Public Consumption to output ratio	0.20
s_t^i	Public Investment to output ratio	0.02

Let us discuss, briefly, the values summarized in Table 1. Workers' and entrepreneurs' labour shares in the production function of the intermediate good firm, α_2 and α_3, are set at 0.45 and 0.20 respectively. The public capital share, α_4, is set equal to 0.02, which is also the GDP share of public investment in the data (see e.g. Baxter and King, 1993, for similar practice for the US). Given the values of α_2, α_3 and α_4, the private capital share is $\alpha_1 = 1 - \alpha_2 - \alpha_3 - \alpha_4 = 0.33$. We normalise the total factor productivity parameter, A, to 1. We also use common values for the intertemporal elasticity of substitution, $1/\sigma = 0.5$ or $\sigma = 2$ and the time discount factor, $\beta = 0.97$. We assume that the depreciation rate of physical capital is 10%, which is the value calculated by Angelopoulos *et al.*, (2009), and also set the same value for the depreciation rate of public capital. Note that the depreciation rates matter for the long-run value of the investment share in GDP, but have little effect on near steady-state dynamics in this class of models (see also e.g. King and Rebelo, 1999). The parameter, ψ, which measures the degree of substitutability/complementary between private and public consumption in the utility function, is set equal to 0; as Christiano and Eichenbaum (1992) explain, this means that government consumption is equivalent to a resource drain in the macro-economy. We set the share of entrepreneurs, n^k, to 0.3. This is the share of households, as calculated by Angelopoulos *et al.* (2013), who have savings above £10,000. We choose a neutral value for union power, $\phi = 0.5$, which is in the middle of the range (i.e. 0.4 to 0.6) of values typically used in the literature, and a value for the market power in the product market, $\theta = 0.9$, implying that profits, in equilibrium, amount to around 10% of GDP. [7, 8]

The effective tax rates on consumption, capital and labour in the data are respectively $\tau^c = 0.1936$, $\tau^k = 0.3209$ and $\tau^w = 0.3667$. The values of the output shares of public spending on consumption and unemployment benefits are respectively $s_t^c = 0.20$ and $s_t^u = 0.024$. At the steady state, the public debt to output ratio is set at 0.60, which is close to the average value in the data over the sample period and has also been the Maastricht Treaty reference value. In turn, government transfers as a share of output, s_t^t, follow residually to close the government budget in this steady state solution.

3.2 Steady state solution or the "status quo"

Given the parameter and policy instrument values in Table 1, the steady state solution of the model economy is reported in Table 2. The solution is meaningful. For instance, the solution for the key ratios, like consumption and private investment as shares of output, as well as the replacement rate, are close to those in the data. This steady state solution is what we call the "status quo" or pre-reformed. We also report that this economy, when log-linearized above its steady state solution, is saddle-path stable. In the next section, departing from this status quo steady state solution, we will study the implications of various structural reforms. In the next sections, departing from this status quo solution, we study the implications of fiscal policy reforms.

Table 2: Pre-reform steady state

C/Y	0.5821	τ^k	0.3209
I^k/Y	0.1979	$u = 1-e$	0.0807
K^k/Y	1.9788	w^w	0.7600
K^g/Y	0.2000	$\tilde{w}^w$	0.4813
B^k/Y	0.6000	r^k	0.1455
s^t	0.1343	$\tilde{r}^k$	0.0309
s^u	0.0240	C	0.6952
s^c	0.2000	C^k	1.0828
s^i	0.0200	C^w	0.5291
π^k/Y	0.1270	U^{Total}	-1.5999
$\bar{G}^u/w^w$	0.4675	U^k	-0.9235
τ^w	0.3667	U^w	-1.8898
τ^c	0.1936		

4 Fiscal policy reforms

This section discusses the hypothetical reforms studied and then reports numerical results.

[7] See e.g. Domeij (2005) for a discussion of the relevant studies and empirical evidence.

[8] This value approximates the magnitude typically employed in New Keynesian models to capture the price mark-up over marginal costs.

4.1 Discussion of structural reforms studied

Departing from this situation, or what we have called the status quo, we study the aggregate and distributional effects of changing the tax-spending mix. We conduct policy experiments in which the government at time t=0 undertakes a permanent, unanticipated change in one of the distorting tax rates or spending categories $\left(\tau^{w},\tau^{k},\tau^{c},\bar{G}^{t},\bar{G}^{i},\bar{G}^{c}\right)$, compensated by a permanent change in another instrument that adjusts to satisfy the intertemporal government budget constraint (Domeij and Heathcote, 2004). In our experiments, we change only one exogenous policy instrument at a time, and allow only one policy instrument to adjust at a time, while keeping all other instrument constant at their initial steady state levels. In addition, during the transition to the new steady state, the end of period public debt follows residually from the within period government budget constrain in each time period.

Especially, we consider reforms that change the composition of the tax mix as well as reforms that alter the composition of the tax-spending mix. In particular, to study the effects of changes in the tax mix, we examine policy experiments in which (i) a 10% permanent reduction in capital tax rate, τ^{k}, is met by a permanent increase in labour tax rate, τ^{w}, (reformed economy 1), (ii) a 10% permanent reduction in capital tax rate, τ^{k}, is met by a permanent increase in consumption tax rate, τ^{c}, (reformed economy 2), (iii) a 10% permanent reduction in consumption tax rate, τ^{c}, is met by a permanent increase in labour tax rate, τ^{w}, (reformed economy 3), (iv) a 10% permanent reduction in consumption tax rate, τ^{c}, is met by a permanent increase in labour tax rate, τ^{k}, (reformed economy 4), (v) a 10% permanent reduction in labour tax rate, τ^{w}, is met by a permanent increase in capital tax rate, τ^{k} (reformed economy 5). To examine the effects of changes in the tax-spending mix, we conduct policy experiment in which a 10% permanent increase in public investment, $\bar{G}^{i}$, is financed by an increase in labour tax rate, τ^{w}, (reformed economy 6). We simulate the economy for 300 periods and obtain the dynamic paths of the endogenous variables along the transition path from the pre-reform equilibrium to the new long run equilibrium associated with the assumed reform.

4.2 How we work

To implement a reform and to solve the model, we work as follows. First, we solve for the pre-reform steady state and assume that the economy has been in this equilibrium until period zero. Second, we solve for the value of the policy instrument that allow adjusting and is consistent with the post-reform steady state exogenously change policy instrument and the pre-reform policy instruments. In particular, we obtain the new, post-reform steady state solution, by setting the new value of the exogenously changed policy instrument, holding all the others policy instruments at their pre-reform levels and letting one policy instrument adjust in the government budget constraint in the new steady state. Third, we impose the tax reform on the pre-reform equilibrium in period zero and obtain the dynamic solution of the system. In particular, we impose the reform in period-0 and solve the dynamic DD system for T=300 periods, keeping the two policy instruments that have been changed flat over time at their post reform values and letting s_{t}^{b} be residually determined so that the government budget constraint is satisfied.

The initial conditions for the model's state variables are given by the steady state solution of the pre-reform economy. For the terminal values of the forward looking variables, we assume that after T years the dynamic system has converged to its new steady state. This implies that the appropriate terminal conditions are obtained by setting the values for these variables equal to those of the preceding period.

The final system is given by 16(T+1) equations, which is solved non-linearly using the Matlab FSOLVE function. This gives the dynamic transition to the new steady state for the variables $\left\{K_{t+1}^{k}, \bar{k}_{t+1}^{g}, B_{t+1}^{k}, \pi_{t}^{k}, e_{t}^{i}, C_{t}^{k}, C_{t}^{w}, r_{t}^{b}, r_{t}^{k}, w_{t}^{i}, Y_{t}^{i}, \bar{G}_{t}^{t}, \bar{G}_{t}^{u}, \bar{G}_{t}^{c}, \bar{G}_{t}^{i}, s_{t}^{b}\right\}_{t=0}^{T}$, where we set T = 300 to ensure that convergence is achieved (see Appendix 4 for more details).

In all cases, we analyse the transition from the initial steady state to the new one and we study both aggregate and distributional implications. Regarding aggregate outcomes, we look, for instance, at output, consumption, employment and welfare.[9] Regarding distribution, we compute separately the income and welfare of the representative member in each social group i.e. entrepreneurs vis a vis workers. The above values are then compared to their respective values had we remain in the status quo economy permanently (see also e.g. Cooley and Hansen, 1992, Economides *et al.*, 2012).

4.3 Steady state and transition results

This section studies the implications of tax-spending policy reforms in terms of efficiency and income distribution, both in the steady state and the transition. Results of steady state solutions for each case, the status quo and the reformed economies, are reported in Table 3a. In Table 3b we present the steady state solutions of the reformed economies in percentage changes of the status quo economy. We also calculate the welfare gains/losses from the tax-spending reform for each type of agent and at the aggregate level, by computing the consumption supplement required to make the agents in the status quo regime as well as in the reformed economy. We denote welfare gains or losses for entrepreneurs, workers and the aggregate economy as $\zeta_{t}^{k}, \zeta_{t}^{w}$ and ζ_{t}, $t=1,10,50,300$ (see Appendix 5 and Table 4). In addition, we present the dynamic transition paths for the most important macroeconomic variables in Figures 1-6.

[9]Aggregate per capita welfare is defined as the weighted average of entrepreneurs' and workers' welfare.

Table 3a: Steady state solutions levels							
Variable	**Status Quo** s^t policy instrument (1)	**Reformed Economy 1** 10% reduction in τ^k τ^w policy instrument (2)	**Reformed Economy 2** 10% reduction in τ^k τ^c policy instrument (3)	**Reformed Economy 3** 10% reduction in τ^c τ^w policy instrument (4)	**Reformed Economy 4** 10% reduction in τ^c τ^k policy instrument (5)	**Reformed Economy 5** 10% reduction in τ^w τ^k policy instrument (6)	**Reformed Economy 6** 10% increase in s^i τ^w policy instrument (7)
Y	3.9811	4.0017	4.0091	3.9711	3.9413	3.9214	3.9966
$netY^w$	0.6316	0.6248	0.6360	0.6166	0.6253	0.6473	0.6312
$netY^k$	2.0803	2.1121	2.1261	2.0616	2.0178	1.9960	2.0855
$netY^k/netY^w$	3.2937	3.3803	3.3428	3.3436	3.2271	3.0834	3.3041
C	0.6952	0.6954	0.6967	0.6935	0.6930	0.6939	0.6956
C^w	0.5291	0.5235	0.5265	0.5251	0.5325	0.5424	0.5288
C^k	1.0828	1.0966	1.0939	1.0865	1.0676	1.0474	1.0846
C^k / C^w	2.0464	2.0948	2.0776	2.0692	2.0050	1.9313	2.0511
K^k	7.8779	8.0319	8.0469	7.8580	7.6414	7.4578	7.9085
K^g	0.2389	0.2401	0.2405	0.2383	0.2365	0.2353	0.2638
$u=1-e$	0.0807	0.0824	0.0807	0.0830	0.0807	0.0766	0.0812
w	0.7600	0.7653	0.7653	0.7600	0.7524	0.7453	0.7634
$\tilde{w}$	0.4813	0.4738	0.4847	0.4667	0.4765	0.4993	0.4803
r^k	0.1455	0.1435	0.1435	0.1455	0.1485	0.1514	0.1455
$\tilde{r}^k$	0.0309	0.0309	0.0309	0.0309	0.0309	0.0309	0.0309
τ^w	0.3667	0.3809	0.3667	0.3860	0.3667	0.3300	0.3708
τ^c	0.1936	0.1936	0.2080	0.1742	0.1742	0.1936	0.1936
τ^k	0.3209	0.2888	0.2888	0.3209	0.3629	0.3987	0.3209
s^i	0.0200	0.0200	0.0200	0.0200	0.0200	0.0200	0.0220

Table 3b: Steady state % changes						
Variable	**Reformed Economy 1** 10% reduction in τ^k τ^w adjusts (1)	**Reformed Economy 2** 10% reduction in τ^k τ^c adjusts (2)	**Reformed Economy 3** 10% reduction in τ^c τ^w adjusts (3)	**Reformed Economy 4** 10% reduction in τ^c τ^k adjusts (4)	**Reformed Economy 5** 10% reduction in τ^w τ^k adjusts (5)	**Reformed Economy 6** 10% increase in s^i τ^w adjusts (6)
Y	0.52	0.70	-0.25	-1.00	-1.50	0.39
$netY^w$	-1.07	0.70	-2.38	-1.00	2.50	-0.06
$netY^k$	1.53	2.20	-0.90	-3.00	-4.05	0.25
$netY^k/netY^w$	2.63	1.49	1.52	-2.02	-6.39	0.32
C	0.03	0.21	-0.25	-0.32	-0.20	0.04
C^w	-1.07	-0.50	-0.77	0.63	2.50	-0.06
C^k	1.27	1.02	0.34	-1.41	-3.27	0.17
C^k/C^w	2.37	1.53	1.11	-2.02	-5.62	0.23
K^k	1.96	2.14	-0.25	-3.00	-5.33	0.39
K^g	0.52	0.70	-0.25	-1.00	-1.50	10.43
$u=1-e$	2.11	0.00	2.88	0.00	-5.05	0.60
w	0.70	0.70	0.00	-1.00	-1.93	0.44
$\tilde{w}$	-1.56	0.70	-3.04	-1.00	3.74	-0.21
r^k	-1.41	-1.41	0.00	2.06	4.05	0.00
$\tilde{r}^k$	0.00	0.00	0.00	0.00	0.00	0.00
τ^w	3.89	0.00	5.25	0.00	-10.00	1.11
τ^c	0.00	7.43	-10.00	-10.00	0.00	0.00
τ^k	-10.00	-10.00	0.00	13.09	24.24	0.00
s^i	0.00	0.00	0.00	0.00	0.00	10.00

4.2.1 Aggregate effects

If the goal of tax policy is to stimulate the economy by changing the composition of distortionary taxes, then it should decrease the tax rate on capital and increase the consumption tax rate; this tax reform leads to the highest increase in output both in the short and long run. In the new long run the output increases by about 0.70%. The reason is that the reduction in the capital tax rate increases in private capital, despite that the increase in consumption tax rate decreases total consumption in the short run. This reduction in the short run consumption is very small in comparison with the increase in investment, and it comes from the larger reduction of the workers' consumption than the entrepreneurs' one in the short run. Furthermore, in the case in which the lower capital tax rate is compensated by a higher labour tax rate, output rise due to the increase in investment, but this increase is less than in the previous case because the increase in labour tax rate increases the unemployment. The increase in output in the long run in this case is 0.52%.

In contrast, when the decrease in the labour tax rate is financed by a higher capital tax rate, there is a decline in output in the short to medium run and in long run, due to the decrease in investment and consumption, despite the increase in employment. The reduction in output in the long run is about 1.50%, because a 10% reduction in labour tax rate is compensated by a 24.24% increase in capital tax rate. Also, tax reforms that reduce the consumption tax rate have negative effects on output both in the short and long run, and this is regardless of the tax rate that adjusts to ensure fiscal solvency.[10] Finally, a rise in government investment to output ratio financed by higher labour taxes stimulates output in the long run, but it leads to a fall in output over short-term-horizons.[11] In this case, it takes a long period of time before the positive impact of public infrastructure on the marginal productivity of private inputs to offset the adverse effects induced by the lower after-tax real wage. Similar conclusions can be found in Leeper et al. (2010) for the US economy.

Concerning the effects of the above policies on public finances, the results indicate that, while a shift of the tax burden from capital taxes towards consumption taxes stimulates the economy, it produces an increase in the primary deficit-to output ratio in the short run. Therefore, consumption tax revenues cannot meet the loss in capital tax revenues in the early stages of the tax reform. One the other hand, reductions in consumption taxes financed by higher income taxes, do not stimulate the economy, but contribute to reducing the debt-to-output ratio in the short run. See subplots (3,1) and (6,3) in figures 2, 3 and 4, where (3,1) and (6,3) refer to row and column numbers respectively.

Let us now consider the effects of the alternative tax-spending structures on welfare. Table 4 illustrates that a reduction in any of the tax rates financed by an increase in capital tax rate leads to a welfare gain between 0.0059% and 0.0202%, for the aggregate economy. In these cases, the aggregate utility rises along the transition path, due to the increase in total consumption. Entrepreneurs' loss in welfare, which comes from the increase in capital tax rate and thus the decrease in their consumption, is smaller than the gain for the workers' welfare, in the short and long run. For all other cases in Table 4 we notice welfare losses for the aggregate economy.

To summarise, our results show that the most effective policy for the government to boost output is to reduce the capital tax rate, regardless the policy instrument that adjusts. In addition, if the goal of tax-spending policy is to promote welfare, then it should decrease the tax rate on labour and increase the consumption tax rate.

[10] In the case that the reduction of the consumption tax rate is financed by a higher labour tax rate the output decreases by 0.25% in the long run and when is financed by a higher capital tax rate the reduction of the output in the long run is about 1%.

[11] The output increases about 0.39% in the long run.

Table 4: Welfare gains and losses over time $\zeta_t^k, \zeta_t^w, \zeta_t$						
	Reform 1	**Reform 2**	**Reform 3**	**Reform 4**	**Reform 5**	**Reform 6**
Capitalists						
$t=1$	0.0052	0.0020	0.0043	-0.0028	-0.0133	-0.0009
$t=10$	0.0072	0.0041	0.0041	-0.0057	-0.0181	-0.0007
$t=50$	0.0099	0.0070	0.0037	-0.0097	-0.0251	0.0002
$t=300$	0.0105	0.0077	0.0037	-0.0106	-0.0267	0.0005
Workers						
$t=1$	-0.0167	-0.0117	-0.0068	0.0161	0.0429	-0.0047
$t=10$	-0.0152	-0.0099	-0.0071	0.0137	0.0385	-0.0039
$t=50$	-0.0130	-0.0076	-0.0074	0.0102	0.0321	-0.0025
$t=300$	-0.0125	-0.0070	-0.0074	0.0094	0.0306	-0.0021
Aggregate						
$t=1$	-0.0130	-0.0093	-0.0049	0.0128	0.0327	-0.0041
$t=10$	-0.0114	-0.0075	-0.0051	0.0103	0.0282	-0.0034
$t=50$	-0.0091	-0.0051	-0.0054	0.0067	0.0217	-0.0020
$t=300$	-0.0086	-0.0045	-0.0055	0.0059	0.0202	-0.0017

4.2.2 Distributional effects

Since there are two different groups of households in the society – workers and entrepreneurs – these income/welfare gains from each particular tax-spending reform may be distributed unequally for each group in society. Thus, we now turn to individual outcomes or, equivalently, to distribution. We start with the net income of each agent, $netY^k$ and $netY^w$. According the results the best policy reform for the workers is to decrease labour tax rate and to increase capital tax rate, but this reform has negative impact on the entrepreneurs' net income. The opposite effect on net incomes we notice when the inverse reform takes place i.e. a reduction of capital tax rate that is financed by an increase on labour tax rate. Furthermore, an increase in government to output ratio raises the net income of entrepreneurs and deteriorates the net income of workers. In the case in which the lower consumption tax rate is compensated by a higher labour or capital tax rate, net incomes of the two groups decreases. Benefits for both groups in society is noticed when a reduction of capital tax rate is compensated by an increase in consumption tax rate.

A key question now is who gains more. Even if a policy reform produces a win-win outcome, in the sense that both $netY^k$ and $netY^w$ rise, relative outcomes can be also important. The political economics literature has pointed out several reasons for this, including political ideology, habit, envy, etc. In our model, relative outcomes will be measured by changes in the ratio of net incomes, $netY^k / netY^w$. Departing from the status quo economy, this ratio falls, or inequality falls, when a reduction in any of the tax rates is financed by an increase in capital tax rate. The fall is bigger, -6.39%, when the reduction has to do with the tax rate on labour instead of -2.02% when the consumption tax rate decreases. In contrast, a reduction in any of the tax rates or an increase in the government investment to output ratio is financed by an increase in labour tax rate deteriorates the equality between the two groups. Again the rise of inequality is bigger when the capital tax rate decreases and this rise is about 2.63% in the long run. Finally, negative result for the equality between the two groups we have also when a reduction on capital tax rate is financed by an increase in consumption tax rate, despite that the net income of workers and entrepreneurs increases relative to status quo economy.

5 Conclusions and possible extensions

We employed a DGE model that incorporates heterogeneous agents (entrepreneurs and workers) and imperfectly competitive product and labour markets, augmented with a relatively rich public sector, to examine the quantitative macroeconomic and welfare implications of fiscal reforms in Euro Area. First, we study the effects of changes in the composition of tax rates, and, second the effects of change in public investment met by adjustment in one of the distorting tax rate. Our main results are as follows: First, the most effective policy for the government to boost output is to reduce the capital tax rate, regardless the policy instrument that adjusts. In addition, if the goal of tax-spending policy is to promote welfare, then it should decrease the tax rate on labour and increase the consumption tax rate. Finally, a reduction in any of the tax rates, financed by an increase in capital tax rate, leads to a fall of inequality between the two social groups. We notice that the results qualitatively are intuitively and quantitatively are small.

In future it would be interesting to extend our analysis to the case of a small open economy. This would allow us to study the effects of alternative fiscal policy reforms on external imbalances and international competitiveness.

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FIGURES

Figure 1: From Status Quo to Reformed Economy 1 (10% reduction in τ^k and τ^w adjusts)

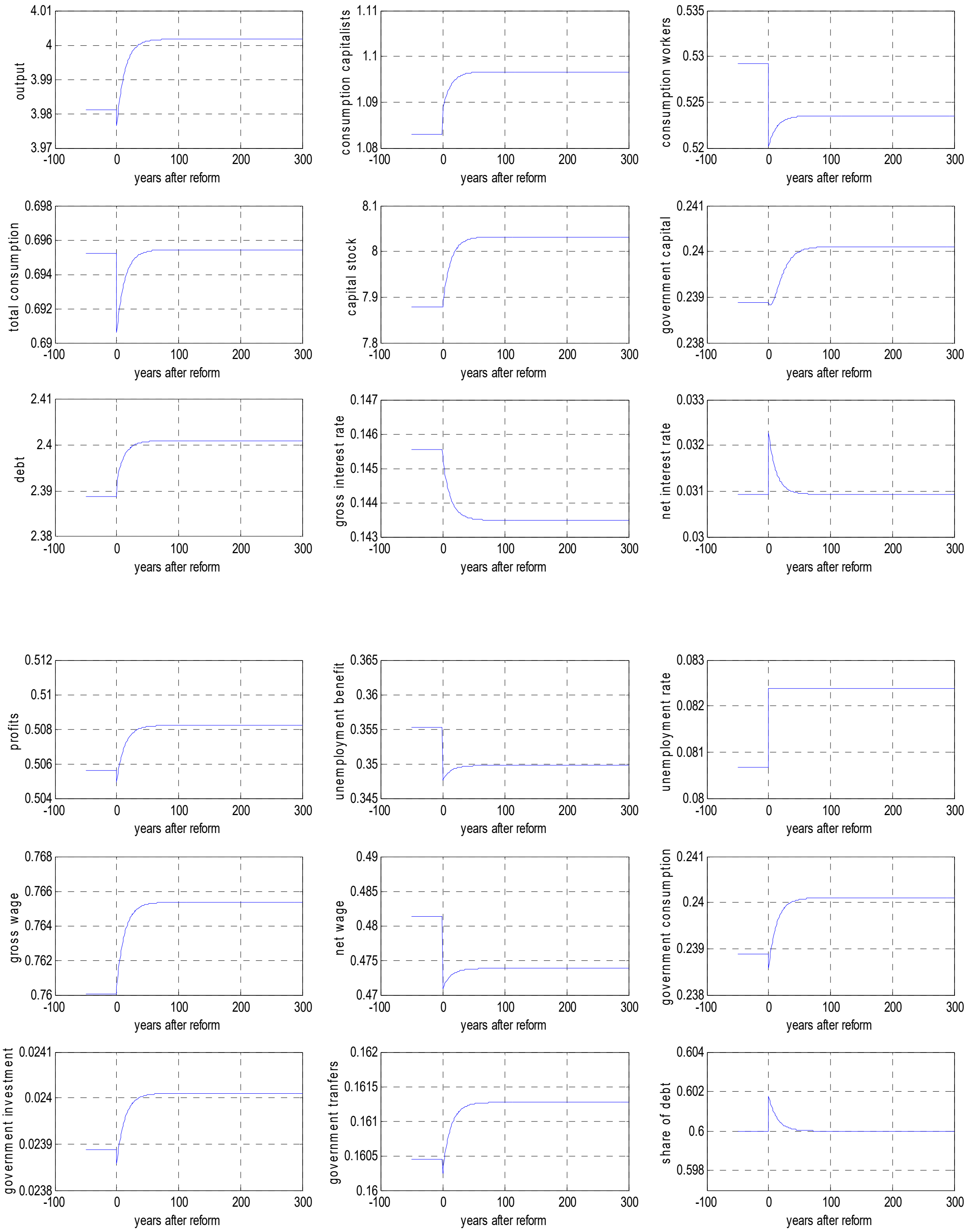


Figure 2: From Status Quo to Reformed Economy 2
(10% reduction in τ^k and τ^c adjusts)

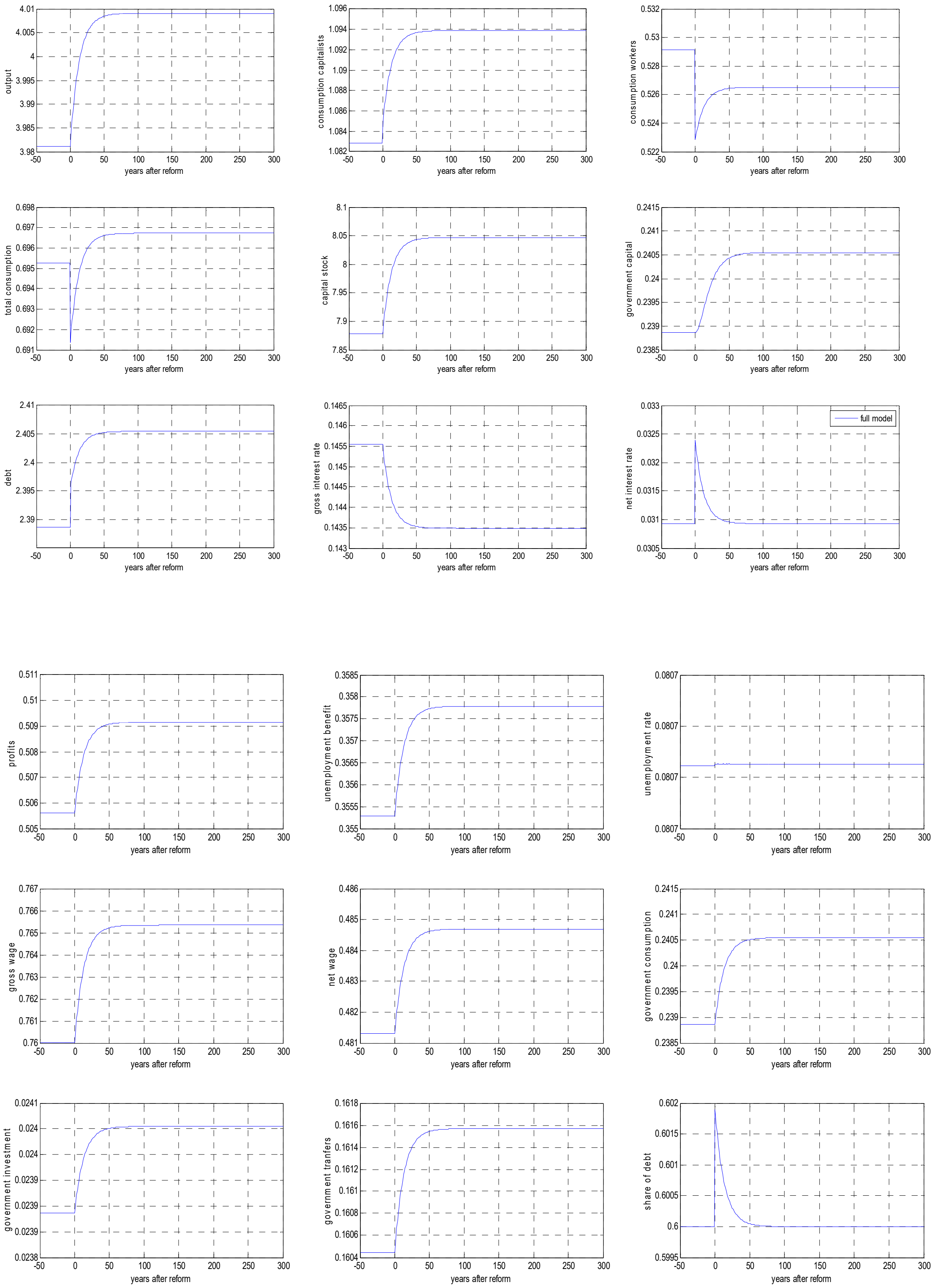


Figure 3: From Status Quo to Reformed Economy 3
(10% reduction in τ^c and τ^w adjusts)

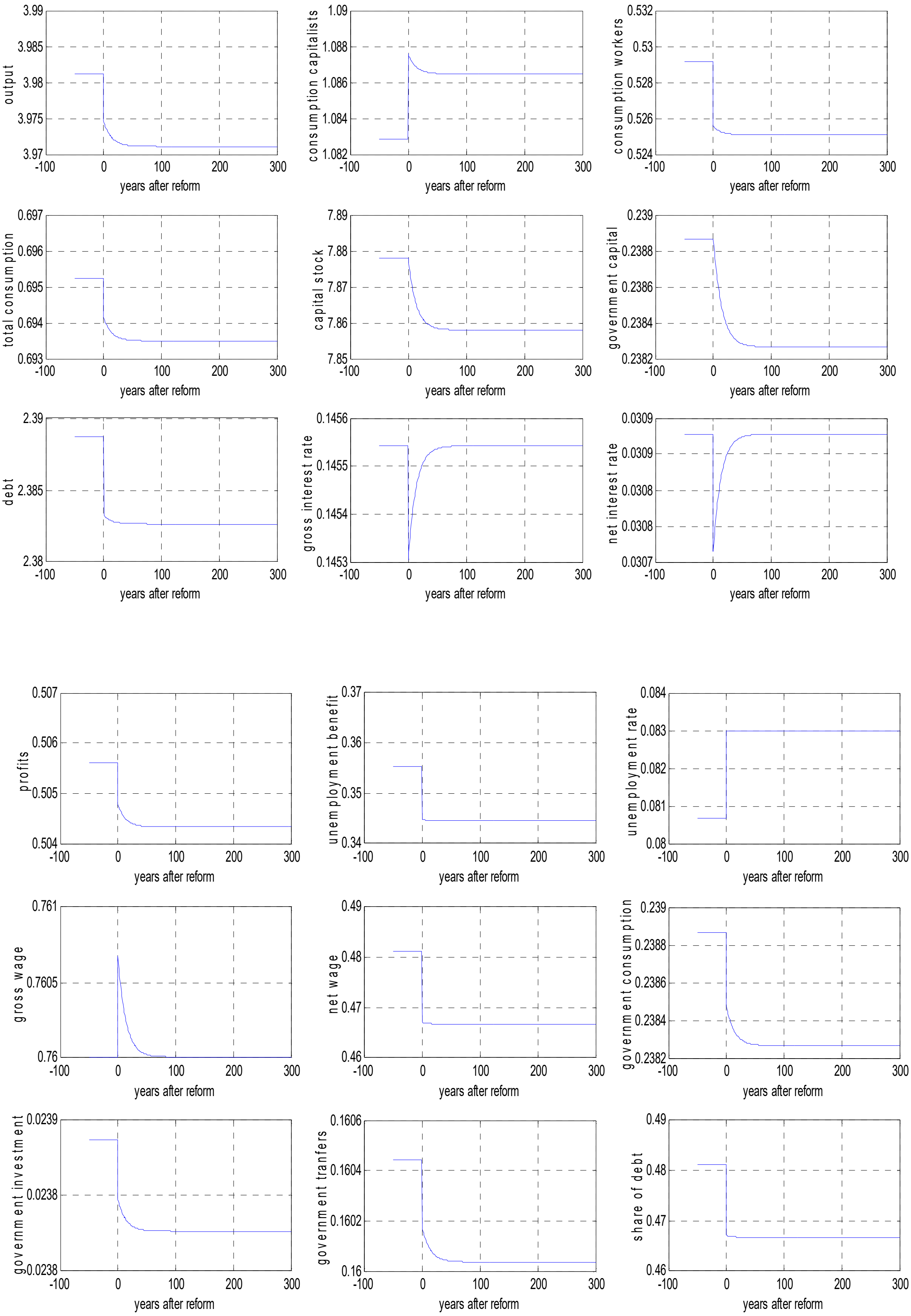


Figure 4: From Status Quo to Reformed Economy 4
(10% reduction in τ^c and τ^k adjusts)

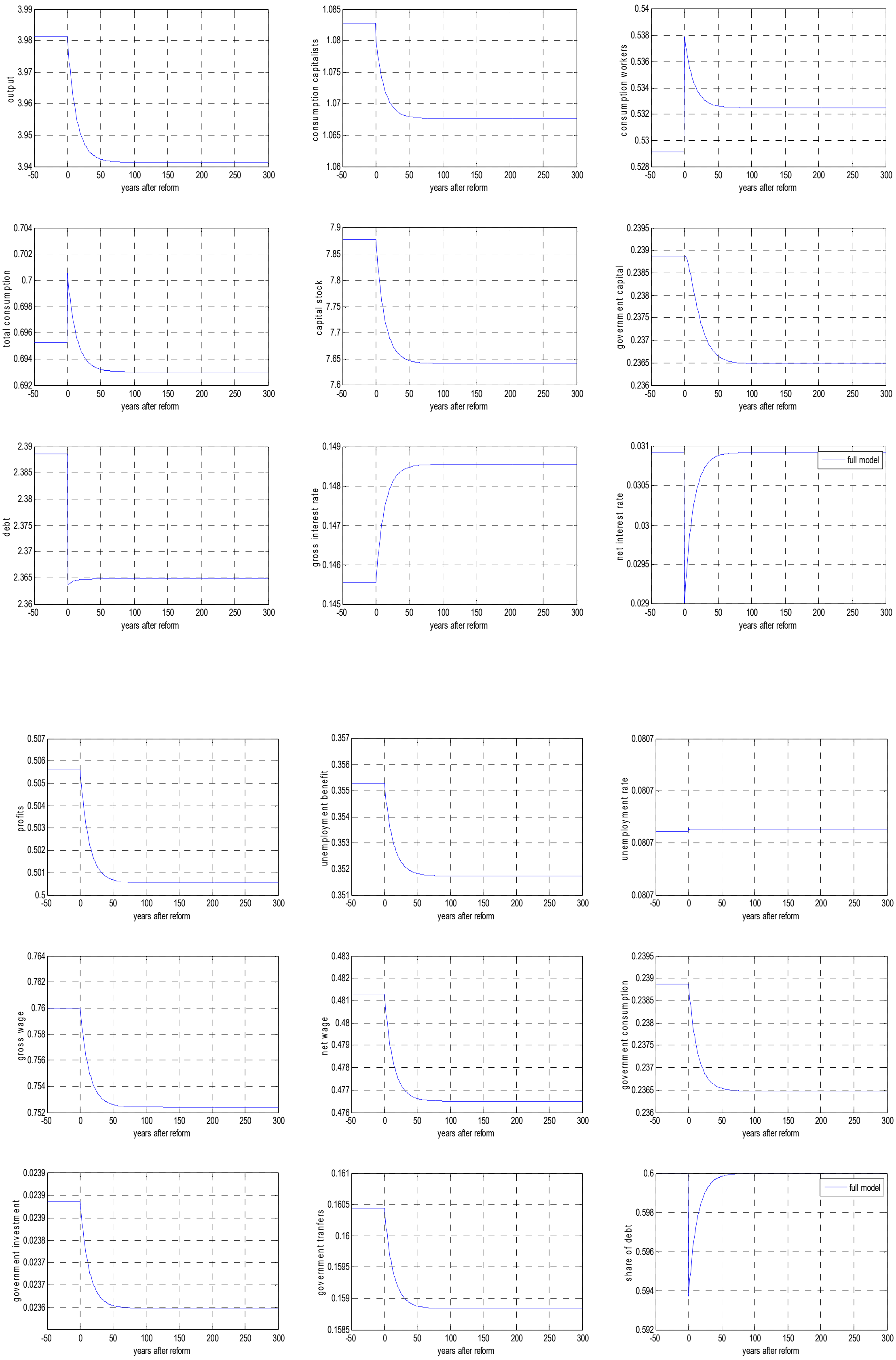


Figure 5: From Status Quo to Reformed Economy 5
(10% reduction in τ^w and τ^k adjusts)

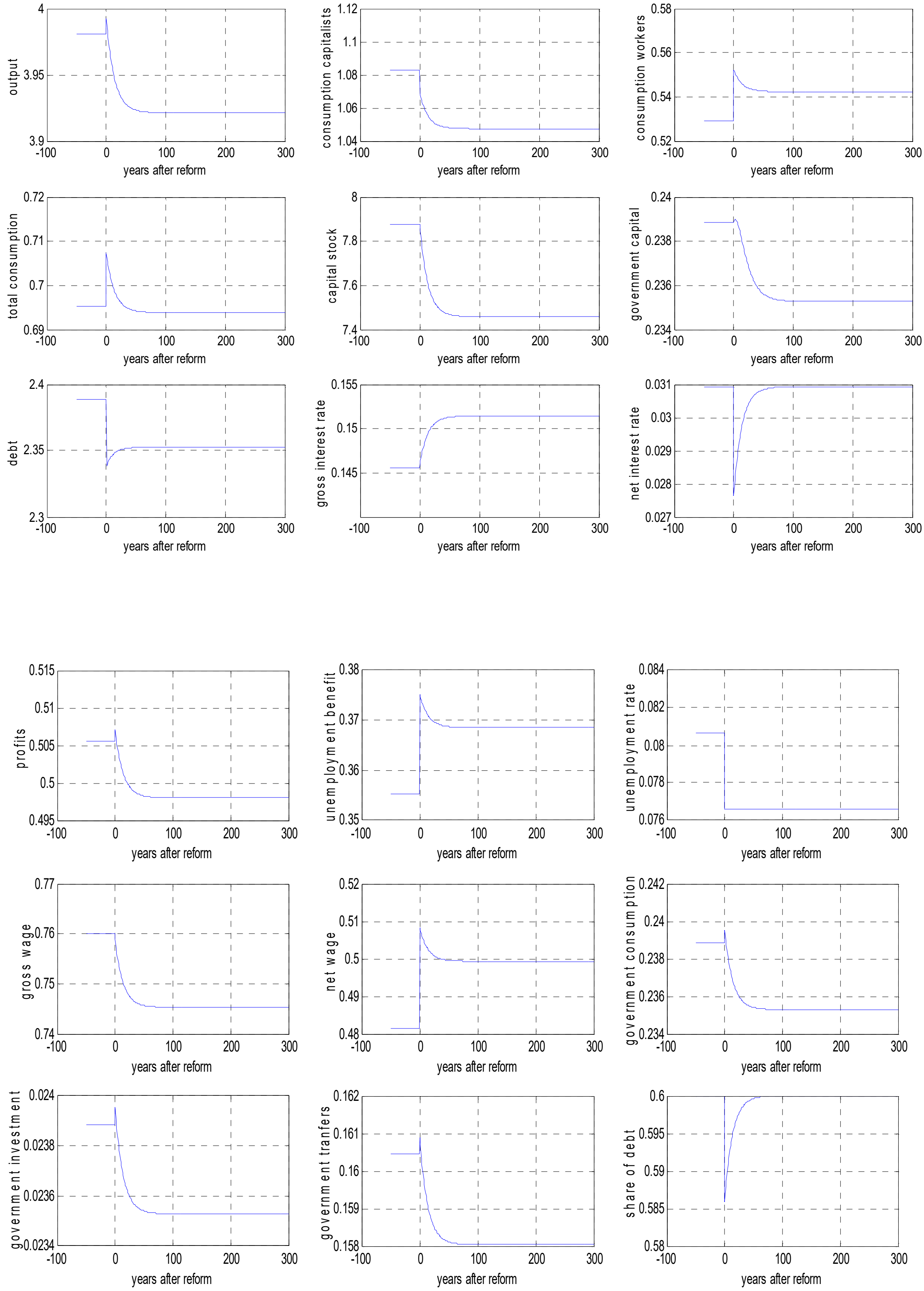
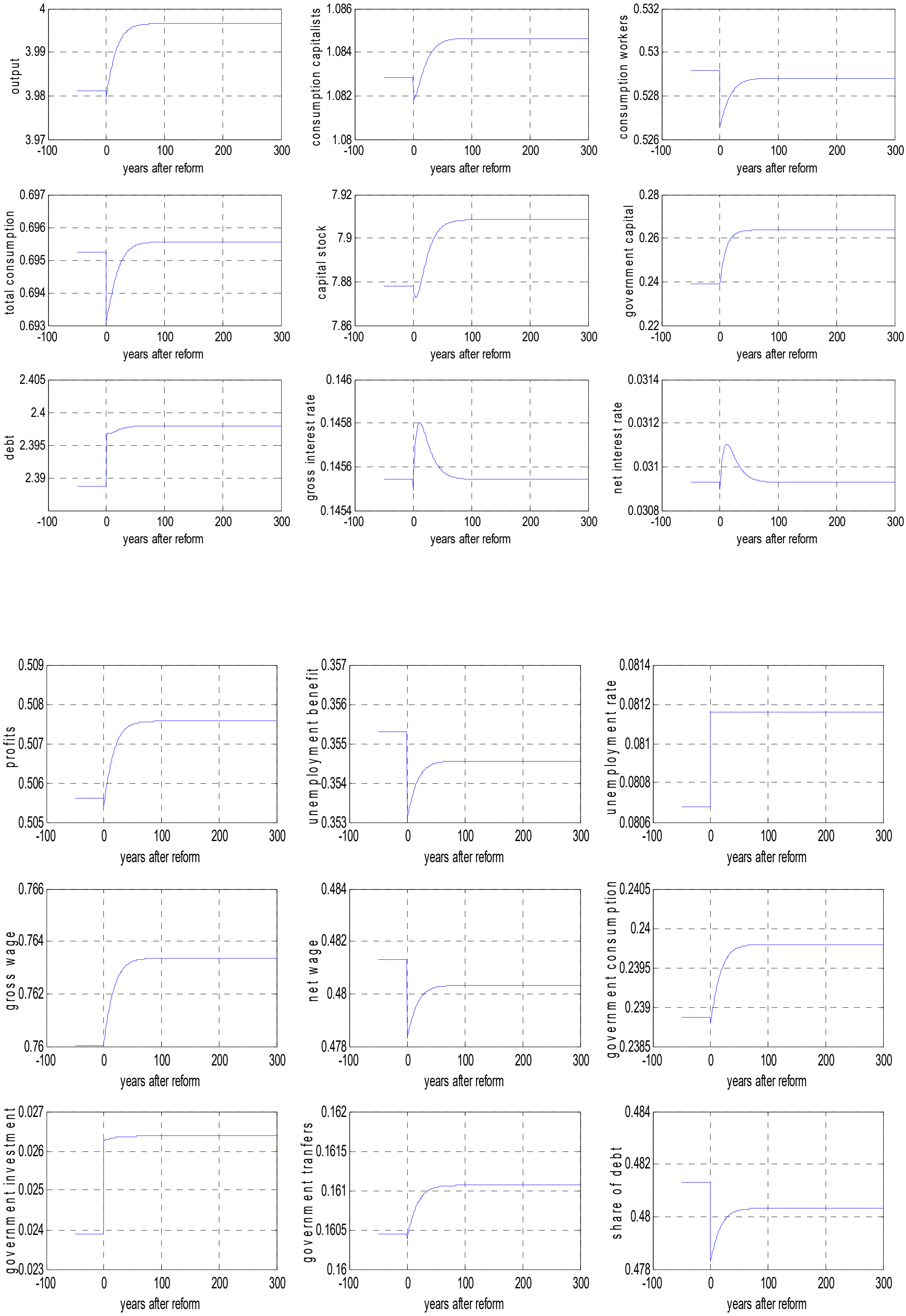


Figure 6: From Status Quo to Reformed Economy 6
(10% reduction in s^i and τ^w adjusts)



APPENDICES

Appendix 1: Market clearing conditions

The market clearing conditions are:

$$\sum_{k=1}^{N^k} K_t^k = \sum_{i=1}^{N^i} K_t^i \Rightarrow N^k K_t^k = N^i K_t^i \xrightarrow{N^k = N^i} K_t^k = K_t^i \tag{A.1a}$$

$$\sum_{k=1}^{N^k} \pi_t^k = \sum_{i=1}^{N^i} \pi_t^i \Rightarrow N^k \pi_t^k = N^i \pi_t^i \xrightarrow{N^k = N^i} \pi_t^k = \pi_t^i \tag{A.1b}$$

$$B_{t+1} = \sum_{k=1}^{N^k} B_{t+1}^k \Rightarrow B_{t+1} = N^k B_{t+1}^k \tag{A.1c}$$

$$\begin{gathered} \sum_{j=1}^{N^k+N^w} e_t^j = \sum_{i=1}^{N^i} L_t^i \Rightarrow (N^k + N^w) e_t^j = N^i L_t^i \Rightarrow \\ \frac{\left(N^k + N^w\right) e_t^j}{N} = \frac{N^i L_t^i}{N} \xrightarrow{N^k = N^i, N^k + N^w = N} \frac{N e_t^j}{N} = \frac{N^k L_t^i}{N} \Rightarrow e_t^j \equiv e_t^i = n^k L_t^i \end{gathered} \tag{A.1d}$$

Finally, in the goods market, the economy's per capita resource constraint is:

$$n^k Y_t^{1-\theta} \left(Y_t^i\right)^{\theta} = n^k C_t^k + n^w C_t^w + n^k \left[K_{t+1}^k - (1-\delta^p) K_t^k\right] + \overline{G}_t^c + \overline{G}_t^i \tag{A.1f}$$

Appendix 2: The Decentralized Disequilibrium

It consists of the following equations:

The entrepreneur's Euler equation with respect to capital:

$$\frac{(1+\tau_{t+1}^c)\left(C_{t+1}^k + \psi s_{t+1}^c n^k Y_{t+1}^i\right)^{\sigma}}{(1+\tau_t^c)\left(C_t^k + \psi s_t^c n^k Y_t^i\right)^{\sigma}} = \beta\left[1 + \left(1-\tau_{t+1}^k\right)\left(r_{t+1}^k - \delta^p\right)\right] \tag{A.2a}$$

The entrepreneur's Euler equation with respect to bonds:

$$r_{t+1}^b = \left(1-\tau_{t+1}^k\right)\left(r_{t+1}^k - \delta^p\right) \tag{A.2b}$$

The worker's budget constraint:

$$\left(1+\tau_t^c\right) C_t^w = \left(1-\tau_t^w\right) w_t e_t + s_t^u n^k Y_t^i + s_t^t n^k Y_t^i \tag{A.2c}$$

The intermediate firm's optimality condition for L_t^i:

$$\theta\alpha_2 \frac{n^k Y_t^i}{e_t} = w_t \tag{A.2d}$$

The intermediate firm's optimality condition for K_t^i:

$$\theta\alpha_1 \frac{Y_t^i}{K_t^k} = r_t^k \tag{A.2e}$$

The intermediate firm's profit function:

$$\pi_t^k = \left(1-\theta\alpha_1-\theta\alpha_2\right)Y_t^i \tag{A.2f}$$

The intermediate firm's production function:

$$n^k Y_t^i = \mathrm{A}\left(n^k K_t^k\right)^{\alpha_1}\left(e_t\right)^{\alpha_2}\left(\bar{k}_t^g\right)^{\alpha_3} \tag{A.2g}$$

The union's optimality condition for the wage rate:

$$\left(1-\tau_t^w\right)\theta\alpha_2 = \frac{\left[\phi+(1-\phi)\alpha_2\theta\right]}{\theta\alpha_2}\frac{s_t^u e_t}{1-e_t} \tag{A.2h}$$

The Government's Budget Constraint:

$$\begin{aligned}&\left(s_t^c+s_t^t+s_t^i+s_t^u\right)n^k Y_t^i + n^k(1+r_t^b)B_t^k = \\ &= n^k\tau_t^k\left(r_t^k-\delta^p\right)K_t^k + n^k\tau_t^k\pi_t^k + \tau_t^w w_t e_t + n^w\tau_t^c C_t^w + n^k\tau_t^c C_t^k + n^k B_{t+1}^k\end{aligned} \tag{A.2i}$$

The law of motion of public capital:

$$\bar{k}_{t+1}^g = (1-\delta^g)\bar{k}_t^g + s_t^i n^k Y_t^i \tag{A.2j}$$

The resource constraint:

$$n^k Y_t^i = n^k C_t^k + n^w C_t^w + n^k\left[K_{t+1}^k-(1-\delta^p)K_t^k\right] + s_t^c n^k Y_t^i + s_t^i n^k Y_t^i \tag{A.2k}$$

Therefore, the DD is a system of eleven non-linear difference equations (A.2a)-(A.2k) in the paths of $Y_t^i, C_t^k, K_{t+1}^k, C_t^w, e_t, \pi_t^k, \bar{k}_{t+1}^g, r_t^b, r_t^k, w_t$ and one of the eight policy instruments, $\tau_t^w, \tau_t^c, \tau_t^k, s_t^u, s_t^t, s_t^c, s_t^i, B_{t+1}^k$, that is residually determined. This equilibrium is given the paths of the other seven tax-spending policy instruments.

Appendix 3: The Steady State

In the long run, variables remain constant. Thus, $x_{t-1} = x_t = x_{t+1} \equiv x$, where variables without time subscript denote long run values. Then we have the system:

$$1=\beta\left[1+\left(1-\tau^{k}\right)\left(r^{k}-\delta^{p}\right)\right] \tag{A.3a}$$

$$r^{b}=\left(1-\tau^{k}\right)\left(r^{k}-\delta^{p}\right) \tag{A.3b}$$

$$(1+\tau^{c})C^{w}=\left(1-\tau^{w}\right)w\,e\;+\left(s^{u}+s^{t}\right)n^{k}Y^{i} \tag{A.3c}$$

$$\theta\alpha_{2}\frac{n^{k}Y^{i}}{e}=w \tag{A.3d}$$

$$\theta\alpha_{1}\frac{Y^{i}}{K^{k}}=r^{k} \tag{A.3e}$$

$$\pi^{k}=\left(1-\theta\alpha_{1}-\theta\alpha_{2}\right)Y^{i} \tag{A.3f}$$

$$n^{k}Y^{i}=\mathrm{A}\left(n^{k}K^{k}\right)^{\alpha_{1}}e^{\alpha_{2}}\left(\overline{k}^{g}\right)^{\alpha_{3}} \tag{A.3g}$$

$$\left(1-\tau^{w}\right)\theta\alpha_{2}=\frac{\left[\phi+\left(1-\phi\right)\alpha_{2}\theta\right]}{\theta\alpha_{2}}\frac{s^{u}e}{1-e} \tag{A.3h}$$

$$\begin{aligned}&\left(s^{c}+s^{t}+s^{i}+s^{u}\right)n^{k}Y^{i}+n^{k}r^{b}B^{k}=\\&=n^{k}\tau^{k}\left(r^{k}-\delta^{p}\right)K^{k}+n^{k}\tau^{k}\pi^{k}+\tau^{w}we+n^{w}\tau^{c}C^{w}+n^{k}\tau^{c}C^{k}\end{aligned} \tag{A.3i}$$

$$\delta^{g}\overline{k}^{g}=s^{i}n^{k}Y^{i} \tag{A.3j}$$

$$\left(1-s^{c}-s^{i}\right)n^{k}Y^{i}=n^{k}C^{k}+n^{w}C^{w}+n^{k}\delta^{p}K^{k} \tag{A.3k}$$

Which is a system of eleven equations (A.3a)-(A.3k) in $K^{k},\overline{k}^{g},\pi^{k},e,C^{k},C^{w},r^{b},r^{k},w,Y^{i}$ and one of the eight policy instruments $\tau^{c},\tau^{w},\tau^{k},s^{u},s^{t},s^{c},s^{i},B^{k}$.

Appendix 4: DD for dynamic transition (T=300)

To implement a tax reform and to solve the model, we work as follows.

First, we solve for the pre-reform steady state and assume that the economy has been in this equilibrium until period zero.

Second, we solve for the value of τ^{w} that is consistent with the post-reform zero capital tax steady state and the pre-reform policy instruments. In particular, we obtain the new, post-reform steady state solution, by setting $\left(\tau^{k}\right)^{new}=\tau^{k}-0.10\tau^{k}$, holding all the others policy instruments at their pre-reform levels and letting τ^w adjust in the government budget constraint in the new steady state.

Third, we impose the tax reform on the pre-reform equilibrium in period zero and obtain the dynamic solution of the system. In particular, we impose the tax reform in period-0 and solve the dynamic DE system for T=300 periods, keeping τ^w and τ^k at over time and letting s_t^b be residually determined so that the government budget constraint is satisfied.
The initial conditions for the model's state variables are given by the steady state solution of the pre-reform economy.
For the terminal values of the forward looking variables, we assume that after T years the dynamic system has converged to its new steady state. This implies that the appropriate terminal conditions are obtained by setting the values for these variables equal to those of the preceding period.
The final system is given by 16(T+1) equations, which is solved non-linearly using the Matlab FSOLVE function. This gives the dynamic transition to the new steady state for the variables $\left\{K_{t+1}^k, \bar{k}_{t+1}^g, B_{t+1}^k, \pi_t^k, e_t^i, C_t^k, C_t^w, r_t^b, r_t^k, w_t^i, Y_t^i, \bar{G}_t^t, \bar{G}_t^u, \bar{G}_t^c, \bar{G}_t^i, s_t^b\right\}_{t=0}^T$, where we set T = 300 to ensure that convergence is achieved.

$$\frac{(1+\tau_{t+1}^c)\left(C_{t+1}^k\right)^\sigma}{(1+\tau_t^c)\left(C_t^k\right)^\sigma} = \beta\left[1+\left(1-\tau_{t+1}^k\right)\left(r_{t+1}^k-\delta\right)\right],\ t=0,1,...,T-1 \tag{A.4a}$$

$$r_{t+1}^b = \left(1-\tau_{t+1}^k\right)\left(r_{t+1}^k-\delta\right),\ t=0,1,...,T-1 \tag{A.4b}$$

$$(1+\tau_t^c)C_t^w = \left(1-\tau_t^w\right)w_t^i e_t^i + \bar{G}_t^u\left(1-e_t^i\right)+\bar{G}_t^t,\ t=0,1,...,T \tag{A.4c}$$

$$\theta\alpha_2 n^k Y_t^i = w_t^i e_t^i,\ t=0,1,...,T \tag{A.4d}$$

$$\theta\alpha_1 Y_t^i = r_t^k K_t^k,\ t=0,1,...,T \tag{A.4e}$$

$$\pi_t^k = \left(1-\theta\alpha_1-\theta\alpha_2\right)Y_t^i,\ t=0,1,...,T \tag{A.4f}$$

$$Y_t^i = \mathrm{A}\left(K_t^k\right)^{\alpha_1}\left(\frac{1}{n^k}e_t^i\right)^{\alpha_2}\left(\frac{\bar{k}_t^g}{n^k}\right)^{1-\alpha_1-\alpha_2},\ t=0,1,...,T \tag{A.4g}$$

$$\left(1-\tau_t^w\right)\theta\alpha_2 n^k Y_t^i = \frac{\left[\phi+\left(1-\phi\right)\alpha_2\theta\right]}{\theta\alpha_2}\bar{G}_t^u e_t^i,\ t=0,1,...,T \tag{A.4h}$$

$$\begin{aligned}&\bar{G}_t^c+\bar{G}_t^t+\bar{G}_t^i+\bar{G}_t^u\left(1-e_t^i\right)+n^k(1+r_t^b)B_t^k = \\ &= n^k\tau_t^k\left(r_t^k-\delta\right)K_t^k+n^k\tau_t^k\pi_t^k+\tau_t^w w_t^i e_t^i+n^w\tau_t^c C_t^w+n^k\tau_t^c C_t^k+n^k B_{t+1}^k,\ t=0,1,...,T\end{aligned} \tag{A.4i}$$

$$\bar{k}_{t+1}^g = (1-\delta^g)\bar{k}_t^g+\bar{G}_t^i,\ t=0,1,...,T \tag{A.4j}$$

$$n^k Y_t^i = n^k C_t^k + n^w C_t^w + n^k \left[K_{t+1}^k - (1-\delta) K_t^k \right] + \bar{G}_t^c + \bar{G}_t^i, \ t = 0,1,...,T \tag{A.4k}$$

$$s_t^t = \frac{\bar{G}_t^t}{Y_t^i n^k} \Rightarrow \bar{G}_t^t = s_t^t Y_t^i n^k, \ t = 0,1,...,T \tag{A.4l}$$

$$s_t^u = \frac{\bar{G}_t^u (N - N^k L_t^i)}{N^k Y_t^i} = \frac{\bar{G}_t^u (1 - n^k L_t^i)}{n^k Y_t^i} = \frac{\bar{G}_t^u (1 - e_t^i)}{n^k Y_t^i} \Rightarrow \bar{G}_t^u = \frac{s_t^u n^k Y_t^i}{1 - e_t^i}, \ t = 0,1,...,T \tag{A.4m}$$

$$s_t^c = \frac{\bar{G}_t^c}{Y_t^i n^k} \Rightarrow \bar{G}_t^c = s_t^c Y_t^i n^k, \ t = 0,1,...,T \tag{A.4n}$$

$$s_t^b = \frac{B_{t+1}^k}{Y_t^i} \Rightarrow B_{t+1}^k = s_t^b Y_t^i, \ t = 0,1,...,T \tag{A.4o}$$

$$s_t^i = \frac{\bar{G}_t^i}{Y_t^i n^k} \Rightarrow \bar{G}_t^i = s_t^i Y_t^i n^k, \ t = 0,1,...,T \tag{A.4p}$$

$$K_{T+1}^k = K_T^k \tag{A.4q}$$

$$B_{T+1}^k = B_T^k \tag{A.4r}$$

This is a system of $14\left(T+1\right) + 2T + 2 = 16T + 16 = 16(T+1)$ equations, in $16(T+1)$ unknowns:

$$\left\{ K_{t+1}^k, \bar{k}_{t+1}^g, B_{t+1}^k, \pi_t^k, e_t^i, C_t^k, C_t^w, r_t^b, r_t^k, w_t^i, Y_t^i, \bar{G}_t^t, \bar{G}_t^u, \bar{G}_t^c, \bar{G}_t^i, s_t^b \right\}_{t=0}^{T-1}$$
$$\left\{ K_{t+1}^k, \bar{k}_{t+1}^g, B_{t+1}^k, \pi_t^k, e_t^i, C_t^k, C_t^w, r_t^b, r_t^k, w_t^i, Y_t^i, \bar{G}_t^t, \bar{G}_t^u, \bar{G}_t^c, \bar{G}_t^i, s_t^t \right\}_{t=T}$$

and seven policy instruments:

$$\left\{ \tau_t^c, \tau_t^w, \tau_t^k, s_t^u, s_t^c, s_t^i, s_t^t \right\}_{t=0}^{T-1}, \left\{ \tau_T^c, \tau_T^w, \tau_T^k, s_T^u, s_T^c, s_T^i, s_T^b \right\}$$

initial values: $\left\{ K_0^k, \bar{k}_0^g, B_0^k \right\}$

Appendix 5: Welfare Comparisons

The discounted lifetime utility in the status quo economy (the pre-reformed economy):

$$U_{sqe}^j = \sum_{t=0}^{T} \beta^t \frac{\left(C_{sqe}^j\right)^{1-\sigma}}{1-\sigma} \tag{A.5a}$$

The discounted lifetime utility in the reformed economy (the post-reform economy):

$$U_{re}^{j}=\sum_{t=0}^{T}\beta^{t}\frac{\left(C_{re,t}^{j}\right)^{1-\sigma}}{1-\sigma} \tag{A.5b}$$

We follow e.g. Lucas (1990) and compute the permanent percentage supplement in private consumption required to make agents in the status quo regime as well as in the reformed economy. This percentage supplement is defined as ζ. More specifically, we find the value of ζ that satisfies the following equation:

$$U_{re}^{j}-\sum_{t=0}^{T}\beta^{t}\frac{\left(\left(1+\zeta\right)C_{sqe}^{j}\right)^{1-\sigma}}{1-\sigma}=0\Rightarrow\zeta=\left(\frac{U_{re}^{j}}{U_{sqe}^{j}}\right)^{\frac{1}{1-\sigma}}-1 \tag{A.5c}$$

If $\zeta > 0$ (respectively $\zeta < 0$), there is a welfare gain (respectively loss) of moving from the initial steady state to the new reform one.