Supply Side Interventions and Redistribution*

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Abstract

We evaluate the effect on welfare of shifting the burden of capital income taxes to labor taxes in a dynamic equilibrium model with heterogeneous agents and 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. When the parameters of the model are calibrated to match the distribution of income in terms of the wage/wealth ratio, the redistributive effect dominates, and agents with a high wage/wealth ratio would experience a large loss in utility if capital income taxes were eliminated.

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1 Introduction

A large part of the literature on dynamic taxation in equilibrium models with rational expectations has reached the conclusion that capital taxes should be abolished or, at the very least, severely reduced. Chamley (1986) showed that in a dynamic equilibrium model with proportional taxes, full commitment and time-varying taxes, it was optimal to suppress capital taxes in the long run. This reduction in capital taxes would promote aggregate investment, increase production and consumption in the long run. This result has been shown to be robust to many extensions.\footnote{For a review of the extensions see the relevant chapters of Ljunqvist and Sargent (2004) and Chari and Kehoe (1999).} In particular, it is robust to the introduction of heterogeneity: even if agents are heterogeneous optimal policies drive capital taxes to zero in the long run.\footnote{The result is obtained in Chamley (1986) and Judd (1985) and (1987). A proof for the model considered in the current paper where no lump sum transfers are available is found in Atkeson, Chari and Kehoe (1999).} In this way the study of capital taxation in dynamic 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 and, perhaps, make everybody better off.

The reduction of capital taxes, is not just a purely academic issue, it has been at the forefront of policy discussions. Some countries have recently reduced capital gains taxes or corporate taxes. To mention a few, Spain, France, Sweden and the US. The economic success of Ireland is often linked to lower capital taxes. Most empirical measures of capital taxes show that these were extremely high, but that they have been going down in the last two decades. Carey and Tchilinguirian (2000), with estimates for the OECD countries for the period 1980-97, conclude that there has been a shift in the relative tax burden from capital to labor, with an average annual decrease of -.2% in capital taxes, and an increase of .3% on labor taxes. For the US these rates are -.5% and .2% respectively.

Chamley’s result is only about long run tax rates: it is well known that optimal capital taxes are not zero in the transition to the steady state. As shown in Jones, Manuelli and Rossi (1993) the transition of optimal taxes shows very large oscillations through time. Optimal taxes can take extreme values in different periods, and the exact shape of the transition is highly dependent on the exact model at hand, making it difficult to implement the correct Ramsey tax policy in the real world. Therefore it is of interest to
study the effect of implementing policies with simpler dynamics, in particular, policies with constant tax rates. Inspired by the long run results of Chamley, one could consider the effect of abolishing capital taxes and to set labor taxes to a new constant level, high enough to keep the same level of government spending. Lucas (1990) performed exactly this experiment in a neoclassical dynamic model of capital accumulation and he found that abolishing capital taxes and shifting the burden of tax revenue to labor taxes was welfare improving. Cooley and Hansen (1992) confirmed these results even when considering inflation tax and consumption taxes.

Lucas (1990), and Cooley and Hansen (1992) used a model with homogeneous agents. Therefore, they could not address issues of equity and redistribution that immediately come to mind when discussing capital vs. labor taxes. The object of the current paper is to study the effects of abolishing capital taxes in a model with heterogeneous agents. In this way we can address both issues of efficiency and equity.

We keep the model as close as possible to that of Chamley. Therefore we consider a model of capital accumulation, infinitely-lived agents, flexible prices, proportional capital and labor taxes, complete markets and competitive equilibrium. We rule out redistributive lump sum taxes, as these would render the redistributive issue irrelevant and such taxes are impossible to implement in the real world. We also consider agents that can both save and work, as in the data the vast majority of agents (excluding retired) do so. We calibrate our model to observed heterogeneity of agents in a relevant way for the exercise at hand. We find 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, abolishing capital taxes also changes the distribution of wealth since it increases the disposable income of capital-rich agents 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 individual welfare are very large: the lowest quintile of the population would suffer a loss of between 20% and 60% (depending on the calibration). Furthermore, depending on the calibration, either 40% or 60% of the population would loose from the reform.

Some papers have shown how it may be difficult to implement Ramsey policies due to time inconsistency. For example, Klein, Krusell and Rios-Rull (2007) show how a time consistent policy under balanced budget would
involve capital taxes that are quite high in the long run. One possible conclusion from these observations is that issues such as lowering capital taxes should be written in the constitution. Our results say the new constitution would have to be written very carefully in order to be approved, since it would have to implement the actual transition of optimal taxes under full commitment. The median voter is likely to disagree with a change in the constitution stating that capital taxes are immediately suppressed, and a significant part of the population would very strongly disagree.

Since we are extrapolating the behavior of the economy into an area where no observations are available, the answer we find is highly dependent on both theoretical and empirical elements introduced in the analysis. In the paper we provide a careful discussion of how to capture the features of the joint distribution of labor and capital income across agents that are relevant for the exercise at hand. Also, we discuss carefully the effects of different assumptions on the elasticity of labour. In the empirical literature on inequality it is standard to focus on either the distribution of wealth or the distribution of income. We argue that the joint distribution of wealth and labor income across the population is what matters and, in particular, that the relevant dimension of this distribution for us is the dispersion of the wage/wealth ratio across agents.\textsuperscript{3} Our approach is to match the observed distribution of the wage/wealth ratio. Another key aspect in the calibration are the parameter values and functional forms that concern the elasticity of labor, since this will influence the efficiency cost of the higher labor taxes that are needed to compensate for the lost capital tax revenue. We argue that the standard neoclassical model does not allow to match both the variability of hours worked across time and across agents. Since we are particularly concerned about agents’ heterogeneity we choose a highly inelastic labor supply to roughly match the cross-section observations.

This is a revised version of our working paper that was first circulated in 1995.\textsuperscript{4} Other papers have analyzed related issues since our first working

\textsuperscript{3} Few papers have stressed the importance of the joint distribution of wealth and wage earnings. Krusell and Ríos-Rull (1999) note how results in a model of political economy are sensitive to whether consumers are ranked according to wealth distribution or to earnings distribution. Domeij and Heathcote (2004) also discuss the correlation of earnings and wealth across agents in the data.

\textsuperscript{4} Some differences with that version is that we have now five agents instead of two, we now only consider a deterministic model, there are many more robustness checks, and we have added the analysis for the high risk aversion case.
paper came out. Correia (1999) shows analytically the source of redistributive effects in a model with aggregation, Domeij and Heathcote (2004) use a model with incomplete markets and focus on the effects of idiosyncratic uncertainty. Flodén (2007) studies a model where the transition of capital taxes is optimal from the point of view of one of the agents in the model. Maliar and Maliar (2001) derive aggregation results, calibrate the model with 8 heterogeneous groups of agents and compare the results with those of our 1995 working paper. Conesa, Kitao and Krueger (2009) find that in a model with overlapping generations and idiosyncratic uninsurable risk it is often ex-ante optimal to have high capital taxes. A summary of these papers is that our main finding is very robust: suppressing capital taxes has large redistributive effects that would strongly decrease the welfare of large parts of the population under many extensions of our model. Our paper still is the closest one to Chamley’s framework, so it shows the effect of heterogeneity in isolation and in a simple model.

Some available work has used models where aggregation obtains. For example, Correia (1999), Domeij and Heathcote (2004) and Flodén (2007) use Greenwood Herkowitz and Huffman (GHH) preferences. In those cases one can solve first for the aggregate solution and then disaggregate the results. But in a model with growth these preferences imply zero hours worked in steady state and, therefore, in the status quo economy. GHH also presents some problems in matching volatility of hours. Therefore we use a model where aggregation does not obtain and we solve explicitly for the disaggregated choices of each type of agent. However, given our approach this only increases mildly the computation costs relative to a homogeneous agent model. Since under GHH preferences one has to resort to numerical solutions for the aggregate variables anyway, the increase in computational cost from having model without aggregation is quite minor.

Along the way, we reexamine the result of Chari Christiano and Kehoe (1994) that suppressing capital taxes would be undesirable in a model with a representative agent and high risk aversion. We find that if the calibration maintains a roughly plausible capital output ratio, suppressing capital taxes is beneficial for a representative agent even with high risk aversion. However, in a model with heterogeneous agents and high risk aversion, the redistributive effects of suppressing capital taxes are even higher.

The layout of the paper is as follows. The model is presented in section 2. Section 3 discusses issues pertaining to parameter calibration using data from the US economy. Section 4 presents the results derived from the simulations.
Section 5 performs sensitivity analysis. The conclusion ends the main paper. Appendix 1 discusses the details of the calibration using PSID data set and Appendix 2 discusses the numerical algorithm in detail.

2 The Model

In this section we describe a simple neoclassical growth model with heterogeneous agents, endogenous production, labor choice, exogenous deterministic growth, and government spending. Government can only use distortionary capital and labor taxes. Agents differ both in terms of their human, and non-human wealth.

2.1 Consumer, Firm, and Government Behavior

Assume that \( n \) infinitely-lived consumer types indexed by \( j = 1, 2, \ldots, n \) derive utility from consumption and leisure, and they are endowed with one unit of time every period. The number of each type of agents is normalized to \( 1/n \). They receive income from working and from renting their capital. All agents can work and accumulate (or divest) capital. Agents are heterogeneous in the productivity of their endowment of labor hours and initial capital stock. Income from labor and capital are taxed at constant rates \( \tau^l \) and \( \tau^k \).

Consumers of type \( j \) solve the following maximization problem:

\[
\begin{align*}
\max_{\{x_{j,t}\}} \sum_{t=0}^{\infty} & \delta^t \left[ u(c_{j,t}) + v(l_{j,t}, \mu^l) \right] \\
\text{s.t.} & \quad c_{j,t} + k_{j,t} = \phi_j \mu^t w_t l_{j,t}(1 - \tau^l) + k_{j,t-1} \left[ 1 + (r_t - d)(1 - \tau^k) \right] \\
& \quad k_{j,-1} \text{ given}
\end{align*}
\]

where \( \{x_{j,t}\} \equiv \{c_{j,t}, l_{j,t}, k_{j,t}\}_{t=0}^{\infty} \) are the choice variables of the consumer.

We assume separability in time and in the consumption-leisure decision. Here, \( c_{j,t}, k_{j,t}, l_{j,t} \) denote consumption, capital stock and hours worked of

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\(^5\)Introducing growth explicitly is important in order to quantify the effect of depreciation allowances. This is because in the stationary version of the model total investment is no longer equal to gross investment, therefore the size of the tax base is not the same as if the analysis was based on the stationary version of the model. This is made explicit in Appendix 2 where we show the equations for the model in deviations from trend.
agent \( j \) at time \( t \); \( w_t \) denotes the wage for efficiency units of work, \( r_t \) capital rental, these prices normalized in terms of the consumption good of the period. The wage obtained per hour worked in period \( t \) by agent \( j \) is \( \phi_j \mu^t w_t \), reflecting the fact that this agent produces \( \phi_j \) efficiency units per hour worked and that labor productivity grows exogenously at the rate \( \mu^t \). Since we concentrate our study on issues of distribution, our agents only differ in their initial wealth \( k_{j,-1} \) and their efficiency of labor \( \phi_j > 0 \); these are normalized so that \( \frac{1}{n} \sum_{j=1}^{n} \phi_j = 1 \). Parameters \( \delta, d \) are in the interval \([0,1]\), they stand for the discount factor of future utility and the depreciation rate of capital. Notice that only the capital income net of depreciation allowances is taxable.

Functions \( u \) and \( v \) are differentiable and satisfy the appropriate Inada conditions to insure interior solutions; \( u(\cdot) \) and \( v(\cdot, \mu) \) are strictly concave; \( u(\cdot) \) and \( v(l, \cdot) \) are strictly increasing and \( v(\cdot, \mu) \) is strictly decreasing. Individual capital holdings could be negative if the agent holds some debt.\(^7\)

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

\[
\max_{(y_t, e_t, k_{t-1})} \quad y_t - w_t e_t - r_t k_{t-1}
\]
\[\text{s.t.} \quad y_t = F(k_{t-1}, e_t) \tag{2}\]

where \( y_t \) represents output, \( k_{t-1} \) 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.

Since total supply of efficiency units of labor is \( \frac{1}{n} \mu^t \sum_{j=1}^{n} \phi_j l_{j,t} \) all variables grow at a rate \( \mu \) in the steady state except labor, which is constant in steady state. Normalizing the group size to \( 1/n \) together with \( \frac{1}{n} \sum_{j=1}^{n} \phi_j = 1 \)

\(^6\)Introducing the trend of labor productivity \( (\mu^t) \) in the utility function is a standard way to insure a non-degenerate solution for hours worked in the long-run in the presence of growth. This formulation has been controversial. Some economists have argued that this is artificial, while others have argued that it is consistent with assuming that higher human capital yields higher utility from leisure. This controversy is not relevant for our benchmark calibration with log utility of consumption, where the term \( \mu^t \) drops out. We only need the term \( \mu^t \) in the utility function for the high risk aversion cases considered in the robustness exercises in section 5.

\(^7\)As usual, some additional lower bound on (possibly negative) capital holding has to be introduced in order to rule out Ponzi schemes. The same will be true for the budget constraint of the government.
guarantees that by setting $\phi_i = \phi_j$ and $k_{i,-1} = k_{j,-1}$ for all $i, j = 1, 2, \ldots, n$ we are back to the homogeneous agent model in Lucas (1990).

We now discuss the constraints of government fiscal policy. Government spending is exogenous and grows at the same rate as output, so the sequence of government consumption is given by $g_t \equiv \mu^t g$ for a given constant $g$.\footnote{Since we maintain $g$ constant across policy experiments, the equilibrium computed and the welfare gains discussed in sections 4 and 5 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 has no productive use.} Tax revenues accrue from constant capital and labor tax rates $\tau^k, \tau^l$. Government can save or dissave by borrowing or lending at equilibrium interest rates. As is well known this is equivalent with assuming that the government has (possibly negative) capital stock holdings $k^g_t$. This amounts to the following budget constraint at period-$t$

$g_t + k^g_t = \tau^k (r_t - d) \frac{1}{n} \sum_{j=1}^{n} k_{j,t-1} + \tau^l w_t e_t + \left[1 + (r_t - d)(1 - \tau^k)\right] k^g_{t-1}$ (3)

Initial government savings $k^g_{-1}$ are given.

### 2.2 Equilibrium

We assume competitive equilibrium. As usual, an equilibrium is a sequence for prices and allocations, and a government policy $(g, \tau^k, \tau^l)$, such that when consumers maximize utility and firms maximize profits taking prices and government policy as given, they choose equilibrium allocations that clear all markets and the budget constraint of the government is satisfied.

The equations determining equilibrium are as follows. Market clearing in capital, labor and consumption good are given, for all $t$, by

$$k^g_t + \frac{1}{n} \sum_{j=1}^{n} k_{j,t} = k_t$$ (4)

$$\frac{1}{n} \mu^t \sum_{j=1}^{n} \phi_j l_{j,t} = e_t$$ (5)

$$\frac{1}{n} \sum_{j=1}^{n} c_{j,t} + g_t + k_t - (1 - d) k_{t-1} = y_t$$ (6)
For interior solutions, the first order conditions for capital and labor in the consumer’s problem are

\[
\begin{align*}
\frac{u'(c_{j,t})}{u'(c_{j,t})} &= \delta u'(c_{j,t+1}) (1 + (r_{t+1} - d)(1 - \tau^k)) \quad (7) \\
- \frac{v'(l_{j,t}, \mu^j)}{u'(c_{j,t})} &= w_t (1 - \tau^l) \mu^j \phi_j \quad (8)
\end{align*}
\]

for all \( t \) and \( j \). Here, \( v' \equiv \frac{\partial v}{\partial l} \). These are familiar conditions setting the intertemporal marginal rate of substitution of consumption (between leisure and consumption) equal to the price of capital (labor) net of taxes.

As usual, equilibrium factor prices equal marginal product to set \( r_t = F_k(k_{t-1}, e_t) \) and \( w_t = F_c(k_{t-1}, e_t) \).

It is easy to see that these equilibrium conditions can be summarized in the following way. Equation (7) implies that for some constants \( \lambda_j \)

\[
\frac{u'(c_{n,t})}{u'(c_{j,t})} = \frac{\phi_j}{\phi_n} \frac{v'(l_{n,t}, \mu^l)}{v'(l_{j,t}, \mu^j)} = \lambda_j \quad \text{for all } t, \text{ all } j = 1, \ldots, n - 1 \quad (9)
\]

For constant relative risk aversion (CRRA) utility of consumption this is the familiar condition that under complete markets and common discount factors the share of consumption is constant through time.

Substituting (7) and (8), and substituting for individual savings in the consumer budget constraint we obtain the present value formulation of the consumers’ budget constraints

\[
\begin{align*}
\sum_{t=0}^{\infty} \delta^t u'(c_{n,t}) \left( c_{j,t} - w_t (1 - \tau^l) \mu^j \phi_j l_{j,t} \right) &= k_{j-1}(1 + (r_0 - d)(1 - \tau^k)) \quad \text{for } j = 1, 2, \ldots, n \quad (10)
\end{align*}
\]

The budget constraint of the government is guaranteed by Walras’ law and, therefore, can be ignored.

It is easy to see that given a policy \((g, \tau^k, \tau^l)\) necessary and sufficient conditions for \( \left\{ (c_{j,t}, l_{j,t})_{j=1}^n, k_t \right\}_{t=0}^\infty \) to be an equilibrium sequence are\(^9\)

1. for all \( t = 0, 1, \ldots \) the following equations hold: (6), (7) for \( j = n \), (8) for \( j = n \), and (9) for some \( \lambda_1, \ldots, \lambda_{n-1} \).

\(^9\)For details see appendix 5 of the 1995 working paper version. That paper presents the case with uncertainty which encompasses the certainty case.
2. \( (10) \) for \( j = 1, \ldots, n \)

This reduces the number of variables and equations that need to be found to compute an equilibrium, since \((7)\) and \((8)\) for \( j = 2, \ldots, n \), period-\( t \) budget constraints \((1)\) and \((3)\) can be ignored. Notice that the way we formulate the problem involves finding the individual variables directly, we do not use any aggregation result, as there is no aggregation result that holds for this model. An algorithm is described in detail in Appendix 2 which in this model implies negligible increase in computational costs due to heterogeneity.

3  Calibration, stylized facts, analytic results and an algorithm

For our calibration we assume the following functional form of the utility function:

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

(11)

for \( \gamma_c, \gamma_l < 0 \) and \( B > 0 \), and we assume that hours worked satisfy \( 0 \leq l_{j,t} \leq 1 \). Notice that, since we choose \( \gamma_c = -1 \) in the benchmark calibration the term \( \mu \) disappears from the utility function in that case.

As usual we use a Cobb-Douglas production function \( F(k_{t-1}, \epsilon_t) = \mu^\alpha A k_{t-1}^{\alpha} \epsilon_t^{1-\alpha} \).

The effects of a tax reform are highly dependent on parameter values. Therefore, we need to use parameter values that can arguably represent the behavior of actual economies in the dimensions that are relevant for our exercise. We now describe the criteria that guided our choice of parameter values in the benchmark economy.

3.1 Preference, technology and policy parameters

To insure comparability with the rest of the literature and to match various empirical regularities that are successfully explained by neoclassical growth models many parameters are chosen in a standard way. The values we use are summarized in Table 1.

We choose log utility, \( \gamma_c = -1 \). This represents a low level of risk aversion but it is the value most commonly found in studies of fiscal policy. In this
case we see from (9) that \( \lambda_j \) gives exactly the consumption ratio relative to agent \( n \):\
\[
\frac{c_{j,t}}{c_{n,t}} = \lambda_j \quad j = 1, \ldots, n-1. \tag{12}
\]

As usual, \( B \) is chosen so that the representative agent works 1/3 of his time endowment in the steady state corresponding to the status quo. Also, \( \alpha \) is chosen to match the labor share of income. Depreciation rate, discount rate of utility, parameter \( A \), and growth rate are set to the usual values for quarterly data.

As for policy parameters \((\tau^l, \tau^k, g)\), tax rates are chosen to match measured average effective marginal tax rates. There is a long literature on this measurement. Papers vary in the method employed to measure these taxes, in the sample used, in the introduction of depreciation allowances and growth. We use McGrattan, Rogerson and Wright (1997) estimates of \( \tau^k = .57 \) and \( \tau^l = .23 \) for the period 1947-87, who follow the procedure of Joines (1981). These values are not too different from the ones estimated for the US in Carey and Tchilinguirian (2000), who updating the Mendoza, Razin and Tesar (1994) methodology obtain estimates of around .5 for capital tax and .22 for labor tax for the period 1980-97.\(^{10}\) We discuss in detail the sensitivity of our results to the value of \( \tau^k \).

Government spending \( g \) is selected to balance the government budget constraint in status quo steady state.\(^{11}\)

Initial aggregate capital is set at the steady state of the status quo policy.\(^{12}\)

\(^{10}\)The rate of \( \tau_k = .57 \) is not as high as it may appear, since it is applied to income after depreciation allowances and since this is the sum of all taxes on capital income paid by consumers and firms. In any case, there is considerable disagreement on the relevant level of labor and income taxes, specially on the level of the capital tax. Feldstein, Dicks-Mireaux and Poterba [1983] obtain estimates of \( \tau^k \) that range between .55 and .85 for the period 1953-1979. Cooley and Hansen 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; Chari, Christiano and Kehoe use \( \tau^k = .27 \); Lucas [1990] considers capital and labor taxes of .4; Greenwood, Rogerson and Wright [1995] set \( \tau^k = .70 \).

\(^{11}\)Since we are interested in the effects of substituting capital taxes by labor taxes, and in keeping with the practice in Lucas (1990) and Cooley and Hansen (1992), we will only consider government spending that is financed from these two taxes. Therefore, total government spending in our model will be lower than the one actually observed.

\(^{12}\)Table 4 shows the values of capital and output. The capital/output ratio in status quo is about seven, lower than the values of ten or twelve that are often used for a quarterly
Initial government debt is set to $-k_{-1}^g = 2$. Since output is close to 1 and the model is calibrated to quarters this amounts to choosing a yearly debt/output ratio of about fifty percent in the status quo.

3.2 Heterogeneity parameters

The parameters that determine agents’ heterogeneity, namely the productivity of labor $\phi_j$ and initial levels of wealth $k_j, -1$, are key to the outcome of the policy reform under study. Therefore it is important to calibrate these parameters so as to capture appropriately the actual joint distribution of wage and wealth across agents. We focus on those aspects of this distribution that are key for the policy outcome.

We argue that the relevant dimension to be matched is the distribution of wage/wealth ratios across agents. This is because two agents with the same wage/wealth ratio are likely to both loose or gain from the reform we consider, even if one of them has a much higher total income than the other. The following concrete example demonstrates this point. Consider the case where the wage/wealth ratio is constant across all agents:

$$\frac{\phi_i}{k_{i,-1}} = \frac{\phi_j}{k_{j,-1}}$$

That is, an agent who is twice as productive is also twice as wealthy. Also, for simplicity, consider $\mu = 1$ and $k_{-1}^g = 0$.

It can be easily checked that for any set of tax rates equilibrium allocations in this example satisfy

$$\frac{c_{i,t}}{c_{j,t}} = \frac{\phi_i}{\phi_j}, \quad l_{i,t} = l_{j,t} \quad \text{for all } t, i, j.$$  

In words, all agents work the same but an agent twice as productive (and, under (13), twice as wealthy) consumes and saves twice as much each period.

It is clear that, in this case, the ratio $\lambda_j$ is equal to $\frac{\phi_j}{\phi_0}$, therefore this ratio is independent of tax rates. It follows that any gain or loss from alternative tax policies affects equally the profile of consumption and leisure of all agents.

model. This lower capital/output ratio is due to the large capital taxes combined with the standard $A = 1$. Changing $A$ so as to match the capital/output ratio does not change the results significantly.

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If agent $i$ consumes double than agent $j$ before the reform, agent $i$ will continue to consume double than $j$ after the reform.

If (13) was a good approximation to the actual distribution of wealth and wages all agents would experience a similar gain from the tax reform we consider. In this case introducing heterogeneity in the model provides no new insights. On the other hand, if we find a lot of dispersion of wage/wealth ratios in actual data some agents may gain and others may loose from suppressing capital taxes. Therefore, we should examine if (13) is a good approximation to the empirical distribution of income.

For this purpose we examine the joint distribution of wealth and wages in actual data. Figure 1 plots wages against wealth for different households computed from the PSID.\textsuperscript{13} Each dot represents the wage and wealth of a family in the sample. If (13) was a good approximation to actual data most dots would be located near a straight line going through the origin (a "ray"). It is obvious, however, that the actual distribution is not grouped along one ray. The dispersion of wage/wealth ratios is very high and therefore abolishing capital taxes may affect different agents differently.

The issue is, then, how to introduce the relevant aspects of the distribution of wages and wealth in the model in a parsimonious way. Agents located either in the upper left corner or in the lower right corner of this figure are both "rich", but those agents in the upper left corner are likely to loose from the abolition of capital taxes because most of their income comes from labor, which will be taxed more heavily after the reform. Agents with a similar wage/wealth ratio either all gain or all loose, regardless of their total wealth.

To give some names to the situation: it is not that important for us to distinguish between a very highly qualified and a low-qualified worker if their levels of wealth are both low. These workers might have a very different level of income but both have a high wage/wealth ratio. It is important, however, to distinguish between a very highly qualified worker and a large land-owner who has zero labor income: they both have a high total income but they have very different wage/wealth ratios. In most studies of the wealth distribution the usual criterion is to classify agents according to their total income or total wealth, so that the large land-owner and the highly qualified worker would be lumped together incorrectly, because the first is likely to gain from the reform we consider while the latter is likely to loose.

In order to capture the observed distribution of wealth/wage ratios we

\textsuperscript{13}The details on how this Figure has been constructed are in Appendix 1.
rank all households by their wage/wealth ratio, and find the quintiles of this distribution. Each type in the model will represent one of the quintiles. Graphically, the split in quintiles would be represented by four rays in Figure 1 such that each of the five areas separated by the rays contain 20% of households. The more traditional criterion of classifying families by total income would correspond instead to splitting the sample with four negatively sloped lines, each line representing a given level of total income. The other traditional criterion of classifying by total wealth would correspond to splitting the sample using four vertical lines.

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, which corresponds to $\phi = 0$ in our model. Almost all of them would belong to group 1, thus confusing the life-cycle effect with the wealth effect. We try to remove this effect from our measures by splitting the sample into six age groups, and dividing each age group in five quintiles according to their wage/wealth ratio. The wage of type 1 agents is then calculated with a weighted average of the observed wages of households in the lowest wage/wealth ratio across age groups; the weights given to each age group correspond to percentages of US population as reported by the Census.\footnote{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).}

To summarize, in the benchmark case heterogeneity parameters $\phi_j, k_{j-1}$ are obtained by matching each type of agents in the model to the average of each quintile of the distribution of wage/wealth ratios, eliminating the life-cycle effects. In the section on robustness exercises we also calculate the heterogeneity parameters splitting the sample with a pure wealth criterion (i.e., splitting the sample by means of vertical lines). The statistics obtained from these two possible criteria are reported in Table 2.

Calibrating the initial wealth of agents in the model with the initial wealth of the quintiles in the data seems problematic, because different assets in the data yield different returns and agents with large wealth are often able to access higher returns. Instead we calibrate $\lambda$ to the ratio of consumption that can be sustained by total labor and capital income of each agent given

\footnote{Conesa, Kitao and Krueger (2009) explore the effect of capital taxes in an overlapping generations model. Therefore, they are better able to match income through the life cycle.}
the actual assets and the actual returns of these assets for the agents in the sample. For a detailed description on how we compute total capital income see Appendix 1. The ratios are reported in Table 2. From these consumption ratios we find the initial wealth of each group in the model consistent with steady state and the calibrated consumption ratios in the status quo tax rates. The heterogeneity parameters found in this way and used in the model are reported in Table 3.\footnote{As can be seen from Table 3 the consumption ratios that we find can only be sustained if wealth of some of the agents 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, while land is not present in our model. An alternative approach would be to introduce land that delivers returns and services of consumption.}

3.3 Elasticity of labor

The choice of $\gamma_l$ is quite important since it governs the elasticity of labor and it will be crucial in determining hours worked after the reform and the impact on welfare of the higher labor taxes.

Ideally we would use a parameter value that matched some basic facts concerning the variability of hours worked. Let us point to two basic well-known facts:

- a) \textit{across time} variability of aggregate hours worked is higher than variability of aggregate consumption.
- b) \textit{across individuals} variability of hours worked is lower than variability of consumption.

These observations have been documented by many authors. Fact a) has been emphasized by a number of papers, for example Hansen (1985) and Rogerson (1986). Fact b) has been documented in several contributions and it is confirmed within our calibration of heterogeneity reported in Table 2: the fourth column indicates that agents with the highest number of hours worked ($type \ j = 2$) work 40\% more than type $j = 5$, but they consume almost three times as much. Similar conclusions are derived from the wealth partition.

Fact a) has to do with the reaction of hours worked to a temporal shock to aggregate wealth, while fact b) has to do with the elasticity of hours worked to changes in wealth and wage. 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 use a model and parameter values that agree with both facts mentioned. Unfortunately, this cannot be done within the standard neoclassical dynamic model.

To see this, we first argue that low values of $|\gamma_l|$ help in explaining fact a), but they are incompatible with fact b). Consider the model with linear utility of leisure, so $\gamma_l = 0$, and assume that agents only differ in their initial wealth, so that $\phi_i = \phi$ for all $i$. Hansen (1985) and Rogerson (1986) showed that fact a) above can be explained under these assumptions. But (8) implies that in this case

$$c_{i,t} = c_{j,t} \quad \text{for all } t, i, j$$

Therefore, linear utility of leisure contradicts fact b) above, because consumption is constant across agents of different wealth.

Conversely, we can see that high values of $|\gamma_l|$ fail to explain fact a), but they are compatible with fact b). It is easy to see that in a stochastic model for our choice of $B$,

$$l_{j,t} \rightarrow 1/3 \quad \text{as } |\gamma_l| \rightarrow \infty,$$

for all $j$ and $t$. This is because for high $|\gamma_l|$ agents are so averse to changes in hours worked that they are likely to choose low volatility of hours across time and they will choose to adapt to fluctuations in income by higher volatility of consumption. Therefore, high values of $|\gamma_l|$ are likely to generate nearly constant hours worked across time in a model with aggregate uncertainty. Hence high $|\gamma_l|$ matches fact b) but it spoils fact a) in a stochastic model.

For our purposes, it seems particularly important to capture fact b) and to have a model where hours worked do not react very strongly to changes in policy. For this reason, we choose $\gamma_l = -10$ in the benchmark case which implies a very low wage elasticity of labor. This calibration is incompatible with fact a).\textsuperscript{17} As with many other parameters, we will check robustness of our main results to this choice.

### 3.4 Numerical issues

Since before the reform the economy is at the steady state it is trivial to find the equilibrium $g$.

\textsuperscript{17}We check that this is the case in a model with heterogeneous agents, taxes and aggregate uncertainty in the 1995 working paper version.
After the reform, there will be a transition period as allocations converge to the new steady state in deviations from trend. The difficulty is, therefore, finding the transition along with the labor tax rate and the ratios $\lambda$ that will balance the budget constraints after the reform. Since analytic solutions under the benchmark parameters are not known we resort to numerical simulation. Details on the algorithm and on the model in deviations from trend are given in Appendix 2. Since there is no aggregation in the model we need to solve for the aggregate variables jointly with the individual variables. Therefore, aggregate variables are solved jointly with the ratios $\lambda$. In Appendix 2 we show that adding the ratios $\lambda$ to the list of variables to be computed implies a small additional computational cost relative to a model with aggregation.

4 Results

We first show that in a homogeneous agent version of our model suppressing capital taxes causes a small improvement in welfare. This confirms the results of Lucas (1990) and Cooley and Hansen (1992) in our slightly different model and calibration. Furthermore, relative to the literature we find these gains are more robust: we find that, contrary to past results, there is an improvement in welfare even for very high values of risk aversion $-\gamma_c$. We then go on to show the results for the heterogeneous agent case.

4.1 Homogeneous agent

4.1.1 Replicating homogeneous agent results

We use the benchmark parameters of Table 1. Steady state values are shown in Table 4. The first column shows values for the status quo, while the second column displays the values after the reform. As expected the level of capital, labor productivity and even the wage net of taxes are higher in the long run if the reform takes place. The labor tax has to increase from 23% to 37% in order to finance the capital tax cut.

Higher output in the long run does not necessarily imply that suppressing capital taxes should lead to higher welfare. Consumption and leisure are lower immediately after the reform (to allow for higher investment and the accumulation of capital), which is a cost of the reform that is ignored
in steady state calculations. Therefore the transition has to be analyzed explicitly.

The welfare benefits of changing the tax system are evaluated, as if is standard, by the permanent increase in consumption that would leave each individual indifferent between the status quo and the reform, keeping leisure unchanged. More precisely, letting \( \{ c_{j,t}^A, l_{j,t}^A \} \) and \( \{ c_{j,t}^B, l_{j,t}^B \} \) be the equilibrium allocations before and after the reform, the welfare gain for agent \( j \) is given by \( \pi_j \) that satisfies

\[
\sum_t \delta^t \left[ u((1 + \pi_j/100) c_{j,t}^A) + v(l_{j,t}^A, \mu^t) \right] = \sum_t \delta^t \left[ u(c_{j,t}^B) + v(l_{j,t}^B, \mu^t) \right].
\]

The last line of Table 4 shows that we find a welfare gain for the homogeneous agent of \( \pi_H = 5.9\% \). This gain is similar to the one reported in previous papers, slightly larger due to the high benchmark capital taxes.

### 4.1.2 Emphasizing the efficiency gains of suppressing capital taxes

It has been pointed out that the benefits of suppressing capital taxes in a homogeneous agent model may disappear if the curvature of the utility function with respect to consumption is sufficiently high. To the extent that we are not sure about the true curvature, this brings a word of caution to the efficiency benefits of actually suppressing capital taxes. We reexamine this result and we find that, under homogeneous agents, if the capital/output ratio is kept constant, there is a gain from suppressing capital taxes even for high risk aversion. This reinforces the view that suppressing capital taxes is a good policy from the point of view of aggregate efficiency and it will be important for the robustness exercises that we perform in section 5.

The reason that higher curvature in the utility function may limit the benefits of suppressing capital taxes is the following. Increasing \(-\gamma_c\) has two effects: first, it causes labor to be more elastic, increasing the costs of a higher labor tax after the reform; second, the initial drop in consumption caused by the cut in capital taxes is more costly if \( u \) has more curvature. Indeed, Chari, Christiano and Kehoe (1994) show that if relative risk aversion is \( \gamma_c = -8 \) suppressing capital taxes would cause a loss in utility in a homogeneous agent case. We find a similar result in Table 5: even though \( \gamma_c = -8 \) still shows a small gain in utility due to our slightly different model and calibration, a utility loss is experienced from suppressing capital taxes when \( \gamma_c = -11 \).
But increasing $-\gamma_c$ and leaving all other parameters constant has some undesirable effects for the calibration of the economy. In the model in deviations from trend the effective discount factor becomes $\tilde{\delta} \equiv \delta \mu^{\gamma_c+1}$ (see appendix 2). Therefore the effective discount factor is lower as $-\gamma_c$ increases and the capital output ratio goes down if all remaining parameters are left unchanged. Table 5 shows that the steady state capital for $\gamma_c = -11$ is about one fifth of the capital for log utility. This means that for $\gamma_c = -11$ labor at the status quo is much less productive than in the log utility case and it explains why the labor tax rate needs to be raised much more (to 70% instead of 37%) in order to compensate for suppressing capital taxes when $\gamma_c = -11$. Therefore changing $-\gamma_c$ relative to the benchmark case not only influences the elasticity of labor and the utility cost of the transition, but it also increases the size of the distortion that labor has to suffer if capital taxes disappear.

In order to analyze the effects of increasing risk aversion in isolation we prefer to increase risk aversion without modifying the capital output ratio. For this purpose we change the scaling constant $A$ in the production function to keep the same capital output ratio for different $\gamma_c$. The results are shown in Table 6. We now find that the gains from suppressing capital taxes are indeed lower for high risk aversion, but the homogeneous consumer never looses utility from suppressing capital taxes, even for very high risk aversion.

In summary, the example discussed by Chari, Christiano and Kehoe certainly serves their purpose, namely, to show how ignoring the transition for optimal capital and labor taxes can result in an even lower utility than at the status quo. But suppressing capital taxes is always beneficial in terms of aggregate efficiency if the calibration is adjusted appropriately.

4.2 Heterogeneous agents

The main goal of this paper is to study the welfare effects of eliminating capital taxes when agents are heterogeneous. Since this is a model where aggregation does not obtain it is not obvious that suppressing capital taxes will lead to higher aggregate output as it did in the model with homogeneous agents. However, probably because of the presence of complete markets, aggregate variables in the heterogeneous agent case behave in a similar way as in the homogeneous agent model of the previous subsection. Therefore, output, investment, capital, gross wages and wages net of taxes increase in steady state under heterogeneity. This can be seen in Figure 2, representing
the evolution of some variables after the reform. Capital nearly doubles and it is halfway through the new steady state in about 30 quarters. Investment is much higher than in the status quo, as it is even higher in the first few periods than in the new steady state after the reform. Wages increase by about 25%. As expected consumption is very low in the initial periods. Hours worked are higher at the beginning of the transition, showing that the effect of the reform is to induce a higher labor supply. The last two graphs show how consumption and hours worked are very different for agents 1 and agent 5.

But under heterogeneous agents abolishing capital taxes also has a redistributive effect. Lower capital taxes mean that a larger part of the tax bill in present discounted terms is paid by agents with a high wage/wealth ratio. This may offset the gains from the higher aggregate efficiency for these agents. Since we labelled \( j = 1 \) the agent with the lowest wage/wealth ratio, a reduction in capital taxes is likely to lower the relative consumption of agent \( j = 5 \). Therefore, according to equation (12), suppressing capital taxes is likely to increase the ratios \( \lambda_j = c_{j,t}/c_{5,t} \) for \( j = 1, \ldots, 4 \).

Table 7 shows the effects of this redistribution of wealth by reporting equilibrium ratios of consumption and labor for different capital taxes, with labor taxes adjusted to maintain the same level of government spending in all cases. The first row corresponds to the status quo capital tax, so it simply describes the equilibrium consumption ratios \( \lambda_j = \frac{c_j}{c_n} \) and labor ratios before the reform. As expected \( \lambda_j \) is lower for higher \( j \), as we consider agents with a higher wage/wealth ratio. As in the data the cross sectional variation of hours worked is much smaller than the cross-section variation of consumption, justifying our choice of a large \(-\gamma_t\) to match fact b) in subsection 3.3.  

The last row of Table 7 corresponding to \( \tau^k = 0 \) shows the effects of suppressing capital taxes. We see that all groups \( j = 1, \ldots, 4 \) will consume more and work less, relative to agent 5, after the reform. Furthermore, the one who benefits the most is agent \( j = 1 \) with the lowest wage/wealth ratio: while his consumption ratio increases by 70% (it goes from 3.23 before the reform to 5.56) the consumption ratio of the agent in the middle quintile, 

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Notice, however, that the level of hours worked across agents does not reproduce the data: in the model hours increase with \( j \) but they decrease with \( j \) in the data. Ideally one would study the effect of suppressing capital taxes with a model that matches this basic observation, but this would mean going away from the standard neoclassical model so we leave this exercise for future research. The differences of hours worked across agents, in any case, are not large so one would not expect large changes in the results on the gains from suppressing capital taxes.

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\(^{18}\)Notice, however, that the level of hours worked across agents does not reproduce the data: in the model hours increase with \( j \) but they decrease with \( j \) in the data. Ideally one would study the effect of suppressing capital taxes with a model that matches this basic observation, but this would mean going away from the standard neoclassical model so we leave this exercise for future research. The differences of hours worked across agents, in any case, are not large so one would not expect large changes in the results on the gains from suppressing capital taxes.
$j = 3$, only increases by about 40% (from 2.1 before the reform to 2.94). It is clear, therefore, that lowering capital taxes has a redistributive effect and it lowers the relative consumption of agents with a high wage/wealth ratio such as agents $j = 5$. This shows that the reform redistributes wealth in favor of the agents with a low wage/wealth ratio.

The middle rows of table 7 report the effect of four less radical reforms, each reform consisting of cutting the capital tax rate by an additional 20%. We see the effect is monotone: all $\lambda$’s increase as capital taxes decrease. These rows will serve to understand the next table.

It is clear from Table 7 that lowering capital taxes increases inequality. But since there is a gain in aggregate efficiency, as shown in Figure 2, it could happen that less wealthy agents experience a net gain from suppressing capital taxes. To resolve this issue we consider the change in welfare for each agent of suppressing capital taxes.

Table 8 shows the gains in utility from each of the possible reforms considered in the previous table. If capital taxes were completely suppressed (last row) 40% of the population would be worse off. Perhaps more importantly, agents of type 5 would experience a very large loss in welfare of 32%. Agents of type 1, on the other hand, benefit greatly from the reform.

We can see that even with a small reduction in capital taxes (first row of table 8) group $j = 5$ with the highest wage/wealth ratio would loose welfare, although the rest of the population would benefit.

These welfare comparisons confirm that eliminating capital income taxation at the expense of labor income taxation is not Pareto improving. If capital taxes were suppressed, the distributional issues dominate the gain in aggregate efficiency in the sense that they are not Pareto improving and a large part of the population may experience a loss in utility. The loss in welfare for these agents is very high, specially if compared with those reported on the aggregate effects of changes in fiscal or monetary policy using dynamic equilibrium models. We will see in section 5 that these features are very robust to changes in parameter values.

In Table 8 the median voter (agent $j = 3$) does gain from any permanent reduction in capital taxes, but this hardly suggests that suppressing capital taxes at the expense of labor taxes is likely to occur in a modern democracy. First of all because given the very large loss in utility experienced by a large part of the population the reform we consider would be difficult to implement. In modern democracies it is not only the median voter’s opinion that matters, as it is difficult to implement a reform in practice if it hurts signifi-
cantly a sufficiently large part of the population. Second, in the robustness experiments of section 5 we will find that for slightly different parameter values the median voter often loose from suppressing capital taxes. Therefore it is not clear ex-ante that even the median voter will favor such a reform.

5 Sensitivity Analysis

Table 9 shows the welfare gains of all agents from suppressing capital taxes when several parameters of the benchmark case are changed one at a time. In all cases we adjust $B$ so that the hours worked are one third of total time endowment. The column labelled $k_{stst}$ refers to the capital steady state before the reform. The next column shows government spending over output before the reform. Column $\tau^l$ contains the labor tax that would operate after the reform. Column $\pi_H$ indicates welfare improvement in the representative agent version of the model. This can be thought of as a rough measure of the aggregate efficiency gain of suppressing capital taxes for each set of parameters, although we have to remember that strictly speaking this does not show the aggregate gains in the model since we do not have aggregation in our model. Columns $\pi_j$ for $j = 1, ..., 5$ show the utility gains of each agent.

We first consider changes in relative risk aversion $-\gamma_c$. Robustness in this dimension is relevant because relative risk aversion is often thought to be larger than one, with values between 2 and 4 much more widely accepted in the literature. For each $\gamma_c$ we adjust the constant $A$ in the production function so as to keep the capital stock constant for the reasons explained in section 4.1.2.

Recall that the row for $\gamma_c = -1$ corresponds to the benchmark case. We find that the pattern of gains and losses across agents is similar to the one of the benchmark case but the size of welfare gains or losses is exaggerated by increasing risk aversion. Only the results up to $\gamma_c = -4$ are reported because the algorithm failed to converge.

\footnote{The following caveat is in order. While it is clear that for log utility the wage/wealth ratio is the relevant criterion for splitting the sample, with higher risk aversions this is not strictly speaking correct, since consumption may less than double when the wage doubles. Nevertheless we maintain the calibration of heterogeneity parameters based on wage/wealth ratios. This is for three reasons: 1- comparability, 2- simplicity, 3- because this is probably a reasonable approximation to the actual equivalent agents. Probably, capturing the relevant joint distribution exactly with high risk aversion requires a more elaborate criterion than the one used in the rest of the paper.}

\footnote{Only the results up to $\gamma_c = -4$ are reported because the algorithm failed to converge}
are much larger as $-\gamma_c$ increases. Now agent 5 loses 60% of his utility for $\gamma_c = -3$. In addition we find that the median voter $j = 3$ experiences a mild utility loss for reasonable values of relative risk aversion such as 3 or 4. We conclude that for more reasonable values of risk aversion the redistributive effects of suppressing capital taxes are much larger than for log utility and that the median voter will be against the reform for likely values of risk aversion.\textsuperscript{21}

It is intuitive that higher risk aversion should increase the inequality effects of suppressing capital taxes. First of all there is the standard effect of making the initial drop in consumption more costly, which means that the efficiency gain is even lower and there is less welfare to gain from suppressing capital taxes. But it is also well known that the wage elasticity of labor is higher for higher risk aversion. This means that for higher $-\gamma_c$ labor goes down more steeply for a given increase in labor taxes and in order to meet the budget constraint the government needs a larger labor tax hike after the reform. As can be seen from Table 9, for a risk aversion of 1 we have $\tau^l = .37$ after the reform, but for risk aversion of 4 we have $\tau^l = .46$. Agents with high wage/wealth ratio have to pay more taxes when risk aversion is higher and they loose relatively more. Also, since labor is more elastic for high risk aversion, the increase in labor taxes is more distortionary and more costly in terms of welfare for the reasons usually considered in public finance taxation.

We also consider robustness to the value of $\gamma_l$. As we explained in section 4 the choice for the benchmark case is questionable because it would fail to account for the variability of hours worked across time in a stochastic version of the model; furthermore, it implies a wage elasticity of about .1 which is lower than usually estimated for the aggregate economy. We see from Table 9 that lower values of $-\gamma_l$ (and, therefore, closer to those used in the RBC literature) only exaggerate the inequality generated by suppressing capital taxes. As is well known, lower $-\gamma_l$ implies higher wage elasticity of labor and the same discussion as in the previous paragraph justifies the results. Again, for a sufficiently high elasticity the median voter $j = 3$ would now be

\textsuperscript{21}For the case considered in Chari Christiano and Kehoe (1994) where $A$ is constant for all levels of relative risk aversion we obtain even larger welfare losses for low wealth agents. For example, for $\gamma_c = -3$, we find $\pi_1 = 64.65\%$, $\pi_2 = 22.12\%$, $\pi_3 = -3.15\%$, $\pi_4 = -22.88\%$, $\pi_5 = -68.49\%$. for higher levels of risk aversion. We do not know if this is a failure of the algorithm or, more likely, this happens because there is no equilibrium with zero capital taxes, that is, there is no way to collect enough from only labor taxes in order to maintain $g$.\!
against the reform.

There is much disagreement about the relevant level of average marginal capital tax rates, so we also study the sensitivity to the tax levels in the status quo. The third panel of Table 9 considers different values for the capital tax before the reform. A lower value for $\tau^k$ in status quo causes the redistributive effect to be smaller: agents with high (low) wage/wealth ratio lose (gain) less for lower initial capital taxes. But it is also true that the aggregate gain represented by $\pi_H$ is smaller if initially the capital tax was not very high. These results are intuitive: if the capital tax is low to begin with the redistributive effect is lower, but there is less to be gained from the reform at an aggregate level. The median voter, again, would be marginally against the reform.

Crucial to our results were the heterogeneity parameters determining $\phi$ and initial wealth of each type of agent. These we calibrated by splitting our sample according to quintiles of the wage/wealth ratio and by removing effects from life cycle. Since this is a relatively non-standard criterion to measure inequality it is worthwhile to explore the effects of the reform using the more traditional criterion of wealth inequality and without adjusting for life cycle. We use the data in the second panel of Table 2 and report the results for this calibration in the fourth panel of Table 9. Again, the large changes in utility are reinforced and the median voter would be against the reform.

It is clear that the results are very robust. If anything, the benchmark calibration understates the redistributive effects of suppressing capital taxes.

6 Conclusion

The Chamley/Judd result says that in a model with heterogenous agents and distortionary taxes all Pareto optimal allocations have the property that capital taxes disappear in the long run, even if the planner cares mostly about workers. One may wonder if this long run result could be implemented immediately and if suppressing capital taxes could benefit all agents. We explore whether this is the case in a model with heterogeneous agents. Our model is as close as possible to that of Chamley so as to explore in isolation the effects of heterogeneity.

We find that if capital taxes were suppressed and the lost revenue would be compensated by higher labor taxes the welfare of at least 20% of the
population would go down dramatically. For all the experiments we have performed 40% of the population would be worse off. This happens despite the fact that there is always an aggregate efficiency gain from suppressing capital taxes. This result is robust to different parameter values and to the criterion for splitting the sample. For some parameter values, including reasonably high values of relative risk aversion, agents in the lowest quintile of the population lose 60% of their utility. For reasonable values of risk aversion the utility loss of workers is even larger.

The effect of suppressing capital taxes on the median voter (our type 3 agent) is always quite small. In fact, whether the median voter would gain or loose from the tax reform depends very much on the parameter values chosen for the model. We find that for reasonable levels of risk aversion the median voter would loose from the reform but for log utility it would gain. Therefore, from the vantage point of traditional political economy the model does not give strong predictions about whether such tax reform would be approved in a once-and-for-all referendum. In any case, the loss in welfare for the lowest quintile is so large that it is not surprising that such a reform has not even been considered in actual policy discussions.

Our model is chosen as close as possible to that of Lucas (1990) in order to study the effects of heterogeneity in isolation. We find that there is an aggregate efficiency gain even with very high risk aversions, but that in this case the redistributive effect is even larger.

In this sense, for the issue of capital taxation, the problem of distribution of wealth is several orders of magnitude more important than other traditional topics of macroeconomics. We think that research on distributive and efficiency issues in dynamic equilibrium models is, therefore, a very promising avenue for research.

Capital taxes in the real world are indeed very high, it is probably the case that if capital taxes are lowered this may result in a widespread gain in efficiency. But transferring the burden to labor taxes is unlikely to be implemented in democratic societies, where large minorities have a strong influence in blocking reforms. Dynamic fiscal policy analysis with equilibrium models should help to find ways that capital taxes can be lowered, thereby achieving higher aggregate efficiency, and at the same time insuring that most of the population can benefit from such a reform.

In addressing the calibration of the model we argue that the relevant dimension is not the distribution of total wealth, but the wage/wealth ratio across agents. Therefore the heterogeneity parameters in our model attempt
to reproduce the features of the distribution of wage/wealth ratios.

Our intention was to examine the effect of heterogeneity in isolation, therefore we stayed as close as possible to the model of Chamley throughout the paper. Along the way we found a number of empirical issues that this model does not address and that should be resolved in order to examine the effects of reforms in factor taxation. For example, we point that the standard neoclassical model cannot match the observed volatility of hours worked and consumption both across time and the variation of these variables across agents at the same time. Several modifications of the model may help in resolving this puzzle such as introducing time non-separability in leisure, endogenous human capital accumulation, the introduction of both an intensive and extensive margin in a model with uninsurable risk. These are left for future research.

Other issues in the calibration of heterogeneity demand a more careful analysis. We treated all families in the same way, but the propensity to consume and work of a family with two children is not the same as that of a single. A better modelling of families of different types would be crucial. Finally, the model has a difficult time explaining total wealth held by all agents and total capital income, due to the fact that all assets in our model yield very similar returns.

This indicates that there is enormous scope for future research in studying tradeoff between efficiency and equity when considering changes in the tax code with equilibrium models and heterogeneous agents.
APPENDIX 1: Calibration of 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. We select families that were interviewed and that kept the same head from 1984 to 1989.

Agents in the model are interpreted as households in the data, not the different individuals that compose each household.

The variables we want to calibrate are the efficiency parameters $\phi_j$, and the value of the initial capital stocks $k_{j,-1}$ for each family. For this purpose we look at wages and assets.

The PSID provides measures for average hourly wages, labor income, and several categories of non-human wealth and asset income. These are reported in Figure 1. From these measures we obtain five quintiles in the distribution of $\frac{\phi_j}{k_{j,-1}}$ ratios.

For the actual calibration we need to estimate the relative consumption of different groups of agents. For this purpose we compare the total labor and capital income of different groups and identify the ratio of income to the ratio of consumption.

PSID provides data on labor income. To measure capital income of each family 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 find the return of each particular component of non-human wealth.

1. Types of assets for which the PSID reports actual 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.

- Stocks, Mutual Funds: S&P’S common stock price index. (Dividends are reported as asset income in the category of 'cash assets').
- Total real estate\(^{23}\): we use the value calculated in Rosenthal [1988, p 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 US 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.

**APPENDIX 2: Numerical algorithm**

We now describe in detail how we solve for the equilibrium quantities after the reform that suppresses capital taxes.

At the end of section 2 we show the equations that characterize the sequence \(\{(c_{j,t}, l_{j,t})_{j=1}^{n}, k_t\}_{t=0}^{\infty}\). To allow for a numerical solution we need to convert the model in deviations from trend, in this way a steady state can exist and we can find transitions to this steady state.

\(^{22}\) All rates of return or price series were extracted from CITIBANK.

\(^{23}\) As the difference between real estate value and principal mortgage remaining.
Let deviations from trend be given by $\tilde{c}_{j,t} = c_{j,t}/\mu^t$, $\tilde{k}_t = k_t/\mu^t$, $\tilde{e}_t = e_t/\mu^t$ and so on. Standard algebra shows that these satisfy

$$
\tilde{c}_t + g + \tilde{k}_t - (1 - \tilde{d})\tilde{k}_{t-1} = A \tilde{k}_{t-1}^{\alpha} \tilde{e}_{t-1}^{1-\alpha}
$$

(14)

$$
\tilde{c}_{\alpha t} w_t (1 - \tau^t) \phi_n = B(1 - l_{n,t})^{\gamma_t}
$$

(15)

$$
\tilde{c}_{\alpha t}^{e_t} = \tilde{\delta} \tilde{c}_{\alpha t+1}^{e_t+1} ((\tilde{r}_{t+1} - d/\mu)(1 - \tau^k) + 1/\mu)
$$

(16)

for $\tilde{r}_t = r_t/\mu$, $\tilde{d} \equiv 1 - (1 - d)/\mu$ and $\tilde{\delta} \equiv \delta \mu^{\gamma_e+1}$

Notice that $\tilde{d}$ does not substitute the original depreciation rate $d$ everywhere. In particular, in the FOC with respect to capital, we have $d/\mu$ instead.

The present value budget constraints can be rewritten in terms of deviations from trend as

$$
\sum_t \delta^t \left( \frac{\tilde{c}_{n,t}}{\tilde{c}_{n,0}} \right)^{\gamma_e} \left[ \tilde{c}_{j,t} - \phi_j w_t l_{j,t} (1 - \tau^t) \right] = \tilde{c}_{j,-1} \mu (1/\mu + (\tilde{r}_0 - d/\mu)(1 - \tau^k))
$$

(17)

for $j = 1, 2, \ldots, n$

Finally, for the welfare calculations we use the equality

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

for $j = 1, 2, \ldots, n$

The numerical problem can be further simplified by noting that, for candidate values $\lambda_1, \ldots, \lambda_{n-1}$ we can use (9) to substitute out consumption and labor in (17) for agents $j = 1, \ldots, n - 1$ in terms of $\{\tilde{c}_{n,t}, l_{n,t}\}_{t=0}^{\infty}$ and the $\lambda$'s.

Therefore the numerical problem at hand reduces to the following: given $\tau^k$ and $g$, find three sequences $\{\tilde{c}_{n,t}, l_{n,t}, \tilde{k}_t\}_{t=0}^{\infty}$, plus $n$ constants $(\lambda_1, \ldots, \lambda_{n-1}, \tau^t)$ such that (14), (16), (15) hold for all $t$ and (17) hold for all $j$.

We convert this into a finite problem by fixing large $T$ and computing a sequence that satisfies:

a) (14), (16), (15) for $t = 0, \ldots, T - 1$

b) (17) for $j = 1, \ldots, n$.

c) Variables dated $t > T - 1$ are set at steady state.

Notice that a) provides $3T$ equations and b) provides $n$ additional equations. We have $3T$ unknowns in $\{\tilde{c}_{n,t}, l_{n,t}, \tilde{k}_t\}_{t=0}^{T-1}$ plus $n$ unknowns in $(\tau^t, \lambda_1, \ldots, \lambda_{n-1})$. 29
This gives $3T + n$ unknowns and the same number of equations. We know this system of equations cannot be solved exactly, for $\bar{k}_T$ cannot be at steady state unless the initial capital is at steady state, but the system can be solved approximately by various numerical solution methods for solving non-linear systems of equations. As $T \to \infty$ we can potentially obtain an arbitrarily accurate approximation. We use $T = 200$ and check with 250 for robustness. From the graphs in Figure 2 we see that this allows the solution to reach steady state.

Notice that conditional on the model being at steady state after $T$ periods infinite discounted sums involved in the calculations can be computed exactly.

It should be clear, therefore, that we do not use any aggregation result: aggregate capital and consumption are determined jointly with the $\lambda$’s. Notice that adding heterogeneity means having to solve for $3T + n$ variables instead of $3T + 1$ in the homogeneous agent case. Therefore, despite the lack of aggregation, the increase in the computational cost from adding heterogeneity is negligible.
REFERENCES


Table 1: Benchmark Calibration. Technology, utility and policy parameters.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>.36</td>
</tr>
<tr>
<td>$\delta$</td>
<td>.99</td>
</tr>
<tr>
<td>$d$</td>
<td>.02</td>
</tr>
<tr>
<td>$\gamma_c$</td>
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</tr>
<tr>
<td>$\gamma_l$</td>
<td>-10.</td>
</tr>
<tr>
<td>$\tau^t$</td>
<td>.23</td>
</tr>
<tr>
<td>$\tau^k$</td>
<td>.57</td>
</tr>
<tr>
<td>$\mu$</td>
<td>1.004</td>
</tr>
<tr>
<td>$k_{g,-1}$</td>
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</tr>
<tr>
<td>$A$</td>
<td>1</td>
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</table>

Table 2: Means and ratios by quintiles, PSID sample

<table>
<thead>
<tr>
<th>Wage/Wealth partition</th>
<th>Means by type</th>
<th>Ratios of type $i$ over type 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td>Wage</td>
</tr>
<tr>
<td>Type 1</td>
<td>2708.03</td>
<td>7.89</td>
</tr>
<tr>
<td>Type 2</td>
<td>2837.86</td>
<td>11.11</td>
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<tr>
<td>Type 3</td>
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<td>9.72</td>
</tr>
<tr>
<td>Type 4</td>
<td>2333.49</td>
<td>9.4</td>
</tr>
<tr>
<td>Type 5</td>
<td>2059.41</td>
<td>7.53</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wealth partition</th>
<th>Means by type</th>
<th>Ratios of type $i$ over type 5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours</td>
<td>Wage</td>
</tr>
<tr>
<td>Type 1</td>
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<td>15.04</td>
</tr>
<tr>
<td>Type 2</td>
<td>2858.14</td>
<td>10.31</td>
</tr>
<tr>
<td>Type 3</td>
<td>2520.16</td>
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<tr>
<td>Type 4</td>
<td>2098.94</td>
<td>6.48</td>
</tr>
<tr>
<td>Type 5</td>
<td>1898.61</td>
<td>5.9</td>
</tr>
</tbody>
</table>

Type 1 corresponds to households with a lower wage/wealth ratio or a higher wealth.
Table 3: **Heterogeneity parameters. Benchmark Economy.**

<table>
<thead>
<tr>
<th>Wage/Wealth Partition</th>
<th>Wealth Partition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\phi_1/\phi_5$</td>
<td>1.05</td>
</tr>
<tr>
<td>$\phi_2/\phi_5$</td>
<td>1.48</td>
</tr>
<tr>
<td>$\phi_3/\phi_5$</td>
<td>1.29</td>
</tr>
<tr>
<td>$\phi_4/\phi_5$</td>
<td>1.25</td>
</tr>
<tr>
<td>$k_{1,-1}/k_{-1}$</td>
<td>5.54</td>
</tr>
<tr>
<td>$k_{2,-1}/k_{-1}$</td>
<td>1.76</td>
</tr>
<tr>
<td>$k_{3,-1}/k_{-1}$</td>
<td>0.35</td>
</tr>
<tr>
<td>$k_{4,-1}/k_{-1}$</td>
<td>-0.63</td>
</tr>
<tr>
<td>$\phi_1/\phi_5$</td>
<td>2.55</td>
</tr>
<tr>
<td>$\phi_2/\phi_5$</td>
<td>1.75</td>
</tr>
<tr>
<td>$\phi_3/\phi_5$</td>
<td>1.35</td>
</tr>
<tr>
<td>$\phi_4/\phi_5$</td>
<td>1.10</td>
</tr>
<tr>
<td>$k_{1,-1}/k_{-1}$</td>
<td>10.39</td>
</tr>
<tr>
<td>$k_{2,-1}/k_{-1}$</td>
<td>0.87</td>
</tr>
<tr>
<td>$k_{3,-1}/k_{-1}$</td>
<td>-0.85</td>
</tr>
<tr>
<td>$k_{4,-1}/k_{-1}$</td>
<td>-2.76</td>
</tr>
</tbody>
</table>

Table 4: **Steady state, homogeneous agent, before and after reform**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Status Quo</th>
<th>Zero capital Tax</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\tau^k$</td>
<td>0.57</td>
<td>0</td>
</tr>
<tr>
<td>$k$</td>
<td>6.72</td>
<td>13.21</td>
</tr>
<tr>
<td>invest</td>
<td>0.16</td>
<td>0.32</td>
</tr>
<tr>
<td>GNP</td>
<td>0.98</td>
<td>1.25</td>
</tr>
<tr>
<td>$l$</td>
<td>0.333</td>
<td>0.331</td>
</tr>
<tr>
<td>$c$</td>
<td>0.57</td>
<td>0.68</td>
</tr>
<tr>
<td>$w$</td>
<td>1.89</td>
<td>2.41</td>
</tr>
<tr>
<td>$r$</td>
<td>0.05</td>
<td>0.03</td>
</tr>
<tr>
<td>$\tau^l$</td>
<td>0.23</td>
<td>0.37</td>
</tr>
<tr>
<td>$w(1-\tau^l)$</td>
<td>1.46</td>
<td>1.52</td>
</tr>
<tr>
<td>$g$</td>
<td>0.25</td>
<td>0.25</td>
</tr>
<tr>
<td>$\pi_H$</td>
<td></td>
<td>5.90%</td>
</tr>
</tbody>
</table>
Table 5: **Utility gain from suppressing capital taxes, homogeneous agent, varying $\gamma_c$.**

<table>
<thead>
<tr>
<th>$-\gamma_c$</th>
<th>$k_{stat}$</th>
<th>$g$</th>
<th>$\tau^l$</th>
<th>$\pi_H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>7.77</td>
<td>0.26</td>
<td>0.35</td>
<td>6.34%</td>
</tr>
<tr>
<td>1</td>
<td>6.72</td>
<td>0.25</td>
<td>0.37</td>
<td>5.90%</td>
</tr>
<tr>
<td>3</td>
<td>4.17</td>
<td>0.21</td>
<td>0.45</td>
<td>4.25%</td>
</tr>
<tr>
<td>5</td>
<td>2.88</td>
<td>0.17</td>
<td>0.51</td>
<td>2.97%</td>
</tr>
<tr>
<td>8</td>
<td>1.87</td>
<td>0.12</td>
<td>0.61</td>
<td>1.39%</td>
</tr>
<tr>
<td>11</td>
<td>1.33</td>
<td>0.08</td>
<td>0.70</td>
<td>-0.17%</td>
</tr>
</tbody>
</table>

The first column refers to the parameter varied. Columns 2 - 5 indicate how the calibration and results change for the homogeneous agent case. $\tau^l$ is the labor tax rate after suppressing capital taxes in this case, while $\pi_H$ measures the welfare gain when agents are homogeneous.

Table 6: **Utility gain from suppressing capital taxes, homogeneous agent, varying $\gamma_c$, keeping $K/L$ constant**

<table>
<thead>
<tr>
<th>$-\gamma_c$</th>
<th>$k_{stat}$</th>
<th>$g/y$</th>
<th>$\tau^l$</th>
<th>$\pi_H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>6.72</td>
<td>0.25</td>
<td>0.35</td>
<td>6.31%</td>
</tr>
<tr>
<td>1</td>
<td>6.72</td>
<td>0.25</td>
<td>0.37</td>
<td>5.90%</td>
</tr>
<tr>
<td>3</td>
<td>6.72</td>
<td>0.27</td>
<td>0.44</td>
<td>4.52%</td>
</tr>
<tr>
<td>4</td>
<td>6.72</td>
<td>0.27</td>
<td>0.46</td>
<td>4.05%</td>
</tr>
<tr>
<td>5</td>
<td>6.72</td>
<td>0.28</td>
<td>0.47</td>
<td>3.69%</td>
</tr>
<tr>
<td>8</td>
<td>6.72</td>
<td>0.28</td>
<td>0.50</td>
<td>3.06%</td>
</tr>
<tr>
<td>11</td>
<td>6.72</td>
<td>0.29</td>
<td>0.52</td>
<td>2.71%</td>
</tr>
<tr>
<td>14</td>
<td>6.72</td>
<td>0.29</td>
<td>0.53</td>
<td>2.20%</td>
</tr>
<tr>
<td>18</td>
<td>6.72</td>
<td>0.30</td>
<td>0.54</td>
<td>0%</td>
</tr>
<tr>
<td>22</td>
<td>6.72</td>
<td>0.30</td>
<td>0.55</td>
<td>0%</td>
</tr>
</tbody>
</table>

The first column refers to the parameter varied. Columns 2 - 5 indicate how the calibration and results change for the homogeneous agent case. $\tau^l$ is the labor tax rate after suppressing capital taxes in this case, while $\pi_H$ measures the welfare gain when agents are homogeneous.
Table 7: Consumption and labor ratios

<table>
<thead>
<tr>
<th>New $\tau^k$</th>
<th>$c_1/c_5$</th>
<th>$c_2/c_5$</th>
<th>$c_3/c_5$</th>
<th>$c_4/c_5$</th>
<th>$l_1/l_5$</th>
<th>$l_2/l_5$</th>
<th>$l_3/l_5$</th>
<th>$l_4/l_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.57</td>
<td>3.23</td>
<td>2.77</td>
<td>2.10</td>
<td>1.77</td>
<td>0.95</td>
<td>0.94</td>
<td>0.92</td>
<td>0.89</td>
</tr>
<tr>
<td>0.456</td>
<td>3.57</td>
<td>3.00</td>
<td>2.21</td>
<td>1.82</td>
<td>0.95</td>
<td>0.93</td>
<td>0.92</td>
<td>0.88</td>
</tr>
<tr>
<td>0.342</td>
<td>3.85</td>
<td>3.11</td>
<td>2.31</td>
<td>1.88</td>
<td>0.95</td>
<td>0.93</td>
<td>0.91</td>
<td>0.88</td>
</tr>
<tr>
<td>0.228</td>
<td>4.34</td>
<td>3.43</td>
<td>2.47</td>
<td>2.00</td>
<td>0.94</td>
<td>0.93</td>
<td>0.91</td>
<td>0.87</td>
</tr>
<tr>
<td>0.114</td>
<td>4.76</td>
<td>3.67</td>
<td>2.62</td>
<td>2.10</td>
<td>0.94</td>
<td>0.92</td>
<td>0.90</td>
<td>0.86</td>
</tr>
<tr>
<td>0</td>
<td>5.56</td>
<td>4.11</td>
<td>2.94</td>
<td>2.28</td>
<td>0.94</td>
<td>0.92</td>
<td>0.90</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Table 8: Welfare gains in benchmark case

<table>
<thead>
<tr>
<th>New $\tau^k$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
<th>$\pi_4$</th>
<th>$\pi_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.456</td>
<td>6.67%</td>
<td>3.56%</td>
<td>2.22%</td>
<td>5.70%</td>
<td>-4.05%</td>
</tr>
<tr>
<td>0.342</td>
<td>12.38%</td>
<td>5.88%</td>
<td>3.08%</td>
<td>-0.07%</td>
<td>-9.90%</td>
</tr>
<tr>
<td>0.228</td>
<td>17.52%</td>
<td>7.44%</td>
<td>3.08%</td>
<td>-1.79%</td>
<td>-16.86%</td>
</tr>
<tr>
<td>0.114</td>
<td>22.33%</td>
<td>8.50%</td>
<td>2.54%</td>
<td>-4.13%</td>
<td>-24.51%</td>
</tr>
<tr>
<td>0</td>
<td>26.98%</td>
<td>9.26%</td>
<td>1.62%</td>
<td>-6.89%</td>
<td>-32.60%</td>
</tr>
</tbody>
</table>
Table 9: Sensitivity analysis: Effects of parameter variations on calibration and welfare gains of fully suppressing capital taxes

<table>
<thead>
<tr>
<th>$-\gamma_c$</th>
<th>$k_{stat}$</th>
<th>$g/y$</th>
<th>$\tau^l$</th>
<th>$\pi_H$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
<th>$\pi_4$</th>
<th>$\pi_5$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>6.72</td>
<td>0.25</td>
<td>0.35</td>
<td>6.31%</td>
<td>20.27%</td>
<td>7.94%</td>
<td>3.01%</td>
<td>-1.92%</td>
<td>-18.56%</td>
</tr>
<tr>
<td>1</td>
<td>6.72</td>
<td>0.25</td>
<td>0.37</td>
<td>5.90%</td>
<td>26.98%</td>
<td>9.26%</td>
<td>1.62%</td>
<td>-6.89%</td>
<td>-32.60%</td>
</tr>
<tr>
<td>3</td>
<td>6.72</td>
<td>0.27</td>
<td>0.44</td>
<td>4.52%</td>
<td>51.09%</td>
<td>17.19%</td>
<td>-2.53%</td>
<td>-19.18%</td>
<td>-60.48%</td>
</tr>
<tr>
<td>4</td>
<td>6.72</td>
<td>0.27</td>
<td>0.46</td>
<td>4.05%</td>
<td>73.28%</td>
<td>22.12%</td>
<td>-3.77%</td>
<td>-22.88%</td>
<td>-66.64%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$-\gamma_l$</th>
<th>$k_{stat}$</th>
<th>$g$</th>
<th>$\tau^l$</th>
<th>$\pi_H$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
<th>$\pi_4$</th>
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<tbody>
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<td>15</td>
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<td>0.37</td>
<td>6.05%</td>
<td>26.12%</td>
<td>9.03%</td>
<td>1.74%</td>
<td>-6.36%</td>
<td>-30.98%</td>
</tr>
<tr>
<td>10</td>
<td>6.72</td>
<td>0.25</td>
<td>0.37</td>
<td>5.90%</td>
<td>26.98%</td>
<td>9.26%</td>
<td>1.62%</td>
<td>-6.89%</td>
<td>-32.60%</td>
</tr>
<tr>
<td>1</td>
<td>6.72</td>
<td>0.25</td>
<td>0.38</td>
<td>4.32%</td>
<td>57.07%</td>
<td>9.72%</td>
<td>-6.82%</td>
<td>-23.15%</td>
<td>-61.58%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>$\tau^k$</th>
<th>$k_{stat}$</th>
<th>$g$</th>
<th>$\tau^l$</th>
<th>$\pi_H$</th>
<th>$\pi_1$</th>
<th>$\pi_2$</th>
<th>$\pi_3$</th>
<th>$\pi_4$</th>
<th>$\pi_5$</th>
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</thead>
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<td>40</td>
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<td>0.23</td>
<td>0.33</td>
<td>1.74%</td>
<td>12.58%</td>
<td>3.41%</td>
<td>-0.55%</td>
<td>-4.99%</td>
<td>-18.74%</td>
</tr>
<tr>
<td>30</td>
<td>10.31</td>
<td>0.21</td>
<td>0.30</td>
<td>0.74%</td>
<td>7.78%</td>
<td>1.81%</td>
<td>-0.78%</td>
<td>-3.68%</td>
<td>-12.75%</td>
</tr>
<tr>
<td>20</td>
<td>11.41</td>
<td>0.20</td>
<td>0.27</td>
<td>0.24%</td>
<td>4.39%</td>
<td>0.86%</td>
<td>-0.67%</td>
<td>-2.39%</td>
<td>-7.79%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Wealth Partition</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.72</td>
</tr>
</tbody>
</table>

The first column refers to the parameter varied. Columns 2 - 5 indicate how the calibration and results change for the homogeneous agent case. $\tau^l$ is the labor tax rate after suppressing capital taxes in this case, while $\pi_H$ measures the welfare gain when agents are homogeneous.
Figure 1: Sample wages and wealth

The wealth and wage ranges have been chosen for a better graphical representation of the diversity of wage/wealth ratios. These ranges leave out 12% of the sample. The positively sloped line shows how the sample would be split in two parts according to the wage/wealth criterion. The vertical line shows the split in two parts according to wealth.
Wages

Consumption

Labor (hours)