Time-consistent fiscal policy under heterogeneity: Conflicting or common interests?*

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Abstract

This paper studies the aggregate and distributional implications of Markov-perfect tax-spending policy in a neoclassical growth model with capitalists and workers. Focusing on the long run, our main findings are: (i) it is optimal for a benevolent government, which cares equally about its citizens, to tax capital heavily and to subsidise labour; (ii) a Pareto improving means to reduce inefficiently high capital taxation under discretion is for the government to place greater weight on the welfare of capitalists; (iii) capitalists and workers preferences, regarding the optimal amount of "capitalist bias", are not aligned implying a conflict of interests.

Keywords: Optimal fiscal policy, Markov-perfect equilibrium, heterogeneous agents

JEL Classification: E62, H21

1 Introduction

An important and ongoing issue for fiscal policy since the research of Edgeworth (1897) relates to whether policy designed to increase efficiency has a negative effect on the distribution of income (see e.g. Atkinson and Stiglitz (1980) and Stiglitz (1987)). Chamley (1986) showed, within a representative agent context, that long-run optimal allocative efficiency can be achieved by imposing a zero tax on capital.[1] This family of models, however, is naturally silent on issues relating to inequality and whether there can be a conflict of interests between different agents. As Atkinson and Stiglitz (1980, p. 14) point out, we need to construct models "that allow us to predict the effects of policy changes not just on aggregate variables (total wealth) but also on the distribution". In a macroeconomic context, heterogeneous agent models are obvious candidates.

A popular type of heterogeneity much employed in the literature on optimal taxation relies on the distinction between "capitalists" and "workers" (see e.g. Judd (1985) and Lansing (1999)). Using this breakdown in a neoclassical growth model, Judd (1985) derived the striking result that a benevolent government under commitment should not impose any redistributive capital taxes in the long-run. This holds even from the perspective of those agents without capital income. Thus, there is no trade-off between efficiency and equity.[2] Although the robustness of this normative long-run result has been challenged,[3] it remains a point of reference in the modern theory of optimal taxation. As Mankiw *et al.* (2009, p. 167) point out, "perhaps the most predominant result from dynamic models of optimal taxation is that the taxation of capital ought to be avoided".

The above results hold when the government can commit itself to future policies. In recent work, within the representative agent framework, Klein and Rios-Rull (2003), Ortigueira (2006), Klein *et al.* (2008) and Martin (2010) have also examined time-consistent optimal fiscal policy. The general message arising from this research is that Markov-perfect policy results in

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[1]For reviews, see e.g. Chari and Kehoe (1999) and Ljungqvist and Sargent (2004, ch. 15).

[2]The trade-off between efficiency and equity has attracted a lot of attention in the literature on exogenous tax reforms in heterogeneous-agent set-ups (see e.g. Domeij and Heathcote (2004), Garcia-Mila *et al.* (2010) and the work reviewed therein). These studies generally conclude that there are important trade-offs between these two objectives, when lifetime utility is considered. Also see Greulich and Marcet (2008) who directly address the issue of Pareto improving optimal tax reforms, albeit in a Ramsey world.

[3]See e.g. Guo and Lansing (1999) for Ramsey taxation in a model with imperfect competition and profits. See also Lansing (1999) who shows, for a special case of Judd's model, that the Ramsey tax policy is constant over time and thus time-consistent.

inefficiently high capital taxes in the long-run relative to Ramsey policy. Martin (2010) further shows the circumstances under which the government would have an incentive to confiscate capital when both capital and labour taxes are optimally chosen. Thus, assuming a single income tax seems to confound the diverse roles of different tax instruments. Krusell (2002) shows that, in a Judd-type model where a single production tax is used to finance lump-sum transfers to workers, the time-consistent tax in the long-run is generally non-zero and non-confiscatory as long as some weight is put on the utility of the capitalists.[4]

The above research, however, leaves a number of important questions unanswered under this popular type of heterogeneity. For example, what is the time-consistent optimal mix of capital and labour taxes and the associated optimal provision of public goods? Does the lack of commitment hurt all agents in the economy? And if yes, are there any substitutes for commitment? Can there be changes in the policy design that are Pareto improving? Or, is it unavoidable to have a conflict of interests between agents under time-consistent policy, in contrast to Ramsey policy?

In an attempt to provide answers to the questions posed above, we study the aggregate and distributional implications of Markov-perfect tax-spending policy in a neoclassical growth model with capitalists and workers. In our model, the government chooses both capital and labour tax rates to finance endogenous utility-enhancing public services. Thus, in contrast to the models used by Krusell (2002) and Azzimonti *et al.* (2008), who also study time-consistent policy and redistribution, we use a relatively rich menu of policy instruments ruling out lump-sum ones. Following Krusell *et al.* (2002) and Klein *et al.* (2008), we focus on the steady-state of Markov-perfect equilibria working with differentiable Generalized-Euler Equations (GEE) and using their numerical perturbation algorithm for the computation of the steady-state. Employing the case of a benevolent government as a benchmark, we study the implications of partisan preferences on the part of the government. As expected, the model reproduces Judd's (1985) benchmark results for optimal policy under commitment, i.e. a zero capital tax and a positive labour tax are optimal for each agent in the long-run. However, our findings for long-run Markov policies under heterogeneity stand in stark contrast to Ramsey policies.

We first find that, in the absence of commitment, it is optimal for a benevolent government, which cares equally about all citizens, to tax capital heavily and to subsidise labour. In particular, this result complements

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[4]Earlier work on time-consistent policy is reviewed in Krusell (2002) and Klein *et al.* (2008).

what we know from the representative agent models discussed above, i.e. lack of commitment results in inefficiently high capital taxation. It is also suggestive of Martin's (2010) result, that, since high future capital taxation discourages labour effort today, the government finds it optimal to subsidise labour. However, Martin (2010) also finds that, for standard calibrations as in Klein *et al.* (2008), it is optimal for the government to impose confiscatory capital taxes. In contrast, we show, for the same calibration used in Klein *et al.* (2008), that a confiscatory capital tax does not follow in a capitalist-worker setup. Thus, heterogeneity in roles (capitalists versus workers) allows us to obtain robust interior time-consistent policy solutions over a range of empirically relevant parameters.[5]

A second key result of our analysis is that time-consistent optimal policies critically depend on the weight that the government attaches to the welfare of each agent, which is also consistent with the results in Krusell (2002). In contrast to Ramsey policies (see e.g. Judd (1985) where the zero capital taxation result holds irrespective of the weight given to capitalists vis-a-vis workers), a government that cares disproportionately for one of the agents will choose different policies. We show that, up to point, a partisan bias towards capitalists on the part of the government works as a substitute for the lack of commitment and this is beneficial to both workers and capitalists. In particular, starting with Benthamite preferences, we find that, as the weight the government places on the worker's utility increases, capital taxation rises and labour taxation falls, until eventually confiscatory capital taxation is invoked. This partisan bias towards workers hurts everybody including workers. On the other hand, as the weight given to workers falls below Benthamite preferences, labour subsidies turn into taxes, while capital taxation decreases. However, beyond a critical point, capital taxation is required to increase to help finance the provision of the public good and eventually confiscatory capital taxation follows. The same analysis further reveals that, up to a point, favouring the capitalist over the worker is Pareto improving.

Finally, we show that capitalists and workers' interests regarding the optimal amount of "capitalist bias", which the government might employ, are not aligned. For example, capitalists' welfare is maximised at a lower capital and higher labour tax rate than for workers'. This implies a conflict of interests between the agents and hence a trade-off between efficiency and equity.

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[5]Our results also complement Krusell (2002), who finds that in a model with a single income tax and lump-sum transfers, a confiscatory tax arises only when a non-Benthamite government attaches a zero weight to capitalists. As we discuss below, the introduction of labour taxation and the endogenous provision of public goods restricts the range of weights for which an interior solution can be obtained for a non-Benthamite government.

This arises under discretion since the fall in the capital tax, as a result of the "capitalist bias", has additional benefits for the capitalist in the form of increased (after-tax) capital income. For the worker, the welfare price he would have to pay, in terms of increased labour taxes, to have the capital tax reduced to what is optimal for the capitalist, is too high. If the government chooses what is best for the capitalist on efficiency grounds, since aggregate welfare is higher in this case, then the inequality between the worker and the capitalist will increase.

The rest of the paper is organized as follows. Section 2 presents the model economy. Section 3 solves for Markov-perfect policy. Sections 4 and 5 report results for the benevolent and partisan cases respectively. Section 6 concludes the paper. An appendix includes technical details.

2 The economy

We next describe a deterministic version of the neoclassical growth model comprised of capitalists, workers, firms and a government.[6] Time is discrete and infinite. In each time-period, the government acts as a Stackelberg leader, so that it moves first choosing its current tax-spending policy and, in turn, private agents move acting competitively. We solve this game by backward induction by first solving for the decentralized competitive equilibrium (DCE), given policy. Then, taking this DCE into account, the government chooses its tax-spending policy to maximize a weighted average of capitalists and workers' welfare.

2.1 Economic agents and their roles

Capitalists consume, work and save in the form of capital. They also own the firms and receive profits which, for simplicity, are zero in equilibrium. Workers in contrast do not have access to capital markets and thus only consume and work. The government taxes income from capital and labour to finance utility-enhancing public spending.

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[6] As in the related literature (see e.g. Judd (1985), Lansing (1999) and Krusell (2002)), we take these roles as given and do not model their microfoundations. See e.g. Aghion and Howitt (2008, ch. 6) for a review of the literature on participation in capital markets and inequality.

2.2 Population composition

Total population size, N, is exogenous and constant. Among N, $N^w < N$ are identical workers, while the rest $N^k = N - N^w$ are identical capitalists. Workers are indexed by the subscript $w = 1, 2, ..., N^w$ and capitalists by the subscript $k = 1, 2, ..., N^k$. Private firms are indexed by the subscript $f = 1, 2, ..., N^f$. We assume that the number of firms equals the number of capitalists, $N^k = N^f$, or that each capitalist owns one firm.[7]

2.3 Households

2.3.1 Utility function

We start by presenting the two types of households, capitalists, k, and workers, w. Each household $h \equiv k, w$ maximises:

$$U_h = \sum_{t=0}^{\infty} \beta^t u \left(C_{h,t}, u_{h,t}, \overline{G}_t^c \right) \tag{1}$$

where $C_{h,t}$ is household h's consumption at t; $u_{h,t}$ is h's leisure at t; $\overline{G}_t^c$ is average government services (i.e. total public consumption services divided by total population, N) at t; and $0 < \beta < 1$ is the time preference rate. The period utility function $u(.)$ is increasing and concave in all arguments.

2.3.2 Budget constraint and optimality conditions of capitalists

The within-period budget constraint of each capitalist (indexed by subscript k) is:

$$C_{k,t} + K_{k,t+1} - (1 - \delta) K_{k,t} = r_t K_{k,t} + \pi_{k,t} -$$
$$-\tau_t^k \left[(r_t - \delta) K_{k,t} + \pi_{k,t} \right] + \left(1 - \tau_t^l \right) w_t l_{k,t} \tag{2}$$

where $K_{k,t+1}$ is the end-of-period capital stock held by each capitalist; r_t is the return to the beginning-of period capital stock; w_t is the wage rate; $l_{k,t}$ is hours of work by each capitalist; $l_{k,t} + u_{k,t} = 1$ is the time constraint in each period; $\pi_{k,t}$ is firms' profit per capitalist; $0 \leq \tau_t^k < 1$ is the tax rate on capital income[8] and profits; $0 \leq \tau_t^l < 1$ is the tax rate on labour income; $0 < \delta < 1$ is the capital depreciation rate; and $K_{k,0} > 0$ is given.

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[7]As in the literature on optimal taxation, we take these population sizes as given and do not allow flows between capitalists and workers.

[8]Following most of the literature on optimal policy, we assume capital taxes net of depreciation. See e.g. Chari *et al.* (1994) and Klein *et al.* (2008).

Each capitalist k acts competitively choosing $\{C_{k,t}, l_{k,t}, K_{k,t+1}\}_{t=0}^{\infty}$. The optimality conditions include the above budget constraint, as well as the following Euler-equation and the labour supply condition:

$$\frac{\partial u_{k,t}}{\partial C_{k,t}} = \beta \frac{\partial u_{k,t+1}}{\partial C_{k,t+1}} \left[1 + \left(1 - \tau_{t+1}^k\right)\left(r_{t+1} - \delta\right)\right] \tag{3}$$

$$\frac{\partial u_{k,t}}{\partial(1 - l_{k,t})} = \frac{\partial u_{k,t}}{\partial C_{k,t}} \left(1 - \tau_t^l\right) w_t. \tag{4}$$

2.3.3 Budget constraint and optimality conditions of workers

The budget constraint of each worker (indexed by subscript w) is:

$$C_{w,t} = \left(1 - \tau_t^l\right) w_t l_{w,t}. \tag{5}$$

Each worker w acts competitively choosing $C_{w,t}$ and $l_{w,t}$ in each period, where as above $l_{w,t} + u_{w,t} = 1$. The optimality conditions of this static problem include the above budget constraint and the labour supply condition:

$$\frac{\partial u_{w,t}}{\partial(1 - l_{w,t})} = \frac{\partial u_{w,t}}{\partial C_{w,t}} \left(1 - \tau_t^l\right) w_t. \tag{6}$$

2.4 Firms

Each firm $f = 1, 2, ..., N^f$ maximizes profits given by:

$$\pi_{f,t} = Y_{f,t} - r_t K_{f,t} - w_t l_{f,t} \tag{7}$$

where $Y_{f,t}$ is each firm's output and $K_{f,t}$ and $l_{f,t}$ are respectively the inputs of capital and labour employed by the firm at each t. The output technology is:

$$Y_{f,t} = f(K_{f,t}, l_{f,t}) \tag{8}$$

where the production function $f(.)$ is increasing and concave in both arguments, and, for simplicity, displays constant returns to scale in the two factors.

Each firm f acts competitively choosing $K_{f,t}$ and $l_{f,t}$ to maximize profits. The standard optimality conditions of this static problem are:

$$r_t = f_k(K_{f,t}, l_{f,t}) \tag{9}$$

$$w_t = f_l(K_{f,t}, l_{f,t}) \tag{10}$$

$$\pi_{f,t} = 0. \tag{11}$$

2.5 Government budget constraint

We assume that the budget is balanced in each period. Thus, in aggregate terms, we have:

$$N\overline{G}_t^c = N^k[\tau_t^k(r_t - \delta)K_{k,t} + \tau_t^l w_t l_{k,t} + \tau_t^k \pi_{k,t}] + N^w \tau_t^l w_t l_{w,t} \qquad (12)$$

so that there are three policy instruments, τ_t^k, τ_t^l and $\overline{G}_t^c$, out of which only two can be independently set.

2.6 Decentralized competitive equilibrium (DCE)

We now summarize the DCE for any feasible policy. In this equilibrium, households maximize utility, firms maximize profits, the government budget constraint is satisfied and markets clear.[9] It is convenient to (i) define the population shares, $n^w \equiv N^w/N$ and $n^k \equiv N^k/N = 1-n^w$; and (ii) work with net factor returns $R_t \equiv \left(1 - \tau_t^k\right)(r_t - \delta)$ and $W_t \equiv \left(1 - \tau_t^l\right)w_t$. Then, the DCE is summarized by the following six equations in six unknowns, which are $\{C_{k,t}, C_{w,t}, l_{k,t}, l_{w,t}, K_{k,t+1}\}_{t=0}^{\infty}$ and the path of one of the three policy instruments:

$$\frac{\partial u(C_{k,t}, l_{k,t}, \overline{G}_t^c)}{\partial C_{k,t}} = \beta \frac{\partial u(C_{k,t+1}, l_{k,t+1}, \overline{G}_{t+1}^c)}{\partial C_{k,t+1}}(1 + R_{t+1}) \qquad (13)$$

$$\frac{\partial u(C_{k,t}, l_{k,t}, \overline{G}_t^c)}{\partial(1 - l_{k,t})} = \frac{\partial u(C_{k,t}, l_{k,t}, \overline{G}_t^c)}{\partial C_{k,t}}W_t \qquad (14)$$

$$\frac{\partial u(C_{w,t}, l_{w,t}, \overline{G}_t^c)}{\partial(1 - l_{w,t})} = \frac{\partial u(C_{w,t}, l_{w,t}, \overline{G}_t^c)}{\partial C_{w,t}}W_t \qquad (15)$$

$$C_{w,t} = W_t l_{w,t} \qquad (16)$$

$$n^k Y_{f,t} = n^k C_{k,t} + n^w C_{w,t} + n^k[K_{k,t+1} - (1 - \delta)K_{k,t}] + \overline{G}_t^c \qquad (17)$$

$$\overline{G}_t^c = n^k Y_{f,t} - \delta n^k K_{k,t} - R_t n^k K_{k,t} - W_t(n^k l_{k,t} + n^w l_{w,t}) \qquad (18)$$

where,

$$Y_{f,t} = f\left(K_{k,t}, l_{k,t} + \frac{n^w}{n^k}l_{w,t}\right). \qquad (19)$$

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[9]The market-clearing conditions in the capital, labor, dividend and goods markets are respectively $N^f K_{f,t} = N^k K_{k,t}$, $N^f l_{f,t}^w = N^k l_{k,t} + N^w l_{w,t}$, $N^f \pi_{f,t} = N^k \pi_{k,t}$ and $N^k C_{k,t} + N^w C_{w,t} + N^k(K_{k,t+1} - (1 - \delta)K_{k,t}) + N\overline{G}_t^c = N^f Y_{f,t}$.

For what follows below, it is useful to note that if we combine the budget constraint of workers (16), the economy's resource constraint (17) and the government budget constraint (18), capitalists' consumption is:

$$\begin{aligned} C_{k,t} &= -K_{k,t+1} + (1 + R_t)K_{k,t} + W_t l_{k,t} \\ &\equiv C(K_{k,t}, W_t, R_t, l_{k,t}, K_{k,t+1}) \end{aligned} \tag{20}$$

while, from (18) and (19), government consumption is written as:

$$\overline{G}_t^c \equiv \overline{G}(K_{k,t}, W_t, R_t, l_{k,t}, l_{w,t}). \tag{21}$$

Thus, equations (16), (20) and (21) are used into the three optimality conditions $(13) - (15)$ to substitute out respectively $C_{w,t}$, $C_{k,t}$, and $\overline{G}_t^c$ at any t.

3   Markov-perfect policy

In each time-period, the government chooses all current policy instruments to maximize a weighted average of capitalists and workers welfare subject to the DCE conditions. The government chooses the tax policy instruments, τ_t^l and τ_t^k, or equivalently the associated net factor returns, W_t and R_t, while public spending, $\overline{G}_t^c$, follows residually from the a-temporal government budget constraint.

To solve for time-consistent optimal policy, we work as follows. We, first, characterize the equilibrium responses of private agents. Among other things, this will transform the government's optimization problem into a recursive one, in the sense that policy choices affect payoffs dated t and later but not earlier. We next solve the government's dynamic programming problem. Finally, we define the Markov-perfect equilibrium conditions and the functional equations to be solved for.

3.1   Response of private agents

We start by characterizing the responses of capitalists and workers. Given the assumed timing of agents' moves within each period, private agents' choices will be functions of the current value of the economy's state variable, $K_{k,t}$, and the current value of the independent policy instruments, W_t and R_t.

In particular, if a Markov-perfect equilibrium exists, equilibrium strategies will be functions of the current value of the economy's state variable, $K_{k,t}$. Thus, as shown in subsection 3.3 below, a solution will include undetermined functions of the form $K_{k,t+1} = h(K_{k,t})$, $l_{k,t} = \lambda(K_{k,t})$, $l_{w,t} = \mu(K_{k,t})$,

$W_t = \Phi(K_{k,t})$ and $R_t = \Psi(K_{k,t})$. We can thus use $h(K_{k,t+1})$, $\lambda(K_{k,t+1})$, $\mu(K_{k,t+1})$, $\Phi(K_{k,t+1})$ and $\Psi(K_{k,t+1})$ to replace respectively $K_{k,t+2}$, $l_{k,t+1}$, $l_{w,t+1}$, W_{t+1} and R_{t+1} on the right-hand side of capitalists' Euler-equation (13). This makes the government's problem recursive. In turn, inspection of the three behavioral optimality conditions $(13) - (15)$, using (16), (20) and (21), reveals that, in general, $K_{k,t+1} = H(K_{k,t}, W_t, R_t)$, $l_{k,t} = \Lambda(K_{k,t}, W_t, R_t)$ and $l_{w,t} = M(K_{k,t}, W_t, R_t)$, where the properties of the functions $H(.)$, $\Lambda(.)$ and $M(.)$ follow from those in (13)-(18).[10] These three functions show the response of private agents given the economy's state is $K_{k,t}$ and the values of the two independent policy instruments are W_t and R_t, under the presumption that we will be in a Markov-perfect equilibrium in the future (see also Klein *et al.*, 2008, p. 795).

3.2 Dynamic programming problem of the government

The government chooses W_t and R_t to solve the recursive dynamic programming problem:

$$
\begin{aligned}
V(K_{k,t}) &= \max[(1-\gamma)u(C_{k,t}, 1 - l_{k,t}, \overline{G}_t^c) + \\
&\quad + \gamma u(C_{w,t}, 1 - l_{w,t}, \overline{G}_t^c) + \beta V(K_{k,t+1})]
\end{aligned} \tag{22}
$$

where $V(K_{k,t})$ denotes the value function of the government at t; and γ, $(1-\gamma)$ are the weights attached by the government to the utility of workers and capitalists respectively. Thus, when the government has a Benthamite utility function, $\gamma = n^w$ and $(1-\gamma) = n^k$. The maximisation is subject to the recursive form of the DCE, namely:

$$
\begin{aligned}
C_{k,t} &= -K_{k,t+1} + (1 + R_t)K_{k,t} + W_t l_{k,t} \\
&\equiv C(K_{k,t}, W_t, R_t, l_{k,t}, K_{k,t+1})
\end{aligned} \tag{23}
$$

$$
l_{k,t} = \Lambda(K_{k,t}, W_t, R_t) \tag{24}
$$

$$
K_{k,t+1} = H(K_{k,t}, W_t, R_t) \tag{25}
$$

$$
C_{w,t} = W_t l_{w,t} \tag{26}
$$

$$
l_{w,t} = M(K_{k,t}, W_t, R_t) \tag{27}
$$

$$
\begin{aligned}
\overline{G}_t^c &= n^k Y_{f,t} - \delta n^k K_{k,t} - R_t n^k K_{k,t} - W_t(n^k l_{k,t} + n^w l_{w,t}) \\
&\equiv \overline{G}(K_{k,t}, W_t, R_t, l_{k,t}, l_{w,t})
\end{aligned} \tag{28}
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[10] To save space, the properties of these response functions will be specified below when we adopt specific forms for the primitive functions to obtain a numerical solution. The analytical expressions in implicit form are however available on request.

where

$$Y_{f,t} = f\left(K_{k,t}, l_{k,t} + \frac{n^w}{n^k} l_{w,t}\right). \tag{29}$$

3.2.1 Optimality conditions for policy instruments

The optimality conditions for W_t and R_t are respectively:

$$(1-\gamma)\left[\frac{\partial u_{k,t}}{\partial C_{k,t}}\frac{\partial C_{k,t}}{\partial W_t} - \frac{\partial u_{k,t}}{\partial(1-l_{k,t})}\frac{\partial l_{k,t}}{\partial W_t} + \frac{\partial u_{k,t}}{\partial \overline{G}_t^c}\frac{\partial \overline{G}_t^c}{\partial W_t}\right] + \tag{30}$$

$$+\gamma\left[\frac{\partial u_{w,t}}{\partial C_{w,t}}\frac{\partial C_{w,t}}{\partial W_t} - \frac{\partial u_{w,t}}{\partial(1-l_{w,t})}\frac{\partial l_{w,t}}{\partial W_t} + \frac{\partial u_{w,t}}{\partial \overline{G}_t^c}\frac{\partial \overline{G}_t^c}{\partial W_t}\right] + \beta\frac{dV_{t+1}}{dK_{k,t+1}}H_w(t) = 0$$

$$(1-\gamma)\left[\frac{\partial u_{k,t}}{\partial C_{k,t}}\frac{\partial C_{k,t}}{\partial R_t} - \frac{\partial u_{k,t}}{\partial(1-l_{k,t})}\frac{\partial l_{k,t}}{\partial R_t} + \frac{\partial u_{k,t}}{\partial \overline{G}_t^c}\frac{\partial \overline{G}_t^c}{\partial R_t}\right] + \tag{31}$$

$$+\gamma\left[\frac{\partial u_{w,t}}{\partial C_{w,t}}\frac{\partial C_{w,t}}{\partial R_t} - \frac{\partial u_{w,t}}{\partial(1-l_{w,t})}\frac{\partial l_{w,t}}{\partial R_t} + \frac{\partial u_{w,t}}{\partial \overline{G}_t^c}\frac{\partial \overline{G}_t^c}{\partial R_t}\right] + \beta\frac{dV_{t+1}}{dK_{k,t+1}}H_r(t) = 0.$$

where H_w and H_r denote the partials of the response function for $K_{k,t+1}$ with respect to W_t and R_t.

3.2.2 Envelope condition

Given W_t and R_t, the envelope condition for the state variable, $K_{k,t}$, is:

$$\frac{dV_t}{dK_{k,t}} = (1-\gamma)\left[\frac{\partial u_{k,t}}{\partial C_{k,t}}\frac{\partial C_{k,t}}{\partial K_{k,t}} - \frac{\partial u_{k,t}}{\partial(1-l_{k,t})}\frac{\partial l_{k,t}}{\partial K_{k,t}} + \frac{\partial u_{k,t}}{\partial \overline{G}_t^c}\frac{\partial \overline{G}_t^c}{\partial K_{k,t}}\right] + \tag{32}$$

$$+\gamma\left[\frac{\partial u_{w,t}}{\partial C_{w,t}}\frac{\partial C_{w,t}}{\partial K_{k,t}} - \frac{\partial u_{w,t}}{\partial(1-l_{w,t})}\frac{\partial l_{w,t}}{\partial K_{k,t}} + \frac{\partial u_{w,t}}{\partial \overline{G}_t^c}\frac{\partial \overline{G}_t^c}{\partial K_{k,t}}\right] + \beta\frac{dV_{t+1}}{dK_{k,t+1}}H_k(t)$$

where H_k denotes the partial of the response function for $K_{k,t+1}$ with respect to the state, $K_{k,t}$.

3.3 Markov-perfect equilibrium

We can now combine equilibrium conditions to solve for the unknown functional equations $K_{k,t+1} = h(K_{k,t})$, $l_{k,t} = \lambda(K_{k,t})$, $l_{w,t} = \mu(K_{k,t})$, $W_t = \Phi(K_{k,t})$, $R_t = \Psi(K_{k,t})$ and the government's value function, $V_t = V(K_{k,t})$. To substitute out the latter, and working as in Klein *et al.* (2008), we use the

optimality condition for W_t in (30) to obtain an expression for $\frac{dV_{t+1}}{dK_{k,t+1}}$ and its one period lead, $\frac{dV_{t+2}}{dK_{k,t+2}}$. These two expressions are in turn substituted into the lead once envelope condition (32) yielding the so-called Generalized Euler-equation (GEE).

Thus, the final system to solve consists of the government's GEE, the government's optimality condition for R_t in (31), the Euler condition of capitalists in (13), the labour supply condition of capitalists in (14) and the labour supply condition of workers in (15), i.e. there are five equations in five functional equations, $K_{k,t+1} = h(K_{k,t})$, $l_{k,t} = \lambda(K_{k,t})$, $l_{w,t} = \mu(K_{k,t})$, $W_t = \Phi(K_{k,t})$ and $R_t = \Psi(K_{k,t})$.

3.4 Quantitative assumptions

To quantitatively address the key questions raised in the Introduction, we employ the numerical perturbation algorithm proposed by Krusell *et al.* (2002) and Klein *et al.* (2008) to solve the system of functional equations derived above at the steady-state. To facilitate comparability with the literature, we adopt the same functional forms for utility and production, as well as the same common parameter values used in and Klein *et al.* (2008). In particular, we use:

$$u\left(C_{h,t}, l_{h,t}, \overline{G}_t^c\right) = \mu_1 \log(C_{h,t}) + \mu_2 \log(1 - l_{h,t}) + \mu_3 \log(\overline{G}_t^c) \qquad (33)$$

$$Y_{f,t} = AK_{f,t}^\alpha l_{f,t}^{1-\alpha} \qquad (34)$$

and $A = 1$, $\alpha = 0.36$, $\beta = 0.96$, $\delta = 0.08$, $\mu_1 = 0.261$, $\mu_2 = 0.609$, $\mu_3 = 1 - \mu_1 - \mu_2$. Since (33) applies to both capitalists and workers, the only additional parameters required by our setup include n^k and $n^w = 1 - n^k$. In our baseline parameterization, we set $n^k = 0.3$. The Appendix derives in detail the set of conditions defining the Markov-perfect equilibrium implied by $(33) - (34)$, and briefly discusses the solution algorithm.[11]

4 Benthamite (benevolent) optimal policy

In this section, we study the case of a benevolent, or Benthamite, government in the sense that the weights γ and $(1 - \gamma)$ attached by the govern-

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[11]Although we employ logarithmic preferences and the government budget is balanced, our remaining model assumptions (i.e. less than full capital depreciation, endogenous labor, two distorting income taxes and endogenous public spending) imply a DCE where current savings decisions do not depend only on current returns and taxes as in Lansing (1999). Hence there is a genuine time-consistency problem. Also note that further details regarding the solution algorithm can be found in the Appendix of Klein *et al.* (2008).

ment to the utility of workers and capitalists are their population shares, i.e. $\gamma = n^w$ and $(1 - \gamma) = n^k$. Following the related literature, we also report results for Ramsey policy and the associated social planner's solution. In the case of Ramsey second-best policy, the government chooses $\{W_t, R_t, \overline{G}_t^c\}_{t=0}^{\infty}$ to maximise a weighted average of capitalists and workers welfare, as specified in (22), subject to the DCE $(13) - (19)$. The social planner's first-best problem is defined as the case in which we choose allocations only, i.e. $\{C_{k,t}, C_{w,t}, l_{k,t}, l_{w,t}, K_{k,t+1}, \overline{G}_t^c\}_{t=0}^{\infty}$, to maximize the same objective subject to the resource constraints (17) and (19).

4.1 Social Planner versus Ramsey

To contextualise the effects of lack of commitment on optimal fiscal policy, we first highlight the differences between the social planner's and Ramsey's allocations. Table 1 shows, as expected, that a Benthamite social planner (SP) will find it optimal to make all agents equal and this also maximises aggregate efficiency. On the contrary, a Ramsey government needs to take into account the distortions introduced by the tax system and thus does not find it optimal to equate the welfare of both agents. Instead, it finds it optimal to support aggregate welfare by financing the public good in the least distorting way. Then, consistent with the results in Judd (1985) and the other related studies discussed in the Introduction, the optimal tax on capital in the long-run is zero under Ramsey policy, while the labour tax rate is positive.

As expected, aggregate welfare, private consumption of both agents, public goods provision and aggregate output are all lower under Ramsey policy than under the social planner's allocation. *Ceteris paribus*, both l_w and l_k are lower under Ramsey since the social planner, by internalising the public good in his choices, finds it optimal to produce more output and provide more public goods. Hence, he commands higher labour and capital inputs relative to the decentralised choices. Notice that the capitalist's labour supply is much lower under Ramsey since it is adversely affected by the positive labour tax rate, whereas the worker's labour supply is inelastic with respect to the labour tax since he does not save and has logarithmic preferences. Thus, the implied rise in leisure time under Ramsey leads to greater welfare than under the social planner for the capitalist, whereas the worker is worse off since the utility associated with his increase in leisure is not enough to compensate for the fall in consumption and public goods provision.

Table 1: Steady-state

	SP	Ramsey	Markov
Y	2.1473	1.5046	1.0141
K/Y	2.9589	2.9589	1.1137
C/Y	0.5095	0.5095	0.7280
I/Y	0.2367	0.2367	0.0891
G^c/Y	0.2538	0.2538	0.1829
t^k	—	0.0000	0.8287
t^l	—	0.3965	-0.0650
C_k	1.0941	0.8964	0.7712
C_w	1.0941	0.7109	0.7242
$\overline{G}_t^c$	0.5450	0.3819	0.1855
l_k	0.3499	0.1174	0.2545
l_w	0.3499	0.3000	0.3000
U	-0.7885	-0.8417	-0.9748
U_k	-0.7885	-0.7005	-0.9364
U_w	-0.7885	-0.9022	-0.9912

4.2 Ramsey versus Markov policy

The results in Table 1 suggest that, under commitment, it is optimal to minimise the efficiency distortions of the tax system by choosing a zero capital and a positive labour tax in the long-run. In other words, as said above, the best long-run policy that the Ramsey government can implement to support aggregate welfare is to increase labour productivity and income through tax-induced increases in the capital stock. In stark contrast, time-consistent Markov policy suggests that it is optimal for the government to impose a very high capital tax and to subsidise labour. Given that the tax system is more inefficient under lack of commitment, the optimal size of the government, $\overline{G}_t^c$, is reduced relative to Ramsey policy, as are total output and welfare (both at average and individual levels).

In contrast to Martin (2010), we find that, for the same calibration used in Klein *et al.* (2008), a confiscatory capital tax does not follow in a capitalist-worker setup. The incentive to tax capital heavily in a Markov-perfect equilibrium and, at the same time, the incentive to subsidise labour, so as to undo the damage from high capital taxes, are weaker in our model. Capital taxation is more distortionary in an heterogeneous economy, since a subset of the population does not hold capital, which means that *ceteris paribus* the per capita capital is lower relative to an economy where all agents have capital holdings. Hence, the incentive to tax capital is weaker here. In turn, the labour supply distortion, at aggregate level, caused by future capital taxation

is smaller here relative to a single agent model (see Martin (2010)). This follows, first because capital taxation is lower and second because the worker's optimal labour supply decision is not affected negatively by future capital taxation. Accordingly, the incentive for the government to subsidise labour is also weaker.[12] Therefore, it appears that heterogeneity and, in particular heterogeneous marginal propensities to save and labour supply elasticities, contribute to well-defined non-confiscatory tax rates on capital. In fact, we find a robust range of interior solutions under heterogeneity based on changes in our base calibration over empirically relevant parameter ranges.

One would expect aggregate welfare to be higher under Ramsey policies and that the capitalist should be better off, given the more efficient aggregate economy and the zero capital tax. The results in Table 1 confirm that this is indeed the case. But what about the worker? Does the increased productivity resulting from higher capital accumulation under Ramsey provide enough compensation in terms of private consumption? As it turns out, Table 1 suggests that consumption for the worker is roughly the same under commitment and discretion. However, the increased efficiency of the tax system under commitment allows the government to provide much more of the public good and this makes the worker better off overall. Therefore, comparing Ramsey to Markov, commitment is beneficial to all agents.

5   Non-Benthamite (partisan) optimal policy

A striking result in Judd's (1985) analysis, which also holds here, is that the optimal allocations under commitment are independent of the weights, γ and $(1-\gamma)$, that the government employs in its objective function (22). This can be easily explained by examining the optimality conditions under Ramsey which we have not been presented to save space. However, in lieu of these, Table 2 aptly illustrates the point. These results suggest that, for all agents, the zero capital taxation policy is the best to adopt in a Ramsey setup and, as a consequence, there is no conflict of interests between agents.

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[12]The inelastic supply of labour for the worker creates the incentive for the government to positively tax this factor on efficiency grounds. However, since the same tax rate also applies to the labour supply of the capitalists, which is adversely affected by high future capital taxation, a labour tax would also have an adverse effect on aggregate labour supply, which is inefficiently low because of high capital taxation and low capital stocks. Hence, the incentive to subsidize labor. These opposing incentives, on balance, lead to a subsidy for a Benthamite government.

Table 2: Steady-state Ramsey

	$\gamma = 0$	$\gamma = 0.7$	$\gamma = 1$
t^k	0.0000	0.0000	0.0000
t^l	0.3965	0.3965	0.3965
C_k	0.8964	0.8964	0.8964
C_w	0.7109	0.7109	0.7109
$\overline{G}^c_t$	0.3819	0.3819	0.3819
l_k	0.1174	0.1174	0.1174
l_w	0.3000	0.3000	0.3000
U	-0.8417	-0.8417	-0.8417
U_k	-0.7005	-0.7005	-0.7005
U_w	-0.9022	-0.9022	-0.9022

However, does this commonality of interests hold when we consider time-consistent policy? Would agents be better off if the government was partisan, attaching a higher weight to a particular income group? Would both agents prefer a Benthamite government? If not, how much partisan behaviour would be optimal for aggregate welfare and for each agent? Does a conflict of interests between agents arise under time-consistent optimal policy?

5.1 "Capitalist bias"

To provide answers to these questions, we next solve the model and evaluate welfare for a range of weights in the government's objective function. Figure 1 below plots the steady-state values for the policy instruments, output, capital, each of the arguments in the utility function, welfare for each agent and aggregate welfare against the weight attached to workers, γ. What becomes immediately apparent is that, in contrast to a commitment equilibrium, the value of γ matters for equilibrium allocations and welfare. The fact that, for both types of agents, welfare is greater for $\gamma < n^w$, implies that caring more for the capitalist relative to the benevolent case, $\gamma = n^w$, is Pareto improving.

Starting from the Benthamite case for the base calibration, $\gamma = n^w = 0.7$, let's first examine optimal allocations as γ increases, i.e. the government cares more (less) for the worker (capitalist). Lack of commitment and partisan preferences make high capital taxes unavoidable. The disincentive for the capitalist to accumulate capital hurts total output and public goods provision. The combination of partisan preferences and adverse total effects, push the government to compensate workers' income by increasing the labour subsidy. The more the government cares about the worker, the higher the

incentive to subsidise labour. This, in turn, implies that the need to generate tax revenue, and thus to tax capital, will be even higher. Therefore, the efficiency distortions introduced by the tax system become higher and higher as γ rises. The outcome of all these changes is a fall in the welfare of all agents. It is important to point out that this is true even for the worker. The adverse income effects from higher capital taxes exceed the increased income generated by labour subsidies, so that workers's consumption falls for $\gamma > 0.7$. Not surprisingly, the capitalist is also directly hurt by capital taxes that reduce his capital income. When the weight on the worker increases above a critical point, i.e. $\gamma > 0.737$ for this model/calibration, the incentive for the government to impose confiscatory capital taxes is so high that an interior solution cannot be obtained.[13]

Let's next consider reductions in the weight for the worker. As γ falls from $n^w = 0.7$, the incentive for the government to tax capital and subsidise labour is initially reduced. Actually, labour subsidies turn quickly into taxes as γ decreases. For the opposite reasons from those explained above, all this is initially good for total output, tax revenues and public goods provision. It is also good for the welfare of both agents, even workers'.

[Figure 1 here]

However, the above results do not hold for all reductions in γ. After a point, a higher labour tax starts hurting the worker, given that it is his only source of income, while a higher quantity of the public good provides the same benefit to all. Thus, as γ decreases, the government redistributes welfare towards the agent that it cares more about, namely, the capitalist in this experiment. In addition, after a critical level, higher levels of public spending are not consistent with further decreases in the capital tax. A low capital tax policy will no longer be sustainable and capital taxes start increasing again. In fact, given that the increase now takes place in a very distorted economy, due to high labour taxes, it quickly leads to confiscatory capital taxation for $\gamma < 0.618$.

The above discussion suggests that, up to a point, a "capitalist bias" on the part of the government can provide a means to reduce the inefficiently high capital taxation inherent in a Markov-perfect equilibrium and so push the economy toward its second-best, Ramsey outcome. This is similar to the finding in the literature on time-consistent monetary policy, where a

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[13]Note that in the model without labour income taxation analysed in Krusell (2002), the capital taxes are not confiscatory when the weight attached to the worker is arbitrarily close to unity, but not equal to one. The introduction of labour taxation reduces the upper bound on the policymaker's partisan preferences that can be consistent with an interior equilibrium.

conservative central banker, who cares predominantly about inflation, helps to reduce the inflation bias. However, although the "capitalist bias" can be a substitute for commitment technology, it cannot eliminate the time-inconsistency problem in fiscal policy since, as pointed out above, the need to supply the public good eventually makes a low capital tax plan unsustainable.

Since a "capitalist bias" is Pareto improving, for a range of $\gamma < n^w$, it seems worth exploiting in fiscal policy design. Over this range, the benefits accruing to the worker, from lower capital taxation, in addition to the higher amount of the public good, more than compensates for the increases in labour taxation. This is clearly the case for the capitalist as well, who, in addition, benefits directly from increased capital income. However, for neither of the two agents is it preferable for the government to set $\gamma = 0$. Actually, the welfare of both agents falls after a critically low value of γ. Thus, the capitalist in this model has an interest in the welfare of the worker. The reason is that overtaxing labour, which hurts the worker, will eventually lead to increased capital taxation, through the increased fiscal spending channel. There is, thus, an optimal degree of "capitalist bias" for both agents, which we further explore below.

It is finally interesting to note that a "capitalist bias" can help this model to generate predictions regarding the tax rates that are consistent with some empirical regularities, i.e. high, but non-confiscatory capital taxes and positive labour taxes that are much lower than the capital taxes (see e.g. Garcia-Mila *et. al.* (2010) for a discussion of tax rates in the US).

5.2   Conflicting or common interests?

Under lack of commitment, Figure 1 showed that, up to a point, it was in both agents' interests for the government to favour capitalists, i.e. $\gamma < n^w$, when designing optimal policy. However, a closer look at this Figure suggests that their interests regarding the size of this bias are not perfectly aligned. Table 3 focuses on the relevant range for γ from Figure 1 to illustrate this point more precisely. We can see, based on maximum welfare for each agent, that the capitalist would prefer $\gamma = 0.629$, while the worker would prefer $\gamma = 0.637$. These in turn imply non-trivial differences for the preferred tax structure by each agent. In particular, capital and labour tax rates of 76.8% and 21.8% respectively would apply to the capitalist, and 77.1% and 15.9% to the worker. These also imply differences in the fiscal size, i.e. a $\overline{G}_t^c$ for the capitalist that is about 12.2% higher than for the worker. Finally, changing γ from 0.637 to 0.629 implies welfare gains for the capitalist of around 1.5%

and welfare losses for the worker of about 1.1%.[14] Reductions of γ below 0.629 make everybody worse off, even capitalists.

Table 3: Steady-state Markov

γ	t^k	t^l	$\overline{G}_t^c$	U	U_k	U_w
0.627	0.7684	0.2360	0.1140	-0.9191	-0.8626	-0.9527
0.629	**0.7683**	**0.2180**	**0.1104**	**-0.9180**	**-0.8625**	**-0.9507**
0.631	0.7685	0.2016	0.1070	-0.9175	-0.8629	-0.9494
0.633	0.7691	0.1864	0.1039	-0.9174	-0.8636	-0.9486
0.635	0.7700	0.1722	0.1010	-0.9176	-0.8646	-0.9481
0.637	**0.7711**	**0.1590**	**0.0984**	**-0.9182**	**-0.8658**	**-0.9480**
0.639	0.7723	0.1466	0.0958	-0.9189	-0.8673	-0.9481

These results suggest that there can be areas of both common and conflicting interests. The former are for partisan preferences above and below the bolded rows in Table 3, whereas the latter are those in between the bolded rows. Conflict of interests arises under discretion since the decrease in the capital tax, as a result of the "capitalist bias", has additional benefits for the capitalist, compared to the worker, in the form of increased (after-tax) capital income. Thus, the capitalist's welfare is maximised when the capital tax is minimised. For the worker, the price he would pay, in terms of increased labour taxes and lost welfare, to have the capital tax reduced below 77.1% is too high. These findings further imply that, in the area of opposing interests, there is a trade-off between equity and efficiency. In particular, decreasing γ below 0.637 is initially good for efficiency, since aggregate welfare increases up to a maximum at $\gamma = 0.633$. However, it is not good for equity, as the welfare of the worker is reduced and thus the inequality between the worker and the capitalist increases.

6   Conclusions

In this paper, we solved for time-consistent (Markov-perfect) optimal fiscal policy in an economy with capitalists and workers. By studying both efficiency and distributional issues, we filled a gap in the related literature that has, with the exception of Krusell (2002), addressed time-consistent policy in models with a representative agent.

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[14]These gains and losses refer to the compensating consumption supplement calculated as $\frac{1}{\mu_1} \ln \left(\frac{U_h^a}{U_h^b} \right)$, where a and b are the welfare levels preferred by the workers and capitalists respectively; and, as defined above, $h = k, w$ denotes the two agents.

Heterogeneity allowed us to obtain interior and robust Markov-perfect solutions for the capital tax rate relative to single agent models. We showed that, for standard calibrations, the socially optimal tax rate on capital is neither zero (see e.g. Judd (1985)) nor confiscatory (see Martin (2010)) in the long-run. We also showed that the labour subsidy can turn into a labour tax depending on government's preferences. Thus, there is room for redistribution.

Our results provide some lessons that are useful for policy makers. A "capitalist bias" on the part of the government can work as an imperfect substitute for the lack of commitment, thereby pushing the economy from its third-best (Markov) in the direction of its second-best (Ramsey). This "capitalist bias", up to a point, can benefit both capitalists and workers. Thus, there is an area of common interest, in the sense that the worker has an interest in the welfare of the capitalist, and vice versa. However, the optimal degree of "capitalist bias" differs between workers and capitalists. Naturally, the capitalist would choose a higher degree than the worker. Between these, there is an area of conflicting interests that implies a trade-off between efficiency and equity.

In generating our findings, we contributed to the related literature on optimal fiscal policy in several ways. First, we expand that branch of the literature that has studied Ramsey policy with heterogeneous agents (e.g. Judd (1985), Lansing (1999) and Greulich and Marcet (2008)) by solving for time-consistent policy. Second, we extend the literature on time-consistent policy with a representative agent (e.g. Ortigueira (2006), Klein *et al.* (2008) and Martin (2010)) by adding heterogeneity and distributional implications. Third, we add to Krusell (2002), Ortigueira (2006) and Klein *et al.* (2008), who have assumed that the government chooses only one tax instrument at a time, by choosing both capital and labour taxes simultaneously.

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7 Appendix

In this appendix, we use the log-linear utility function (33) and the Cobb-Douglas production function (34) into the more general model presented in the main body of the paper. We specify what changes in each step of the solution.

7.1 Decentralized competitive equilibrium (DCE)

Equations (13)-(19) become respectively:

$$\frac{1}{C_{k,t}} = \frac{\beta(1 + R_{t+1})}{C_{k,t+1}} \tag{35}$$

$$\frac{\mu_2}{(1 - l_{k,t})} = \frac{\mu_1 W_t}{C_{k,t}} \tag{36}$$

$$\frac{\mu_2}{(1 - l_{w,t})} = \frac{\mu_1 W_t}{C_{w,t}} \tag{37}$$

$$C_{w,t} = W_t l_{w,t} \tag{38}$$

$$n^k Y_{f,t} = n^k C_{k,t} + n^w C_{w,t} + n^k [K_{k,t+1} - (1 - \delta)K_{k,t}] + \overline{G}_t^c \tag{39}$$

$$\overline{G}_t^c = n^k Y_{f,t} - \delta n^k K_{k,t} - R_t n^k K_{k,t} - W_t(n^k l_{k,t} + n^w l_{w,t}) \tag{40}$$

$$Y_{f,t} = \frac{A\left[n^k K_{k,t}\right]^\alpha \left[n^k l_{k,t} + n^w l_{w,t}\right]^{1-\alpha}}{n^k}. \tag{41}$$

Since (36) implies $l_{k,t} = 1 - \frac{\mu_2 C_{k,t}}{\mu_1 W_t}$ and $(37) - (38)$ imply $l_{w,t} = \frac{\mu_1}{\mu_1 + \mu_2}$ and $C_{w,t} = \frac{\mu_1 W_t}{\mu_1 + \mu_2}$, equations (20) and (21) become respectively:

$$\begin{aligned} C_{k,t} &= \frac{1}{(1 + \frac{\mu_2}{\mu_1})}[-K_{k,t+1} + (1 + R_t)K_{k,t} + W_t] \\ &\equiv C(K_{k,t}, W_t, R_t, K_{k,t+1}) \end{aligned} \tag{42}$$

and

$$\overline{G}_t^c = n^k Y_{f,t} - \delta n^k K_{k,t} - R_t n^k K_{k,t} - W_t n^k [1 - \frac{\mu_2 C_{k,t}}{\mu_1 W_t}] -$$

$$- W_t n^w \frac{\mu_1}{(\mu_1 + \mu_2)} \equiv \overline{G}(K_{k,t}, W_t, R_t, K_{k,t+1}) \tag{43}$$

where the latter follows by using (42) for $C_{k,t}$.

7.2 Response of private agents

In this special case, since $l_{k,t} = 1 - \frac{\mu_2 C_{k,t}}{\mu_1 W_t}$ and $l_{w,t} = \frac{\mu_1}{\mu_1 + \mu_2}$, we need to specify only one response function, $K_{k,t+1} = H(K_{k,t}, W_t, R_t)$. To do so, we work as in Klein *et al.* (2008). In particular, using (42), we have from the Euler-equation of capitalists in (35):

$$\eta(K_{k,t}, W_t, R_t, K_{k,t+1}) \equiv \frac{1}{C(K_{k,t}, W_t, R_t, K_{k,t+1})} -$$

$$-\frac{\beta(1 + \Psi(K_{k,t+1}))}{C(K_{k,t+1}, \Phi(K_{k,t+1}), \Psi(K_{k,t+1}), h(K_{k,t+1}))} = 0 \tag{44}$$

which confirms that, if there is a solution, this is of the form $K_{k,t+1} \equiv H(K_{k,t}, W_t, R_t)$. We next specify the properties of this response function $H(.)$.

First, using $H(K_{k,t}, W_t, R_t)$ for $K_{k,t+1}$, we have:

$$\eta(K_{k,t}, W_t, R_t, H(K_{k,t}, W_t, R_t)) = 0 \tag{45}$$

so that at the optimum:

$$\eta_k(t) + \eta_{k'}(t)H_k(t) = 0 \text{ or } H_k(t) = \frac{-\eta_k(t)}{\eta_{k'}(t)} \tag{46}$$

$$\eta_w(t) + \eta_{k'}(t)H_w(t) = 0 \text{ or } H_w(t) = \frac{-\eta_w(t)}{\eta_{k'}(t)} \tag{47}$$

$$\eta_r(t) + \eta_{k'}(t)H_r(t) = 0 \text{ or } H_r(t) = \frac{-\eta_r(t)}{\eta_{k'}(t)} \tag{48}$$

where $\eta_k(t)$, $\eta_w(t)$, $\eta_r(t)$ and $\eta_{k'}(t)$ denote the partials of $\eta(K_{k,t}, W_t, R_t, K_{k,t+1})$ and $H_k(t)$, $H_w(t)$ and $H_r(t)$ denote the partials of $H(K_{k,t}, W_t, R_t)$.

Second, we also have, for given $K_{k,t+1}$:

$$\eta(K_{k,t}, W_t, R_t, K_{k,t+1}) \equiv \frac{1}{C(K_{k,t}, W_t, R_t, K_{k,t+1})} -$$

$$-\frac{\beta(1 + \Psi(K_{k,t+1}))}{C(K_{k,t+1}, \Phi(K_{k,t+1}), \Psi(K_{k,t+1}), h(K_{k,t+1}))} = 0 \tag{49}$$

so that we get:

$$\eta_k(t) = -\frac{1}{(C_{k,t})^2} C_k(t) \tag{50}$$

$$\eta_w(t) = -\frac{1}{(C_{k,t})^2} C_w(t) \tag{51}$$

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$$\eta_r(t) = -\frac{1}{(C_{k,t})^2}C_r(t) \tag{52}$$

$$
\begin{aligned}
\eta_{k'}(t) &= -\frac{1}{(C_{k,t})^2}C_{k'}(t) - \frac{\beta}{C_{k,t+1}}\Psi_k(K_{k,t+1}) + \frac{\beta(1+\Psi(K_{k,t+1}))}{[C_{k,t+1}]^2} \times \\
&\quad \times \{C_k(t+1) + C_w(t+1)\Phi_k(K_{k,t+1}) + C_r(t+1)\Psi_k(K_{k,t+1}) + \\
&\quad + C_{k'}(t+1)h_k(K_{k,t+1})\}
\end{aligned}
\tag{53}
$$

where $C_k(t)$, $C_w(t)$, $C_r(t)$ and $C_{k'}(t)$ denote the partials of $C(K_{k,t}, W_t, R_t, K_{k,t+1})$ as defined above. This completes the properties of the private response function, $K_{k,t+1} \equiv H(K_{k,t}, W_t, R_t)$.

7.3 Dynamic programming problem of the government

The government solves the problem specified in subsection 3.2. The constraints in (23)-(29) are now simplified to:

$$C_{k,t} = \frac{1}{(1 + \frac{\mu_2}{\mu_1})}[-K_{k,t+1} + (1 + R_t)K_{k,t} + W_t] \tag{54}$$

$$l_{k,t} = 1 - \frac{\mu_2 C_{k,t}}{\mu_1 W_t} \tag{55}$$

$$K_{k,t+1} = H(K_{k,t}, W_t, R_t) \tag{56}$$

$$C_{w,t} = \frac{\mu_1 W_t}{\mu_1 + \mu_2} \tag{57}$$

$$l_{w,t} = \frac{\mu_1}{\mu_1 + \mu_2} \tag{58}$$

$$\overline{G}_t^c = n^k Y_{f,t} - \delta n^k K_{k,t} - R_t n^k K_{k,t} - W_t(n^k l_{k,t} + n^w l_{w,t}) \tag{59}$$

where

$$Y_{f,t} = \frac{A\left[n^k K_{k,t}\right]^\alpha \left[n^k l_{k,t} + n^w l_{w,t}\right]^{1-\alpha}}{n^k}. \tag{60}$$

7.4 Markov-perfect equilibrium

The final system is now reduced to three equations, namely, the government's GEE, the government's optimality condition for R_t in (31) and the Euler

condition of capitalists in (35). These three equations in three functional equations, $K_{k,t+1} = h(K_{k,t})$, $W_t = \Phi(K_{k,t})$ and $R_t = \Psi(K_{k,t})$ are respectively:

$$
\begin{aligned}
\frac{dV_{t+1}}{dK_{k,t+1}} &= (1-\gamma)[\frac{\partial u_{k,t+1}}{\partial C_{k,t+1}}\frac{\partial C_{k,t+1}}{\partial K_{k,t+1}} - \frac{\partial u_{k,t+1}}{\partial(1-l_{k,t+1})}\frac{\partial l_{k,t+1}}{\partial K_{k,t+1}} \\
&\quad + \frac{\partial u_{k,t+1}}{\partial \overline{G}^c_{t+1}}\frac{\partial \overline{G}^c_{t+1}}{\partial K_{k,t+1}}] + \gamma[\frac{\partial u_{w,t+1}}{\partial C_{w,t+1}}\frac{\partial C_{w,t+1}}{\partial K_{k,t+1}} - \frac{\partial u_{w,t+1}}{\partial(1-l_{w,t+1})}\frac{\partial l_{w,t+1}}{\partial K_{k,t+1}} + \\
&\quad + \frac{\partial u_{w,t+1}}{\partial \overline{G}^c_{t+1}}\frac{\partial \overline{G}^c_{t+1}}{\partial K_{k,t+1}}] + \beta\frac{dV_{t+2}}{dK_{k,t+2}}H_k(t+1) \qquad (61)
\end{aligned}
$$

$$
\begin{aligned}
(1-\gamma)&\left[\frac{\partial u_{k,t}}{\partial C_{k,t}}\frac{\partial C_{k,t}}{\partial R_t} - \frac{\partial u_{k,t}}{\partial(1-l_{k,t})}\frac{\partial l_{k,t}}{\partial R_t} + \frac{\partial u_{k,t}}{\partial \overline{G}^c_t}\frac{\partial \overline{G}^c_t}{\partial R_t}\right] + \gamma[\frac{\partial u_{w,t}}{\partial C_{w,t}}\frac{\partial C_{w,t}}{\partial R_t} - \\
&-\frac{\partial u_{w,t}}{\partial(1-l_{w,t})}\frac{\partial l_{w,t}}{\partial R_t} + \frac{\partial u_{w,t}}{\partial \overline{G}^c_t}\frac{\partial \overline{G}^c_t}{\partial R_t}] + \beta\frac{dV_{t+1}}{dK_{k,t+1}}H_r(t) = 0 \qquad (62)
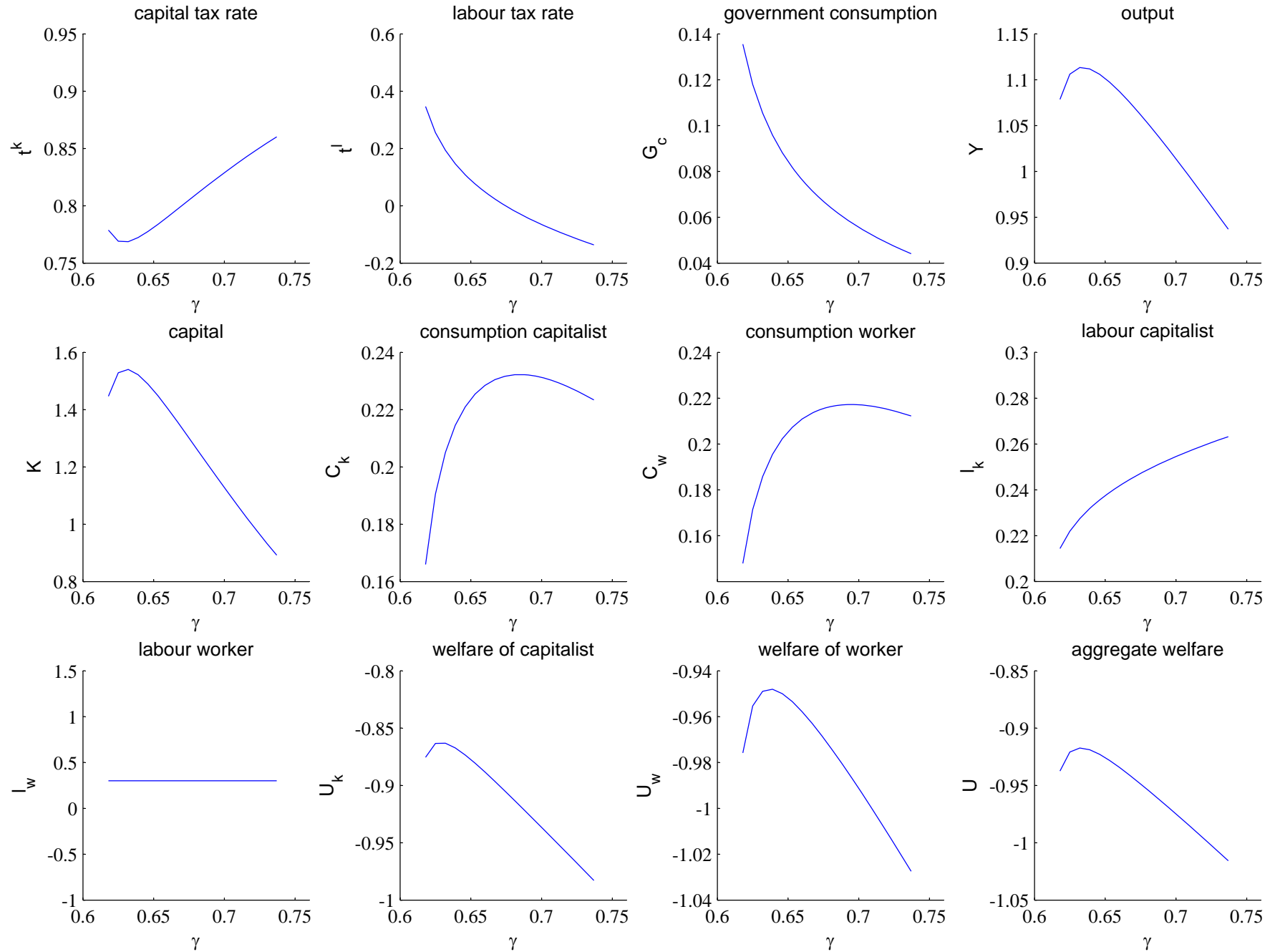\end{aligned}
$$

$$
\frac{1}{C_{k,t}} = \frac{\beta(1+R_{t+1})}{C_{k,t+1}} \qquad (63)
$$

where $C_{k,t}$, $l_{k,t}$, $K_{k,t+1}$, $C_{w,t}$, $l_{w,t}$, $\overline{G}^c_t$ and $Y_{f,t}$ have been specified above and $\frac{dV_{t+1}}{dK_{k,t+1}}$ follows from the optimality condition for W_t. Similarly, $\frac{dV_{t+2}}{dK_{k,t+2}}$ follows from the same condition led once also written in subsection 3.2.

7.5 Solution algorithm

To solve the system of functional equations in (61)-(63) for the steady-state, we follow the perturbation method proposed by Krusell *et al.* (2002) and Klein *et. al.* (2008). In particular, we approximate the unknown functions, $K_{k,t+1} = h(K_{k,t})$, $W_t = \Phi(K_{k,t})$ and $R_t = \Psi(K_{k,t})$ in equilibrium by polynomials of some degree n and then iterate on n until the steady-state values for the endogenous variables do not change. When $n = 0$, the system in (61)-(63) can be solved for the three unknown constant-guess functions. For higher order approximations, this system also contains derivatives of the guessed policy functions and thus has more unknowns than equations. The methodology employed circumvents this problem by augmenting (61)-(63) to include the nth derivatives of (61)-(63) with respect to K, evaluated at the steady-state. All results reported in the paper are based on cubic polynomials, as this was sufficient to guarantee convergence of the endogenous variables at the steady-state.

Figure 1: Partisan preferences

Benthamite preferences: $\gamma = n^w = 0.7$