Supply Side Interventions and Redistribution

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Abstract

In this paper we study the welfare impact of alternative tax schemes on labor and capital. We evaluate the effect of lowering capital income taxes on the distribution of wealth in a model with heterogeneous agents, restricting our attention to policies with constant tax rates.

We calibrate and simulate the economy; we find that lowering capital taxes has two effects: *i)* it increases efficiency in terms of aggregate production, and *ii)* it redistributes wealth in favor of those agents with a low wage/wealth ratio. We find that the redistributive effect dominates, and that agents with a low wage/wealth ratio would experience a large loss in utility if capital income taxes were eliminated.

Keywords: Taxation, Heterogeneity, Redistribution, Simulation

Journal of Economic Literature classification: E61, E62, E63, E37, H23

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1 Introduction

The study of distortionary taxation in neoclassical growth models with rational expectations has received considerable attention in the last ten years. These models integrate the study of public finance and macroeconomic issues in a consistent framework; they generate predictions about the effect of taxes on the dynamics of the economy, the model can be tested with time series data, changes in policy can be analyzed without falling prey to the Lucas critique, and the benefits of a given policy can be analyzed with measures of agents' utilities.

Much of the literature has reached the conclusion that capital taxes should be abolished or, at the very least, severely reduced; the decrease in revenues should be compensated by a higher labor tax. Then aggregate investment and production would grow and, in the long run, consumption would also be larger. The study of taxation in rational expectations models has provided rigorous ground for an old idea in economics: a decrease in capital taxes would increase the size of the pie.

This conclusion agrees with the recommendations of the so-called Supply-side economics and with the economic policy prevalent in the 80's; for example, according to the average effective marginal tax rates reported by McGrattan, Rogerson and Wright (1993) for the US, capital taxes were on average .5 from 1981-87, down from an average of .6 in the period 1947-80, while labor taxes were .27, up from .22, during the same periods.

Unfortunately, most of the literature uses homogeneous agent models, and it ignores redistributive effects.[1] Abolishing capital taxes would also imply a redistribution of wealth against those agents with a lower proportion of capital income over labor income; these agents may or may not be better off depending on whether the aggregate efficiency effect dominates the redistributive effect. This is precisely the issue studied in this paper. The answer to this question is not obvious because, if only distortionary taxes can be implemented by governments, it may be impossible to guarantee that all agents gain from a change in policy, since lump-sum redistribution is not available.[2]

Our model has two types of agents differing in the level of wealth. In order to make our results comparable to the existing literature, everything in the model is as close as possible to the standard neoclassical paradigm: we assume time-separable utilities, exogenous growth, endogenous production, complete markets for loans, competitive markets for all goods, full information, productivity shocks, rational

[1] Notable exceptions are Judd (1985), Krusell and Rios (1993) and McGrattan (1993).

[2] Also, in the framework of optimal taxation, we know that capital taxes should be eliminated in the long run, but the transition must take care of the redistributive issues; the transition in optimal taxation would be ignored if capital taxes are eliminated from period zero.

expectations, etc.. We reproduce the usual result that a reduction in capital taxes enhances economic activity: wages, aggregate investment, aggregate consumption and aggregate output all increase by a significant amount. Nevertheless, we find that abolishing capital taxes also changes the distribution of wealth in a major way; the redistributive effect is so important that the utility of agents with a high wage/wealth ratio decreases dramatically; only consumers with a low wage/wealth are better off. The effects on welfare are very large. In the model, the pie would grow by abolishing capital taxes, but the piece left to half of the population would be considerably smaller.

We choose most parameter values in order to match some basic observations from aggregate time series data, as is usually done in RBC studies. The parameters that determine the relative wealth of individuals are chosen by splitting observations on households in the PSID data set in two halves; the criterion for splitting the sample is such that, within our model, agents in the same group would be affected in a similar way by the change in economic policy that we are considering. The elasticity of leisure is chosen so as to match variability across agents of hours worked. Finally, as a validation of our model, we discuss how well it matches some basic empirical facts. We will find that the model does not agree with the following empirical fact: across time, volatility of aggregate hours worked is higher than the volatility of aggregate consumption, but across individuals of different wealth, variation of consumption is higher than variation of hours worked.

The model is analyzed by simulation techniques, since analytic results are not available. Finding a numerical solution is complicated by three features of the model: *i)* no planner problem supports the equilibrium, *ii)* non-linearities are important since, after the change in policy, the initial condition is far from the steady state, and *iii)* the share of output that each agent consumes is endogenous to the tax system. Difficulties *i)* and *iii)* have usually been solved in the literature by introducing lump-sum taxes back in the model, but we avoid this alternative, since it would mask the redistributive effects of a pure change in distortionary taxes. We solve the model with the Parameterized Expectations Approach (PEA) described in Marcet and Marshall (1994).

The plan of the paper is as follows: the literature is reviewed in section 2. The deterministic model is presented in section 3. Section 4 discusses some analytic results for special cases. Section 5 discusses issues of calibration of the parameters using data from the US economy. Section 6 presents the results derived from the simulations. The conclusion ends the main paper. The appendices discuss the introduction of uncertainty, computational issues as well as the conversion of the model with growth to one in terms of deviations from growth, and details on the calibration of heterogeneity parameters from the PSID data set.

2 Review of the Literature

The progress in the study of taxation in dynamic equilibrium models has been notorious in the last ten years. In his seminal contribution, Chamley (1986) showed that the optimal policy should tax the capital already in place in the first few periods, and eliminate all distortions on investment decisions by suppressing capital taxes in the long run. In other words, the optimum tax satisfies $\tau_t^k \to 0$ as $t \to \infty$). This conclusion is robust to many different environments. Subsequent papers have qualified this conclusion: Chari, Christiano and Kehoe (1993), Zhu (1992) and Aiyagari (1993) in models with uncertainty[3] and Jones, Manuelli and Rossi (1993), Milesi-Ferretti and Roubini (1994) in models with human capital[4].

The optimal policy calls for raising enormous tax rates on capital in the first few periods, and a decrease of tax rates only after the government has very high savings. In the long run, government would finance its expenditures by interest income and, perhaps, other taxes. Unfortunately, actual governments would find it difficult to implement this policy for two reasons: private agents should be able to accumulate huge amounts of debt in the first few periods, so that consumers' liquidity constraints are likely to be binding; also, governments might find it difficult to make the optimal policy credible due to its extreme time-inconsistency. This motivated some authors to study policies with constant tax rates; for example, Lucas (1990) studied the benefits of establishing the long-run optimum from period zero (i.e., setting $\tau_t^k = 0$ for $t = 0, 1, ...$); he found that the gains in welfare would be significant. Cooley and Hansen (1992) (=CH) show that the qualitative conclusions of Lucas are robust even if other types of taxes are introduced and if the transition to the new steady is properly incorporated. Chari, Christiano and Kehoe (1993) (=CCK) in their 'Constant Policy Experiments' show that the result is robust to introducing uncertainty, and variations in certain parameter values; they find that the welfare gain would be small and, for some parameter values, it may be slightly negative; they also argue that the behavior of taxes along the transition path is what drives most of the gain in welfare of the optimal policy.

Most of the above work assumes homogeneous consumers. Several papers on optimal taxation have introduced heterogeneity, including Chamley (1986), Judd

[3]Strictly speaking, these papers show that, under uncertainty, the optimal tax on capital may not be zero at all periods in the long run. Nevertheless, the optimal tax is still small in absolute value and, in fact, taxes are negative in some periods.

[4]These papers argue that in endogenous growth models with human capital, labor should not be taxed in the long run either. Nevertheless, optimal taxation with human capital suffers from time inconsistency in the same way that taxation of physical capital does, (see next paragraph).

(1987) and Zhu (1992), often to find that results are not affected by heterogeneity. In particular, they show that the optimal tax on capital is zero (or near zero) in the long run even with heterogeneous consumers. The point of our paper can be interpreted as saying that, with heterogeneous agents, the transitional path of the optimal policy is crucial in reaching allocations where both agents improve; this is because, in the absence of agent-specific taxes, the budget constraint of the agents acts as a binding constraint that slows down reaching the long-run optimum of $\tau^k = 0$. We will show that, if the optimum is implemented from period zero, since there is only one implied weight (or, more precisely, only one share of output for each agent) that is consistent with a given tax rate, half of the population may suffer a large welfare loss.

A few papers have introduced heterogeneity in models of non-optimal taxation. Judd (1985) studies the effect of *small* changes in the capital tax rate under some simplifying assumptions, for particular parameter values and in a continuous time model; he finds cases where a small decrease in capital taxes would benefit all agents, while in other cases a small decrease would hurt the less wealthy agents; our purpose is to study the effect of a large change in taxes in a model where parameters are calibrated from the data, so that Judd's results are helpful to build intuition, but they are inconclusive given our purpose. Also, Krusell and Ríos (1993) show that, in a model where agents vote in every period, a reduction in taxes would never be approved democratically; they interpret their result as implying that a reduction in taxes should be voted at time 0 and then written in the constitution; our result in section 5 argues that abolishing capital taxes may not be voted, even if it were written in the constitution.[5]

3 The Model

In this section we describe a simple neoclassical growth model with heterogeneous agents, endogenous production, labor choice, uncertainty, exogenous growth[6], and government spending that is financed exclusively with distortionary taxes[7]. We think of each agent as representing wealth groups of equal size; in order to match observations, the two types of agents will be allowed to differ both in terms of their

[5]There are other differences with Krusell and Rios' model, for example, they study the trade-off between income taxes and lump-sum redistribution, not between capital and labor taxes. Also, they introduce incomplete markets.

[6]Introducing growth influences the effect of depreciation allowances, since total investment would be equal to gross investment when there is no growth. We introduce growth as in CCK.

[7]In this section we present a deterministic model purely for reasons of simplicity. The model with uncertainty is described in the Appendix 5. Uncertainty is introduced in a straightforward manner, but having contingent claims makes the notation more cumbersome.

human, and non-human wealth.

3.1 Consumer, Firm, and Government Behavior

Two infinitely-lived consumers indexed by $j = 1, 2$ derive utility from consumption and leisure, are endowed with one unit of time every period and a certain amount of capital stock in the initial period. They receive income from working and from renting their capital. Agents can borrow and lend. Their labor and capital incomes are taxed at constant rates τ^l and τ^k.

Consumers of type j solve the following maximization problem:

$$\max_{\{x_{jt}\}} \quad \sum_{t=0}^{\infty} \delta^t \left(\, u(c_{j,t}) + v(l_{j,t}, \mu^t) \, \right)$$

subject to

$$\begin{aligned} c_{j,t} + k_{j,t} - k_{j,t-1} + q_t \; b_{j,t} \; = & \\ \phi_j \; \mu^t \; l_{j,t} \; w_t(1-\tau^l) \quad + & \quad k_{j,t-1}(r_t - d)(1-\tau^k) + b_{j,t-1} \end{aligned} \tag{1}$$

$$\begin{aligned} k_{j,t} \quad &= \quad (1-d)k_{j,t-1} + i_{j,t} \\ k_{j,-1} \text{and } b_{j,-1} & \quad\quad \text{given} \end{aligned}$$

where the consumer chooses over $\{x_{j,t}\} \equiv \{c_{j,t}, l_{j,t}, b_{j,t}, i_{j,t}, k_{j,t}\}_{t=0}^{\infty}$. We assume separability in time and in the consumption-leisure decision. Since we concentrate our study on issues of distribution, agents only differ in initial wealth and the efficiency of labor.

Here, $c_{j,t}$, $i_{j,t}$, $k_{j,t}$, $b_{j,t}$, $l_{j,t}$ denote consumption, investment, capital stock, bond holdings and hours worked of agent j at time t; q_t, w_t, r_t denote prices for bonds, efficiency units of work, and capital rental, normalized in terms of the consumption good of the period. Variables without a subindex j represent economy-wide variables (i.e., prices or aggregate allocations). Parameters δ and d are in the interval [0,1] and they represent the discount factor of future utility and the depreciation rate of capital. Taxes on labor and capital are given by τ^l and τ^k; taxes on capital are after depreciation allowances. Functions u and v are differentiable and satisfy the appropriate Inada conditions; furthermore, $u(\cdot)$ and $v(\cdot, \mu)$ are strictly concave; $u(\cdot)$ and $v(l, \cdot)$ are strictly increasing and $v(\cdot, \mu)$ is strictly decreasing.[8].

Growth will be introduced through exogenous accumulation of human capital

[8] Strictly speaking, some additional constraint has to be introduced in order to rule out Ponzi schemes. This can be accomplished by imposing an upper limit on the amount of bonds that can be sold, such that the limit is never binding in equilibrium. The same will be true for the budget constraint of the government.

in the production function at a rate $\mu \geq 1$. This is the simplest alternative that avoids degenerate solutions for hours worked in the long-run. In section 4 we are more precise about a functional form for u and v that maintains interior solutions along the growth path; most of the simulations we report are for $u(c) = \log(c)$, in which case μ^t drops out from the utility function altogether. The efficiency of each agent's labor is indexed by parameters $\phi_j > 0$; these are normalized so that $\phi_1 + \phi_2 = 1$. Notice that we assume that both agents are allowed to hold capital. This completes the description of the consumer side of the economy.

There is one representative firm that maximizes period-by-period profits; it manages a production technology, rents capital at a price r_t and hires efficiency units of labor at a wage w_t to solve

$$\max_{(y_t, e_t, k_{t-1})} y_t - w_t e_t - r_t k_{t-1} \tag{2}$$

$$\text{s.t.} \qquad y_t = F(k_{t-1},\ e_t) \tag{3}$$

$$.5\ (\phi_1\ l_{1,t} +\ \phi_2\ l_{2,t})\mu^t = e_t \tag{4}$$

where y_t represents output, k_t the demand of capital, and e_t the demand for efficiency units of labor. F is the production function gross of depreciation, strictly concave and homogeneous of degree one with respect to $(k_{t-1},\ e_t)$. Equation (4) represents efficiency units in terms of hours worked by each agent; notice that the number of each type of agents is normalized to 1/2; this, and the assumption that the ϕ's add up to one guarantees that setting $\phi_1 = \phi_2$, $b_{1,-1} = b_{2,-1}$ and $k_{1,-1} = k_{2,-1}$ we are back to a version of the homogeneous agent model used by Lucas, Cooley and Hansen, and CCK.

Government spending grows at a constant rate starting at a level g, so the sequence of government consumption is given by $g_t \equiv \mu^t g$ [9]. Government can accumulate debt by selling contingent claims, and its period-t budget constraint is given by

$$g_t = (r_t - d)\ k_{t-1}\tau^k + w_t\ e_t\tau^l - q_t\ b_{g,t}\ + b_{g,t-1} \tag{5}$$

Agents are assumed to observe all variables realized at time t.

[9] Since we maintain g constant across policy experiments, the equilibrium computed and the welfare gains discussed in section 6 are consistent with a model where government spending enters the utility function or the production function; to keep notation simple, we write the paper as if government spending had no productive use.

3.2 Definition and Characterization of Equilibrium

We assume competitive equilibrium. An equilibrium is defined as a sequence for prices and allocations, and a government policy for (g, τ^k, τ^l) such that: when consumers maximize utility and firms maximize profits taking prices and government policy as given, they choose allocations such that all markets clear, and the budget constraint of the government is satisfied. Market clearing in consumption good, capital, and bonds is given by

$$.5\ (c_{1,t} + c_{2,t}) + g_t + k_t - (1-d)k_{t-1} = y_t \tag{6}$$

$$.5\ (k_{1,t} + k_{2,t}) = k_t \tag{7}$$

$$.5\ (\ b_{1,t} + b_{2,t}) + b_{g,t} = 0 \tag{8}$$

for all t, and clearing in the labor market is given by (4).

With interior solutions, the first order conditions for debt, capital, and labor choice in the consumer's problem are as follows:

$$q_t\ u'(c_{j,t}) = \delta\ u'(c_{j,t+1}) \tag{9}$$

$$u'(c_{j,t}) = \delta\ u'(c_{j,t+1})\ \left((r_{t+1} - d)(1-\tau^k) + 1\right) \tag{10}$$

$$u'(c_{j,t})\ w_t\ (1-\tau^l)\ \mu^t \phi_j\ + v'(l_{j,t}, \mu^t) = 0 \tag{11}$$

for all t and $j = 1, 2$. Here, $v' \equiv \frac{\partial v}{\partial l}$. As usual, equilibrium factor prices equal marginal product to set $r_t = F_1(k_{t-1},\ e_t)$ and $w_t = F_2(k_{t-1},\ e_t)$.

The Appendix 5 lays out the model with uncertainty and it also shows that equilibrium is uniquely determined by equations (6), (10) for $j = 1$, equation (11) for $j = 1, 2$, the present value budget constraints (PVBC):

$$\sum_{t=0}^{\infty} \frac{u'(c_{1,t})}{u'(c_{1,0})} \delta^t \Big(\ c_{1,t} + dk_{1,-1}(1-\tau^k) -$$

$$r_t\ k_{1,-1}(1-\tau^k) - w_t\ \mu^t\ \phi_1\ l_{1,t}(1-\tau^l)\Big) = b_{1,-1} \tag{12}$$

$$\sum_{t=0}^{\infty} \frac{u'(c_{1,t})}{u'(c_{1,0})}\ \delta^t\ \left(g_t - (r_t - d)\ k_{t-1}\tau^k - w_t\ e_t \tau^l\right) = b_{g,-1} \tag{13}$$

and a constant λ such that

$$\frac{u'(c_{1,t})}{u'(c_{2,t})} = \lambda \qquad \text{for all } t \tag{14}$$

This reduces the number of equations that need to be checked in equilibrium.[10]

Equation (14) expresses the familiar condition that, with complete markets and common discount factors, the share of output that each agent obtains is constant. The constant λ determines this share; for example, if u has a constant relative risk aversion parameter equal to γ_c, agent 1 obtains a fraction $\zeta \equiv 2/(1+\lambda^{-1/\gamma_c})$ of total consumption in all periods. Except for some special cases where aggregation obtains[11], λ depends on the tax rates and on the initial distribution of wealth; in turn, aggregate variables depend on this constant. The fact that constants λ and g are endogenous to the tax system. adds to the difficulties of finding a numerical solution (point *iii)* in the introduction).

4 Some Stylized facts and Analytic Results

For the rest of the paper we assume the following functional form of the utility function:

$$u(c) = \frac{c^{\gamma_c+1}}{\gamma_c+1} \qquad \text{and} \qquad v(l,\mu^t) = B\ \frac{(1-l)^{\gamma_l+1}}{\gamma_l+1}\mu^{t(\gamma_c+1)}$$

for $\gamma_c, \gamma_l < 0$ and $B > 0$, and we assume that hours worked satisfy $0 \leq l_{j,t} \leq 1$. Introducing human capital in this form in the utility function insures that the solution for leisure is not degenerate in steady state. For most of our simulations we take $\gamma_c = -1$, a case in which the term $\mu^{t(\gamma_c+1)}$ disappears.

First of all, we mention two simple empirical observations:

a) variability of aggregate consumption *across time* is *lower* than variability of aggregate hours worked

b) variability of consumption *across individuals of different wealth* is *higher* than variability of hours worked.

These observations are supported by casual empiricism; they have also been documented formally by many authors. For example, Hansen (1985) documents fact a).

[10] In particular, it means that equations (10) for $j = 2$, equation (9), period-t budget constraints (1) and (5) can be ignored when solving for consumption, labor, capital and government spending.

[11] See subsections 4.2, 4.3

Fact b) is documented by our Table 1. This table reports several statistics on individual variables from a representative sample of households in the PSID data set. Households are split in two income-groups according to four different criteria; the precise method for splitting the sample will be discussed in detail in subsection 5.2. It can be seen that, under all four criteria, the ratio of hours worked of the two groups is much closer to one than the ratio of consumption; in particular, using the 'wage/wealth ratio' and 'weighted average by age' criteria, the ratio of consumption is 1.76, while the ratio of hours worked is 1.05.[12].

Fact a) has to do with how the hours worked in the economy react to a temporal change in production, while fact b) has to do with the wealth-elasticity of hours worked. The policy experiment that we are considering will cause both a change over time of aggregate hours worked and a redistribution of wealth so that, ideally, we would like to have a model and parameter values that agree with both of the above observations.

We now study the equilibrium of the model for particular values of the parameters. The derivations in this section are quite simple, and they are spelled out here for future reference. They will be useful when we select parameter values in the next section.

For the rest of this section we make the simplifying assumption that $\mu = 1$ and $b_{g,-1} = b_{j,-1} = 0$. Also, subsections 4.1 and 4.2 below assume $\phi_1 = \phi_2$.

4.1 Linear utility of leisure

Hansen (1985) and Rogerson (1986) showed that fact a) above can be explained if leisure enters lineraly in the utility function, to set $\gamma_l = 0$; they also showed how this utility arises in a model with indivisible labor and lotteries.

Nevertheless, this parameter value implies in our model that,

$$c_{1,t} = c_{2,t} \qquad \text{for all } t.$$

This can be obtained from (11) and simple algebra. This is incompatible with fact b); in this case, the model predicts that agents with the same efficiency of labor but different levels of wealth consume the same amount, and higher wealth is only used to enjoy a higher level of leisure.

[12]We are, by no means, the first to report this particular fact. For example, Kydland (1984) reports a similar observation. The advantage of Table 1 is that it confirms the usual observation when the sample is split according to the criteria discussed in subsection 5.2.

4.2 Gorman Aggregation

Consider now the case that $\gamma_c = \gamma_l$. Here, the economy behaves as if there were a representative consumer, and aggregate variables are unaffected by distribution of wealth.

First of all, observe that equations (14) and (11) imply

$$c_{1,t} = \zeta \; c_t \qquad \text{and} \qquad 1 - l_{1,t} = \zeta(1 - \; l_t) \tag{15}$$

where $\zeta = 2/(1+\lambda^{-1/\gamma_c})$; so that individual consumption and labor are fixed proportions of the aggregates. It is easy to check that all equilibrium conditions described in the previous section hold if individual quantities are replaced by aggregate quantities. In order to solve this model, one can first solve for the aggregate quantities and then find the individual quantities with (15).

All that is left to compute is the constant ζ. From aggregate allocations we substitute (15) into equation (12) and obtain

$$\zeta \; = \frac{k_{1,-1}\left[\sum_t \delta^t \; c_t^{\gamma_c}\left(r_t - d\right)(1-\tau^k)\right] + \left[\sum_t \delta^t \; c_t^{\gamma_c} \, w_t(1-\tau^l)\right]}{\left[\sum_t \delta^t c_t^{\gamma_c}\left(c_t + w_t(1-l_t)(1-\tau^l)\right)\right]} \tag{16}$$

This gives us an expression for ζ (and, therefore, λ) that depends only on aggregate variables calculated beforehand, and the initial distribution of wealth.

This example brings about two points: first, equation (16) is an explicit expression for the weight λ, and it shows that this weight is endogenous to the tax system. Second, in this case the variability of consumption and hours worked are equal, as can be seen from equation (15). Therefore, in this case both facts a) and b) are violated.

4.3 Proportional wealth

Consider the case where the efficiency of labor and the initial wealth of agent 1 are higher than agent 2's in the same proportion, so that

$$\frac{\phi_1}{k_{1,-1}} = \frac{\phi_2}{k_{2,-1}} \tag{17}$$

Also, assume that $\gamma_c = -1$.

Given any feasible fiscal policy (τ^l, τ^k, g), equilibrium allocations satisfy

$$\frac{c_{1,t}}{c_{2,t}} = \frac{\phi_1}{\phi_2} \quad , \quad l_{1,t} = l_{2,t} \quad \text{for all } t \tag{18}$$

This can be easily derived from the first order conditions for optimality. Therefore, in this case $\lambda = \phi_1/\phi_2$ independently of tax policies, so that the share of consumption of each agent is invariant to changes in taxes. Also, as in the previous case, it is easy to show that we have perfect aggregation.

Since λ is independent of tax rates, any gain or loss in aggregate consumption is shared between the two agents. If aggregate consumption changes due to a change in tax rates, both agents gain or loose in the same amount.

If, in addition to the assumptions in this subsection we add the assumption that γ_l is close to zero, we could explain both facts described above. Furthermore, this example shows that it is possible to find parameter values for which the distribution of consumption is not affected by tax policies. Nevertheless, assuming proportional wealth is not a satisfactory approximation to the heterogeneity observed in the actual economy. This can be seen in Figure 1, which plots wages against wealth for different households in a representative sample (see discussion in subsection 5.2); the dispersion of wage/wealth ratios is clearly very high, while equation (17) implies that most points in that figure would lie close to a ray going through the origin. This analysis shows that it is very important for our purposes to calibrate the parameters from individual income appropriately. Also, it shows that the wage/wealth ratio is what determines if an agent gains or looses from a policy change, so that this ratio is the appropriate criterion for splitting the sample of households that are likely to be affected by the policy change in a similar way into two groups .

5 Parameter Choice and Solution Algorithm.

We have presented the deterministic model in section 3 for simplicity. The rest of the paper proceeds by introducing uncertainty in the model through a productivity shock. It turns out that the gains or losses in utility are similar with or without uncertainty. We choose to discuss in full detail the results with uncertainty since this is the least restrictive version and since it will then be possible to discuss stylized fact a). The full details of the stochastic model are given in the appendix 5.

We assume the usual Cobb-Douglass production function normalized to account for balanced growth: $F(k_{t-1},\ e_t,\ \theta_t) = \mu^\alpha\ k_{t-1}^\alpha\ e_t^{1-\alpha}\ \theta_t$, where θ_t is a Markov stochastic shock to productivity.

We now describe the choice of parameter values for the benchmark case.

5.1 Utility and Technology parameters

With the exception of γ_l, we choose values in the benchmark case for utility and technology that are standard in the real business cycle literature. This makes the results comparable with the rest of the literature; it also insures that our model matches some first and second moments of aggregate time series. Notice that, since we introduce depreciation allowances, it is important to model growth explicitely in order to distinguish between gross and net investment.

The utility function depends on parameters, γ_c, γ_l and B. As in Cooley and Hansen, we use log-utility of consumption, so that $\gamma_c = -1$, and we choose B in order to have the representative agent working 1/3 of his time endowment in the deterministic steady state. The parameters of the production function are chosen to match the labor share of income and aggregate fluctuations of output. Depreciation rate, discount rate of utility, and growth rate are set to the usual values for quarterly data. Initial aggregate capital is equal to the mean of capital in the benchmark economy.

The choice of γ_l is particularly important for matching the stylized facts described at the beginning of section 4. Now, the cases studied in sections 4.1 and 4.2 suggest that in order to match fact b) we need to choose $|\gamma_l| > |\gamma_c|$; furthermore, it is easy to check that, for our choice of B,

$$l_{j,t} \to 1/3 \qquad \text{as} \qquad \gamma_l \to -\infty,$$

for both $j = 1, 2$ and for all t. For our purposes, it seems particularly important to capture how hours worked by agents will react due to a change in capital and labor taxes. For this reason, we choose $\gamma_l(= -10)$, which makes our model close to satisfying fact b).

5.2 Heterogeneity parameters

In our model, agents differ only in the efficiency level of their work ϕ_j and their initial wealth $k_{j,-1}$. It is important to choose these parameters appropriately since in some cases (for example, in subsection 4.3) changing the tax system has no effects on distribution.

Figure 1 represents a scatterplot of the households' wage and wealth in the Panel Study of Income Dynamics. Our next task is to split the sample in two groups of equal size and calibrate the heterogeneity parameters of each kind of agent with the observations on each group.

First of all, we discuss how the households have been grouped to produce the two representative agents of our model.

In the literature on distribution, households have been often classified as 'rich' or 'poor' according to measures of total income or wealth. However, this is not an appropriate criterion given the experiment we consider: households with relatively low (high) salaries compared to their total wealth, i.e., agents with a low (high) salary/wealth ratio $\phi_j/k_{j,-1}$, are likely to gain (loose) from a drop in capital taxation. Both the households in the upper-left corner and those in the lower-right corner of Figure 1 are 'rich', but those in the upper-left corner are likely to be hurt if capital taxes go down. Our discussion in section 4.3 shows that agents with the same salary/wealth ratio are equally affected by a change in capital taxes.

This is why we split our sample in terms of the salary/wealth ratio identifying the parameters for agents of type 1 from observations on households with a salary-wealth ratio lower than the median. Graphically, we seek a ray such that half of the points in Figure 1 are on each side of the ray; the households below the ray represented in that figure correspond to type 1 agents in the model. By contrast, the more traditional criterion of splitting the sample by total income would correspond to splitting the sample with a negatively sloped line, and the 'total wealth criterion' would use a vertical line.

Another complication stems from the fact that our measures are affected by a pure life cycle effect, something that our model does not take into account. For example, older people are usually wealthier than younger people and they are likely to be retired. Almost all of them would belong to group 1, amounting to a high percentage of the sample and leaving little room to representatives of other age groups. To remove that effect from our measures, we first split the sample into six age groups, and divide each age group according to their salary/wealth ratio. The wage of type 1 agents is calculated with a weighted average of the observed wages of households in the low wage/wealth ratio across age groups; the weights given to each age group correspond to percentages of US. population as reported by the Census.[13]. In order to match consumption ratios we proceed similarly.

To summarize, the benchmark heterogeneity parameters are obtained by splitting the sample in two groups with the salary/wealth criterion and eliminating the life-cycle effects. In order to check the robustness of our results, we have also calculated the heterogeneity parameters splitting the sample without eliminating life-cycle effects and with a pure wealth criterion (i.e., splitting the sample by means of a vertical line). The statistics obtained from the four possible criteria are reported in Table 1.[14].

[13]The six age groups are as follows: Less than 25 years old (14.4% of U.S. population), from 25 to 34 (with 23.32% of the population), from 35 to 44 (20.30%), 45 to 54 (13.62%), 55 to 64 (11.43%) and older than 64 (with a 16.89% of total U.S. population).

[14]The consumption ratio of 1.76 can only be sustained if wealth of agents of type 1 is higher than total capital. This happens because, in the real world, assets such as land play a very important role in the portfolios of individuals. Modelling land ownership and land rental appropriately may be important for the issues we discuss, but its introduction goes beyond the scope of this paper. We simply assume that agents of type 1 hold enough bonds to maintain the consumption ratio observed in the data.

Initial wealth is calibrated so as to obtain an implied consumption ratio $c_{1,t}/c_{2,t}$ matching the one observed in the data. The PSID does not provide a direct measure of total consumption, but it provides detailed information on asset holdings of different types by the households. We calibrate the consumption ratio by finding the ratio of total labor income plus income that can be obtained from asset holdings. We consider net asset returns, after corporate taxes, depreciation, etc. have been paid, so that this is the capital income that can be used to sustain higher consumption for all subsequent periods in steady state. The net real return assigned to each kind of asset is obtained from a variety of sources; multiplying asset holdings by the corresponding net real return we obtain the net total return to each agent's portfolio. For a more detailed description see Appendix 4.

5.3 Government Parameters.

Finally, we discuss the benchmark choice for the triplet (τ^l, τ^k, g).

Since we are particularly interested in the effects of substituting capital taxes by labor taxes, the only kind of government spending that we will consider is the one that comes from these tax revenues. Therefore, total government spending in our model will be lower than the one observed in the economy.

As in most predecessors of this paper, we use the measures of average marginal tax rates calculated with the procedure of Joines (1981). We use McGrattan, Rogerson and Wright (1993) estimates of $\tau^k = .57$ and $\tau^l = .23$ for the period 1947-87. Government spending is selected to balance the budget with these taxes.

There is considerable disagreement on the relevant level of labor and income taxes, specially on the level of the capital tax; for the latter, Feldstein, Dicks-Mireaux and Poterba (1983) obtain estimates that range between .55 and .85 for the period 1953-1979. Papers also vary on the introduction of depreciation allowances and growth. [15] Hence, our benchmark value is around the middle range of these estimates. We will discuss in detail the sensitivity of our results to the value of τ^k, as we are going to experiment with different levels of capital taxes.

The considerations in this section lead us to choose the list of parameters in Table 2.

[15] For example, CH use a lower tax rate, setting $\tau^k = .5$, (this number is based on Joines (1981) with the data ending in 1979), and they do not substract growth from the depreciation allowances; CCK use $\tau^k = .27$; Lucas (1990) considers capital and labor taxes of .4; Greenwood, Rogerson and Wright (1995) set $\tau^k = .70$.

5.4 A Solution Algorithm Based on PEA

Given that it is impossible to find analytic solutions under the benchmark parameters, we resort to numerical simulation. The solution algorithm we use is based on the Parameterized Expectations Approach described in Marcet and Marshall (1994). The problem at hand is: for fixed functional forms and parameter values for preferences and technology, and given two government-policy parameters (for example, τ^k and τ^l), find the equilibrium allocations and a feasible government policy (i.e. government spending g)

The general procedure is, given τ^k and τ^l

- *Step a).* Fix λ and g to some arbitrary levels.
- *Step b).* Solve for a stochastic process $\left\{\overline{c}_{1,t}, \overline{c}_{2,t}, \overline{l}_{1,t}, \overline{l}_{2,t}, \overline{k}_t\right\}$ that satisfies equations (6), (14), (28) for $j = 1$,and (11) for these values of λ and g.
- *Step c).* Check if expected present value constraints (29) and (30) are satisfied for the stochastic processes found in Step b). If not, iterate on the above steps until values for λ and g are found such that EPVBC's are satisfied.

Since, for fixed λ, g, equations (6), (14), (28) for $j = 1$,and (11) are a special case of the stochastic difference equation system described in Marcet and Marshall (1994), Step b) is performed with PEA.

The evaluation of EPVBC introduces another computational difficulty. For this purpose and for finding individual savings we follow Hollyfield, Ketterer and Marcet (1988). More details are given in Appendix 1.

Finally, since good approximations to non-linear laws of motion can only be found on a finite interval, we need to translate the model with growth into deviations from trend, and solve for the law of motion for these deviations. This is done in the usual (but tedious) way in Appendix 2 [16].

6 Simulations Under Different Tax Systems

6.1 Effects of supressing capital taxes

The main goal of this paper is to study the welfare effects of eliminating capital taxes. We compare the equilibrium of the model under the benchmark parameters (A) with the equilibrium when $\tau^k = 0$ and labor taxes are increased to maintain

[16] The claim in Judd (1992) that PEA can not be used for policy analysis when initial conditions are away from the steady state distribution is shown to be incorrect in this paper. Similar applications of PEA to solve away from the steady state have preceded the publication of Judd's statement; see, for example, Marshall (1988, 1992), and Marcet and Marimon (1992).

the level of government expenditure (B). The behavior of the model under both policies is described by Figures 2 and 3, and Tables 3 and 4.

Figures 2 and 3, contain plots of one typical realization for the series of the model under both policies. For each one of these variables we present two figures: the graphs labelled 'initial periods' cover periods 0 to 100 of the simulation, while the graphs labelled 'steady state' cover periods 1000 to 1100, long after the variable has attained the support of the steady state distribution. Tables 3 and 4 summarize some first and second moments of the solution at the steady state distribution.

The effect on aggregate variables of abolishing capital taxes is clearly to enhance economic activity in the long run. If capital income taxes are suppressed, investment is higher, and consumption and leisure are lower in the first few periods. But we see from Table 3 that the steady state mean of aggregate GNP increases by about 25%, total consumption increases by 16%, investment almost doubles, wages increase by 28%, and total labor income of type 2 agents also by 28%. All of these indicators would normally be taken as evidence that the economy as a whole benefits from suppressing capital taxes.[17] Not surprisingly, the response of aggregate variables is similar to the effect described in previous studies of models with homogeneous agents.

Nevertheless, the effect on individual decisions is harder to predict from those studies, since the redistributive effect of abolishing capital taxes may offset the higher aggregate production. It is clear that hours worked of agent 1 are likely to decrease, since both the substitution effect (lower net wages) and the wealth effect (higher wealth from lower capital taxes) work in the same direction, but the effect on most of the other individual variables is uncertain before seeing the calculations. From Figures 2 and 3 is is clear that consumption of agent 1 is much higher in the new steady state, while consumption of agent 2 is lower in almost all periods. The effect on leisure is similar. These figures anticipate the fact that agent 2 will loose welfare if capital taxes are abolished.

Table 4 describes aspects of the effect on individual consumers of the tax change. The labor tax rate is 0.37 (up from .23) when capital taxes are abolished; this increase is sufficient to offset the higher wage for agent 2. This causes the change in the equilibrium weight λ and, consequently, a large drop in the ratio $c_{2,t}/c_{1,t}$, which goes from .57 to .47.

Welfare gains of changing the tax system are evaluated as in previous papers (say, as in Lucas, CH or CCK) by finding the percentage change in consumption that each individual should experience to be as well off as under the benchmark policy, leaving leisure unchanged. More precisely, letting $\bar{c}_{j,t}, \bar{l}_{j,t}$ be the equilibrium

[17]Subsection 6.2 provides a more concrete measure of aggregate welfare gains within the model.

under the benchmark policy, and $\hat{c}_{j,t}, \hat{l}_{j,t}$ be the equilibrium under the alternative tax policy, the welfare gain is given by π_j that satisfies

$$E_0 \sum_t \delta^t \left(\; u((1+\pi_j/100)\, \bar{c}_{j,t}) + v(\bar{l}_{j,t}, \mu^t) \; \right) = E_0 \sum_t \delta^t \left(\; u(\hat{c}_{j,t}) + v(\; \hat{l}_{j,t}, \mu^t) \; \right).$$

Table 5 summarizes the individual welfare and distributional effects of reducing capital taxes to several alternatives between the benchmark case and zero.

These welfare comparisons confirm that a policy change that eliminates capital income taxation at the expense of labor income taxation is not beneficial for *all* agents in the economy. If capital taxes were suppressed, the distributional issues dominate the gain in aggregate efficiency, and the agents with a high wage/wealth ratio will experience a utility loss. The loss in welfare is very high, specially if compared with that reported in recent papers studying the effects of changes in fiscal or monetary policy.

6.2 A Pareto improving policy.

We do not conclude from these results on welfare that a policy of high capital taxes, as in the benchmark case, is adequate. Indeed, consider the Laffer curve in Figure 4, relating levels of spending that could be financed with different values of capital taxes (keeping labor taxes at the benchmark level). It can be seen that the current level of capital taxes of $\tau^k = .57$ is close to the top of the Laffer curve, an indication that there may be potential gains from lowering them. But our results point to the fact that, without some explicit redistribution, half of the population would be against abolishing capital taxes. Interestingly, Table 5 shows that a moderate reduction in capital taxes to $\tau^k = .45$ would achieve a moderate gain in utility for both agents[18].

An improvement in the welfare of both agents could be achieved with a policy that combined the elimination of capital income taxes with a redistribution of wealth. This policy calls for an expropriation of agents of type 1's wealth in the first period; this wealth should then be given to agents of type 2. This total wealth redistribution should be done in such a way that the equilibrium share of output of the new policy does not change λ, to insure that both agents gained if this policy were implement. We have calculated that, for the benchmark case of Table 2, the Pareto-improving policy achieves a welfare gain for both types of agents of about

[18]It must be pointed out, though, that this feature is highly sensitive to small changes in the parameter values. More importantly, it is highly sensitive to the assumption of only two agents in the economy; the uniform improvement in welfare would be unlikely to arise if a wide variety of agents with different wage/wealth ratios were introduced. This is why we do not emphasize this feature of our solution.

5.9%. The size of the expropiation is about a 22% of the capital initially held by type 1 agents. Obviously, the same effect could be achieved by raising τ^k in the first period, since the tax on capital in the first period acts as a lump sum transfer. We find that a tax rate of 7.2 (i.e., 720 %) in the first period would be necessary to generate the same redistributive effect.[19] This example shows that the high levels of the *optimal* capital taxes in the first few periods, in models with heterogeneous agents, serve the purpose of redistribution of wealth, in addition to the usual Chamley-effect of minimizing the distortions introduced by capital taxation.

6.3 Sensitivity and Empirical performance: An unresolved puzzle.

In order to study the reliability of our results, we end by discussing the sensitivity to changes in parameter values and empirical performance.

First of all, Table 6 summarizes the individual gains in utility if capital taxes were set to zero when the utility parameters γ_c, γ_l and B are different from those in the benchmark case. It is clear that the large gains (or losses) in individual welfare are fairly robust to changes in the parameter values; if anything, they are understated by the benchmark parameters, since for most other parameter values that we consider the gains (or losses) are even larger.

A crucial parameter forour results came from the criterion we used for splitting our sample of households into two groups of wealth. The benchmark case used the wage/wealth ratio and eliminated life-cycle effects. We have also calculated the welfare gains using different combinations of splitting criteria or life-cycle elimination. As can be seen from the second column of Table 5, the result of large changes in utility are again reinforced if we use other partition criteria.

Finally, we study the sensitivity to the tax levels. There is large discussion in the literature about what is the relevant level of average marginal tax rates. The rate of $\tau_k = .57$ reported in MacGratten, Rogerson and Wright is not as high as it may appear, since it is applied to income after depretiation allowances and since this is the sum of taxes paid by consumers and firms. Estimates in the literature range from .27 (CCK) to .85, and therefore our benchmark value stands in the middle; also, some authors do not consider depreciation allowances.

Not surprisingly, if the benchmark parameter for capital tax is lower, the individual welfare gains (or losses) are smaller. But it is also true that for lower benchmark values of capital taxes, the gains in aggregate efficiency are also lower. Table 7 summarizes individual and aggregate gains in efficiency when the bench-

[19]Notice that with more than two agents this redistribution can not be achieved with a linear tax schedule.

mark capital taxes are set at different levels. We define 'aggregate gains' as those that could be achieved with the redistributive policy discussed in the previous subsection. It is clear that, as we vary the capital tax rates, the loss in welfare for agents of type 2 is positively related to the gain in aggregate efficiency, so that those initial levels of taxes that do not cause a big loss in utility of type 2 agents are also parameter values for which a reduction in capital taxes is not of much interest. For example, if $\tau^k = .2$, type 2 agents loose only 2% in utility, but the aggregate gain is nearly insignificant.

We end this section by discussing the empirical performance of the model in terms of matching some first and second moments observed in the data. The moments of aggregate variables in the model are summarized in Tables 3 and 8.

We have already pointed out that variability of consumption is lower than variability of hours worked across time, but the opposite is true across agents of different wealth. Unfortunately, this is a puzzle that can not be resolved within the simple framework of our model; either we set $\gamma_l = 0$, (as in Hansen (1985)), to match the time series behaviour and fail on the cross section fact, or we choose a high $|\gamma_l|$ (as in this paper) in order to match the cross section behaviour; then, Table 3 shows that the volatility of hours worked is very low in our model, so that we fail on the time series dimension. It may be important to study the effects of capital taxation in a model that reconciled these observations, since eliminating capital taxes affects the evolution of hours worked over time as well as across individuals. We do not resolve this issue here becase we do not know of a model available in the literature that can resolve this puzzle at this point, and because we wanted to keep our model similar to those used in the recent literature of taxation in dynamic equilibrium models. Several modifications of the model may help in resolving this puzzle; such as introducing time non-separability in leisure, endogenous human capital accumulation, or the introduction of both an intensive and extensive margin in a model with uninsurable risk. These are left for future research.

Roughly speaking, most of the correlations among variables are as in the usual RBC models. The main exception (in addition to the low volatility of hours worked discussed in the previous paragraph) is that the correlation of hours worked with GNP is now much lower than in other RBC studies; in fact, as can be seen from Table 8, it is slightly negative. It turns out that the value of this correlation is highly sensitive to small changes in the parameters. Table 9 reports second moments as we change one of the parameters in the benchmark case at a time, and it can be seen that this correlation is strongly affected by these changes. This sensitivity is due to the low volatility of hours worked, which makes the correlation nearly ill-defined, since both the numerator and the denominator of the correlation now contain very small numbers in absolute value; hence, this negative correlation seems to be driven by the empirical puzzle discussed in the previous paragraph.

7 Conclusion

This paper questions the seemingly robust conclusion that a neoclassical growth model with explicit microfoundations supports the supply-side view that capital taxes should be abolished. Even though all aggregate indicators of economic activity respond positively to abolishment of capital taxes, the welfare of one half of the population goes down. The relevant criterion for determining who benefits from supply-side changes is not total wealth, but the wage/capital ratio. Agents with a higher wage/wealth ratio experience a large decrease in welfare, while agents with a low wage/capital ratio would enjoy a large welfare improvement. Therefore, the redistributive effect of abolishing capital taxes strongly dominates the efficiency gain in terms of aggregate production in this model. This result is robust to changes in the parameters and the criterion for splitting the sample. In order for both kinds of agents to gain from eliminating capital taxes, it is important to follow the optimal transition path dictated by the Ramsey problem, and not to implement the long-run optimum from period zero[20]; this may be achieved by some explicit redistribution of wealth in the first few periods.

In all respects, the model and the parameter values are chosen as close as possible to the traditional neoclassical growth model and RBC studies; the conclusion is robust to changes in parameter values along many directions. For some parameter values (for example, if we simulate the model under a low τ^k), the loss in welfare is small, but precisely for those parameter values a pure supply-side intervention has negligible effects on aggregate economic activity. In the model, supply-side interventions are either irrelevant or highly regressive.

We find that the changes in welfare are very large and affect a large part of the population. It is well known that the difference in income between the richest and poorer 20% of the population is very high; for 1992, the ratio of total income between the upper and lower quintile reported by CPS is 12.5; the differences in welfare from being in one or other quintile must be very important. It seems that the problem of distribution of wealth is several orders of magnitude more important than other traditional topics in macroeconomics, and that dynamic equilibrium models are able to deliver striking results on this issue.

Our model is fairly general within the class of models used in most papers study-

[20] CCK also point out the importance of following the transition of optimal taxes in a homogeneous agent model.

ing taxation in dynamic equilibrium models. Several modifications could capture important aspects of the economy; in particular, the diversity of agents should be enriched to allow for a dispersion closer to the one observed in the data and represented in Figure 1; this could endogeneize the proportion of the population that gains or looses from the change in taxes; we could also introduce the skewness in capital ownership that is observed in the real world. Also, the dispersion of income represented could be endogenized in a model of incomplete markets. Introducing progressive taxation would change the type of agents that gain or loose from the change in policy. Finally, it would be interesting to address these issues with a model that resolves the puzzle of relative variability of hours worked and consumption across individuals and across time. We feel that the redistribution effects we find in this paper are likely to be present, or even stronger, if such modifications were introduced in the model, but a more accurate description of the diversity of agents is crucial in order to design policies that improve the welfare of all (or at least most) agents.

Despite the redistributive effects that we document, our model is consistent with the view that capital taxes are very high, since the observed capital taxes seem to be close to the maximum of the Laffer curve. If it were possible to reduce capital taxes and maintain the old distribution of wealth, all agents in the economy would increase their welfare, but it is not easy to do this in a model without lump-sum taxes. In our model we can achieve a pareto improvement if wealth is redistributed in the first period. It is possible that a path for taxes that is time-dependent (for example, having very high capital taxes in the first few periods and zero capital taxes in the long run) could improve the welfare of both agents; this is the subject of future research.

APPENDIX 1
PEA algorithm

We describe here how to apply PEA to perform Step b) in section 5.5. Given μ, g, τ^k and τ^l, we find $\left\{\overline{c}_{j,t}, \overline{l}_{j,t}, \overline{k}_t\right\}_{t;j=1,2}$ that satisfy equations (6), (14), (10) for $j = 1$,and (11)

- Step 1; substitute the conditional expectation in the right side of (10) by a flexible functional form of the state variables of the model to obtain

$$u'(\overline{c}_{1,t}) = \delta \ \psi(\beta; \overline{k}_{t-1}, \theta_t) \tag{19}$$

  Here, we choose ψ as an exponentiated polynomial that is insured to take on only positive values; the parameters β are the parameters in the polynomial. Fix β.

- Step 2. Obtain a long simulation $\left\{\overline{c}_{j,t}(\beta), \overline{l}_{j,t}(\beta), \overline{k}_t(\beta)\right\}_{t=0;j=1,2}^{T}$, consistent with this parameterized expectation for large T. This is done by, in each period, for given state variables, obtaining $\overline{c}_{1,t}(\beta)$ from (19), $\overline{c}_{2,t}(\beta)$ from (14); $\overline{l}_{1,t}(\beta)$ and $\overline{l}_{2,t}(\beta)$ from (11); finally, $\overline{k}_t(\beta)$ is obtained from (6) and we can move to the next period.

- Step 3. Perform a non-linear regression of

$$u'(\overline{c}_{1,t+1}(\beta)) \ \left((\overline{r}_{t+1}(\beta) - d)(1 - \tau^k) + 1\right)$$

  (the expression inside the conditional expectation in (10)) on the functional form

$$\psi(\cdot; \overline{k}_{t-1}(\beta), \theta_t).$$

  Call the result of this regression $G(\beta)$

- Step 4. Iterate on β to find $\beta_f = G(\beta_f)$.

The approximate solution is given by $\left\{\overline{c}_{j,t}(\beta_f), \overline{l}_{j,t}(\beta_f), \overline{k}_t(\beta_f)\right\}_{t=0;j=1,2}^{T}$

In the case that the initial capital stock is away from the steady state distribution of capital (as when taxes change), Step 2 has to be modified by, instead of running one long simulation for large T, run many short run simulations based on independent realizations of the stochastic shock. More precisely, we draw N independent realizations $\{\theta_{t,n}\}_{t=0,n=1}^{T',N}$ and substitute Step 2 by

- Step 2'. Obtain simulations $\left\{\overline{c}_{j,t,n}(\beta), \overline{l}_{j,t,n}(\beta), \overline{k}_{t,n}(\beta)\right\}_{t=0,n=1;j=1,2}^{T',N}$, consistent with this parameterized expectation for large N, starting all simulations at fixed initial conditions, and using the steady-state β_f to solve the series at $t = T'$.

as is done, for example, in Marcet and Marimon (1992).

In order to evaluate the expectations involved in EPVBC, for example in (30), one could draw N realizations of length T'' and approximate the conditional expectation

$$\frac{1}{N}\sum_{n=1}^{N}\sum_{t=0}^{T''}\frac{u'(\overline{c}_{1,t,n})}{u'(\overline{c}_{1,0,n})}\delta^t \left(g - (\overline{r}_{t,n} - d)\ \overline{k}_{t-1,n}\ \tau^k - \overline{w}_{t,n}\ \overline{e}_{t,n}\ \tau^l\right)$$

here, N and T'' both have to be large. It turns out that this approximation necessitates extremely large T'' ; the reason is that when capital taxes are lowered, the government accumulates large amounts of debt, and interest payments in the steady state are very high. Since N has to be large, it would be computationally costly to also set T'' very large; in order to obtain accurate solutions for low T'' we add to each element in the the above sum

$$\frac{\delta^{T''}}{u'(\overline{c}_{1,0})}\ E_t\left(\sum_{i=0}^{\infty}\delta^i\ u'(\overline{c}_{1,t+i})\ \left(g - (\overline{r}_{t+i} - d)\ \overline{k}_{t-1+i}\ \tau^k - \overline{w}_{t+i}\ \overline{e}_{t+i}\ \tau^l\right)\right) \tag{20}$$

which approximates the tail of the infinite sum. The conditional expectation can be easily approximated by parameterizing the conditional expectation in (20) with a flexible functional form in the steady state, using long run simulations.

Assuming that N is large enough, this method for evaluating EPVBC eliminates inaccuracies by letting T'' be large and by letting the polynomial that parameterizes the expectation in (20) be of high order. By comparison, CH relied only on T'' being very large (since they did not use (20)), which was computationally feasible due to the fact that they were using a deterministic model. CCK relied only on the conditional expectation being well approximated (since their method amounts to using $T'' = 1$); by comparison, our evaluation of the EPVBC is much less affected by miscalculations of the nonlinearities of the savings functional around the initial condition, and it does not need to iterate in order to find this functional.

APPENDIX 2

Introducing Balanced Growth

We show how the equilibrium in the model in the paper can be converted into a stationary model, by removing growth from the solution. This is a necessary step for obtaining nonlinear approximations to the law of motion. The formulas can be derived with simple but annoying algebra; they are offered to save the reader some time and because the depreciation allowances introduce some differences with the case of no taxes.

Let the deviations from growth be given by

$$\widetilde{c}_{j,t} = c_{j,t}/\mu^t \qquad \widetilde{i}_t = i_t/\mu^t \qquad \widetilde{k}_t = k_t/\mu^t \tag{21}$$

and so on. We want to find equilibrium conditions expressed in terms of these variables; we'll see that the resulting equilibrium conditions can be interpreted as arising from a purely stationary model with the exception of the way depreciation allowances enter the model.

Substituting the variables using formula (21) in the equilibrium conditions one obtains the following: the production function given by

$$\widetilde{c}_t + g + \widetilde{i}_t = \widetilde{F}(\widetilde{k}_{t-1}, \widetilde{e}_t, \theta_t) = \widetilde{k}_{t-1}^{\alpha}\ \widetilde{e}_t^{1-\alpha}\ \theta_t$$

satisfies feasibility condition, and $\widetilde{r}_t = \widetilde{F}_1(\widetilde{k}_{t-1},\ \widetilde{e}_t,\ \theta_t) = r_t/\mu$ and $\widetilde{w}_t = \widetilde{F}_2(\widetilde{k}_{t-1},\ \widetilde{e}_t,\ \theta_t) = w_t$. Given the utility function introduced in section 4, hours worked satisfy

$$\widetilde{c}_{j,t}^{\gamma_c}\ \widetilde{w}_t\ (1-\tau^l)\phi_j\ - B(1-l_{j,t})^{\gamma_l} = 0 \tag{22}$$

Therefore, hours worked are stationary and we can take $\widetilde{l}_t = l_t$. On the other hand, letting $\widetilde{\delta} \equiv \delta\,\mu^{\gamma_c+1}$, and $\widetilde{d} \equiv 1-(1-d)/\mu$, the transition for capital, first order condition for capital, and EPVBC's can be written as

$$\widetilde{k}_t = \left(1-\widetilde{d}\right)\widetilde{k}_{t-1} + \widetilde{i}_t$$

$$\widetilde{c}_{j,t}^{\gamma_c} = \widetilde{\delta} E_t \left(\widetilde{c}_{j,t+1}^{\gamma_c}\ \left((\widetilde{r}_{t+1} - d/\mu)(1-\tau^k) + 1/\mu\right)\right) \tag{23}$$

$$E_0 \sum_t \left(\frac{\widetilde{c}_{1,t}}{\widetilde{c}_{1,0}}\right)^{\gamma_c} \widetilde{\delta}^t \cdot \left(\widetilde{c}_{1,t} + \widetilde{d}\ \widetilde{k}_{1,-1}\right.$$

$$-\widetilde{k}_{1,-1}(\widetilde{r}_t(1-\tau^k)+\tau^k d/\mu)-\phi_1\widetilde{w}_t\ l_{1,t}(1-\tau^l)\Big)=\widetilde{m}_{1,-1}/\mu \qquad (24)$$

for the government's EPVBC

$$E_0\sum_t\left(\frac{\widetilde{c}_{1,t}}{\widetilde{c}_{1,0}}\right)^{\gamma_c}\widetilde{\delta}^t\ \left(g-(\widetilde{r}_t-d/\mu)\ \widetilde{k}_{t-1}\tau^k-\widetilde{w}_t\ \widetilde{e}_t\tau^l\right)=\widetilde{m}_{g,-1}/\mu \qquad (25)$$

Finally, total utility is given by

$$E_0\sum_t\widetilde{\delta}^t[\ u(\widetilde{c}_{j,t})+v(\widetilde{l}_{j,t},1)\ ]=E_0\sum_t\widetilde{\delta}^t[\ u(c_{j,t})+v(l_{j,t},\mu^t)\ ].$$

Notice that, as in the no-government model, deviations from an exogenous trend can be interpreted as a purely stationary model with utility discount factor given by $\widetilde{\delta}=\delta\mu^{\gamma_c+1}$, depreciation rate $\widetilde{d}=1-\mu^{-1}\ (1-d)$, and using μ to normalize the returns on capital; the exception is that only a portion $1/\mu$ of the depreciation of the deviations can now be claimed as allowance, so that in the Euler equation (23) and the budget constraints depreciation allowances enter as a function of d and μ, but not of $\widetilde{d}$. Intuitively, the reason for this difference is that in the purely stationary case all investment can be claimed as a depreciation allowance, but if growth is taken explicitly into account, a fraction μ^{-1} of the new capital is not tax deducible.

APPENDIX 3
Calculations

The calculations reported in the paper were performed by parameterizing the conditional expectations in the steady state with a 2d. degree polynomial, with zero coefficients on those elements of the polynomial that had no predictive power. The number of observations was 40.000. The total computation time of Table 5 in an Hewlett Packard Apollo 715/33 workstation was 45 minutes (notice that this solves, in effect, 12 models for different values for τ^k) . Calculating the solution with 10.000 observations and 1st degree polynomial gave essentially the same numbers reported in that table, except for the calculation of λ, which needed a second degree polynomial for the tails of the EPVBC. Nevertheless, calculating the solution ignoring the transition path gave solutions that were very inaccurate. For short-run simulations and for calculating EPVBC's we used $N = 400$ and $T'' = 100$.

We run a number of accuracy tests. The orthogonality condition accuracy tests were satisfactory. Another test involved testing Walras' law: given the approximations made in calculating budget constraints, even if the EPVBC of agent 1 and government are satisfied given our approximations, it may be the case that EPVBC of agent 2 is not close to being satisfied. It turned out that Walras' law was only after the tails in (24) were included with a 2d degree polynomial. Calculating the laws of motion with five different realizations of the whole series $\{\theta_t\}$ and $\{\theta_{n,t}\}$ gave the same numbers reported in the tables up to the third digit of accuracy, reflecting evidence that the Monte-Carlo approximation error is small.

APPENDIX 4

Data used in the calibration of the heterogeneity parameters

We have used the Panel Study of Income Dynamics (PSID) to obtain several distributive measures involved in the calibration of the model. This is a well known data set that collects information on families and their offspring and at present runs from 1969 to 1989. We select families that were interviewed and that kept the same head from 1984 to 1989.

Our agents in the model will be households in the data, and not the different individuals that compose them. The reason for that lies in the difficulty to extract individual values from family aggregates.[21]

The variables we want to calibrate are the efficiency parameters ϕ_1 and ϕ_2, and the value of the initial capital stocks $k_{1,-1}$ and $k_{2,-1}$. As discussed in section 5.2, we need estimates of wages and returns from assets.

The PSID provides measures for average hourly wages, labor income, and several categories of non-human wealth and asset income. We use the reported measures of asset returns whenever these are available,averaging asset income or rates of return over the last five years of the sample period. Otherwise we multiply each asset's value by average long-run net rate of return as reported in several studies.

In what follows we specify how we treat each particular component of non-human wealth.

1. Types of assets for which the PSID reports asset returns.

    - Net value of Business or Farms, market and gardening activities , or rooming and boarding activities.
    - Cash assets (savings and checking accounts, CD's, IRA's, etc.) and dividends.

2. Types of assets for which we impute an asset return.

    Here we multiply the current value of the asset held by an average (over five years) real rate of return. The following is a list of these assets and the return series we use.

    - Net value of Bonds, Insurance Policies and Collectible Goods: Moody's average corporate bond yield[22].
    - Stocks, Mutual Funds: S&P'S common stock price index. (Dividends are reported as asset income in the category of 'cash assets').

[21] The PSID provides some individual variables, but it is by no means comprehensive.
[22] All rates of return or price series were extracted from CITIBANK.

- Total real estate[23] : we use the value calculated in Rosenthal (88), page 95. Rents perceived by the families are already embedded in that rate of return, therefore we do not use the rents reported in the PSID, as to avoid double counting.
- Pensions and Annuities: we use the U.S Government Security Yield, 10 years or more, Treasury compiled.
- Other Debts: we use the secondary market yields on FHA mortgages since this is composed, mostly, of second mortgages.

We deflate these nominal returns or rates by the wholesale consumer price index. The PSID also reports the net value of autos, mobile homes etc. We do not impute any rent for this category.

[23] As the difference between real estate value and principal mortgage remaining.

APPENDIX 5

The model with uncertainty and characterization of equilibrium

Consumers of type j solve the following maximization problem:

$$\max_{\{x_{jt}\}} \quad E_0 \sum_{t=0}^{\infty} \delta^t \left(\ u(c_{j,t}) + v(l_{j,t}, \mu^t) \ \right)$$

subject to

$$\begin{array}{rcl} c_{j,t} + k_{j,t} - k_{j,t-1} & + & \int q_t(\theta) \ m_{j,t}(\theta) \ d\theta = \\ \phi_j \ \mu^t \ l_{j,t} \ w_t(1-\tau^l) & + & k_{j,t-1}(r_t - d)(1-\tau^k) + m_{j,t-1}(\theta_t) \end{array} \tag{26}$$

$$\begin{array}{rcl} k_{j,t} & = & (1-d)k_{j,t-1} + i_{j,t} \\ k_{j,-1} \text{and } m_{j,-1}(\theta) & & \text{given} \end{array}$$

where $m_{j,t}(\theta)$ is the demand of contingent claims that pay one unit of consumption in period $t+1$ if $\theta_{t+1} = \theta$ claims and $q_t(\theta)$ is the price of the claim.

With interior solutions, the first order conditions for contingent claims, capital, and labor choice in the consumer's problem are as follows:

$$q_t(\theta) \ u'(c_{j,t}) = \delta \ u'(c_{j,t+1}(\theta))P(\theta = \theta_{t+1}|\theta_t) \tag{27}$$

$$u'(c_{j,t}) = \delta \mathrm{E}_t \left(\ u'(c_{j,t+1}) \ \left((r_{t+1} - d)(1-\tau^k) + 1 \right) \right) \tag{28}$$

and equation (11) for all t and $j = 1, 2$.. In equation (27) , $c_{j,t+1}(\cdot)$ denotes explicitly equilibrium consumption of agent j in period t+1 as a function of the realization $\theta = \theta_{t+1}$; $P(\cdot|\cdot)$ denotes the conditional probability.[24] Equilibrium factor prices equal marginal product to set $r_t = F_1(k_{t-1}, \ e_t, \theta_t)$ and $w_t = F_2(k_{t-1}, \ e_t, \theta_t)$.

The following proposition reduces the number of equilibrium conditions; this simplifies greatly the calculation of equilibrium.

Proposition 1 *Given tax rates τ^k, τ^l, if a unique equilibrium exists and it is interior, then the equilibrium process for $\{c_{j,t}, l_{j,t}, k_t\}_{j,t}$ and the equilibrium value of g are determined uniquely by the following conditions:*

- *equation (6), equation (28) for $j = 1$ and equation (11) for $j = 1, 2$*
- *there is a constant λ such that equation (14) holds for all t.*

[24] That is, given information at t and a possible value θ, the expression $c_{j,t+1}(\theta)$ represents a number, while $c_{j,t+1} \equiv c_{j,t+1}(\theta_{t+1})$ is a random variable.

- *expected value budget constraints (EPVBC) are satisfied:*

$$E_0 \sum_{t=0}^{\infty} \frac{u'(c_{1,t})}{u'(c_{1,0})} \delta^t \Big(c_{1,t} + dk_{1,-1}(1-\tau^k) -$$

$$r_t \; k_{1,-1}(1-\tau^k) - w_t \; \mu^t \; \phi_1 \; l_{1,t}(1-\tau^l) \Big) = m_{1,-1} \qquad (29)$$

$$E_0 \sum_{t=0}^{\infty} \frac{u'(c_{1,t})}{u'(c_{1,0})} \, \delta^t \, \Big(g_t - (r_t - d) \; k_{t-1}\tau^k - w_t \; e_t \tau^l \Big) = m_{g,-1} \qquad (30)$$

- $\left\{ c_{j,t}/\mu^t, l_{j,t}, k_t/\mu^t \right\}_{j,t}$ *is a stationary process*

Proof

First, we show that (14) is necessary and sufficient for (27). From (27) we obtain

$$\frac{u'(c_{1,t})}{u'(c_{2,t})} = \frac{u'(c_{1,t+1}(\theta))}{u'(c_{2,t+1}(\theta))}$$

for all t and θ; this implies that the ratio of marginal utilities at t is equal to the ratio at $t-1$ with probability one. By induction $u'(c_{1,0})/u'(c_{2,0}) = u'(c_{1,t})/u'(c_{2,t})$ for all t; since the consumptions at $t = 0$ are independent of the realization for the stochastic process, we have equation (14). On the other hand, for the contingent claim prices q that satisfy (27) for $j = 1$, (14) implies that (27) is satisfied for $j = 2$, so that (14) implies (27) for $j = 1, 2$.

Clearly, (14) together with (28) $j = 1$, are necessary and sufficient for (28) $j = 2$.

With concave utility and production functions, if an equilibrium with interior solutions exists and is unique, the solution to the maximization problem of consumers and firm is uniquely determined by first order conditions and the transversality condition, so that the above conditions are sufficient for maximization of utility and profits.

Now we show that the EPVBC's are a necessary condition for the period–by-period budget constraints (for more details see Hollyfield, Ketterer and Marcet (1988)). Applying forwards recursion to (26) and using (27) to substitute for the prices of contingent claims, we find (30) and

$$E_0 \sum_t \frac{u'(c_{1,t})}{u'(c_{1,0})} \, \delta^t \; (c_{1,t} + i_{1,t} - r_t \; k_{1,t-1} +$$

$$(r_t - d)k_{1,t-1}\tau^k - \phi_1 w_t\ \mu^t\ l_{1,t}(1-\tau^l)\Big) = m_{1,-1}$$

In order to drop the terms $k_{1,t-1}$ from this equation we can set $k_{1,t-1} = k_{1,-1}$,and $i_{1,t-1} = dk_{1,-1}$ for all t to obtain (29). Since the individual choice for capital holdings is arbitrary, this substitution is valid. Also, a similar constraint for agent 2 is satisfied by Walras' law.

Finally, we show that EPVBC are sufficient for the period-by-period budget constraints. For example, contingent claims holdings for the government are given by

$$m_{g,t-1}(\theta) = E\left[\sum_i \frac{u'(c_{1,t+i})}{u'(c_{1,t})}\delta^i\ \Big(g_{t+i} - (r_{t+i} - d)\ k_{t-1+i}\tau^k - e_{t+i}w_{t+i}\tau^l\Big)\Big|\ \theta = \theta_t, \theta_{t-1}, \theta_{t-2}, \ldots\right]$$

(end of proof)

Table 1: **Means of variables in the groups of PSID sample.***

	Variable Name	$\frac{\text{Wage}}{\text{Wealth}}$ ratio			Total wealth		
		type 1	type 2	Ratio	type 1	type 2	Ratio
Weighted Average by age	Hourly wage	14.87	13.14	1.13	18.58	9.43	1.97
	Perm. net income	50528	28652	1.76	59287	19893	2.98
	Labor Income	30934	22360	1.38	36699	16596	2.21
	Hours worked	1712	1629	1.05	2025	1692	1.2
	Total Wealth	180366	31804	5.67	201821	10351	19.5
Total Average	Hourly wage	15.66	15.60	1.00	19.91	11.36	1.75
	Perm. net Income	56379	3116	1.81	64443	23104	2.79
	Labor Income	32079	28258	1.14	39563	20774	1.90
	Hours worked	2048	1811	1.13	1987	1829	1.09
	Total Wealth	219930	12331	17.84	225251	7010	32.13

* Each square reports averages of variables for households in the PSID sample; each income group represents one type of agent in the model. There are four alternative averages, since the sample can be split according to two alternative criteria and averages can be calculated with or without the lyfe-cycle effect. The benchmark case corresponds to the upper-left square. Recall that, splitting the sample by wage/wealth ratio, type 1 corresponds to households with a low wage/wealth ratio; splitting the sample by total wealth, type 1 households are those with high wealth. See subsection 5.2 for a full discussion.

Table 2: **Parameter Values of the Benchmark Economy.**

α	.36	τ^l	.23
δ	.99	τ^k	.57
d	.02	μ	1.004
γ_c	-1.	ρ	.95
k_{-1}	6.7	σ_ϵ^2	.01
γ_l	-10.	$m_{g,-1}$	-2.0
Heterogeneity parameters			
Salary/Wealth Partition		*Wealth Partition*	
ϕ_1/ϕ_2	1.13	ϕ_1/ϕ_2	1.97
$k_{1,-1}/k_{-1}$	2.92	$k_{1,-1}/k_{-1}$	2.84

Table 3: **First and second moments of aggregate variables**

	Benchmark Economy $\tau^k = 0.57$			Zero Capital Tax $\tau^k = 0$		
Variable	Mean	Std. Error	Volatility	Mean	Std. Error	Volatility
k	6.77	0.47	0.07	13.12	0.64	0.04
i	0.16	0.02	0.13	0.31	0.03	0.10
GNP	0.99	0.05	0.05	1.24	0.06	0.04
l	0.33	0.0009	0.0027	0.33	0.0011	0.0034
c	0.58	0.03	0.05	0.67	0.03	0.04
w	1.89	0.09	0.05	2.42	0.11	0.044
r	0.05	0.002	0.03	0.03	0.0010	0.03
τ^l	0.23	-	-	0.37	-	-
g	0.25	-	-	0.25	-	-

Table 4: **Means of individual consumption and leisure(*).**

	Salary/Wealth Partition		*Wealth Partition*	
Variable	Benchmark	Zero Capital Tax	Benchmark	Zero Capital Tax
c_1	0.73	0.92	0.86	1.05
c_2	0.42	0.43	0.29	0.29
l_1	0.32	0.31	0.32	0.31
l_2	0.35	0.35	0.35	0.35

(*) These, and all the moments in the rest of the tables, are for the steady-state distribution.

Table 5: **Welfare gains in benchmark case**

τ^k	*Salary/Wealth Partition*				*Wealth Partition*			
	π_1	π_2	$\frac{c_2}{c_1}$	$\frac{1-l_2}{1-l_1}$	π_1	π_2	$\frac{c_2}{c_1}$	$\frac{1-l_2}{1-l_1}$
0.57	-	-	0.59	0.96	-	-	0.33	0.96
0.456	4.5%	0.004%	0.55	0.95	4.0%	0.01%	0.32	0.96
0.342	7.9%	-7 %	0.53	0.95	6.9%	-1.6 %	0.31	0.95
0.228	10.5%	-2.8%	0.51	0.95	9.0 %	-4.2 %	0.30	0.95
0.114	12.7%	-5.5%	0.49	0.94	10.6%	-7.4%	0.29	0.95
0	14.6 %	-8.7%	0.47	0.94	11.9 %	-11.1 %	0.28	0.88

Table 6: **Sensitivity of welfare gains to utility parameters**

	$\gamma^c = -1.2$	$\gamma^c = -0.8$	$\gamma^c = -0.6$
π_1	16.68%	14.76%	13.32%
π_2	-13.41%	-8.70%	-6.08%
	$\gamma^L = -13.0$	$\gamma^L = -7.0$	$\gamma^L = -4.0$
π_1	14.99%	15.44%	16.10%
π_2	-11.87%	-8.46%	-8.10%
	B=0.024	B= 0.064	B= 0.084
π_1	16.14%	15.48%	15.28%
π_2	-11.70%	-11.62%	-11.66%

Table 7: **Sensitivity of aggregate and individual welfare gains of suppressing capital taxes for different initial τ^k**

Initial τ_k	Aggregate	π_1	π_2
0.2	0.034%	1.96%	-2.74%
0.3	0.56%	3.64%	-4.23%
0.4	1.60%	6.26%	-5.94%
0.5	3.72%	10.26%	-7.51%
0.57	6.02%	14.62%	-8.69%
0.6	7.24%	16.56%	-8.68%
0.7	14.67%	29.49%	-10.38%

Table 8: **Correlations**

	Benchmark Economy	Zero Capital Tax
k - i	0.53	0.49
GNP - l	-0.19	0.19
GNP - c	0.97	0.92
w - l	-0.23	0.13
r - i	0.22	0.57
k - k_{-1}	0.999	0.999
GNP - GNP_{-1}	0.98	0.97

Table 9: **Sensitivity of second moments.**

Variable	$k_{1,-1} = k_{2,-1}$	$\gamma^l = 0$	$\tau^k = 0$	$\tau^l = 0$	$g = 0^{(*)}$	$m_{g,-1} = 0$
λ	1.06	0.84	2.10	1.60	0.88	1.68
c_2/c_1	0.94	0.89	0.48	0.62	1.14	0.60
$(1-l_2)/(1-l_1)$	0.99	0.84	0.94	0.97	1.05	0.96
g	0.26	0.22	0.17	0.11	0	0.27
Means						
k	6.75	6.62	13.41	6.75	6.68	6.76
i	0.16	0.16	0.32	0.16	0.16	0.16
GNP	0.98	0.96	1.26	0.98	0.97	0.98
l	0.33	0.33	0.33	0.33	0.33	0.33
c	0.57	0.59	0.78	0.72	0.81	0.55
r	0.05	0.05	0.03	0.05	0.05	0.05
w	1.89	1.89	2.41	1.89	1.89	1.89
Std. deviations						
k	0.46	0.53	0.64	0.44	4.45	0.47
i	0.02	0.02	0.03	0.02	0.02	0.02
GNP	0.05	0.05	0.06	0.05	0.05	0.05
l	0.0009	0.006	0.001	0.001	0.002	0.001
c	0.03	0.03	0.03	0.03	0.03	0.03
r	0.0002	0.003	0.001	0.002	.002	.002
w	0.09	0.10	0.10	0.09	0.09	0.10
Correlations						
k-i	0.53	0.45	0.48	0.51	0.48	0.54
GNP-l	-0.19	0.28	0.40	0.42	0.71	-0.28
GNP-c	0.97	0.93	0.92	0.96	0.96	0.97
r-i	0.22	0.32	0.62	0.33	0.40	0.20
w-l	-0.23	-0.06	0.35	0.39	0.64	-0.32
GNP-GNP_1	0.98	0.96	0.97	0.98	0.97	0.98
k-k_1	0.99	0.99	0.99	0.99	0.99	0.99

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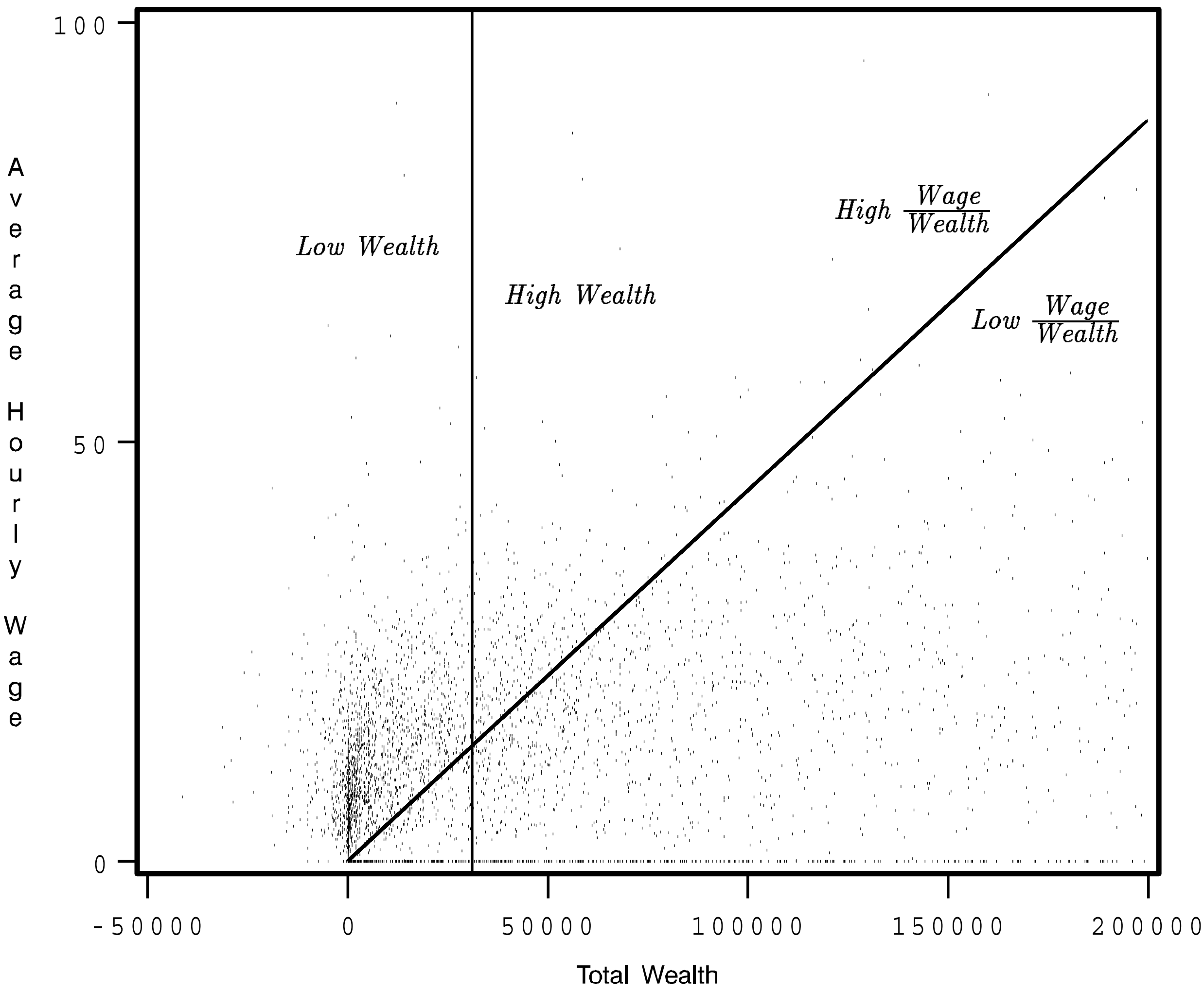
Figure 1: **Sample Distribution of Wealth and Wages**



Note: The (non-human) wealth and wage ranges have been chosen to leave out 12% of the sample. We exclude these outliers from the picture to allow for a better graphical representation. The vertical and positively sloped lines shown in the picture divide the *whole sample* in two halves for each criterion.

Figure 2: **Simulated Paths**

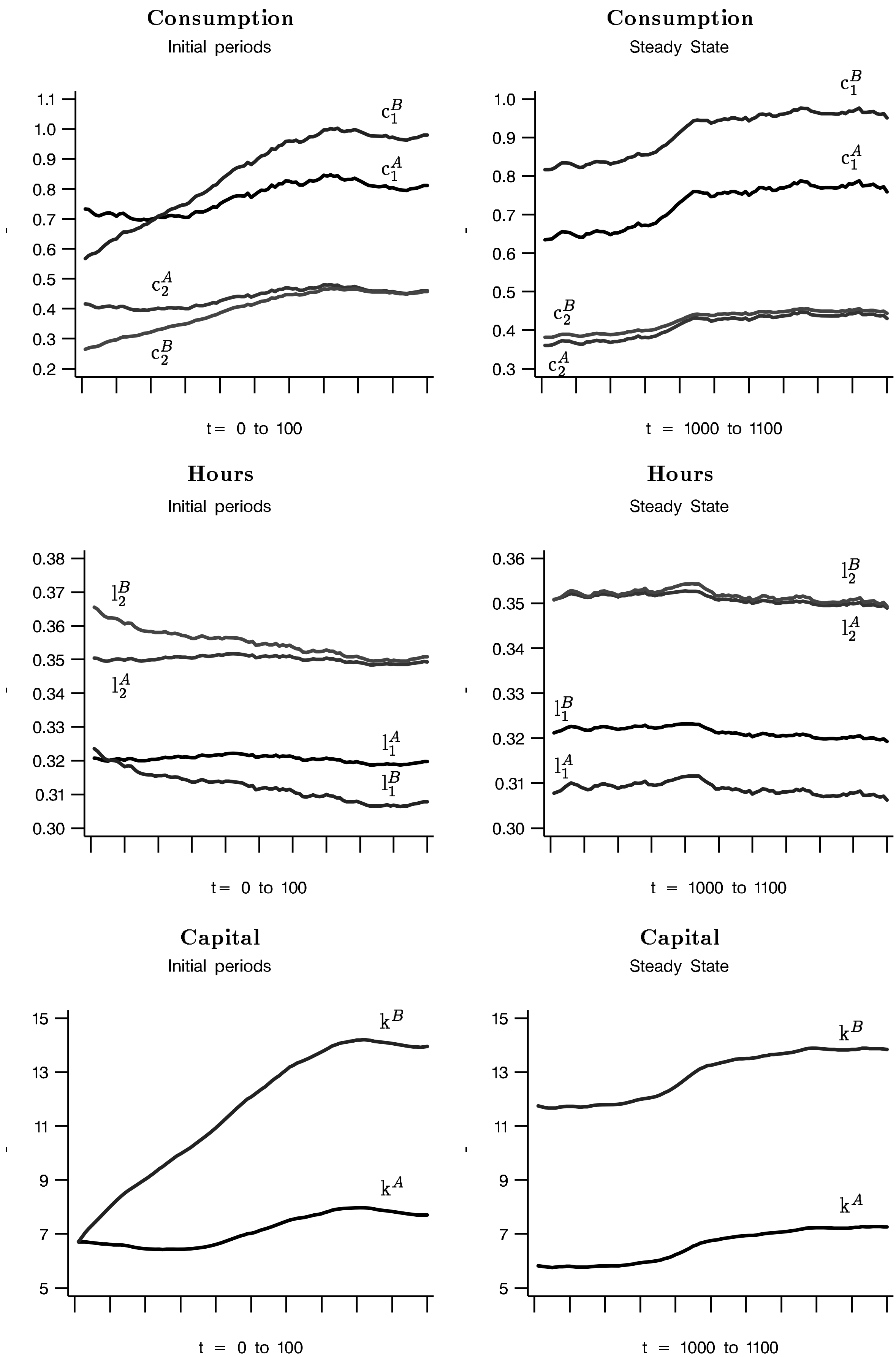


Figure 3: **Simulated Paths**

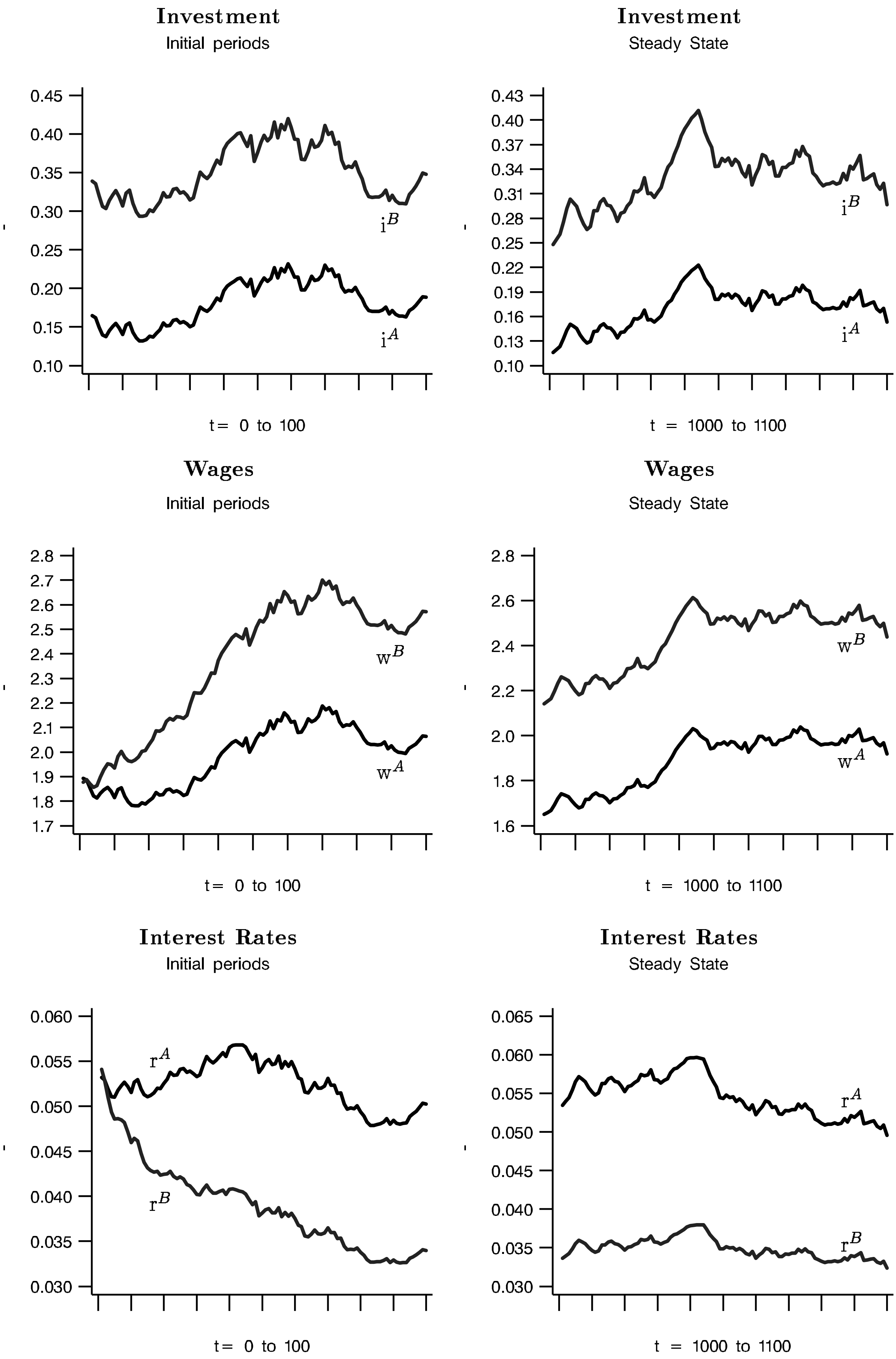
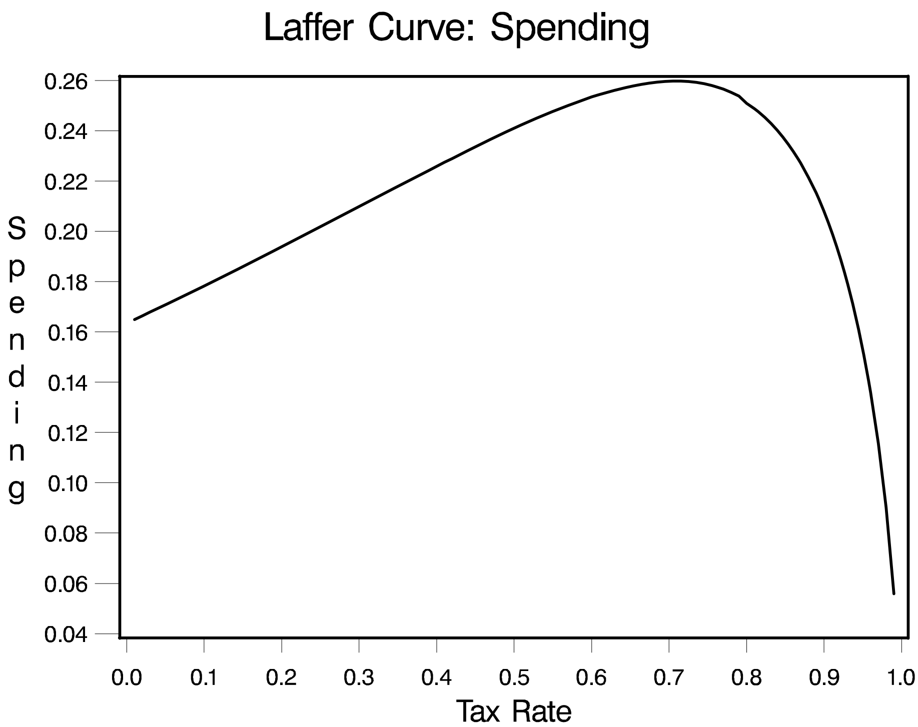


Figure 4:



Laffer Curve: Spending
0.26
0.24
0.22
0.20
0.18
0.16
0.14
0.12
0.10
0.08
0.06
0.04
Spending
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Tax Rate