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OPTIMAL TAXATION AND THE TRADEOFF BETWEEN EFFICIENCY AND REDISTRIBUTION

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Optimal taxation and the tradeoff between efficiency and redistribution

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Abstract

This paper studies the aggregate and distributional implications of introducing consumption taxes into an otherwise deterministic version of the standard neoclassical growth model with income taxes only and heterogeneity across agents. In particular, the economic agents differ among each other with respect to whether they are allowed to save (in physical capital) or not. Policy is optimally chosen by a benevolent Ramsey government. The main theoretical finding comes to confirm the widespread belief that the introduction of consumption taxes into a model with income taxes only, creates substantial efficiency gains for the economy as whole, but at the cost of higher income inequality. In other words, consumption taxes reduce the progressivity of the tax system, and maybe, from a normative point of view, this result justifies the design of a set of subsidies policies which will aim to outweigh the regressive effects of the otherwise more efficient consumption taxes.

Keywords: Ramsey taxation, heterogeneity, efficiency, inequality.

JEL classification: H21, H23, E62.

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1 Introduction

The literature on optimal taxation typically focuses on income taxes and rules out consumption taxes. For example, Chamley (1986), Judd (1985) and Lucas (1990) assumed that the consumption of goods is untaxed in each period and that there are only taxes on income from savings and labour. However, consumption taxes are a very popular tax policy instrument, in the hands of policymakers, and this can be confirmed by their widespread use in most industrialised economies. For instance, according to Table 1 below, average effective consumption tax rates are about 22.1% in a sample of 25 countries, where data are taken by Eurostat for a ten year period (2002-2010). The estimates regarding average effective consumption tax rates vary considerably across countries. For example, in the aforementioned sample of countries, the average effective consumption tax rates are between 15.1 and 32.7. Furthermore, revenues from consumption taxes represent a significant proportion of total tax revenues. For instance, the average percentage of revenues from consumption taxes over total tax revenues for the same sample is about 33.2%. For a number of countries, such as Cyprus, Latvia, Lithuania, Hungary and Portugal, this percentage is even higher and exceeds 38%.

This popularity of consumption taxes, as a policy instrument in the hands of policymakers, can be explained by the widespread belief, that they are a less distortive policy instrument relative to income taxes and, thus, increase agregate efficiency (see e.g. Coleman (2000), Correia (2010) and many others). However, consumption taxes are also believed to increase income inequality and, thus, benefit the wealthy social classes. Motivated by the above, this paper aims to study the role of consumption taxes in a two-period deterministic version of the neoclassical growth model where the government is able to commit to future policies. In particular, by allowing the government to choose optimally the tax mix (between income and consumption taxes), we aim to study the tradeoff between efficiency and redistribution .

Most of the relevant literature typically focuses on the Ramsey approach to the optimal tax policy problem. Namely, the government can commit to future policies[1]. For instance, Coleman (2000) finds that the implications of consumption taxes on welfare are more important than those associated with taxing income. In particular, it seems that there are substantial welfare gains for an economy when a Ramsey government is allowed to choose optimally income and consumption taxes compared to the case in which the same type of government chooses only income or a constant consumption tax. According to Diamond and Mirrlees (1971), although commodity and income taxes can certainly be used to increase welfare, the tax mix can also help the government to achieve any desired income redistribution. Correia (2010) introduces heterogeneity across agents and finds that an exogenous revenue-neutral policy reform

[1] Following most of the relevant literature, we focus only on the optimal tax setting under commitment and rule out the study of time-consistent fiscal policies (for a review of the literature on time-consistent optimal tax policy with consumption taxes in infinite-horizon models, see e.g. Laczo and Rossi (2014) and Motta and Rossi (2015)).

that combines an increase in consumption taxes and a decrease in capital or labour income taxes could increase efficiency and reduce inequality.

Table 1		
Consumption taxes		
Average:	Effective taxes	As a percentage of total taxation
Belgium	21.5	24.4
Czech Rep.	20.6	30.5
Denmark	32.7	32.1
Germany	19.4	27.4
Estonia	22.8	40.0
Ireland	23.8	36.6
Greece	15.8	36.5
Spain	15.1	26.6
France	19.8	25.5
Italy	17.5	25.2
Cyprus	18.8	39.5
Latvia	18.0	38.7
Lithuania	17.3	38.2
Hungary	26.4	38.0
Netherlands	24.7	29.8
Austria	21.7	28.1
Poland	19.8	37.6
Portugal	18.6	38.2
Slovenia	23.6	36.0
Slovakia	18.9	35.9
Finland	26.7	31.0
Sweden	27.3	27.3
UK	18.2	31.5
Norway	29.4	27.2
Average	22.1	33.2
Source: European Commission / Sample: 25 countries		
Period: 2002-2012		

To capture the distributional implications, we need to distinguish among the various economic agents so as to generate a potential conflict of interests. According to Turnovsky (2000), the most common distinction in the literature that creates a potential conflict of interests is the functional distribution between income going to capital and that going to labour. Thus, we work with a two-period deterministic version of Judd's (1985) neoclassical growth model, in which households differ in capital holdings. In particular, we assume that there are two groups of households, called capitalists and workers, where capital is in the hands of capitalists, while workers, who form the majority in our economy, are not allowed to save[2]. Moreover, we assume that capitalists are

[2] This has been one of the most commonly used models with heterogeneity in the literature on optimal taxation. See also Lansing (1999), Krusell (2002) and Fowler and Young (2006).

more skilled than workers and, thus, the aggregate labour input is a linear function of high-skilled and low-skilled labour, which are supplied by capitalists and workers respectively (as in Hornstein et al. (2005)). This differentiation between high-skilled and low-skilled labour is driven by differences in labour factor productivities. The government is allowed to finance the provision of utility-enhancing public goods by choosing not only the level of government spending but also the mix between income and consumption taxes. All types of taxes are proportional to their own tax base[3].

Our paper differs to the existing relevant literature in that we introduce consumption taxes in an otherwise standard model with heterogeneous agents and income taxes only. We focus on optimal Ramsey policies. Furthermore, within this setup, we investigate the aggregate and distributional implications of the optimal tax policy mix. Coleman (2000) uses the same modelling approach, however, he focuses on the problem of a representative household and investigates only the aggregate implications of introducing consumption taxes. Correia (2010), in a paper related to ours, allows for heterogeneity across agents but does not examine optimal tax policies. She shows that the substitution of income taxes with a flat consumption tax increases aggregate efficiency and reduces income inequality but, in the presence of nondiscriminatory lump-sum transfers that increase the progressivity of the tax policy mix.

Our main result is that the introduction of consumption taxes into a model with income taxes only generates a tradeoff between efficiency and redistribution. Particularly, the economy with both income and consumption taxes is more efficient than the economy with income taxes only. Both groups of households are better off, in terms of income and welfare, once consumption taxes are introduced in the economy. Also, output is higher when the government chooses optimally both taxes. On the other hand, income inequality increases with the introduction of consumption taxes and, which simply implies that capitalists benefit more than workers from the introduction of consumption taxes. Hence, we confirm the widespread belief mentioned above that a switch to a mix of income and consumption taxes creates welfare gains for both the economy as a whole and the various social classes individually, but at the cost of higher net income inequality. Therefore, the introduction of consumption taxes reduces the progressivity of the tax system. From a normative point of view, this may also justify the design of a set of subsidies policies which will aim to outweigh the regressive effects of the otherwise more efficient consumption taxes.

The rest of the paper is organised as follows. Section 2 describes the economic environment and defines the Decentralized and Ramsey General equilibria. Section 3 discusses the parameter values used in numerical solutions. Section 4 presents and discusses the numerical results. Finally, Section 5 concludes. Various algebraic details are included in an appendix.

[3]We do not allow for the provision of subsidies by the government, since in that case, and given that we have a two-agent model, our tax system would become progressive (as in Atkinson and Stiglitz, 1980). We leave it for future work.

2 The economy

2.1 Description of the model

The setup is a two-period deterministic version of the standard neoclassical growth model comprised of households, firms and a government. This model is extended to allow for heterogeneity among agents. In particular, the private sector consists of two groups of households that are assumed to differ in capital holdings and labour productivity. Following Judd (1985) and Lansing (1999), capital is in the hands of a small group of agents, called capitalists, while workers, who, by assumption, form the majority in our economy, are not allowed to make savings. Also, as in Hornstein et al. (2005), the aggregate labour input is a linear function of high-skilled and low-skilled labour, for capitalists and workers respectively, with different factor productivities. Households derive utility from private consumption, leisure and the provision of public goods. For simplicity, we use a logarithmic utility function in which preferences are separable in all three components. In the first period, capitalists consume, work and save, while workers only consume and work. In the second period both groups of households consume and work. In the production sector of the economy, private firms, which are owned to capitalists, maximize their profits by using capital and labour inputs to produce a single homogeneous good. They produce this good using a constant returns to scale production function, which is strictly concave, differentiable and stictly increasing in both inputs. There are competitive factor markets. Each capitalist owns a firm and, thus, profits, if any, are distributed to capitalists. Also, there is private good production in both periods.

The government needs revenues to provide public goods in both periods[4]. To finance these utility - enhancing public goods, it imposes linear taxes on income and consumption spending. For simplicity, we abstract from public debt so the government budget is balanced in each period. Policy is chosen optimally. We will examine optimal policy with commitment, the so-called Ramsey policy, in which policy is chosen once-and-for-all at the beginning of the time horizon. Thus, the government will maximize a weighted average of capitalists' and workers' welfare by choosing income taxes, consumption taxes, as well as the associated amount of the public good.

Total population size, N, is exogenous and constant. Workers are indexed by the subscript $w = 1, 2, ...N^w$ and capitalists by the subscript $k = 1, 2, ...N^k$. In particular, among N, $N^k < N$ are identical capitalists, while the majority $N^w = N - N^k$ and $N^w > N^k$ are identical workers. There are also $f = 1, 2, ..N^f$ private firms where the number of firms, for simplicty, equals the number of capitalists, $N^k = N^f$. Notice also, that there is no social mobility between the two groups.

[4]The simplifying assumption that there is public good provision only in second period is very common in the relevant literature (see e.g. Fischer (1980), Persson and Tabellini (1994),(2000) and many others). Here, we assume that there are both public good provision and private good production in both periods (as in Martin (2010)).

2.2 Households as capitalists

Each capitalist k chooses consumption, $c_{k,1}$ and $c_{k,2}$, labour effort, $l_{k,1}$ and $l_{k,2}$, in both periods and savings in the first period, $k_{k,2}$ in order to maximize her two-period lifetime welfare:

$$\begin{aligned} U_k &= \mu_1 \log c_{k,1} + \mu_2 \log(1 - l_{k,1}) + \mu_3 \log g_1 + \\ &\quad + \beta \left[\mu_1 \log c_{k,2} + \mu_2 \log(1 - l_{k,2}) + \mu_3 \log g_2\right] \end{aligned}$$

subject to her two consecutive budget constraints:

$$(1 + \tau_1^c)c_{k,1} + k_{k,2} = (1 - \delta)k_{k,1} + (1 - \tau_1^y)(r_1 k_{k,1} + w_1^k l_{k,1}) \tag{1.1}$$

$$(1 + \tau_2^c)c_{k,2} + k_{k,3} = (1 - \delta)k_{k,2} + (1 - \tau_2^y)(r_2 k_{k,2} + w_2^k l_{k,2}) \tag{1.2}$$

where the parameters $\mu_1, \mu_2, \mu_3 > 0$ are preference weights, r_1, r_2, w_1^k, w_2^k are gross returns to capital and labour respectively in both periods, $0 < \beta < 1$ is the discount rate, $0 \leq \delta \leq 1$ is the capital depreciation rate and $0 \leq \tau_1^y, \tau_2^y, \tau_1^c, \tau_2^c < 1$ are tax rates on income and consumption spending in both periods. Notice that capitalists are not allowed to leave bequests and, thus, we set $k_{k,3} \equiv 0$. Since the assumptions we make, regarding the operation of firms (see below), imply zero profits in equilibrium, we omit them from the capitalist's budget constraints.

The first order conditions include the two consecutive budget constraints and the optimallity conditions with respect to $l_{k,1}, l_{k,2}, k_{k,2}$:

$$\frac{\mu_2}{(1 - l_{k,1})} = \frac{\mu_1(1 - \tau_1^y)w_1^k}{c_{k,1}(1 + \tau_1^c)} \tag{1.3}$$

$$\frac{\mu_2}{(1 - l_{k,2})} = \frac{\mu_1(1 - \tau_2^y)w_2^k}{c_{k,2}(1 + \tau_2^c)} \tag{1.4}$$

$$\frac{1}{c_{k,1}(1 + \tau_1^c)} = \frac{\beta\left[1 - \delta + (1 - \tau_2^y)r_2\right]}{c_{k,2}(1 + \tau_2^c)} \tag{1.5}$$

Note that $k_{k,1}$ is the beggining-of-the-first period capital stock and is predetermined. The first two static equations are the labour-supply decisions for the capitalist in each period whereas the last one is the standard Euler equation.

2.3 Households as workers

Each worker w chooses consumption, $c_{w,1}$ and $c_{w,2}$, and labour effort, $l_{w,1}$ and $l_{w,2}$, in both periods in order to maximize her two-period lifetime welfare:

$$\begin{aligned} U_w = {} & \mu_1 \log c_{w,1} + \mu_2 \log(1 - l_{w,1}) + \mu_3 \log g_1 + \\ & + \beta \left[\mu_1 \log c_{w,2} + \mu_2 \log(1 - l_{w,2}) + \mu_3 \log g_2\right] \end{aligned}$$

subject to her two consecutive budget constraints:

$$(1+\tau_1^c)c_{w,1} = (1-\tau_1^y)w_1^w l_{w,1} \tag{1.6}$$

$$(1+\tau_2^c)c_{w,2} = (1-\tau_2^y)w_2^w l_{w,2} \tag{1.7}$$

The first order conditions include the two consecutive budget constraints and the optimallity conditions with respect to $l_{w,1}$, $l_{w,2}$:

$$\frac{\mu_2}{1-l_{w,1}} = \frac{\mu_1(1-\tau_1^y)w_1^w}{c_{w,1}(1+\tau_1^c)} \tag{1.8}$$

$$\frac{\mu_2}{1-l_{w,2}} = \frac{\mu_1(1-\tau_2^y)w_2^w}{c_{w,2}(1+\tau_2^c)} \tag{1.9}$$

Note that the workers cannot save. The above two static equations are the labour-supply decisions for the worker.

2.4 Firms

There is production in each period. There are $f = 1, 2, .., N^f$ firms owned by capitalists. Thus, each capitalist owns a firm and there are $N^f = N^k$ firms. Each firm maximizes profits in each period:

$$\Pi_1 = y_{f,1} - r_1 k_{f,1} - w_1^k l_{f,1}^k - w_1^w l_{f,1}^w \tag{1.10}$$

$$\Pi_2 = y_{f,2} - r_2 k_{f,2} - w_2^k l_{f,2}^k - w_2^w l_{f,2}^w \tag{1.11}$$

where output is produced according to the following standard Cobb-Douglas production functions:

$$y_{f,1} = A\left(k_{f,1}\right)^{\alpha}\left(L_{f,1}\right)^{(1-\alpha)} \tag{1.12}$$

$$y_{f,2} = A\left(k_{f,2}\right)^{\alpha}\left(L_{f,2}\right)^{(1-\alpha)} \tag{1.13}$$

where $k_{f,1}, k_{f,2}$ are the capital inputs supplied by capitalists, $L_{f,1}$ and $L_{f,2}$ are the aggregate labour inputs supplied by both agents, while $A > 0$ and $0 < \alpha < 1$ are usual technology parameters.

We assume that capitalists are more skilled than workers, and, therefore, the two types of agents face different factor productivities. Thus, as in Hornstein et al. (2005), we generalize the production function by dissagregating the contributions to production of the two labour inputs. We assume that the aggregate labour input $L_{f,t}$ is a linear function of high-skilled (for the capitalist) and low-skilled (for the worker) labour, $l_{f,t}^k$ and $l_{f,t}^w$ respectively, with factor productivities $A^k > A^w$:

$$L_{f,t} = A^k l_{f,t}^k + A^w l_{f,t}^w$$

Thus, the production functions with the different contribution of labour inputs to the production are:

$$y_{f,1} = A\left(k_{f,1}\right)^{\alpha}\left(A^k l_{f,1}^k + A^w l_{f,1}^w\right)^{(1-\alpha)} \tag{1.12'}$$

$$y_{f,2} = A\left(k_{f,2}\right)^{\alpha}\left(A^k l_{f,2}^k + A^w l_{f,2}^w\right)^{(1-\alpha)} \tag{1.13'}$$

where $k_{f,1}, k_{f,2}$ are the capital inputs, $l_{f,1}^k$, $l_{f,2}^k$ are the labour inputs supplied by the capitalists and $l_{f,1}^w, l_{f,2}^w$ are the labour inputs supplied by the workers.

The first order conditions of the above profit maximization problems are:

$$r_1 = \alpha A(k_{f,1})^{a-1}(A^k l_{f,1}^k + A^w l_{f,1}^w)^{(1-a)} \tag{1.14}$$

$$w_1^k = (1-\alpha)A^k A(k_{f,1})^a(A^k l_{f,1}^k + A^w l_{f,1}^w)^{(-a)} \tag{1.15}$$

$$w_1^w = (1-\alpha)A^w A(k_{f,1})^a(A^k l_{f,1}^k + A^w l_{f,1}^w)^{(-a)} \tag{1.16}$$

$$r_2 = \alpha A(k_{f,2})^{a-1}(A^k l_{f,2}^k + A^w l_{f,2}^w)^{(1-a)} \tag{1.17}$$

$$w_2^k = (1-\alpha)A^k A(k_{f,2})^a(A^k l_{f,2}^k + A^w l_{f,2}^w)^{(-a)} \tag{1.18}$$

$$w_2^w = (1-\alpha)A^w A(k_{f,2})^a(A^k l_{f,2}^k + A^w l_{f,2}^w)^{(-a)} \tag{1.19}$$

where $w_1^k > w_1^w$ and $w_2^k > w_2^w$ since $A^k > A^w$.

2.5 Government

The government operates in each period. It needs revenues to provide utility-enhancing public goods and, therefore, we assume that it finances the provision of these public goods by a mix of linear income and consumption taxes, which are both proportional to their own tax base.

The two consecutive government budget constraints, written in aggregate terms, are:

$$G_1 = N^k\left[\tau_1^y(r_1 k_{k,1} + w_1^k l_{k,1}) + \tau_1^c c_{k,1}\right] + N^w\left[\tau_1^y w_1^w l_{w,1} + \tau_1^c c_{w,1}\right] \tag{1.20}$$

$$G_2 = N^k\left[\tau_2^y(r_2 k_{k,2} + w_2^k l_{k,2}) + \tau_2^c c_{k,2}\right] + N^w\left[\tau_2^y w_2^w l_{w,2} + \tau_2^c c_{w,2}\right] \tag{1.21}$$

where $G_t \equiv N g_t$ is the total provision of the public good in each period t.

2.6 Market clearing Conditions

Each capitalist owns a firm. Hence, it holds that $N^f = N^k = N - N^w$. It is convenient to define the population shares of the two groups as $n^k = \frac{N^k}{N}$ and $n^w = \frac{N^w}{N} = 1 - n^k$. The market clearing conditions for the capital market are:

$$N^f k_{f,1} = N^k k_{k,1} \Leftrightarrow \; k_{f,1} = k_{k,1}$$

$$N^f k_{f,2} = N^k k_{k,2} \Leftrightarrow \; k_{f,2} = k_{k,2}$$

The labour market clearing conditions imply that labour demand equals labour supply. Hence the labour market clearing conditions are:

$$N^f l^k_{f,1} = N^k l_{k,1} \Leftrightarrow l^k_{f,1} = l_{k,1}$$

$$N^f l^k_{f,2} = N^k l_{k,2} \Leftrightarrow l^k_{f,2} = l_{k,2}$$

$$N^f l^w_{f,1} = N^w l_{w,1} \Leftrightarrow n^k l^w_{f,1} = n^w l_{w,1} \Leftrightarrow l^w_{f,1} = \frac{n^w}{n^k} l_{w,1}$$

$$N^f l^w_{f,2} = N^w l_{w,2} \Leftrightarrow n^k l^w_{f,2} = n^w l_{w,2} \Leftrightarrow l^w_{f,2} = \frac{n^w}{n^k} l_{w,2}$$

2.7 Decentralized Competitive Equilibrium (for given policy)

Now we can define the Decentralized Competitive Equilibrium (DCE) for any feasible policy.

Definition 1 *(Decentralized Competitive Equilibrium). Given the paths of the independent policy instruments* $\{\tau^y_t, \tau^c_t, g_t\}_{t=1,2}$ *a decentralized equilibrium is defined to be a sequence of allocations* $\left\{c^k_t, l^k_t, k^k_{t+1}\right\}_{t=1,2}$ *for the capitalist and* $\{c^w_t, l^w_t\}_{t=1,2}$ *for the worker and prices* $\left\{r_t, w^k_t, w^w_t\right\}_{t=1,2}$*, such that households maximize utility and firms maximize profits given prices and economic policy, all markets clear and all constraints are satisfied.*

In the DCE, both types of households (capitalists and workers) maximize lifetime utility, firms maximize profits, all constraints (including the government's budget constraint) are satisfied and all markets clear. This DCE is summarized by the following equations. Notice that all quantities are in per capita terms:

$$(1 + \tau^c_1)c_{k,1} + k_{k,2} = (1 - \delta)k_{k,1} + (1 - \tau^y_1)(r_1 k_{k,1} + w^k_1 l_{k,1}) \tag{2.1}$$

$$(1 + \tau^c_2)c_{k,2} = (1 - \delta)k_{k,2} + (1 - \tau^y_2)(r_2 k_{k,2} + w^k_2 l_{k,2}) \tag{2.2}$$

$$\frac{\mu_2}{(1 - l_{k,1})} = \frac{\mu_1(1 - \tau^y_1)w^k_1}{c_{k,1}(1 + \tau^c_1)} \tag{2.3}$$

$$\frac{\mu_2}{(1-l_{k,2})} = \frac{\mu_1(1-\tau_2^y)w_2^k}{c_{k,2}(1+\tau_2^c)} \tag{2.4}$$

$$\frac{1}{c_{k,1}(1+\tau_1^c)} = \frac{\beta\left[1-\delta+(1-\tau_2^y)r_2\right]}{c_{k,2}(1+\tau_2^c)} \tag{2.5}$$

$$(1+\tau_1^c)c_{w,1} = (1-\tau_1^y)w_1^w l_{w,1} \tag{2.6}$$

$$(1+\tau_2^c)c_{w,2} = (1-\tau_2^y)w_2^w l_{w,2} \tag{2.7}$$

$$\frac{\mu_2}{1-l_{w,1}} = \frac{\mu_1(1-\tau_1^y)w_1^w}{c_{w,1}(1+\tau_1^c)} \tag{2.8}$$

$$\frac{\mu_2}{1-l_{w,2}} = \frac{\mu_1(1-\tau_2^y)w_2^w}{c_{w,2}(1+\tau_2^c)} \tag{2.9}$$

$$g_1 = \tau_1^y n^k(r_1 k_{k,1} + w_1^k l_{k,1}) + \tau_1^y n^w w_1^w l_{w,1} + \tau_1^c(n^k c_{k,1} + n^w c_{w,1}) \tag{2.10}$$

$$g_2 = \tau_2^y n^k(r_2 k_{k,2} + w_2^k l_{k,2}) + \tau_2^y n^w w_2^w l_{w,2} + \tau_2^c(n^k c_{k,2} + n^w c_{w,2}) \tag{2.11}$$

where in the above equations we use:

$$n^k y_{f,1} = A\left(n^k k_{k,1}\right)^{\alpha}\left(n^k A^k l_{k,1} + n^w A^w l_{w,1}\right)^{(1-\alpha)}$$

$$n^k y_{f,2} = A\left(n^k k_{k,2}\right)^{\alpha}\left(n^k A^k l_{k,2} + n^w A^w l_{w,2}\right)^{(1-\alpha)}$$

$$r_1 = \alpha A(k_{k,1})^{a-1}(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(1-a)}$$

$$w_1^k = (1-\alpha)A^k A(k_{k,1})^a(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a)}$$

$$w_1^w = (1-\alpha)A^w A(k_{k,1})^a(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a)}$$

$$r_2 = \alpha A(k_{k,2})^{a-1}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(1-a)}$$

$$w_2^k = (1-\alpha)A^k A(k_{k,2})^a(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)}$$

$$w_2^w = (1-\alpha)A^w A(k_{k,2})^a(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)}$$

Instead of the equations $2.1 - 2.2$ (capitalist's budget constraints), we can use the two resource constraints of the economy:

$$n^k c_{k,1} + n^w c_{w,1} + n^k k_{k,2} - (1-\delta) n^k k_{k,1} + g_1 = n^k y_{f,1}$$

$$n^k c_{k,2} + n^w c_{w,2} - (1-\delta) n^k k_{k,2} + g_2 = n^k y_{f,2}$$

Hence, we end up with a system of 11 equations $(2.1 - 2.11)$ in 9 endogenous variables: $\{c_{k,1}, c_{k,2}, k_{k,2}, l_{k,1}, l_{k,2}, c_{w,1}, c_{w,2}, l_{w,1}, l_{w,2}\}$ and 2 of the policy instruments $\{g_1, g_2\}$ which adjust to satisfy the two consecutive government's budget constraints. This is for any tax policy $\{\tau_1^y, \tau_2^y, \tau_1^c, \tau_2^c\}$. In the case of Ramsey policy the above equations will serve as the constraints to the Ramsey government when the latter chooses the policy instruments in the beggining of the time horizon subject to the above equations. Irrespectevily of how policy is chosen below we need to make sure that the DCE system delivers a meaningful numerical solution. We check this below.

2.8 Ramsey General Equilibrium

We will consider optimal policy with commitment. In this case, the so-called Ramsey General Equilibrium, policy is chosen once-and-for-all at the beginning of the time horizon before private agents make their choices. Notice that the government is benevolent and, thus, maximizes a weighted average of the utilities of the two groups of households, taking into account the DCE equations. The problem is solved by backward induction. This means that we first solve private agents' problem and then solve for optimal policy.

We now define the Ramsey equilibrium, i.e. when the policy-maker is able to commit to future policies.

Definition 2 *(Ramsey General Equilibrium). A Ramsey General Equilibrium is a sequence of government policies $\{\tau_t^y, \tau_t^c, g_t\}_{t=1,2}$, allocations $\{c_t^k, l_t^k, k_{t+1}^k\}_{t=1,2}$ for the capitalist and $\{c_t^w, l_t^w\}_{t=1,2}$ for the worker which solve:*

$$\max_{\{\tau_t^y, \tau_t^c, g_t\}_{t=1,2}} [(1-\gamma)U_k + \gamma U_w]$$

subject to the DCE equations and given $k_{k,1}$, i.e. the beggining of the first period capital stock.

Notice that, in order to make the Ramsey policy problem non-trivial, we impose a restriction on the first-period income tax rate τ_1^y, for example by taking it as given at a small number (for instance, 0.15 at our numerical solution - see also below). This approach rules out taxing heavily the initial capital stock which would be equivalent to a non-distorting lump-sum tax, since $k_{k,1}$ is in fixed supply.

We assume commitment technologies, i.e. the government can commit itself to the policies that will be in place arbitrarily into the second period. The sequence of time is as follows. Policy is chosen once-and-for-all in the beggining of period 1 before any private decisions are made. We solve the problem by backward induction. This means that the agents first solve their optimization problems for given policy and then the government chooses the policy instruments $\tau_2^y, \tau_1^c, \tau_2^c, g_1, g_2$ to maximize a weighted average of the utility of the two agents, $(1-\gamma)U_k + \gamma U_w$ subject to the DCE equations derived earlier, where the given political preferences $0 \leq \gamma \leq 1$ and $0 \leq 1-\gamma \leq 1$ measure respectively the influence of the two social classes, workers and capitalists, in policy setting.

The Lagrangian equation of the Ramsey government is:

$$
\begin{aligned}
L \quad = \quad & (1-\gamma)\{\mu_1 \log c_{k,1} + \mu_2 \log(1-l_{k,1}) + \beta\mu_1 \log c_{k,2} + \beta\mu_2 \log(1-l_{k,2})\} + \\
& +\gamma\{\mu_1 \log c_{w,1} + \mu_2 \log(1-l_{w,1}) + \beta\mu_1 \log c_{w,2} + \beta\mu_2 \log(1-l_{w,2})\} + \\
& +\mu_3 \log\{\tau_1^y n^k (r_1 k_{k,1} + w_1^k l_{k,1}) + \tau_1^y n^w w_1^w l_{w,1} + \tau_1^c (n^k c_{k,1} + n^w c_{w,1})\} + \\
& +\beta\mu_3 \log\{\tau_2^y n^k (r_2 k_{k,2} + w_2^k l_{k,2}) + \tau_2^y n^w w_2^w l_{w,2} + \tau_2^c (n^k c_{k,2} + n^w c_{w,2})\} + \\
& +\lambda_1\{(1-\delta)k_{k,1} + (1-\tau_1^y)(r_1 k_{k,1} + w_1^k l_{k,1}) - (1+\tau_1^c)c_{k,1} - k_{k,2}\} + \\
& +\beta\lambda_2\{(1-\delta)k_{k,2} + (1-\tau_2^y)(r_2 k_{k,2} + w_2^k l_{k,2}) - (1+\tau_2^c)c_{k,2}\} + \\
& +\lambda_3\{\mu_1(1-\tau_1^y)w_1^k(1-l_{k,1}) - \mu_2 c_{k,1}(1+\tau_1^c)\} + \\
& +\beta\lambda_4\{\mu_1(1-\tau_2^y)w_2^k(1-l_{k,2}) - \mu_2 c_{k,2}(1+\tau_2^c)\} + \\
& +\lambda_5\{\beta c_{k,1}(1+\tau_1^c)\left[1-\delta+(1-\tau_2^y)r_2\right] - c_{k,2}(1+\tau_2^c)\} + \\
& +\lambda_6\{(1-\tau_1^y)w_1^w l_{w,1} - (1+\tau_1^c)c_{w,1}\} + \\
& +\beta\lambda_7\{(1-\tau_2^y)w_2^w l_{w,2} - (1+\tau_2^c)c_{w,2}\} + \\
& +\lambda_8\{\alpha A(k_{k,1})^{a-1}(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(1-a)} - r_1\} + \\
& +\beta\lambda_9\{\alpha A(k_{k,2})^{a-1}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(1-a)} - r_2\} + \\
& +\lambda_{10}\{(1-\alpha)A^k A(k_{k,1})^a(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a)} - w_1^k\} + \\
& +\beta\lambda_{11}\{(1-\alpha)A^k A(k_{k,2})^a(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)} - w_2^k\} + \\
& +\lambda_{12}\{(1-\alpha)A^w A(k_{k,1})^a(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a)} - w_1^w\} + \\
& +\beta\lambda_{13}\{(1-\alpha)A^w A(k_{k,2})^a(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)} - w_2^w\}
\end{aligned}
$$

That is, we follow the *dual approach*[5] to the Ramsey policy problem, where the government re-chooses the allocations and the policy variables subject to the DCE. The first-order conditions of the Ramsey policy are presented in detail at the appendix. Next, we move to the numerical results using common parameter values.

[5] We use the dual approach, in contrast to the primal where all prices and taxes are eliminated so that the government is thought of as directly choosing a feasible allocation (see also Economides et al. (2008)).

3 Parameterization

Since the above described general equilibrium cannot be solved analytically, we present numerical solutions using common parameter values. In particular, we assume the following benchmark parameter values:

Table 2

Benchmark parameter values		
Parameter	Value	Definition
α	0.3	Share of private capital to total output
μ_1	0.3	Weight given to private consumption
μ_2	0.5	Weight given to leisure
μ_3	0.2	Weight given to public consumption
A	1	Total factor productivity (TFP)
A^k	5	TFP for capitalists' productivity
A^w	1	TFP's for workers' productivity
δ	0.12	Depreciation rate of private capital
β	0.9	Discount rate
n^k	0.3	Capitalists' population share
n^w	0.7	Workers' population share
γ	0.7	Weight given to workers' welfare
$k_{k,1}$	0.05	Initial capital stock
τ_1^y	0.15	1st period income tax rate

We assume the following parameter values: $A = 1$ for the total factor productivity, $\beta = 0.9$ for the discount rate, $\delta = 0.12$ for the depreciation rate of the private capital, $\alpha = 0.3$ for the capital elasticity and $\mu_1 = 0.3, \mu_2 = 0.5, \mu_3 = 0.2$ for the weights given by the households to private consumption, leisure and public consumption respectively. Also, we set $A^k = 5$ and $A^w = 1$, since capitalists are assumed to be more skilled than workers and, therefore, face a higher productivity factor for their labour supply, resulting, in turn, in higher wages[6]. Moreover, the capitalists' and workers' population shares in total population are 0.3 and 0.7 respectively. Notice that γ is the weight given by the government to worker's welfare. Thus, when we assume that the government is utilitarian, the policy is chosen by a government that attaches weights γ and $(1-\gamma)$ to the utility of workers and capitalists equal to their population shares (see Angelopoulos et al. (2011)). Therefore, we set $\gamma = n^w$ and $(1-\gamma) = n^k$. Furthermore, the first-period capital stock $k_{k,1}$ is exogenously given and set at 0.05. Finally, we assume that the first-period income tax rate τ_1^y is exogenously determined and equal to 0.15.

[6] Notice that our results are robust to changes in these parameter values.

4 Numerical Results

4.1 Revenue-neutral tax reforms when policy is exogenous

Before we study optimal policy, it is useful to study some exogenous policy reforms. In particular, we examine a revenue-neutral change in the second-period income tax rate τ_2^y and the impact of this reform on efficiency and redistribution incentives. Initially, we assume that $\tau_1^y = 0.15$ (as in the parameterization), $\tau_2^y = 0.3$ and $\tau_1^c = \tau_2^c = 0.2$ and g_1, g_2 are residually determined by the two consecutive government's budget constraints. Next, we change the second-period income tax rate τ_2^y and, at the same time, we keep the total tax revenues constant. As a result, the consumption taxes are determined residually by the Tax Revenue equation (in each period), which is given by:

$$TR_t = \tau_t^y n^k (r_t k_{k,t} + w_t^k l_{k,t} + \Pi_t) + \tau_t^y n^w w_t^w l_{w,t} + \tau_t^c [n^k c_{k,t} + n^w c_{w,t}]$$

The quantitative and qualitative effects of this tax revenue-neutral reform are presented in Tables 3.1 and 3.2 (see also Figure 1 in the appendix). In particular, a decrease in second-period income tax rate τ_2^y results in an increase in the second-period consumption tax rate. Hence, income taxes are substituted by higher consumption taxes, since the government has to generate the required revenues to finance the provision of public goods, which, as said, is held constant.

Table 3.1				
Decentralized competitive equilibrium				
	$\tau_2^y = 0.4$	Benchmark	$\tau_2^y = 0.2$	$\tau_2^y = 0.1$
Allocations				
$c_{k,1}$	0.2970	0.3000	0.3022	0.3040
$c_{k,2}$	0.5066	0.5077	0.5074	0.5065
$k_{k,2}$	0.2050	0.1967	0.1903	0.1852
$l_{k,1}$	0.3462	0.3414	0.3378	0.3349
$l_{k,2}$	0.1780	0.1908	0.2002	0.2074
$c_{w,1}$	0.0568	0.0569	0.0570	0.0571
$c_{w,2}$	0.0770	0.0784	0.0793	0.0799
$l_{w,1}$	0.3750	0.3750	0.3750	0.3750
$l_{w,2}$	0.3750	0.3750	0.3750	0.3750
$y_{f,1}$	0.7959	0.7908	0.7869	0.7838
$y_{f,2}$	0.7329	0.7492	0.7601	0.7677
Y_1	0.2388	0.2372	0.2361	0.2351
Y_2	0.2199	0.2248	0.2280	0.2303
$\frac{c}{y}^{(1)}$	0.5397	0.5474	0.5532	0.5579
$\frac{c}{y}^{(2)}$	0.9366	0.9220	0.9109	0.9025

Table 3.2				
Decentralized competitive equilibrium				
	$\tau_2^y = 0.4$	Benchmark	$\tau_2^y = 0.2$	$\tau_2^y = 0.1$
Policy				
τ_1^c	0.2001	$0.2(given)$	0.2006	0.2007
τ_2^c	0.0717	$0.2(given)$	0.3329	0.4682
g_1	0.0616	0.0616	0.0616	0.0616
g_2	0.1258	0.1258	0.1258	0.1258
$\frac{g_1}{Y_1}$	0.2580	0.2595	0.2609	0.2620
$\frac{g_2}{Y_2}$	0.5722	0.5595	0.5517	0.5462
$TR1$	0.0616	0.0616	0.0616	0.0616
$TR2$	0.1258	0.1258	0.1258	0.1258
Welfare				
U_k	-1.7790	-1.7790	-1.7794	-1.7800
U_w	-2.9297	-2.9242	-2.9206	-2.9182
U	-2.5845	-2.5807	-2.5782	-2.5767
Net income				
y_1^k	0.4581	0.4527	0.4485	0.4452
y_1^w	0.0568	0.0569	0.0570	0.0571
y_2^k	0.3262	0.3347	0.3399	0.3435
y_2^w	0.0770	0.0784	0.0793	0.0799
$\frac{y_1^k}{y_1^w}$	8.0664	7.9499	7.8621	7.7924
$\frac{y_2^k}{y_2^w}$	4.2340	4.2668	4.2866	4.3002

Moreover, savings $k_{k,2}$ are lower. This happens because the savings decision is made in the first period only, where the income tax rate is given. Thus, the introduction of a positive consumption tax in the first period reduces the disposable income of the capitalists and, thus, private consumption and savings. On the other hand, there is a positive effect on savings from the decrease in the second-period income tax rate. However, as the former effect dominates the latter effect, the net effect is a lower capital stock in the second period. Also, labour supply $l_{k,2}$ increases when second-period income tax falls and consumption tax rises, resulting in higher output and welfare in the economy. Thus, the economy is more efficient as income taxes are substituted by consumption taxes. Also, at an individual level, workers can benefit from a more efficient economy, as can be seen in Table 3.2, where U_w has increased. On the other hand, the welfare of the capitalists U_k does not behave monotonically. In particular, it initially increases and then it decreases as τ_2^y falls. This happens because high consumption taxes hurt capitalists more. Net income inequality[7] decreases in the first-period (where the first-period income tax rate is given), while in the second period, net income inequality increases, implying that capitalists' net income y_2^k increases more than workers' net income y_2^w. Thus, although the

[7]Notice that net income is defined as: $y_t^k \equiv (1-\tau_t^y)(r_t k_{k,t} + w_t^k l_{k,t}) - \tau_t^c c_{k,t}$ for each capitalist and $y_t^w \equiv (1-\tau_t^y) w_t^w l_{w,t} - \tau_t^c c_{w,t}$ for each worker.

substitution of income taxes with consumption taxes is Pareto improving, the associated efficiency gains come at the cost of higher income inequality. This means that there is a tradeoff between efficiency and inequality.

The above analysis is for given policy. Next, we move to optimal policy with commitment, the so-called Ramsey equilibrium, in which second-best policy is optimally chosen by a benevolent Ramsey government.

4.2 Optimal policy with commitment / Ramsey General Equilibrium

4.2.1 Results from the representative agent model

First, it is useful for what follows to present the numerical results from the representative agent model, using the same benchmark parameter values[8]. Thus, we work as follows: Initially, we solve for the commitment equilibrium when the government chooses optimally only the second-period income tax rate. Hence, the government chooses τ_2^y, g_1, g_2 to maximize the utility of the representative agent subject to the decentralized competitive equilibrium, when we exogenously set $\tau_1^c = \tau_2^c = 0$. This serves as our benchmark regime. Next, we assume that the government can choose optimally both income and consumption taxes and we solve for two different cases. In the first regime, we introduce a flat consumption tax $\tau^c = \tau_1^c = \tau_2^c$ that is common in both periods and the government chooses optimally $\tau_2^y, g_1, g_2, \tau^c$. In the second regime, we assume that the government chooses optimally, among others, two different consumption taxes, one in each period, $\tau_1^c \neq \tau_2^c$. A numerical solution for these regimes is presented in Tables 4.1 and 4.2 below.

The main results are the following: There are welfare gains when the government is able to choose optimally both income and consumption taxes. For instance, welfare U and second-period output $y_{f,2}$ are higher with the introduction of consumption taxes. Moreover, the second-period net income Y_2^n of the representative household increases. This happens because the government finds it optimal to raise revenues by setting a positive consumption tax rate. Given that, ceteris paribus, there is an increase in total tax revenues, this allows for a decrease in the more distorting income tax rate in the second period.

[8] Notice that, in this case, we simply assume that $n^k = 1$, $n^w = 0$ and $\gamma = 0$.

Table 4.1			
Ramsey equilibrium / Representative agent			
	Benchmark	Flat consumption tax	Consumption taxes
	$\tau^c = 0$	$\tau^c \neq 0$	$\tau_1^c \neq \tau_2^c$
Allocations			
c_1	0.1317	0.0977	0.0996
c_2	0.1372	0.1281	0.1263
k_2	0.0759	0.0643	0.0623
l_1	0.3429	0.3252	0.3222
l_2	0.1773	0.2237	0.2308
r_1	1.1547	1.1127	1.1055
r_2	0.5431	0.7183	0.7506
w_1	0.3929	0.3992	0.4003
w_2	0.5428	0.4815	0.4725
$y_{f,1}$	0.1925	0.1854	0.1843
$y_{f,2}$	0.1375	0.1539	0.1558
$\frac{c}{y}(1)$	0.6841	0.5270	0.5405
$\frac{c}{y}(2)$	0.9983	0.8327	0.8110

Table 4.2			
Ramsey equilibrium / Representative agent			
	Benchmark	Flat consumption tax	Consumption taxes
	$\tau^c = 0$	$\tau^c \neq 0$	$\tau_1^c \neq \tau_2^c$
Policy Instruments			
τ_2^y	0.4878	0.1970	0.1208
τ_1^c	–	–	0.3892
τ_2^c	–	–	0.5177
τ^c	–	0.4056	–
g_1	0.0289	0.0675	0.0664
g_2	0.0671	0.0823	0.0842
$\frac{g}{y}(1)$	0.1500	0.3638	0.3604
$\frac{g}{y}(2)$	0.4878	0.5348	0.5407
Welfare Outcome			
U	-2.6377	-2.5519	-2.5509
Net Income			
Y_1^n	0.1636	0.1180	0.1179
Y_2^n	0.0704	0.0716	0.0715

Also, consumption is lower due to the high consumption taxes while the lower second-period income tax rate triggers an increase in the second-period labour supply, which, in turn, increases second-period output $y_{f,2}$. Savings k_2 are lower with the introduction of the consumption taxes, although the second-period income tax rate τ_2^y decreases. This happens because the savings decision about k_2 is made in the first period, where the income tax rate is given and equal to 0.15. The introduction of a consumption tax in the first period (or a flat consumption tax that affects both periods) reduces the household's first-period disposable income, which in turn reduces savings k_2 and consumption c_1. Thus, there are two opposite effects on savings, where the negative effect from the introduction of the consumption tax rate in the first-period dominates the positive effect from the reduction of the second-period income tax rate.

To sum up, the economy with income and consumption taxes is more efficient than the economy without consumption taxes. In other words, a mix of income and consumption taxes increases welfare and output. Next, we move to the heterogeneous agents case so as to investigate the distributional implications of the introduction of consumption taxes.

4.2.2 Results when heterogeneity is allowed

In this section, our aim is to highlight the aggregate and distributional implications of introducing consumption taxes into a model with income taxes only and heterogeneous agents, when the government chooses optimally the mix of income and consumption taxes. Thus, we choose to work as follows. First, we solve for the Ramsey/commitment equilibrium when the government chooses optimally the second-period income tax rate only. Thus, the government chooses τ_2^y, g_1, g_2 to maximize a weighted average of the utilities of the two agents, capitalists and workers, subject to the decentralized equilibrium equations, when we exogenously set $\tau_1^c = \tau_2^c = 0$. This serves as our benchmark regime. Next, we assume that the government can choose optimally both income and consumption taxes and we solve for two different cases. In the first regime, we introduce a flat consumption tax $\tau^c = \tau_1^c = \tau_2^c$ that is common for both periods and the government chooses optimally $\tau_2^y, g_1, g_2, \tau^c$. In the second regime, we assume that the government chooses optimally, among others, two different consumption taxes, one in each period, $\tau_1^c \neq \tau_2^c$. A numerical solution for these regimes is presented in Tables 5.1 and 5.2 below.

The main results from the comparison of these regimes are as follows: First, the economy with the consumption taxes is welfare superior than the economy without (benchmark regime). For instance, second-period total output Y_2 and aggregate welfare U are now higher and this is reasonable since the government has one more policy instrument at its disposal that is less distorting relative to income taxes. Second, at an individual level, both capitalists and workers are better off and benefit from a more efficient economy. For instance, second-period net incomes, Y_2^k and Y_2^w, and individual welfares, U_k and U_w, are higher when the government is allowed to choose optimally both income and consumption taxes.

Notice that savings $k_{k,2}$ are lower with the introduction of the consumption taxes. This happens because the savings decision is made by the capitalists in the first period, in which the income tax rate is given. Thus, high positive consumption taxes in the first-period hurt substantially the first-period net income of the capitalists, since τ_1^y is given, and, in turn, reduce the savings and the private consumption. This negative effect on savings dominates the positive effect from the decrease in the second-period income tax rate. Notice here, however, that if we allow for a three period economy where in the second period both the beggining-of-period and the end-of-period capital stock are endogenously determined, the effect of the introduction of consumption taxes on second-period savings $k_{k,3}$ is positive. Hence, the capital stock in the third period is higher, since the capitalists can benefit from the lower income tax rate in the second period. We present the results for this special case in the appendix.

Table 5.1			
Ramsey equilibrium			
	Benchmark	Flat consumption tax	Consumption taxes
	$\tau^c = 0$	$\tau^c \neq 0$	$\tau_1^c \neq \tau_2^c$
Allocations			
$c_{k,1}$	0.3547	0.2604	0.2740
$c_{k,2}$	0.5156	0.5014	0.4781
$k_{k,2}$	0.2093	0.1883	0.1597
$l_{k,1}$	0.3486	0.3367	0.3206
$l_{k,2}$	0.1713	0.2030	0.2406
$c_{w,1}$	0.0681	0.0491	0.0504
$c_{w,2}$	0.0778	0.0786	0.0787
$l_{w,1}$	0.3750	0.3750	0.3750
$l_{w,2}$	0.3750	0.3750	0.3750
r_1	4.7908	4.7143	4.6104
r_2	1.3168	1.5072	1.8077
w_1^k	1.0675	1.0749	1.0852
w_2^k	1.8568	1.7523	1.6210
w_1^w	0.2135	0.2150	0.2170
w_2^w	0.3714	0.3505	0.3242
Output			
$y_{f,1}$	0.7985	0.7857	0.7684
$y_{f,2}$	0.7235	0.7631	0.7937
$Y_1 = n^k y_{f,1}$	0.2395	0.2357	0.2305
$Y_2 = n^k y_{f,2}$	0.2171	0.2289	0.2381
$\frac{c}{y}^{(1)}$	0.6430	0.4772	0.5096
$\frac{c}{y}^{(2)}$	0.9634	0.8974	0.8337

Third, for the regime with the flat consumption tax, the government finds it optimal to set τ_2^y at a lower value (0.1645), since the income tax rate is a more distorting tax instrument relative to the consumption tax. Thus, the Ramsey government realizes this and chooses to generate the required revenues to finance the provision of public goods by taxing consumption ($\tau^c = 0.3964$), so as to mitigate the distortionary effects imposed on the economy by high income taxation. Also, for the regime with the two different consumption taxes, the government chooses a positive consumption tax in the first period ($\tau_1^c = 0.3723$)[9]and an extremely high second-period consumption tax ($\tau_2^c = 2.6258$)

[9]First-period income tax rate τ_1^y is given and set equal to 0.15 and, therefore, there is no

so as to finance the increased provision of public goods and a very high income subsidy in the second period ($\tau_2^y = -1.3471$).This is a reminiscent of the quite large income subsidy and consumption tax, well in excess of 100%, in Coleman (2000) and many others. The related literature on optimal taxation derives that the optimal tax mix implies the same constant tax rate on consumption and leisure in each period and a zero tax on capital income. Hence, the tax mix that achieves the first best allocation is one that taxes consumption, provides the same amount of subsidy to labour and imposes a zero capital income tax rate (see Lansing (1999), Coleman (2000) and Correia (2010)). The quantitative difference in our results, where the amount of labour subsidy is lower than the amount of the consumption tax, is driven by the fact that we use a single income tax, rather than separate taxes on capital income and labour income. Otherwise, if the Ramsey government can use capital income taxes, labour income taxes and consumption taxes, it could attain the first-best allocation.

Table 5.2

Ramsey equilibrium

	Benchmark	Flat consumption tax	Consumption taxes
	$\tau^c = 0$	$\tau^c \neq 0$	$\tau_1^c \neq \tau_2^c$
Policy Instruments			
τ_2^y	0.4416	0.1645	-1.3471
τ_1^c	–	–	0.3723
τ_2^c	–	–	2.6258
τ^c	–	0.3964	–
g_1	0.0359	0.0799	0.0783
g_2	0.1217	0.1281	0.1324
$\frac{g}{y}(1)$	0.1500	0.3391	0.3398
$\frac{g}{y}(2)$	0.5605	0.5597	0.5558
Welfare Outcome			
U_k	-1.8331	-1.7725	-1.7782
U_w	-2.9867	-2.9126	-2.9025
U	-2.6406	-2.5706	-2.5652
Income Inequality			
$\frac{Y_1^k}{Y_1^w}$	7.6397	8.2479	7.7303
$\frac{Y_2^k}{Y_2^w}$	4.2620	4.2682	4.2894
Y_1^k	0.5199	0.4048	0.3897
Y_1^w	0.0681	0.0491	0.0504
Y_2^k	0.3314	0.3356	0.3376
Y_2^w	0.0778	0.0786	0.0787

need for the government to offset any distortionary effects. Hence, the government chooses a first-period consumption tax that is lower than 100%, since there is no need to finance an income subsidy and the additional revenues by the consumption tax are used to finance a larger amount of public good g_1 in the first period.

Fourth, net income inequality increases when we move from the benchmark regime with income taxes to the regimes where the government chooses optimally both income and consumption taxes. Hence, the reduction in the optimal second-period income tax benefits capitalists more, since they work more, while workers' labour supply is unaffected from changes in the optimal income tax rate. Thus, there is a tradeoff between efficiency and redistribution. Although the introduction of consumption taxes by a Ramsey government is Pareto improving and benefits both capitalists and workers, income inequality increases.

4.3 Revenue-neutral tax reforms when policy is chosen optimally

In this section, we study again the aggregate and distributional implications of introducing consumption taxes into a model with income taxes only, when the government chooses optimally both income and consumption taxes, but we focus mainly on the case in which the overall public spending remains constant and equal to its value when the government chooses optimally only the income tax rate. Thus, we choose to work as follows. First, we solve for the Ramsey/commitment equilibrium when the government chooses optimally the second-period income tax rate only. Thus, the government chooses τ_2^y, g_1, g_2 to maximize a weighted average of the utilities of the two agents, capitalists and workers, subject to the decentralized equilibrium equations, when we exogenously set $\tau_1^c = \tau_2^c = 0$. This serves as our benchmark regime. Next, we assume that the government can choose optimally both income and consumption taxes and we distinguish between two different cases. In the first case, we set g_1, g_2 as in the benchmark regime and allow for the government to choose optimally $\tau_2^y, \tau_1^c, \tau_2^c$. In the second case, we assume that the government chooses optimally all the policy instruments and, particularly, $\tau_2^y, \tau_1^c, \tau_2^c, g_1, g_2$. Tables **6.1** and 6.2 below present the numerical results for these cases.

A comparison of the above cases reveals the following: The economy with the consumption taxes is welfare superior, even if we keep g_1, g_2 constant. For instance, aggregate welfare U and second-period output $y_{f,2}$ are higher. At an individual level, workers are better off, since both their welfare U_w and their second-period net income Y_2^w are higher. On the contrary, capitalists are worse off when we allow for the government to set the public spending as in the benchmark regime. Notice also that the government chooses to subsidize income and generate the necessary revenues to finance its activity by taxing only consumption. This happens because consumption taxes are less distorting tax instruments than income taxes. Moreover, in terms of inequality, the second-period net income of capitalists relative to workers Y_2^k/Y_2^w increases when the government can choose optimally both income and consumption taxes, even if we keep public spending constant. Hence, the introduction of consumption taxes by a Ramsey government increases the aggregate efficiency but also increases net income inequality, even in the case with constant public spending.

Table 6.1			
Ramsey equilibrium - $\tau_1^c \neq \tau_2^c$			
	Benchmark	Consumption taxes	Consumption taxes
	endogenous g_t	exogenous g_t	endogenous g_t
Allocations			
$c_{k,1}$	0.3547	0.3707	0.2740
$c_{k,2}$	0.5156	0.5079	0.4781
$k_{k,2}$	0.2093	0.1656	0.1597
$l_{k,1}$	0.3486	0.3239	0.3206
$l_{k,2}$	0.1713	0.2333	0.2406
$c_{w,1}$	0.0681	0.0685	0.0504
$c_{w,2}$	0.0778	0.0828	0.0787
$l_{w,1}$	0.3750	0.3750	0.3750
$l_{w,2}$	0.3750	0.3750	0.3750
r_1	4.7908	4.6317	4.6104
r_2	1.3168	1.7409	1.8077
w_1^k	1.0675	1.0831	1.0852
w_2^k	1.8568	1.7409	1.6210
w_1^w	0.2135	0.2166	0.2170
w_2^w	0.3714	0.3295	0.3242
Output			
$y_{f,1}$	0.7985	0.7720	0.7684
$y_{f,2}$	0.7235	0.7895	0.7937
$Y_1 = n^k y_{f,1}$	0.2395	0.2316	0.2305
$Y_2 = n^k y_{f,2}$	0.2171	0.2368	0.2381
$\frac{c}{y}(1)$	0.6430	0.6875	0.5096
$\frac{c}{y}(2)$	0.9634	0.8880	0.8337

Table 6.2			
Ramsey equilibrium - $\tau_1^c \neq \tau_2^c$			
	Benchmark	Consumption taxes	Consumption taxes
	endogenous g_t	exogenous g_t	endogenous g_t
Policy Instruments			
τ_2^y	0.4416	-0.7130	-1.3471
τ_1^c	$-$	0.0073	0.3723
τ_2^c	$-$	1.5560	2.6258
g_1	0.0359	0.0359	0.0783
g_2	0.1217	0.1217	0.1324
$\frac{g}{y}^{(1)}$	0.1500	0.1550	0.3398
$\frac{g}{y}^{(2)}$	0.5605	0.5139	0.5558
Welfare Outcome			
U_k	-1.8331	-1.8404	-1.7782
U_w	-2.9867	-2.9677	-2.9025
U	-2.6406	-2.6296	-2.5652
Income Inequality			
$\frac{Y_1^k}{Y_1^w}$	7.6397	7.1827	7.7303
$\frac{Y_2^k}{Y_2^w}$	4.2620	4.3733	4.2894
Y_1^k	0.5199	0.4923	0.3897
Y_1^w	0.0681	0.0685	0.0504
Y_2^k	0.3314	0.3621	0.3376
Y_2^w	0.0778	0.0828	0.0787

5 Concluding remarks

In this paper, we study the aggregate and distributional implications of introducing consumption taxes into a model with income taxes only, extended to allow for heterogeneity across agents. This heterogeneity is based on the wealth distribution of income. In particular, capitalists are allowed to save while workers cannot save. The government is allowed to choose optimally a mix of single income and consumption taxes and the associated amount of the provided public good. Notice that we solve for optimal policy with commitment (the so-called Ramsey equilibrium) in which policy instruments are chosen once-and-for all at the beggining of the time horizon.

The main theoretical findings can be summarized as follows: Assuming that a benevolent Ramsey government.chooses optimally the tax policy mix, consumption taxes turn out to be Pareto improving, since they are less distortionary policy instruments. The government chooses to decrease the second-period income tax rate and generate the required revenues to finance its activity by setting positive consumption taxes. Also, these welfare gains hold at an individual level too. In particular, both groups of households, capitalists and workers, are better off. On the contrary, these welfare gains are accompanied by higher inequality.

For instance, the net income of capitalists relative to workers increases. Thus, we confirm the widespread belief that the introduction of consumption taxes into a model with income taxes only, creates substantial efficiency gains for the economy as whole, but at the cost of higher income inequality. Thus, there is a tradeoff between efficiency and redistribution, since the introduction of consumption taxes reduces the progressivity of the tax system. Therefore, from a normative point of view, this may also justify the design of a set of subsidies policies which will aim to outweigh the regressive effects of the otherwise more efficient consumption taxes.

This study can be extended in several ways. For example, one can study the aggregate and distributional implications of introducing consumption taxes in the presence of tax evasion or progressive (non-linear) income taxation. Second, one can solve for time-consistent policies and compare them with the commitment / Ramsey equilibrium. We leave these extensions for future work.

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A Appendix

A.1 First-order conditions of the Ramsey government's problem

The first-order conditions with respect to allocations $\{c_{k,1}, c_{k,2}, k_{k,2}, l_{k,1}, l_{k,2}\}$ of capitalists, allocations $\{c_{w,1}, c_{w,2}\}$ of workers[10], prices $\{r_1, r_2, w_1^k, w_2^k, w_1^w, w_2^w\}$, tax instruments $\{\tau_2^y, \tau_1^c, \tau_2^c\}$ and the Lagrange multipliers $\lambda_i, i = 1-13$ include the following equations:

wrt $c_{k,1}$:

$$0 = (1-\gamma)\frac{\mu_1}{c_{k,1}} + \frac{\mu_3}{g_1}\tau_1^c n^k - \lambda_1(1+\tau_1^c) - \lambda_3\mu_2(1+\tau_1^c) + \lambda_5\beta(1+\tau_1^c)\left[1-\delta+(1-\tau_2^y)r_2\right] \tag{3.1}$$

wrt $c_{k,2}$:

$$0 = (1-\gamma)\frac{\beta\mu_1}{c_{k,2}} + \beta\frac{\mu_3}{g_2}\tau_2^c n^k - \beta\lambda_2(1+\tau_2^c) - \beta\lambda_4\mu_2(1+\tau_2^c) - \lambda_5(1+\tau_2^c) \tag{3.2}$$

wrt $k_{k,2}$:

$$\begin{aligned} 0 \quad = \quad & \beta\frac{\mu_3}{g_2}\tau_2^y n^k r_2 - \lambda_1 + \beta\lambda_2\{(1-\delta) + (1-\tau_2^y)r_2\} + \\ & +\beta\lambda_9(a-1)\alpha A(k_{k,2})^{a-2}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(1-a)} + \\ & +\beta\lambda_{11}a(1-\alpha)A^k A(k_{k,2})^{a-1}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)} + \\ & +\beta\lambda_{13}a(1-\alpha)A^w A(k_{k,2})^{a-1}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)} \end{aligned} \tag{3.3}$$

wrt $l_{k,1}$:

$$\begin{aligned} 0 \quad = \quad & -(1-\gamma)\frac{\mu_2}{1-l_{k,1}} + \frac{\mu_3}{g_1}\tau_1^y n^k w_1^k + \lambda_1(1-\tau_1^y)w_1^k - \lambda_3\mu_1(1-\tau_1^y)w_1^k + \\ & +\lambda_8\,(1-a)\,\alpha A^k A(k_{k,1})^{a-1}(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a)} + \\ & +\lambda_{10}(-a)(1-\alpha)A^k A(k_{k,1})^a(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a-1)}A^k + \\ & +\lambda_{12}(-a)(1-\alpha)A^w A(k_{k,1})^a(A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a-1)}A^k \end{aligned} \tag{3.4}$$

wrt $l_{k,2}$:

[10] Note that we can derive closed-form solutions for the worker's labour supply, given by: $l_{w,1} = l_{w,2} = \frac{\mu_1}{\mu_1+\mu_2}$

$$
\begin{aligned}
0 \quad = \quad & -(1-\gamma)\frac{\beta\mu_2}{1-l_{k,2}} + \beta\frac{\mu_3}{g_2}\tau_2^y n^k w_2^k + \beta\lambda_2(1-\tau_2^y)w_2^k - \beta\lambda_4\mu_1(1-\tau_2^y)w_2^k + \\
& +\beta\lambda_9(1-a)\alpha A^k A(k_{k,2})^{a-1}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)} + \\
& +\beta\lambda_{11}(-a)(1-\alpha)A^k A(k_{k,2})^{a}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a-1)}A^k + \\
& +\beta\lambda_{13}(-a)(1-\alpha)A^w A(k_{k,2})^{a}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a-1)}A^k \qquad (3.5)
\end{aligned}
$$

wrt $c_{w,1}$:

$$0 = \gamma\frac{\mu_1}{c_{w,1}} + \frac{\mu_3}{g_1}\tau_1^c n^w - \lambda_6(1+\tau_1^c) \qquad (3.6)$$

wrt $c_{w,2}$:

$$0 = \gamma\frac{\beta\mu_1}{c_{w,2}} + \beta\frac{\mu_3}{g_2}\tau_2^c n^w - \beta\lambda_7(1+\tau_2^c) \qquad (3.7)$$

wrt r_1 :

$$0 = \frac{\mu_3}{g_1}\tau_1^y n^k k_{k,1} + \lambda_1(1-\tau_1^y)k_{k,1} - \lambda_8 \qquad (3.8)$$

wrt r_2 :

$$0 = \beta\frac{\mu_3}{g_2}\tau_2^y n^k k_{k,2} + \beta\lambda_2(1-\tau_2^y)k_{k,2} + \lambda_5\beta c_{k,1}(1+\tau_1^c)(1-\tau_2^y) - \beta\lambda_9 \qquad (3.9)$$

wrt w_1^k :

$$0 = \frac{\mu_3}{g_1}\tau_1^y n^k l_{k,1} + \lambda_1(1-\tau_1^y)l_{k,1} + \lambda_3\mu_1(1-\tau_1^y)(1-l_{k,1}) - \lambda_{10} \qquad (3.10)$$

wrt w_2^k :

$$0 = \beta\frac{\mu_3}{g_2}\tau_2^y n^k l_{k,2} + \beta\lambda_2(1-\tau_2^y)l_{k,2} + \beta\lambda_4\mu_1(1-\tau_2^y)(1-l_{k,2}) - \beta\lambda_{11} \qquad (3.11)$$

wrt w_1^w :

$$0 = \frac{\mu_3}{g_1}\tau_1^y n^w l_{w,1} + \lambda_6(1-\tau_1^y)l_{w,1} - \lambda_{12} \qquad (3.12)$$

wrt w_2^w :

$$0 = \beta\frac{\mu_3}{g_2}\tau_2^y n^w l_{w,2} + \beta\lambda_7(1-\tau_2^y)l_{w,2} - \beta\lambda_{13} \qquad (3.13)$$

wrt τ_2^y :

$$0 = \beta\frac{\mu_3}{g_2}[n^k(r_2k_{k,2}+w_2^kl_{k,2})+n^ww_2^wl_{w,2}]-\beta\lambda_2(r_2k_{k,2}+w_2^kl_{k,2})- -\lambda_4\beta\mu_1w_2^k(1-l_{k,2})-\lambda_5\beta c_{k,1}(1+\tau_1^c)r_2-\beta\lambda_7w_2^wl_{w,2} \quad (3.14)$$

wrt τ_1^c :

$$0 = \frac{\mu_3}{g_1}(n^kc_{k,1}+n^wc_{w,1})-\lambda_1c_{k,1}-\lambda_3\mu_2c_{k,1}+ +\lambda_5\beta c_{k,1}\left[1-\delta+(1-\tau_2^y)r_2\right]-\lambda_6c_{w,1} \quad (3.15)$$

wrt τ_2^c :

$$0=\beta\frac{\mu_3}{g_2}(n^kc_{k,2}+n^wc_{w,2})-\beta\lambda_2c_{k,2}-\beta\lambda_4\mu_2c_{k,2}-\lambda_5c_{k,2}-\beta\lambda_7c_{w,2} \quad (3.16)$$

wrt λ_1 :

$$0=(1-\delta)k_{k,1}+(1-\tau_1^y)(r_1k_{k,1}+w_1^kl_{k,1})-(1+\tau_1^c)c_{k,1}-k_{k,2} \quad (3.17)$$

wrt λ_2 :

$$0=\beta\{(1-\delta)k_{k,2}+(1-\tau_2^y)(r_2k_{k,2}+w_2^kl_{k,2})-(1+\tau_2^c)c_{k,2}\} \quad (3.18)$$

wrt λ_3 :

$$0=\mu_1(1-\tau_1^y)w_1^k(1-l_{k,1})-\mu_2c_{k,1}(1+\tau_1^c) \quad (3.19)$$

wrt λ_4 :

$$0=\beta\{\mu_1(1-\tau_2^y)w_2^k(1-l_{k,2})-\mu_2c_{k,2}(1+\tau_2^c)\} \quad (3.20)$$

wrt λ_5 :

$$0=\beta c_{k,1}(1+\tau_1^c)\left[1-\delta+(1-\tau_2^y)r_2\right]-c_{k,2}(1+\tau_2^c) \quad (3.21)$$

wrt λ_6 :

$$0=(1-\tau_1^y)w_1^wl_{w,1}-(1+\tau_1^c)c_{w,1} \quad (3.22)$$

wrt λ_7 :

$$0=\beta\{(1-\tau_2^y)w_2^wl_{w,2}-(1+\tau_2^c)c_{w,2}\} \quad (3.23)$$

wrt λ_8 :

$$0=\alpha A(k_{k,1})^{a-1}(A^kl_{k,1}+A^w(\frac{n^w}{n^k})l_{w,1})^{(1-a)}-r_1 \quad (3.24)$$

wrt λ_9 :

$$0 = \beta\{\alpha A(k_{k,2})^{a-1}(A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(1-a)} - r_2\} \tag{3.25}$$

wrt λ_{10} :

$$0 = (1-\alpha)A^k A(k_{k,1})^a (A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a)} - w_1^k \tag{3.26}$$

wrt λ_{11} :

$$0 = \beta\{(1-\alpha)A^k A(k_{k,2})^a (A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)} - w_2^k\} \tag{3.27}$$

wrt λ_{12} :

$$0 = (1-\alpha)A^w A(k_{k,1})^a (A^k l_{k,1} + A^w(\frac{n^w}{n^k})l_{w,1})^{(-a)} - w_1^w \tag{3.28}$$

wrt λ_{13} :

$$0 = \beta\{(1-\alpha)A^w A(k_{k,2})^a (A^k l_{k,2} + A^w(\frac{n^w}{n^k})l_{w,2})^{(-a)} - w_2^w\} \tag{3.29}$$

Moreover, for the regime with the flat consumption tax rate, the associated first-order condition is:

wrt τ^c :

$$\begin{aligned} 0 \quad = \quad & \frac{\mu_3}{g_1}(n^k c_{k,1} + n^w c_{w,1}) - \lambda_1 c_{k,1} - \lambda_3 \mu_2 c_{k,1} + \\ & + \lambda_5 \beta c_{k,1} \left[1 - \delta + (1 - \tau_2^y) r_2\right] - \lambda_6 c_{w,1} + \\ & + \beta \frac{\mu_3}{g_2}(n^k c_{k,2} + n^w c_{w,2}) - \beta\lambda_2 c_{k,2} - \beta\lambda_4 \mu_2 c_{k,2} - \\ & - \lambda_5 c_{k,2} - \beta\lambda_7 c_{w,2} \end{aligned}$$

A.2 A three-period model

Notice that for the three-period model we assume the same parameter values as in those presented in table 2. We choose to work as follows. First, we solve for the Ramsey/commitment equilibrium when the government chooses optimally the second-period and the third period income tax rates. Thus, the government chooses $\tau_2^y, \tau_3^y, g_1, g_2, g_3$ to maximize a weighted average of the utilities of the two agents, capitalists and workers, subject to the decentralized equilibrium equations, when we exogenously set $\tau_1^c = \tau_2^c = \tau_3^c = 0$. This serves as our benchmark regime. Next, we assume that the government can choose optimally both income and consumption taxes and we solve for two different cases. In the first regime, we introduce a flat consumption tax $\tau^c = \tau_1^c = \tau_2^c = \tau_3^c$ that is common for all periods and the government chooses optimally $\tau_2^y, \tau_3^y, g_1, g_2, g_3, \tau^c$. In the second regime, we assume that the government chooses optimally, among others, three different consumption taxes, one in each period, $\tau_1^c \neq \tau_2^c \neq \tau_3^c$. A numerical solution for these regimes is presented in Tables 7.1 and 7.2 below.

Table 7.1			
Ramsey equilibrium - 3 periods			
	Benchmark	Flat consumption tax	Consumption taxes
	$\tau^c = 0$	$\tau^c \neq 0$	$\tau_1^c \neq \tau_2^c \neq \tau_3^c$
Allocations			
$c_{k,1}$	0.3244	0.2336	0.2589
$c_{k,2}$	0.5201	0.4680	0.3918
$c_{k,3}$	0.6156	0.6633	0.7340
$k_{k,2}$	0.2805	0.2536	0.2246
$k_{k,3}$	0.3526	0.4027	0.4625
$l_{k,1}$	0.3903	0.3743	0.3574
$l_{k,2}$	0.3008	0.3130	0.3148
$l_{k,3}$	0.1290	0.1672	0.2177
$c_{w,1}$	0.0655	0.0467	0.0504
$c_{w,2}$	0.0930	0.0852	0.0715
$c_{w,3}$	0.0883	0.0996	0.1173
$l_{w,1}$	0.3750	0.3750	0.3750
$l_{w,2}$	0.3750	0.3750	0.3750
$l_{w,3}$	0.3750	0.3750	0.3750
Output			
$y_{f,1}$	0.8425	0.8258	0.8079
$y_{f,2}$	1.0621	1.0538	1.0192
$y_{f,3}$	0.7416	0.8704	1.0359
$Y_1 = n^k y_{f,1}$	0.2527	0.2477	0.2424
$Y_2 = n^k y_{f,2}$	0.3186	0.3161	0.3058
$Y_3 = n^k y_{f,3}$	0.2225	0.2611	0.3108

Table 7.2			
Ramsey equilibrium - 3 periods			
	Benchmark	Flat consumption tax	Consumption taxes
	$\tau^c = 0$	$\tau^c \neq 0$	$\tau_1^c \neq \tau_2^c \neq \tau_3^c$
Policy			
τ_2^y	0.3273	0.0805	-0.3641
τ_3^y	0.4783	0.1588	-1.1535
τ_1^c	–	–	0.3447
τ_2^c	–	–	1.4461
τ_3^c	–	–	2.1233
τ^c	–	0.4371	–
g_1	0.0379	0.0821	0.0753
g_2	0.1230	0.1173	0.1117
g_3	0.1407	0.1702	0.2015
Welfare			
U_k	-2.4459	-2.3911	-2.3955
U_w	-4.0304	-3.9545	-3.9379
U	-3.5550	-3.4855	-3.4752
Income Inequality			
$\frac{Y_1^k}{Y_1^w}$	8.4339	9.4961	8.7266
$\frac{Y_2^k}{Y_2^w}$	6.7303	7.6038	9.1867
$\frac{Y_3^k}{Y_3^w}$	3.4564	3.1027	2.7884
Y_1^k	0.5609	0.4433	0.4394
Y_1^w	0.0665	0.0467	0.0504
Y_2^k	0.6258	0.6475	0.6567
Y_2^w	0.0930	0.0852	0.0715
Y_3^k	0.3054	0.3089	0.3271
Y_3^w	0.0883	0.0996	0.1173

Notice that a three period model encapsulates the three interesting regimes of optimal tax policy: in the first period, the beggining-of-period capital stock is exogenously given; in the second period, both the beggining-of-period and the end-of-period capital decisions are endogenous; the third period is the long run where expectations about the future do not matter.

A.3 Figures - Policy Reforms

Figure 1: Policy Reforms