ON THE DISTRIBUTIONAL EFFECTS OF REDUCING CAPITAL TAXES*

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This article asks whether household heterogeneity and market incompleteness have quantitatively important implications for the welfare effects of tax changes. We compare a representative-agent economy to an economy in which households face idiosyncratic uninsurable income risk. The income process is consistent with empirical estimates and implies a realistic wealth distribution. We find that capital tax cuts imply large welfare gains in the representative-agent economy. However, when households are heterogeneous, substantial redistribution during transition means that only a minority will support capital tax cuts, whereas most households can expect large welfare losses.

1. INTRODUCTION

The goal of this article is to assess the consequences of changing the mix between labor and capital income taxation for allocations and welfare. Much of the previous literature has studied this issue within a representative-agent framework, and concluded that significant welfare gains can be obtained from eliminating capital income taxes.[2] However, although the representative-agent paradigm delivers clear policy prescriptions, it abstracts from heterogeneity and asset market incompleteness. In most economies, capital income is much more unevenly distributed than labor income, and the cross-sectional correlation between capital and labor income is low.[3] Changes in the mix between capital and labor income taxes will thus redistribute the tax burden across households, and tax reforms will generally not be Pareto improving.[4] Furthermore, the assumption of complete markets

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[2] See, for example, Lucas (1990). Lucas builds on the seminal work on optimal taxation in the complete-markets infinite-horizon setting by Judd (1985) and Chamley (1986).

[3] For data on wealth and earnings inequality in the United States, see Días-Giménez et al. (1997). They report a wealth–earnings correlation of 0.23 for 1992.

[4] Examples of experiments in which some agents gain and some lose from changing capital taxes include Auerbach and Kotlikoff (1987) and Garcia-Milà et al. (1995, 1996). Chamley (2001) is able to characterize tax reforms that leave all households better off, by focusing on tax changes pre-announced

has been seriously challenged by many empirical studies.[5] If asset markets are incomplete, then changing the tax mix will change the amount of insurance against idiosyncratic risk provided in equilibrium through the tax system and through buffer-stock saving behavior. In this article we ask whether introducing heterogeneity and market incompleteness are likely to have quantitatively important implications for the welfare effects of tax changes, or whether the lessons from the representative-agent framework survive more or less intact.

To answer this question we study two economies. Our benchmark is the workhorse incomplete-markets model developed by Bewley (1986), Huggett (1993), and Aiyagari (1994a). Here households differ endogenously in terms of their asset/labor income composition because of idiosyncratic uninsurable earnings shocks. In our second economy there are no idiosyncratic earnings shocks, but the (exogenous) distribution of wealth at the time of the tax reform is assumed identical to that in the benchmark model. We call this the no-earnings-risk economy. At the aggregate level, the response of the no-earnings-risk economy to tax changes is observationally equivalent to the response in a representative-agent framework.

To quantitatively assess the importance for welfare issues of (i) heterogeneity and (ii) market incompleteness we perform the following accounting exercise. For each reform we consider, we compare the expected welfare gain for the representative agent (i.e., a household with mean wealth in the no-earnings-risk economy) with (i) the average expected gain across all households in the no-earnings-risk economy and (ii) the average expected gain in the benchmark economy. The tax reforms we study are permanent unanticipated changes in the capital tax rate. The labor tax rate is simultaneously adjusted to maintain long-run budget balance.

We emphasize two distinctive features of our analysis, which have important implications for interpreting our welfare results. First, we explicitly take into account transitional dynamics. Pure steady-state welfare comparisons are very misleading (as we will show) in part because tax changes imply substantial redistribution in the short run.[6] Second, our calibration strategy is designed to ensure that the amount of the total tax burden that is redistributed as a result of tax reform is realistic. In particular, we construct an earnings process that satisfies two criteria: (i) The implied wealth distribution closely resembles that observed in the United States and (ii) the labor income uncertainty is consistent with empirical estimates from the Panel Study of Income Dynamics. We consider our ability to construct such an earnings process to constitute a significant contribution to the literature on wealth and income inequality. Although various authors have specified processes

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so far in advance that a household's expected welfare gain is independant of its current income and wealth. Note that a common assumption in all these articles is that households cannot insure against the risk of tax changes. This is a necessary condition for tax changes to have asymmetric welfare effects.

[5] See Attanasio and Browning (1995) for a discussion, and Hayashi et al. (1996) and Attanasio and Davis (1996) for recent emprical work on risk sharing.

[6] As an alternative to our choice of rather simple tax reforms, we could have attempted to characterize optimal policy when tax rates may be freely chosen at each future date. The problem with the optimal taxation approach is that it is generally very difficult to characterize transition outside the representative-agent framework. Aiyagari (1995) describes the optimal taxation (Ramsey) problem for an incomplete-markets economy similar to ours, but only characterizes the final steady state.

for earnings that satisfy one of the two criteria, this is the first article in which the earnings process satisfies both.[7]

Our main result is that both heterogeneity and market incompleteness are quantitatively very important for the welfare effects of tax changes. One reform that illustrates this involves moving from the current calibrated U.S. capital income tax rate of 39.7% to a capital income tax rate of 0%. Eliminating capital income taxation is a natural benchmark because this policy would be optimal in a representative-agent economy. The reason is that our assumption that labor is supplied inelastically means that this policy would amount to a shift to lump-sum taxation.[8] We compute the expected welfare gain for the representative agent and find it to be equivalent to a permanent 1.5% increase in consumption.[9]

When household heterogeneity is introduced, however, the welfare effects of the same policy change dramatically. The average welfare gain in the no-earnings-risk economy is equivalent to a permanent 0.7% fall in consumption. When uninsurable earnings risk is introduced things look even worse; the average change in expected utility is now equivalent to a permanent 1.4% fall in consumption. Moreover, the majority of households expect to lose from eliminating capital income taxation: 73% of households would prefer to stay with current tax rates rather than eliminate capital taxation in the benchmark economy.

In order to assess the robustness of our results to specific model features, we consider two variations on the experiments described above. First, we introduce endogenous labor supply. Second, we consider replacing capital taxes with a tax on consumption rather than higher labor taxes.

With valued leisure, reducing capital taxation is even less attractive since higher labor taxes are now distortionary. On the other hand, if capital taxes are replaced with consumption taxes the policy does not look quite as bad. Nonetheless, our three main conclusions extend to both these experiments: (i) expected welfare gains vary dramatically across agents depending on their initial position in the distribution over wealth and wages, (ii) the welfare gain of the representative agent is a very poor proxy for the average welfare change, and (iii) few households support reducing capital taxes.

The rest of the article is organized as follows. Section 2 outlines the economic environment. Section 3 presents the results, and Section 4 concludes.

2. THE MODELS

We consider two model economies, one with earnings risk and one without. Both economies are populated by a continuum of infinitely lived households. Households supply labor inelastically (we consider a version with an hours choice later) and maximize the expected discounted utility from consumption. In aggregate,

[7] See Quadrini and Ríos-Rull (1997) and Castañeda et al. (2003) for discussion of previous attempts to account for wealth inequality.

[8] Of course, with exogenous labor supply there are many alternative optimal tax reforms in a representative-agent economy, since taxing initial capital is equivalent to taxing labor at any date.

[9] This is in line with Lucas' (1990) estimate of the welfare gain from eliminating capital taxation. Moreover, it is a very large gain relative, for example, to Lucas' (1987) estimate of a 0.008% gain from eliminating business cycles.

household savings decisions determine the evolution of the aggregate capital stock, which in turn determines aggregate output and the return to saving.

There is a government that finances constant government consumption by issuing one-period debt and levying taxes. From the households' perspective, debt and capital are perfect substitutes, since the one period return to both is risk free and there are no transaction costs. An equilibrium condition is that aggregate asset holdings at each date must equal the sum of the capital stock and the stock of outstanding government debt. To focus on the effects of tax changes, we abstract from aggregate productivity shocks or other sources of aggregate risk, and we hold government consumption constant throughout.

In the benchmark model economy, households face idiosyncratic labor productivity shocks, and markets that in principle could allow complete insurance against this risk do not exist. Instead, there is a single risk-free savings instrument, which enables households to partially self-insure by accumulating precautionary asset holdings, as in Huggett (1993), Aiyagari (1994a), and Aiyagari and McGrattan (1998). An important assumption is that no borrowing is permitted. This limits the ability of a low-wealth household to smooth consumption when faced with a fall in disposable income.

In the no-earnings-risk economy, by contrast, all households have the same constant labor productivity. Another difference relative to the benchmark model is that the equilibrium evolution of aggregate variables does not depend on the distribution of wealth and is the same as in a representative-agent economy. This result depends on the momentary utility function having the property that in the absence of risk, period t consumption is linear in period t wealth (see Chatterjee, 1994). The initial distribution of wealth is therefore indeterminate in this economy.

If households differed in their initial endowment of wealth but could insure against tax shocks, then in the absence of earnings risk they would share equally in any welfare gains associated with tax changes. We make the standard assumption in this type of exercise that tax reform is a zero probability event, and that households are not insured against tax risk. Thus the welfare implications of tax reform will be sensitive to the shape of the initial wealth distribution. To facilitate comparison across the two economies, we set the pre-reform wealth distribution in the no-earnings-risk economy equal to the pre-reform wealth distribution in the benchmark economy.[10]

We now give a more formal description of the benchmark economy. The no-earnings-risk economy is a special case in which all households have the same productivity. This economy-wide household productivity level is normalized to the average of that in the benchmark economy, which is 1.[11]

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[10] The aggregate capital stock in the pre-reform steady state differs across market structures (see Figure 2). Prior to imposing the incomplete-markets wealth distribution on the complete markets economy we therefore scale the distribution so that the sum of individual asset holdings equals the sum of initial steady-state aggregate capital and government debt.

[11] We do not impose a no-borrowing constraint in the no-earnings-risk economy. However, such a constraint would never be binding in this economy under capital tax reductions, which are the primary focus of the article.

The environment: Each infinitely lived household supplies $\bar{n}$ labor hours per period. A household's effective labor supply depends both on the hours it works and on its labor productivity, which is stochastic. At each date, household productivity takes one of $l < \infty$ values in the set E. Productivity evolves through time according to a first-order Markov chain with transition probabilities defined by the $l \times l$ matrix Π. The probability distribution at any date t over E is represented by a vector $p_t \in R^l : p_t \geq 0$ and $\sum_{i=1}^{l} p_{it} = 1$. If the initial distribution is given by p_0 the distribution at date is given by $p_t = p_0 \Pi^t$. Given certain assumptions (which will be satisfied here), E has a unique ergodic set with no cyclically moving subsets and $\{p_t\}_{t=0}^{\infty}$ converges to a unique limit p^* for any p_0.

Let A be the set of possible values for household wealth (the endogenous individual state variable). We assume that a household's wealth at date zero, a_0, is nonnegative and that households are unable to borrow. Thus $A = R_+$. Let $(A, \mathcal{A})$ and $(E, \mathcal{E})$ be measurable spaces, where $\mathcal{A}$ denotes the Borel sets that are subsets of A and $\mathcal{E}$ is the set of all subsets of E. Let $(X, \mathcal{X}) = (A \times E, \mathcal{A} \times \mathcal{E})$ be the product space. Thus X is the set of possible individual states.

Let $e^t = \{e_0, \ldots, e_t\}$ denote a partial sequence of productivity shocks from date 0 up to date t. Let $(E^t, \mathcal{E}^t)$, $t = 0, 1, \ldots$ denote product spaces, and define probability measures $\mu^t(x_0, \cdot) : \mathcal{E}^t \to [0, 1]$, $t = 0, 1, \ldots$, where, for example, $\mu^t(x_0, e^t)$ is the probability of history e^t given initial state $x_0 \in X$.

The household's problem: The timing convention is that e_t is observed before decisions are made in period t.[12] In period 0, given the initial state $x_0 = (a_0, e_0) \in X$, the household chooses savings for each possible sequence of individual productivity shocks. Let the sequence of measurable functions $s_t : E^t \to A$, $t = 0, 1, \ldots$ describe this plan, where $s_t(e^t; x_0)$ denotes the value for a_{t+1} that is chosen in period t if the history up to t is e^t, conditional on the individual state at date 0 being x_0. Let $c_t : E^t \to R_+$ describe the associated plan for consumption.

Expected discounted lifetime utility is given by

$$(1) \qquad \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big(c_t(e^t; x_0)\big) \mu^t\big(x_0, e^t\big)$$

where β is the subjective discount factor and the momentary utility function is CRRA:

$$(2) \qquad u(c) = \frac{c^{1-\gamma}}{1 - \gamma}, \quad \gamma > 0$$

Let $t = 0$ denote the date of the tax change. At the start of period 0, a pair of new permanent proportional tax rates τ^k and τ^n are announced and implemented, where τ^k is the tax rate on asset income[13] and τ^n the tax rate on labor income.

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[12] This means that for $Z \in \mathcal{E}^0$, $\mu^0(x_0, Z) = 1$ if $e_0 \in Z$ and 0 otherwise.

[13] The tax on asset income applies to interest income on government debt and rents to capital net of a depreciation allowance.

The real pretax return at t to one unit of the asset purchased at $t - 1$ is r_t. The real return to supplying one unit of effective labor at date t is w_t.

The household budget constraints are therefore given by

$$(3) \qquad c_t(e^t; x_0) + s_t(e^t; x_0) = \left[1 + (1 - \tau^k)r_t\right]a_t + (1 - \tau^n)w_t e_t \bar{n}$$

$$\text{all } e^t \in E^t, t = 0, 1, \dots$$

where $a_{t+1} = s_t(e^t; x_0) \geq 0$.

Thus the solution to the household's problem is a set of choices $s_t(e^t; x_0) \, \forall \, t$ and $\forall \, e^t \in E^t$ such that $s_t(e^t; x_0)$ maximizes (1) subject to (3) and $s_t(e^t; x_0) \in A = R_+$, taking as given sequences for prices $\{r_t\}_{t=0}^\infty$ and $\{w_t\}_{t=0}^\infty$, tax rates τ^k and τ^n, and the initial household state $x_0 = (a_0, e_0)$.

Aggregate variables: From date 0 forward, each household's productivity evolves independently according to the Markov chain defined by Π. Thus we can interpret p_t as describing the mass of the population in each productivity state at date t, given a population of measure 1 and an initial distribution across types described by the measure p_0. Since the measure p_t converges to a unique limit, aggregate effective labor supply will therefore converge to a constant given by $\sum_{i=1}^l p_i^* e_i \bar{n}$. We assume that $p_0 = p^*$, and impose an appropriate normalization such that $\sum_{i=1}^l p_i^* e_i = 1$. Thus aggregate labor supply is equal to $\bar{n}$ for all t.

The distribution of households across both individual wealth and individual productivity at time 0 is described by a measure $\lambda : \mathcal{X} \to [0, 1]$. By integrating with respect to λ we can compute other aggregate variables. Let aggregate asset holdings at the start of period t be denoted A_t, where

$$(4) \qquad\qquad\qquad A_0 = \int_X a_0 \lambda(dx_0)$$

$$(5) \qquad A_t = \int_X \sum_{e^{t-1} \in E^{t-1}} s_{t-1}(e^{t-1}; x_0) \mu^{t-1}(x_0, e^{t-1}) \lambda(dx_0) \qquad t \geq 1.$$

Real per capita government consumption is constant and equal to G. The government makes no transfers. Government debt issued at date t is denoted B_{t+1} and is assumed to be risk free; the government guarantees the one period real return between t and $t + 1$ at the start of period t. Debt evolves according to

$$(6) \qquad B_{t+1} + \tau^k r_t A_t + \tau^n w_t \bar{n} = \left[1 + (1 - \tau^k)r_t\right]B_t + G \qquad t \geq 0$$

where B_0 is given.

Aggregate per capita output at t, Y_t, is produced according to a Cobb–Douglas technology from aggregate per capita capital at date t, K_t, and aggregate per capita labor supply:

$$(7) \qquad\qquad\qquad Y_t = K_t^\alpha \bar{n}^{1-\alpha} \qquad t \geq 0$$

where $\alpha \in [0, 1]$.

Output can be transformed into future capital, private consumption, and government consumption according to

$$(8) \qquad C_t + G + K_{t+1} - (1 - \delta)K_t = Y_t$$

where $\delta \in [0, 1]$ is the rate of depreciation.

Product and factor markets are assumed to be competitive. This and the absence of aggregate productivity shocks implies a certain one period real return to saving in the form of capital.[14] Since the real one period return to debt is also known in advance (the government guarantees it), in equilibrium the two assets must pay the same real return. This is why it is not necessary to specify the division between capital and bonds in an individual's portfolio.

Equilibrium: We assume that conditions are satisfied that guarantee that a unique invariant measure λ^* on wealth and productivity exists for the initial constant tax rates and quantity of government debt (see Aiyagari, 1994a). Corresponding to λ^* and the constant fiscal policy are an initial steady-state capital stock, value for government consumption, and factor prices. We assume that at date 0, the economy is in the steady state associated with λ^*.

A post-reform equilibrium for this economy is a pair of constant tax rates τ^k and τ^n and sequences of pretax prices $\{r_t\}_{t=0}^{\infty}$ and $\{w_t\}_{t=0}^{\infty}$ such that when all households take prices and taxes as given and solve their maximization problems, the markets for capital, labor, and output clear, and government debt is stationary. A formal definition of equilibrium is given in Appendix A.1.

2.1. *Parameterization.* The model period is one year. All parameter values used are reported in yearly terms in Table 1. The parameters relating to aggregate production and preferences are set to standard values. Capital's share in the Cobb–Douglas production function is 0.36 and the depreciation rate is 0.06. The risk aversion parameter γ is set to 1, implying logarithmic utility. The discount factor β is set to target a capital/output ratio in the benchmark economy of 3.32, which is the value reported for the United States in Cooley and Prescott (1995).

The household productivity process: The main question addressed in the article is how the presence of heterogeneity changes the welfare implications of tax reform, and the approach taken is to generate heterogeneity endogenously as a consequence of households receiving uninsurable idiosyncratic productivity shocks. Thus the specification of the process for these shocks is critical, since the choices here will determine how different households are in equilibrium, and therefore how differently they experience changes in fiscal policy. Broadly speaking, there are two desiderata for the earnings process. The first is that the persistence and variance of earnings shocks in the model are consistent with empirical estimates from panel data. The second is that the model economy generates

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[14] Of course, prior to the tax reform, households' expectations over future after-tax interest rates are incorrect.

TABLE 1

PARAMETER VALUES (YEARLY BASIS)

Capital's share α	0.36	Debt to GDP B/Y	0.67
Depreciation rate δ	0.06	Labor tax τ^n	0.269
		Capital tax τ^k	0.397
Risk aversion γ	1.0		

	Benchmark	No-Earnings-Risk	Endogenous Labor
Individual productivity process			
e_3	5.087	1.0	4.740
e_2	0.839	1.0	0.847
e_1	0.167	1.0	0.170
Π_{33}	0.900		0.900
Π_{22}	0.990		0.990
Π_{11}	0.900		0.900
Discount factor β	0.965	0.965	0.961

realistic heterogeneity in terms of the distributions of labor and capital income, so that tax reforms involve a realistic redistribution of the tax burden.

We assume that the set E has three elements, $E = \{e_1, e_2, e_3\}$, since we found this to be the smallest number of states required to match overall wealth concentration and at the same time reproduce the fact that in the data the wealth-poorest two quintiles hold a positive fraction of total wealth.[15] To reduce the number of free parameters, we assume that households cannot move between the high and low productivity levels directly, that the fraction of high productivity households equals the fraction of low productivity households, and that the probabilities of moving from the medium productivity state into either of the others are the same. These assumptions constitute four restrictions on the transition probability matrix, π_e. Since each row must add up to 1, we are left with two independent transition probabilities, Π_{11} and Π_{22}, where $\Pi_{11} = prob(e_{t+1} = e_1 | e_t = e_1)$ and $\Pi_{22} = prob(e_{t+1} = e_2 | e_t = e_2)$, and where Π_{11} and Π_{22} jointly define Π as follows:

$$(9) \qquad \Pi = \begin{bmatrix} \Pi_{11} & 1 - \Pi_{11} & 0 \\ \frac{1-\Pi_{22}}{2} & \Pi_{22} & \frac{1-\Pi_{22}}{2} \\ 0 & 1 - \Pi_{11} & \Pi_{11} \end{bmatrix}$$

Assuming that average productivity equals 1, the total number of free parameters is four: transition probabilities Π_{11} and Π_{22}, and two of the three values for productivity.

Various authors have estimated stochastic AR(1) processes for logged labor earnings using data from the PSID. Such a process may be summarized by the serial correlation coefficient, ρ, and the standard deviation of the innovation term, σ. Allowing for the presence of measurement error and the effects of observable characteristics such as education and age, work by Card (1991), Flodén

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[15] In an earlier version of the article, we constructed a two-state Markov process for earnings with the same persistence and variance that reproduced the U.S. wealth Gini.

and Lindé (2001), Hubbard et al. (1995) and Storesletten et al. (2001) indicates a ρ in the range 0.88–0.96, and a σ in the range 0.12–0.25.[16] We therefore impose two restrictions on our finite state Markov process for productivity: (i) that the first-order autocorrelation coefficient equals 0.9 and (ii) that the variance for productivity is $0.05/(1 - 0.9^2)$, corresponding to a standard deviation for the innovation term in the continuous representation of 0.224.

To generate realistic heterogeneity, we require that the Markov process for productivity be such that when the model economy is simulated, on average it reproduces certain features of the wealth distribution recently observed in the United States.[17] Given the two restrictions above, the number of remaining free parameters is two, and we therefore seek to match two properties of the empirical asset holding distribution: (i) the Gini coefficient and (ii) the fraction of aggregate wealth held by the two poorest quintiles of the population. The first criterion ensures a realistic overall wealth distribution. The second criterion is designed to capture the bottom tail of the wealth distribution, and we include it because we expect that the households most likely to lose from reducing capital taxation are those with below average wealth. Using data from the 1992 Survey of Consumer Finances, Díaz-Giménez et al. (1997) report a wealth Gini of 0.78, and find that the two poorest quintiles of the distribution combined hold 1.35% of total wealth.[18]

The calibration procedure, described in more detail in Appendix A.2, delivers parameter values that satisfy all four criteria. The finding that a model driven by a plausible earnings process can generate realistic wealth inequality is important in light of the debate as to whether uninsurable fluctuations in earnings can account for U.S. households' wealth accumulation patterns (see Quadrini and Ríos-Rull, 1997). In a recent article, Castañeda et al. (2003) are able to match more cross-sectional moments but they are not concerned with the time-series properties of labor productivity at the household level. Table 2 provides a detailed comparison between the asset holding distribution observed in the data, and the steady-state pre-reform distribution implied by the calibrated benchmark model. In addition to matching the Gini and the wealth holdings of the poorest 40% of households, the model also comes close to replicating the fraction of wealth held by the richest 10 and 20% of households.

The wealth Gini in the United States is very high because a small fraction of the population accounts for a large fraction of the wealth. In the model, productivity and wealth are positively correlated, so having a small minority of the population enjoying relatively high productivity helps generate high wealth inequality. Thus

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[16] Heaton and Lucas (1996) allow for permanent but unobservable household-specific effects, and find a much lower ρ of 0.53 and a σ of 0.25.

[17] In an earlier version of the article, we experimented with including the Gini coefficient for earnings as one of our targets. We abandoned this approach for two reasons. First, while estimates of the wealth Gini are stable across different data sources, estimates of Gini coefficients for earnings and income differ substantially. For example, Quadrini (2000) reports a Gini coefficient for income of 0.45 using PSID data, compared to 0.57 using SCF data. Second, in the model, we abstract from various types of observable heterogeneity, such as differences in education and age, that we believe are essential for explaining the observed distribution of earnings. This is why our model generates a Gini coefficient for earnings of only 0.21.

[18] Kennickell and Woodburn (1999) report a wealth Gini of 0.788 for the 1995 SCF data.

TABLE 2

DISTRIBUTIONAL PROPERTIES OF INITIAL STEADY STATE: NEW $\tau^k = 0$

	Data U.S. 1992	Model Economy		
		Benchmark	No-Earnings-Risk	Endog. Labor
Asset holding distribution in initial steady state				
Gini	0.78	0.78	0.78	0.78
99–100%	29.6	11.7	11.7	11.5
90–100%	66.1	60.0	60.0	60.5
80–100%	79.5	83.7	83.7	83.8
0–40%	1.35	1.33	1.33	1.36
Earnings Gini	0.63	0.21	0.00	0.31
Wealth–earnings correlation	0.23	0.31	0.00	0.34
Asset holding Gini in final steady state		0.73	0.70	0.73

NOTE: The data column is taken from Díaz-Giménez et al. (1997), whose data source is the 1992 Survey of Consumer Finances. "Endog. labor" denotes the extension of the benchmark economy to include a labor choice.

the calibration procedure delivers transition probabilities such that at any point in time only a small fraction of households (4.5%) have the high productivity level and the same fraction have the low productivity level. The implied values for Π_{11} and Π_{22} are 0.9 and 0.99 (see Table 1). The actual values for productivity are widely and asymmetrically spaced: The ratios between the three values are $\frac{e_3}{e_2} = 6.06$, $\frac{e_2}{e_1} = 5.02$.

Fiscal policy parameters: All remaining parameters relate to fiscal policy. The initial tax rates are calibrated to match the actual tax rates in the United States. Using the method outlined in Mendoza et al. (1994) we calculate average tax rates for the United States using OECD data (see OECD, 1999). For the period 1990–96, the capital income tax rate averaged 39.7%, while the labor income tax rate averaged 26.9%.[19]

Constant government debt B in the pre-reform steady state is set to match the 67% debt/GDP ratio observed in postwar U.S. data. Initial constant government consumption G is set to ensure budget balance and is therefore not an independent parameter choice. However, the implied ratio of government consumption to annual output is 0.22 (see Table 3) which is close to the U.S. average of 0.19 for 1990–96.

2.2. *Solution Method.* Although techniques for solving for steady states in models with incomplete markets and heterogenous agents are fairly well established, less work has been done on developing methods for solving for transition between steady states in economies with production and incomplete markets.

[19] Alternative methodologies for estimating tax rates give very similar numbers. For example, King and Fullerton (1984, Table 7.12) report an overall capital tax rate of between 37.2 and 49.9% for the United States in 1980. McGrattan (1994), using a methodology developed by Joines (1981), reports effective marginal tax rates on capital and labor for 1980 of 48.0 and 27.7%, respectively. Mendoza et al. (1994) report tax rates for 1980 of 46.9 and 27.7%.

TABLE 3
AGGREGATE PROPERTIES OF INITIAL AND FINAL STEADY STATES: NEW $\tau^k = 0$

	Benchmark		No-Earnings-Risk		Endogenous Labor		Cons. Tax
	Initial	Final	Initial	Final	Initial	Final	Final
τ^k	0.397*	0.000*	0.397*	0.000*	0.397*	0.000*	0.000*
τ^n	0.269*	0.350	0.269*	0.358	0.269*	0.361	0.269*
							$\tau^c = 0.093$
G/Y	0.216	0.196	0.219	0.194	0.217	0.200	0.196
B/Y	0.670*	0.918	0.670*	0.965	0.670*	0.957	0.975
K/Y	3.36	3.98	3.00	3.74	3.31	3.89	4.01
Y	0.647	0.711	0.606	0.687	0.681	0.736	0.714
R (% post-tax)	2.84	3.05	3.63	3.63	2.94	3.25	2.99
Post-tax asset to labor income ratio							
	0.245	0.359	0.284	0.415	0.250	0.385	0.318

NOTE: Starred values indicate exogenous parameters. "Cons. tax" denotes the experiment when capital taxes are replaced with consumption taxes rather than labor income taxes in the benchmark (exogenous labor) economy.

Exceptions are Huggett (1997) and Conesa and Krueger (1999). We describe our approach in Appendix A.3.

2.3. *Welfare Measures.*   Our measure of welfare gains and losses is standard, and we now describe it for the benchmark economy (the no-earnings-risk economy is treated analogously).[20] Let $c_t^R(e^t; x_0)$ be equilibrium consumption after history e^t for a household with initial state $x_0 = (a_0, e_0)$ in the case in which there is a tax reform at date 0. Let $c_t^{NR}(e^t; x_0)$ be the same thing in the case in which there is no tax reform. The *welfare gain* for this household as a result of the reform is defined as the constant percentage increment in consumption in the no-reform case that gives the household the same expected utility as when the reform is implemented. Thus the welfare gain is the Δ_{x_0} that solves the following equation:

$$(10) \qquad \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big(c_t^R(e^t; x_0)\big) \mu^t\big(x_0, e^t\big)$$
$$= \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big((1 + \Delta_{x_0}) c_t^{NR}(e^t; x_0)\big) \mu^t\big(x_0, e^t\big)$$

Using Equation (10) we calculate expected welfare gains for households with various initial combinations of wealth and productivity. These numbers are computed by first creating a large artificial population, each member of which starts out with the initial wealth and productivity level of interest. The economy is then simulated forward (using the appropriate equilibrium sequence for interest rates) under both scenarios for fiscal policy.

[20] In the no-earnings-risk economy, a household's welfare gain or loss is a known function of initial household wealth. In the economy with idiosyncratic earnings shocks we focus on expected welfare gains.

The *average welfare gain* for the whole economy as a result of the reform is defined as the constant percentage increase in consumption in the no-reform case that gives the same utility under a utilitarian social welfare function as when the reform is implemented. Thus the average welfare gain is the Δ that solves the following equation:

$$(11) \qquad \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big(c_t^R(e^t; x_0)\big) \mu^t(x_0, e^t) \lambda(dx_0)$$

$$= \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big((1 + \Delta)c_t^{NR}(e^t; x_0)\big) \mu^t(x_0, e^t) \lambda(dx_0)$$

We would like to be able to assess whether the changes in welfare that result from a particular tax reform occur because the reform affects the time series for aggregate variables, or because it involves a redistribution of existing resources. We therefore decompose the welfare gain into two components: an aggregate component (associated with the change in the aggregate allocation as a result of the reform) and a distributional component.

To define the aggregate component of the welfare gain, let $\hat{c}_t^R(e^t; x_0)$ denote the hypothetical value for consumption in the case of reform if the household got to consume the same fraction of aggregate consumption as in the case of no reform. Thus

$$(12) \qquad \hat{c}_t^R(e^t; x_0) = \frac{c_t^{NR}(e^t; x_0)}{C_t^{NR}} C_t^R$$

where $C_t^R (C_t^{NR})$ denotes aggregate consumption at date t in the case of reform (no reform). The aggregate component of the welfare gain for a household with initial state x_0 is then defined as the $\Delta_{x_0}^a$ that satisfies

$$(13) \qquad \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big(\hat{c}_t^R(e^t; x_0)\big) \mu^t(x_0, e^t)$$

$$= \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big((1 + \Delta_{x_0}^a)c_t^{NR}(e^t; x_0)\big) \mu^t(x_0, e^t)$$

The average aggregate component, Δ^a, is defined analogously to the average welfare gain:

$$(14) \qquad \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big(\hat{c}_t^R(e^t; x_0)\big) \mu^t(x_0, e^t) \lambda(dx_0)$$

$$= \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t u\big((1 + \Delta^a)c_t^{NR}(e^t; x_0)\big) \mu^t(x_0, e^t) \lambda(dx_0)$$

With logarithmic utility, the aggregate component of the welfare gain is the same for all households.

PROPOSITION 1. *If* $u(c) = \log(c)$, *then* $\Delta^{\mathrm{a}}_{x_0} = \Delta^{\mathrm{a}}$ *for all* $x_0 \in X$.

PROOF. See Appendix A.4.

In light of this result, we shall henceforth simply refer to Δ^{a} as the *aggregate component* of the welfare gain.

If the aggregate component of the welfare gain from a tax reform is positive, the reform will be Pareto-improving if it leaves unchanged the distribution of consumption across households at each date (i.e., so that each household gets to consume $\hat{c}^{R}_{t}(e^{t}; x_0)$). When linear tax rates are the only policy instruments, however, tax reforms will effectively redistribute income and consumption across households and thus the average welfare gain will not equal the aggregate component.

The *distributional component*, Δ^{d}, is defined as the difference between the average welfare gain and the aggregate component:

$$(1 + \Delta) = (1 + \Delta^{\mathrm{a}})(1 + \Delta^{\mathrm{d}})$$

3. RESULTS

The tax reforms we consider involve moving from the current U.S. capital income tax rate of 39.7% to a range of new capital tax rates between 0 and 50%. Figure 1 describes the average welfare gains associated with the reforms, and the decomposition of these gains into aggregate and distributional components (see above). This figure contains some key results, which we now briefly summarize prior to providing a more detailed explanation in Section 3.1.

The first thing to note is that average welfare gains are very different across economies. In particular, whereas any reduction in capital taxes is welfare improving in a representative-agent economy, large reductions reduce welfare in the no-earnings-risk economy and any reduction is welfare-reducing in the benchmark economy. Why is this so?

At the aggregate level, the response of the no-earnings-risk economy to tax changes is observationally equivalent to the response in the representative-agent framework. The aggregate components of welfare gains are thus identical in these two economies. However, the average welfare gain in the no-earnings-risk economy is not equal to the welfare gain for the representative agent. This is because reducing capital income taxes implies significant distributional losses. The average welfare gain is maximized by reducing the capital tax rate to 28.3% in the no-earnings-risk economy, whereas the representative agent would prefer to see capital taxes eliminated.

Introducing market incompleteness changes the picture in two ways. First, the aggregate components of welfare gains from reducing capital taxes are

Ave. welfare gain

Aggregate component

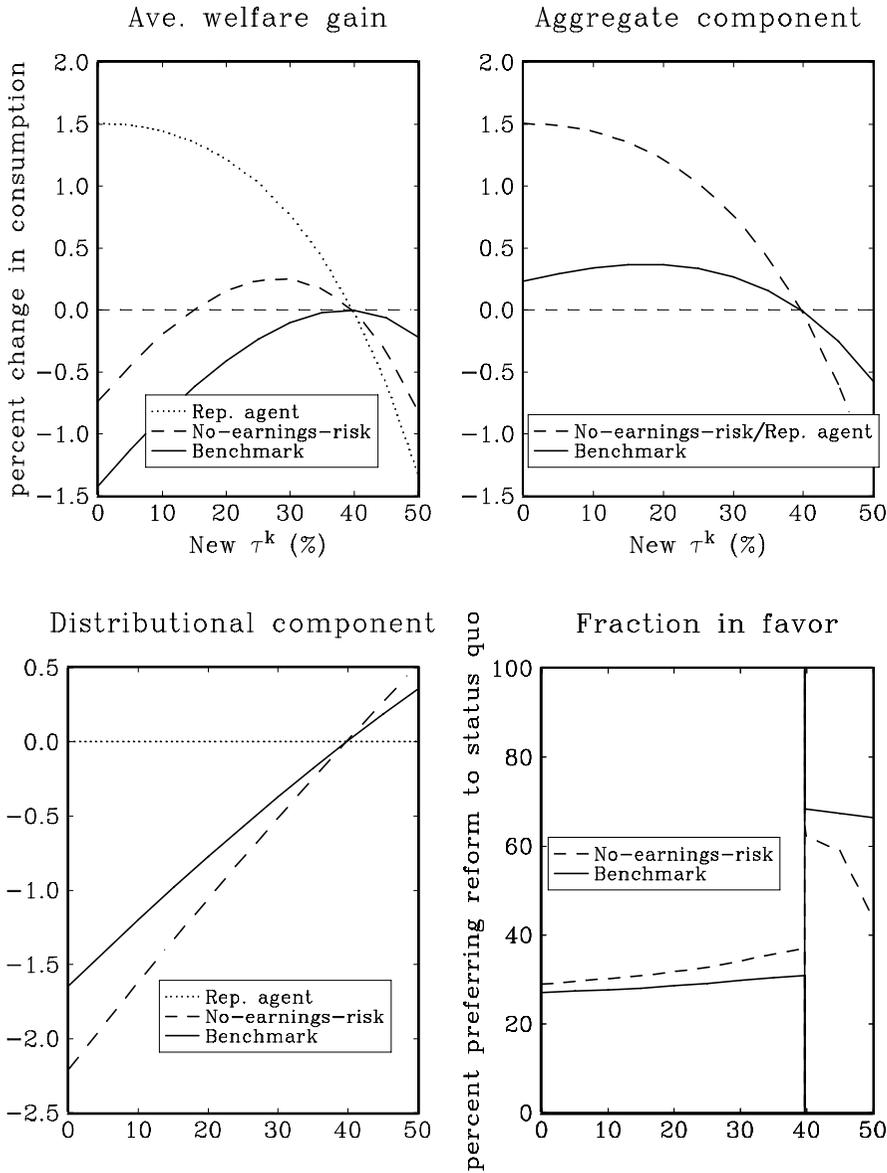## Distributional component

Fraction in favor

FIGURE 1

WELFARE EFFECTS IN BENCHMARK ECONOMY: INITIAL $\tau^k = 39.7\%$

substantially smaller; the aggregate component is maximized when the capital tax is reduced to 17.6%. Second, the distributional losses from capital tax cuts are somewhat smaller than in the no-earnings-risk economy. Nonetheless, in the benchmark model the negative distributional component outweighs the positive aggregate component for all capital tax reductions. In fact, the average welfare gain is maximized by remaining at the current U.S. capital tax rate (39.7%).

TABLE 4

AGGREGATE WELFARE EFFECTS OF TAX REFORMS: NEW $\tau^k = 0$

	Benchmark	No-Earnings-Risk	Rep. Agent	Endog. Labor	Endog. Labor, No-Earnings-Risk	Cons. Tax	Cons. Tax, No-Earnings-Risk
Welfare gain	−1.42	−0.73	1.50	−3.04	−2.11	−0.41	0.55
Aggregate component	0.23	1.50	1.50	−1.18	0.86	0.21	1.50
Distributional component	−1.65	−2.23	0.00	−1.86	−2.97	−0.62	−0.95
Fractions in favor of reform:							
Low prod.	21.2			19.3		18.2	
Medium prod.	24.5			22.7		24.6	
High prod.	86.6			79.9		100.0	
Entire pop.	27.1	29.0	100.0	25.3	27.1	27.7	34.8

NOTE: For each experiment in model economies with heterogenous agents we report results with and without idiosyncratic productivity shocks. In each case the second version is labelled, "no-earnings-risk."

The last panel of Figure 1 shows the fraction of households that ex ante prefer the various tax reforms to the status quo. In the benchmark economy, between 69 and 73% of households face an expected loss from reducing capital taxation. Capital tax cuts are only slightly more popular in the no-earnings-risk economy. Thus in both economies a substantial majority favors the current tax system over any reduction in capital income taxes.

The distribution of expected welfare gains and losses from tax reforms is very wide, so that for a large fraction of the population, expected gains are many times larger in absolute value than the average welfare gain. For example, when eliminating capital taxes in the benchmark economy, the average expected welfare loss is equivalent to a permanent 1.4% decline in consumption (see Table 4). However, for a household with medium productivity and median wealth, the expected loss is equivalent to a 4.4% cut in consumption (see Table 5).

3.1. *Interpretation.*   To understand our results, we primarily focus on the case of eliminating capital taxes. This is a natural benchmark, since our assumption that labor is inelastically supplied means that this policy is in the class of optimal tax reforms for a representative-agent economy. The results for this reform are summarized in Tables 3–5 and Figures 2 and 3.

The representative-agent economy: Following the elimination of capital taxes, aggregate consumption falls and investment rises as households take advantage of the increase in the after-tax return to saving. Aggregate consumption stays below its initial steady-state value for 12 years, but in the long run, the capital stock, output, consumption, and government debt all exceed the initial steady-state values (see Table 3). The capital stock increases by 41% during transition, which suggests large potential welfare gains in our economy. In fact, the expected welfare gain for the representative agent is equivalent to a permanent 1.5% increase in consumption (see Table 4). Of course, it should come as no surprise that long-run

TABLE 5

EXPECTED WELFARE GAIN FROM TAX REFORMS: NEW $\tau^k = 0$

	Productivity	Wealth		
		Zero	Median	Mean
Benchmark	Low	−4.88	−4.14	1.64
	Medium	−4.75	−4.43	0.67
	High	−2.09	−1.93	1.02
No-earnings-risk		−4.18	−3.87	1.50
				(rep. agent)
Endog. labor	Low	−6.70	−5.48	1.16
	Medium	−6.55	−6.15	0.02
	High	−3.83	−3.67	−0.68
Endog. labor, no-earnings-risk		−5.62	−5.26	0.86
				(rep. agent)
Consumption tax	Low	−2.03	−1.87	0.41
	Medium	−1.90	−1.80	0.34
	High	0.55	0.61	1.78
Consumption tax, no-earnings-risk		−1.00	−0.86	1.50
				(rep. agent)

consumption gains are quantitatively more important for welfare than short-run losses, since eliminating capital taxes solves the traditional Ramsey problem for this economy.

Introducing heterogeneity: the no-earnings-risk economy: Garcia-Milà et al. (1995, 1996) and Auerbach and Kotlikoff (1987) point out that if households differ in the initial fractions of their income they receive from asset holdings versus labor supply, then reducing capital income taxation shifts the burden of taxation away from households who receive a large fraction of their income from capital and towards those who receive a disproportionate fraction from labor.[21] This is clear from Figure 2, which shows that immediately after the reform the after-tax wage falls and the after-tax return to capital rises. Subsequently, as the capital stock increases, wages rise and the return to capital falls. Even in the long run, however, the after-tax wage is below its pre-reform level.

This redistribution of the tax burden has dramatic implications for welfare. The average welfare gain of eliminating the capital income tax in the no-earnings-risk economy is equivalent to a permanent 0.7% fall in consumption.[22] The welfare effect is negative because the reform hurts wealth-poor households with a high marginal utility of consumption, and benefits wealthy households whose marginal

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[21] In their economy with two types of agent, Garcia-Milà et al. find that capital tax cuts typically leave the wealth-poor type worse off. The switch from a general income tax to a labor income tax considered by Auerbach and Kotlikoff mainly benefits the current old (who receive a high fraction of income from wealth) while imposing large welfare costs on the current young generations (whose income consists mainly of labor earnings).

[22] In a previous version of the article we experimented with a smaller capital-to-output ratio. The qualitative results in that case are very similar, but with a smaller capital stock redistribution is less problematic and welfare gains and losses are smaller.
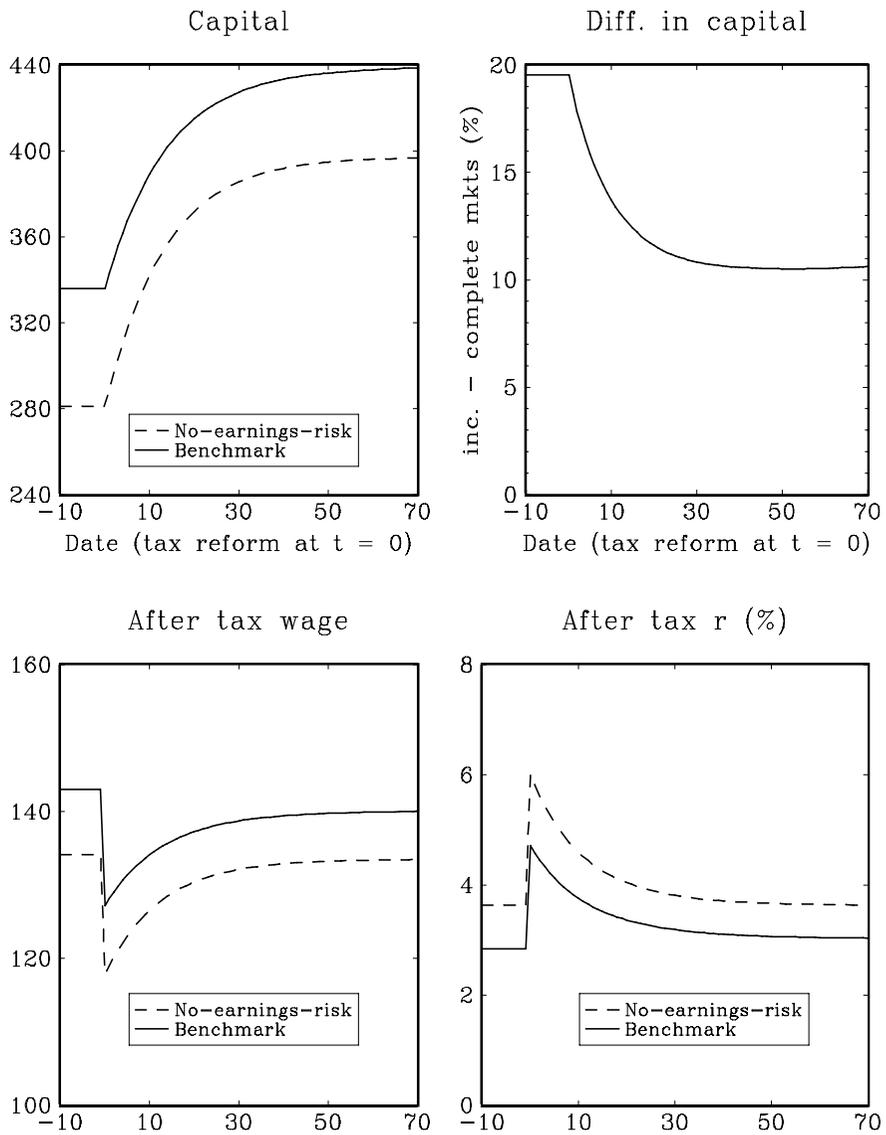
FIGURE 2

AGGREGATE CAPITAL AND AFTER-TAX PRICES: τ^k FROM 39.7% TO 0.0%

utility of consumption is relatively low. Figure 3 shows the value for wealth (68.4% of mean per capita wealth) such that all richer households benefit from the tax reform, while all poorer households lose.[23]

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[23] This finding is simlar to Judd (1985), who studies tax reforms for an economy in which households differ in their initial capital holdings, and face no earnings risk. He shows that agents with below average wealth will desire an immediate permanent capital income tax increase if the current tax rate is sufficiently low.
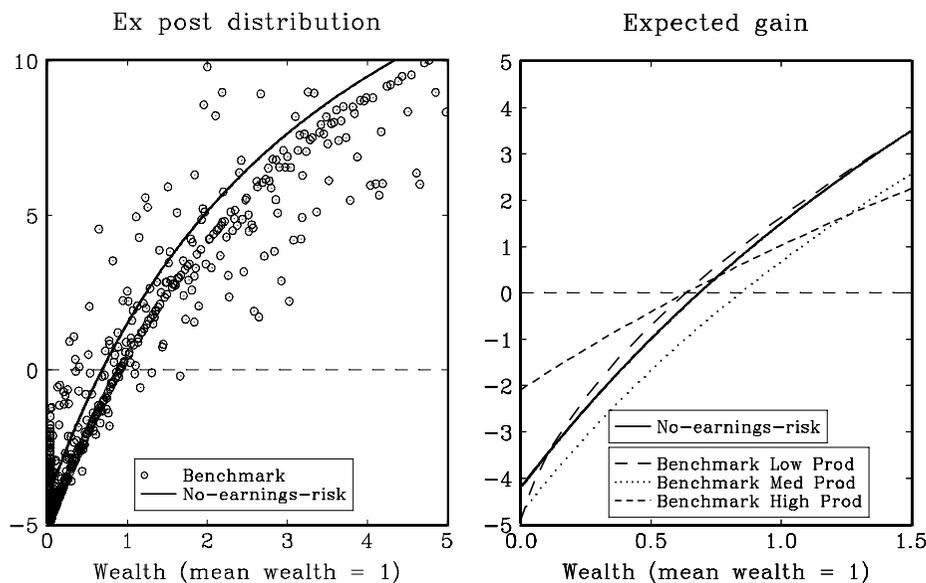
FIGURE 3

DISTRIBUTION OF WELFARE GAINS (% OF PERMANENT CONS): τ^k FROM 39.7% TO 0.0%

We can now account for the finding that most households lose from eliminating capital taxation in the no-earnings-risk economy. Because the initial wealth distribution is so skewed, only 29% of households have more than 68.4% of mean wealth. This is why 71% of households oppose the tax reform.

Introducing market incompleteness: the benchmark economy: Introducing market incompleteness makes capital income tax reductions even less attractive. The main reason is that the aggregate component of the welfare gain from reducing capital taxes is smaller than in the no-earnings-risk case.

The aggregate component is smaller in the benchmark model because the precautionary savings motive means that on average households accumulate more capital than when they face no idiosyncratic risk. With positive capital taxes, the stimulative effect of precautionary saving on capital accumulation partially offsets the depressive effect of distortionary capital taxation. Thus the potential welfare gains associated with the change in the aggregate allocation induced by capital tax cuts are small.[24] Similar intuition underlies Aiyagari's (1995) result that if the optimal tax program in this type of economy converges to a steady state, then

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[24] Note that when the capital tax is eliminated, the increase in the stock of aggregate capital in the benchmark model is smaller than in the no-earnings-risk economy (see Figure 2). This is because the demand for precautionary savings falls during transition for two reasons. First, as average asset holdings rise, the typical household becomes better able to smooth consumption in response to income shocks. Second, the share of capital income in after-tax income increases (see Table 3) and asset income is riskless by assumption.

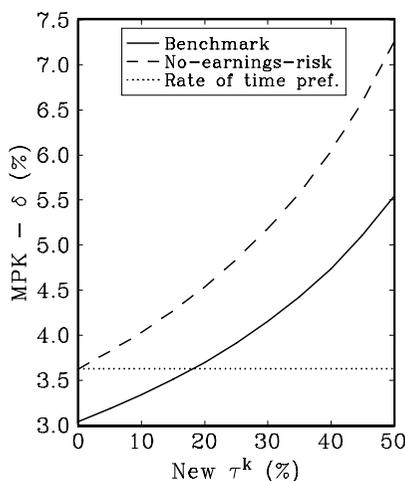Pre−tax interest rate in final steady state

FIGURE 4

AIYAGARI'S LONG-RUN PRESCRIPTION: INITIAL $\tau^k = 39.7\%$

the optimal tax rate on capital in that steady state is positive.[25] Aiyagari finds that the optimal capital tax should ensure that the long-run pretax interest rate equals the households' rate of time preference (see Proposition 1, p. 1170). Figure 4 shows that in our economy, Aiyagari's prescription involves a reduction in the capital income tax rate to 18.1%.[26,27] This is close to the tax rate that maximizes the aggregate component of the welfare gain within the class of tax reforms we consider—that rate is 17.6% (see Figure 1).

The negative distributional components of welfare gains are also smaller in the benchmark economy (see the bottom left panel of Figure 1). This is because households now face nonpermanent idiosyncratic earnings shocks and, in contrast to the no-earnings-risk economy, move around within the distribution over income and wealth. Since a household's expected productivity and wealth in the distant future converge to the economy-wide averages, the extent to which a tax change redistributes the tax burden is mitigated relative to the no-earnings-risk economy. Note, however, that there is considerable variation in the experienced welfare gains of households with identical initial wealth (see Figure 3).[28]

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[25] Similarly, İmrohoroğlu (1998), in an overlapping-generations economy with incomplete markets, finds that the steady-state welfare-maximizing capital tax is positive.

[26] Figure 4 also indicates that in the no-earnings-risk economy, the long-run optimal tax rate is zero.

[27] Aiyagari (1994b) finds the long-run optimal tax rate in a similar model calibrated to the U.S. economy to be between 25% and 45% depending on parameter values.

[28] For example, in our sample population with 20,000 households, the poorest household to gain ex post had 3.7% of mean initial wealth, whereas the richest household to lose started with 193% of mean initial wealth.

Negative distributional effects still swamp positive aggregate components in the overall welfare calculus for three reasons. First, the aggregate components of welfare gains are much smaller than in the model without earnings risk, as discussed above. Second, the initial distribution of wealth is so skewed that tax reform involves substantial redistribution in the short run. Third, idiosyncratic productivity shocks are very persistent relative to the households' rate of time preference.[29] These last two points explain why a household's initial position in the distribution over productivity and wealth is so important in determining its expected welfare gain from a tax reform (see Figure 3 and Table 5).

Wealth versus productivity: Clearly, if two households have equal productivity at the time of the tax reform but different levels of wealth, the wealthier household has more to gain from capital tax cuts. Holding constant wealth, it is less obvious whether high or low productivity households should gain most. On the one hand, high productivity households receive a larger fraction of their income from labor and therefore face the largest percentage tax increases following the elimination of capital income taxation. On the other hand, high productivity households also want to accumulate wealth rapidly, while low productivity households are typically dis-saving. Thus high productivity households are well placed to take advantage of the temporary increase in the after-tax return to saving.[30] These two effects largely offset each other, so that the value for initial wealth such that a household is indifferent between eliminating capital income taxation and maintaining the initial tax system is similar for high and low productivity households (see the right panel of Figure 3).

Transition versus steady state: An alternative way to decompose the welfare effects is to focus on short versus long-run effects. We therefore compare the welfare numbers presented above with those obtained by pure steady-state comparisons. In the benchmark economy, the average steady-state welfare gain of eliminating capital taxation is equivalent to a 3.6% increase in consumption.[31]

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[29] There is some disagreement as to the true persistence of household productivity shocks. We therefore recomputed the effects of eliminating capital income taxes using the estimates of Heaton and Lucas (1996), which suggest an autocorrelation coefficient of 0.53 and a variance for productivity of $0.251^2/(1 - 0.53^2)$. With this process for productivity, the model generates much less wealth concentration than is observed in the United States, and eliminating capital taxes increases average welfare. However, when we impose the same initial distribution over wealth and productivity as in the baseline (high persistence) calibration, eliminating capital taxes is almost as unpopular a policy as in our benchmark experiment. We conclude that initial wealth inequality is a more important determinant of the welfare effects of tax reform than the persistence of the productivity process.

[30] It is important to note that in the long run, the after-tax return to capital falls towards its pre-reform level. Thus only those with significant assets early in the transition see much gain in the form of higher returns following the capital tax cut.

[31] The wealth-earnings distribution differs across steady states, which makes welfare comparisons nontrivial. To calculate steady-state welfare gains we impose the same initial wealth distribution on all steady states, but scale the distribution so that the sum of individual asset holdings equals the sum of steady-state aggregate capital plus government debt.

In the no-earnings-risk economy the steady-state welfare gain is larger, 5.5%. Comparing with the welfare losses in Table 4 it is clear that the short-run pain associated with capital tax cuts must dominate these substantial long-run gains.[32] Thus we conclude that steady-state welfare comparisons are misleading in these models, and that solving explicitly for transition is an important feature of our analysis.

Which reform is best? When we consider a range of possible new capital tax rates between 0 and 50%, we find that a utilitarian planner in our benchmark model would neither want to reduce nor increase the capital tax rate (see Figure 1). Any reduction in capital taxation from the initial 39.7% rate is welfare-reducing since it effectively redistributes the tax burden in favor of a few wealthy households whose expected marginal utility from consumption is typically low. On the other hand, increasing capital taxation also reduces average welfare since capital taxation becomes increasingly distortionary.

The result that the best reform is no reform stands in stark contrast to the finding discussed previously that a capital tax reduction to 18.1% is required to satisfy Aiyagari's long-run prescription for efficiency. We conclude that Aiyagari's prescription does not offer much guidance on how to set taxes in the short run. The broader implication is that in assessing the welfare effects of tax reform, one should pay at least as much attention to short-run redistribution as to long-run efficiency.

The importance of short-run redistribution is further illustrated by the following experiment. Suppose, counterfactually, that the initial capital tax rate is 18.1% rather than 39.7%. Figure 5 indicates that in this case maximizing the aggregate component of the welfare gain dictates leaving tax rates approximately unchanged. However, this does not imply that the utilitarian planner prefers the status quo to changing the capital tax. Rather the planner would like to increase the capital tax to 39.0%, which is essentially the level estimated for the United States in the 1990s. The reason is that although small tax increases in this experiment have negligible effects on the aggregate component of welfare, the size of the (positive) distributional component is close to linear in the size of the tax increase. Since we set the initial tax rate in this experiment to Aiyagari's long-run optimal level, the fact that a utilitarian planner would like increase the tax rate indicates that Aiyagari's Ramsey plan is not time consistent.

3.2. *Introducing Endogenous Labor Supply.* The planner's preferred policy is, not surprisingly, somewhat sensitive to specific model features. One important feature is our assumption that labor is supplied inelastically, which means that any shift towards labor taxation reduces distortions in the economy. With

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[32] Building up the aggregate capital stock during transition implies temporarily lower average consumption and utility. Thus the steady-state welfare gain for the representative agent is worth a 9.7% increase in consumption, whereas the corresponding figure incorporating transition is only 1.5%.

Ave. welfare gain

Aggregate component

Distributional component
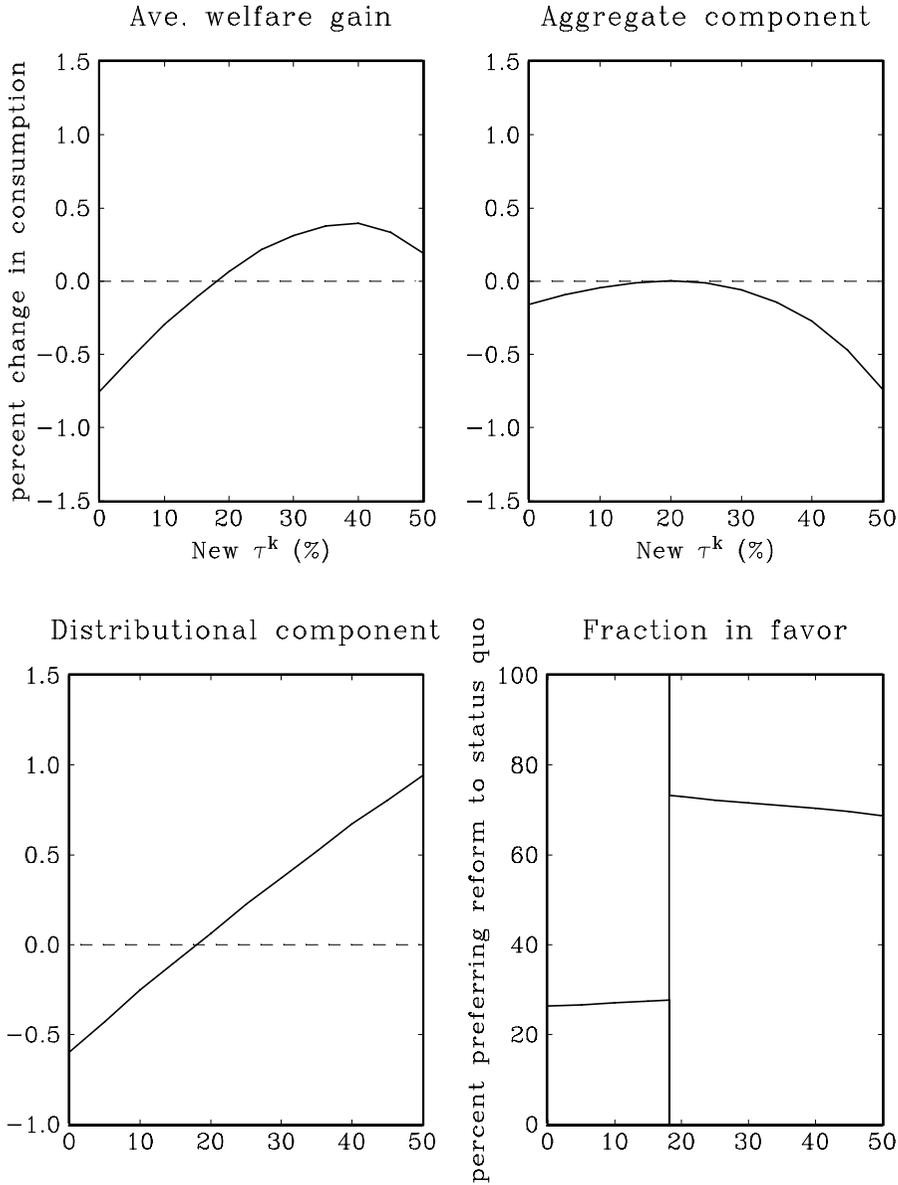

Fraction in favor

FIGURE 5

WELFARE EFFECTS IN BENCHMARK ECONOMY: INITIAL $\tau^k = 18.1\%$

valued leisure, reducing capital taxation is therefore likely to be even less at-
tractive since higher labor taxes will now be distortionary. We quantify this in-
tuition by recomputing the effects of tax reform when households choose labor
supply.

Following Greenwood et al. (1988), we assume that the momentary utility function is given by[33]

$$(15) \qquad u(c, n) = \log \left(c - \chi \frac{n^{1 + \frac{1}{\varepsilon}}}{1 + \frac{1}{\varepsilon}} \right)$$

where n is hours worked, and $\varepsilon > 0$ is the Frisch labor supply elasticity. We set ε to 0.3 as suggested in the survey by Blundell and MaCurdy (1999), and we set χ so that the average number of hours supplied in the economy is approximately 0.3.[34] We recalibrate other parameters following the same procedure used for the benchmark economy, and in particular choose the parameters defining the productivity process so that once again the model generates realistic wealth inequality.

The results (see Tables 4 and 5 and Figure 6) confirm our intuition. With endogenous labor the average welfare loss of abolishing capital income taxes increases to -3.0%. The main reason for the larger welfare loss is that eliminating capital taxes is now associated with a large decline in the aggregate component of the welfare gain, as opposed to the increase in the aggregate component seen in the benchmark (exogenous-labor) model. In this environment a utilitarian planner does not prefer the status quo (39.7%) but instead would choose to increase the capital tax rate to 51%.[35] Nonetheless, our three main conclusions are preserved with elastic labor supply: (i) expected welfare gains vary dramatically across agents, (ii) the welfare gain of the representative agent is a very poor proxy for the average welfare change, and (iii) few households support reducing capital taxes.

3.3. *Consumption Taxation.* Several studies find large welfare gains from switching to a consumption tax rather than to a labor tax (see, e.g., Auerbach and Kotlikoff, 1987; İmrohoroğlu, 1998; Judd, 2001).[36] In the representative-agent exogenous-labor economy, these two tax reforms are equivalent since we restrict attention to constant taxes.[37] When households are heterogenous however, a switch to consumption taxes seems more attractive a priori. First, the aggregate components of the welfare gain should be similar since the reforms involve the same reduction in distortions. Second, the distributional losses should be smaller since the strong correlation between consumption and wealth means that switching to a consumption tax involves relatively little redistribution of the tax burden.

[33] This utility function is convenient when solving numerically for allocations out of steady state in heterogeneous agent economies. This is because it implies that aggregate labor supply is independent of the distribution of wealth. See Heathcote (2004) for a discussion.

[34] For a recent study on estimation of the Frisch labor supply elasticity in the presence of borrowing constraints, see Domeij and Flodén (2003).

[35] The representative agent's preferred policy with endogenous labor supply is to reduce the capital tax to 14% rather than to 0% (see Figure 6).

[36] Krusell et al. (1996), on the other hand, find that when tax rates are chosen through a political process, the median voter may prefer an income-tax-based constitution to a consumption-tax-based one.

[37] See Coleman (2000) for a discussion of consumption taxation in a calibrated representative-agent economy.
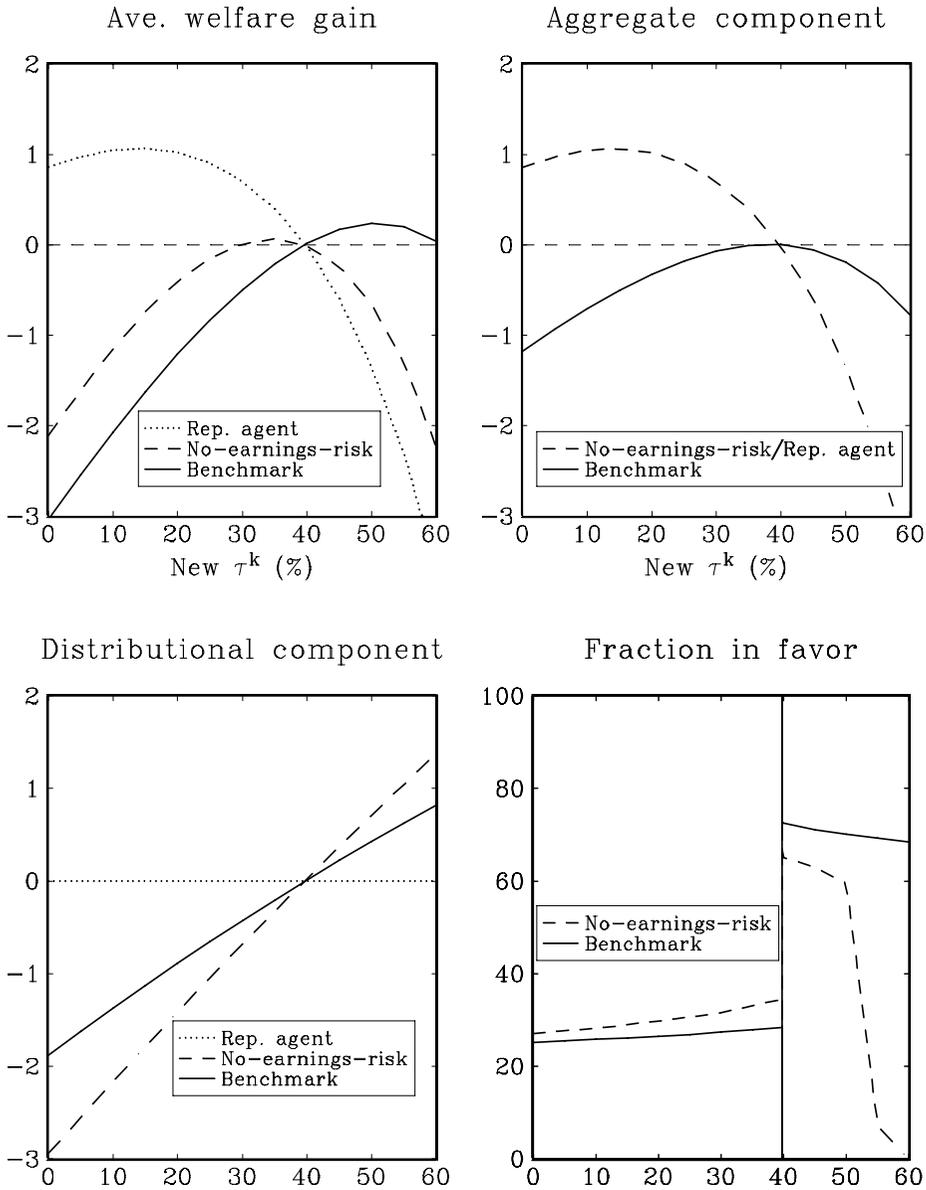
FIGURE 6

WELFARE EFFECTS WITH ENDOGENOUS LABOR: INITIAL $\tau^k = 39.7\%$

The numerical findings in Tables 4 and 5 support this intuition for the case of eliminating capital taxation. The average welfare loss from eliminating capital taxes is equivalent to a 0.4% drop in consumption, compared to 1.4% when switching to a higher labor tax. However, eliminating capital taxes is still welfare reducing

for the majority of households. Thus, as in the economies considered previously, incorporating heterogeneity changes dramatically the welfare implications of tax reform.

4. CONCLUSION

The main conclusion we take from this article is that changing the balance between capital and labor income taxation is likely to have very large distributional implications. Reducing taxes on capital income in our model *does* stimulate investment, raising aggregate output and consumption in the long run. However, the short-run cost in the form of higher labor taxes is too heavy a price to pay for all except the wealth-richest households. The implication is that in thinking about welfare one should pay at least as much attention to these short-run distributional effects as to the familiar results from the Ramsey literature that point towards lowering capital taxes in the long run.

APPENDIX

A.1. *Definition of Equilibrium.* We now describe the conditions that jointly characterize the equilibrium path of the benchmark incomplete-markets economy following a tax reform at date $t = 0$.

An equilibrium is a pair of constant tax rates τ^k and τ^n and sequences of decision rules $\{s_t(e^t; x_0)\}_{t=0}^{\infty}$ and $\{c_t(e^t; x_0)\}_{t=0}^{\infty} \, \forall \, x_0 \in X$ and $\forall \, e^t \in E^t$, probability measures $\{\mu^t(x_0, Z)\}_{t=0}^{\infty} \, \forall \, x_0 \in X$ and $\forall Z \in \mathcal{E}^t$, prices $\{r_t\}_{t=0}^{\infty}$ and $\{w_t\}_{t=0}^{\infty}$, values for aggregate capital, debt, and asset holdings $\{K_t\}_{t=0}^{\infty}$, $\{B_t\}_{t=0}^{\infty}$, and $\{A_t\}_{t=0}^{\infty}$, and a measure $\lambda(D) \, \forall D \in \mathcal{X}$ describing the initial distribution across individual states such that $\forall \, e^t \in E^t$:

1. $\forall \, x_0 \in X, s_t(e^t; x_0)$ solves the household maximization problem (described in the text) given $\{r_t\}_{t=0}^{\infty}$, $\{w_t\}_{t=0}^{\infty}$, the sequence of measures $\{\mu^t(x_0, \cdot)\}_{t=0}^{\infty}$, and the pair of constant tax rates $\{\tau^k, \tau^n\}$.
2. $\forall \, x_0 \in X$, the measure $\mu^t(x_0, e^t)$ is consistent with the transition probability matrix Π in that $\forall s \in \{1, \ldots, t\}$,

   $$(A.1) \qquad \mu^s(x_0, e^s) = \mu^{s-1}(x_0, e^{s-1})\Pi_{ij}, \quad t = 1, 2, \ldots$$

   where $e^s = \{e_0(e^t), \ldots e_s(e^t)\}$, where $e_s(e^t)$ denotes the sth element of e^t, and where $e_{s-1}(e^t) = e_i$ and $e_s(e^t) = e_j$.
3. The market for savings clears:

   $$(A.2) \qquad K_0 + B_0 = \int_X a_0 \lambda(dx_0) = A_0$$

   $$(A.3) \quad K_t + B_t = \int_X \sum_{e^{t-1} \in E^{t-1}} s_{t-1}(e^{t-1}; x_0) \mu^{t-1}(x_0, e^{t-1}) \lambda(dx_0)$$

   $$= A_t \quad t = 1, 2, \ldots$$

4. Factor markets clear:

$$(A.4) \qquad r_t = \alpha K_t^{\alpha-1} \bar{n}^{1-\alpha} - \delta \qquad t = 0, 1, \ldots$$

$$(A.5) \qquad w_t = (1 - \alpha) K_t^{\alpha} \bar{n}^{-\alpha} \qquad t = 0, 1, \ldots$$

5. The government budget constraint is satisfied and debt remains bounded:

$$(A.6) \quad B_{t+1} + \tau^k r_t A_t + \tau^n w_t \bar{n} = \left[1 + (1 - \tau^k) r_t \right] B_t + G \qquad t = 0, 1, \ldots$$

$$(A.7) \qquad B_t \in [0, \infty) \qquad t = 0, 1, \ldots$$

where B_0 is given.

6. The goods market clears:

$$(A.8) \qquad C_t + G + K_{t+1} - (1 - \delta) K_t = Y_t \qquad t = 0, 1, \ldots$$

where

$$(A.9) \qquad C_t = \int_X \sum_{e^t \in E^t} c_t(e^t; x_0) \mu^t(x_0, e^t) \lambda(dx_0)$$

A.2. *Calibrating the Productivity Process.* Consider the following AR(1) process for labor productivity:

$$(A.10) \qquad \ln e' = \rho \ln e + \varepsilon' \qquad \varepsilon \sim N(0, \sigma^2)$$

and note that

$$(A.11) \qquad \rho = \frac{\text{cov}(\ln e', \ln e)}{\text{var}(\ln e)}$$

and

$$(A.12) \qquad \text{var}(\ln e) = \frac{\sigma^2}{1 - \rho^2}$$

Equations resembling (A.10) have been estimated on panel data. Our goal is to approximate Equation (A.10) by a three-state Markov chain, preserving the estimated autocorrelation and variance of log productivity. The matrix Π, reproduced

here, defines the probabilities of moving between productivity levels as functions of two parameters, Π_{11} and Π_{22}:

$$(A.13) \qquad \Pi = \begin{bmatrix} \Pi_{11} & 1 - \Pi_{11} & 0 \\ \frac{1 - \Pi_{22}}{2} & \Pi_{22} & \frac{1 - \Pi_{22}}{2} \\ 0 & 1 - \Pi_{11} & \Pi_{11} \end{bmatrix}$$

Given the symmetry of Π, $p_1 = p_3$, and p_1 is related to Π_{11} and Π_{22} as follows:

$$(A.14) \qquad p_1(1 - \Pi_{11}) = p_2 \frac{1 - \Pi_{22}}{2}$$

$$= (1 - 2p_1) \frac{1 - \Pi_{22}}{2}$$

To enable comparison with the estimated process for log productivity, assume that mean (natural) log productivity equals 1:

$$(A.15) \qquad \overline{\ln e} = \sum_i p_i \ln e_i = 0$$

The variance and covariance of log productivity are given by

$$(A.16) \qquad \mathrm{var}(\ln e) = \sum_i (\ln e_i - \overline{\ln e})^2$$

and

$$(A.17) \qquad \mathrm{cov}(\ln e', \ln e) = \sum_i (\ln e_i' - \overline{\ln e})(\ln e_i - \overline{\ln e})$$

Let p_1 and e_2 be such that when the model economy is simulated, on average it reproduces the two chosen moments characterizing the wealth distribution as discussed in Section 2.1. Once values for these parameters have been chosen, the goal is to adjust the remaining free parameters so that the process for log productivity inherits the properties estimated in the data. During this second stage, p_1 and e_2 are treated as exogenously fixed.

Since $p_3 = p_1$, and $\sum_i p_i = 1$, (A.14) can be rearranged to express Π_{22} as a known function of Π_{11}:

$$(A.18) \qquad \Pi_{22} = \frac{p_2 - 2p_1(1 - \Pi_{11})}{p_2}$$

Equation (A.15) can be rearranged to give an expression for $\ln e_3$:

$$(A.19) \qquad \ln e_3 = -\frac{p_1 \ln e_1 + p_2 \ln e_2}{p_1}$$

Given p_1 and e_2, and expressions (A.18) and (A.19), the only remaining free parameters are Π_{11} and e_1.

From (A.12) and (A.16), equating the variances of the discrete and continuous processes for log productivity implies that

$$(A.20) \qquad \sigma_e^2 = (1 - \rho^2)\left(p_1(\ln e_1)^2 + p_2(\ln e_2)^2 + p_1(\ln e_3)^2\right)$$

Substituting (A.19) into (A.20) then implies

$$(A.21) \qquad 2(\ln e_1)^2 + 2k\ln e_1 \ln e_2 + k(1+k)(\ln e_2)^2 - \frac{\sigma^2}{(1-\rho^2)p_1} = 0$$

where $k = p_2/p_1$. This is a quadratic equation that can be solved for $\ln e_1$. The relevant root is

$$(A.22) \qquad \ln e_1 = \frac{-2k\ln e_2 - \sqrt{(2k\ln e_2)^2 - 4\times 2 \times \left(k(1+k)(\ln e_2)^2 - \frac{\sigma^2}{(1-\rho^2)p_1}\right)}}{2\times 2}$$

From (A.11), (A.16), and (A.17), equating the autocorrelation of the discrete and continuous processes for log productivity implies that

$$(A.23) \qquad \rho = \Pi_{11} + \frac{(-1+\Pi_{11})(\ln e_2)^2}{p_1(\ln e_1)^2 + p_2(\ln e_2)^2 + p_1(\ln e_3)^2}$$

Substituting in Equation (A.20) this simplifies to

$$(A.24) \qquad \rho = \Pi_{11} + \frac{(-1+\Pi_{11})(1-\rho^2)(\ln e_2)^2}{\sigma^2}$$

Equation (A.24) can then be used to solve for Π_{11}:

$$(A.25) \qquad \Pi_{11} = \frac{\rho + \frac{(1-\rho^2)(\ln e_2)^2}{\sigma^2}}{1 + \frac{(1-\rho^2)(\ln e_2)^2}{\sigma^2}}$$

A.3.   *Solution Algorithm.*

1. Solve for the initial steady state given the initial capital tax rate as follows: (a) Guess a value for the capital stock (and implicitly for output and prices). (b) Compute the value for government consumption such that given the labor tax, government debt remains constant at the target debt-to-GDP ratio. (c) Solve for household savings decisions. We use the finite-element method (see McGrattan, 1999). (d) Simulate the economy to generate a stationary asset-holding distribution. (e) Check that aggregate

household savings equal aggregate capital plus aggregate debt. (f) Adjust the guess for capital and iterate until the market for savings clears.

2. Choose a new value for the capital tax τ^k. Assume this is announced before households make decisions in period 1.
3. Assume that the economy converges to a new steady state and that it is in this steady state in period T.
4. Guess a sequence $K_2, \ldots, K_{T-1}$ for capital during transition.
5. Solve for the new proportional tax on labor τ^n such that given $K_2, \ldots, K_{T-1}$ and τ^k, government debt is unchanged between $T-1$ and T. Compute the associated path for government debt, $B_2, \ldots, B_T$.
6. Solve for the final steady state using the same procedure outlined in step 1, taking as given tax rates τ^k and τ^n and B_T. Compute the capital stock in the new steady state, K_T.
7. Solve for household savings decisions in transition as follows: (a) Start in period $T-1$ and assume that: (i) capital today is K_{T-1} and capital tomorrow is K_T, and (ii) consumption tomorrow (in period T) is given by the consumption function in the new steady state, $c_T(\cdot)$. (b) Given these assumptions, solve for the consumption decision rule at $T-1$ across the grid on individual states, $c_{T-1}(a, e : K_{T-1}, K_T, c_T(\cdot))$. (c) Continue moving back through time until we have decision rules $c_i(a, e : K_i, K_{i+1}, c_{i+1}(\cdot))$, $i = 1, \ldots, T-1$.
8. Now start updating the path of capital. The strategy is to take the initial steady-state distribution over wealth and productivity, to use the decision rules to simulate the economy forward, to check for market clearing at each date, and to then adjust $K_2, \ldots, K_{T-1}$ appropriately. For example, let $\hat{K}_2$ be the value for capital in period 2 that is implied by $c_1(a, e : K_1, K_2, c_2(\cdot))$. We set $K_2 = K_2 + \phi(\hat{K}_2 - K_2)$, where $0 < \phi < 1$.
9. If the new sequence for capital is the same as the old, we have found the equilibrium path. Otherwise go back to step 5, resolve for the new labor tax given the updated capital sequence, and proceed.
10. Once the sequence for capital has converged, check whether T is sufficient by increasing T and checking whether the equilibrium path is affected.

A.4. *The Aggregate Component of Welfare Gains.* In this appendix we prove Proposition 1. Beginning with the case of an individual household, let $\Delta^a_{x_0}$ satisfy Equation (13) given $\{\hat{c}^R_t(e^t; x_0)\}^\infty_{t=0}$ and $\{c^{NR}_t(e^t; x_0)\}^\infty_{t=0}$. Substituting Equation (12) into (13) gives

$$(A.26) \qquad \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log\left(\frac{c^{NR}_t(e^t; x_0)}{C^{NR}_t} C^R_t\right) \mu^t(x_0, e^t)$$

$$= \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log\left((1 + \Delta^a_{x_0}) c^{NR}_t(e^t; x_0)\right) \mu^t(x_0, e^t)$$

which may be rewritten as

$$(A.27) \qquad \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log \left(c_t^{NR}(e^t; x_0)\right) + \sum_{t=0}^{\infty} \beta^t \log \left(\frac{C_t^R}{C_t^{NR}}\right)$$

$$= \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log \left(c_t^{NR}(e^t; x_0)\right) + \sum_{t=0}^{\infty} \beta^t \log \left(1 + \Delta_{x_0}^a\right)$$

Now, consider the aggregate component of the welfare gain. Let Δ^a be such that Equation (14) is satisfied given $\{\hat{c}_t^R(e^t; x_0)\}_{t=0}^{\infty}$ and $\{c_t^{NR}(e^t; x_0)\}_{t=0}^{\infty}$ and aggregate consumption streams $\{C_t^R\}_{t=0}^{\infty}$ and $\{C_t^{NR}\}_{t=0}^{\infty}$. Then for all x_0, substituting Equation (12) into (14) gives

$$(A.28) \qquad \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log \left(\frac{c_t^{NR}(e^t; x_0)}{C_t^{NR}} C_t^R\right) \mu^t(x_0, e^t) \lambda(dx_0)$$

$$= \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log \left((1 + \Delta^a) c_t^{NR}(e^t; x_0)\right) \mu^t(x_0, e^t) \lambda(dx_0)$$

which can be rewritten as

$$(A.29) \quad \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log \left(c_t^{NR}(e^t; x_0)\right) \mu^t(x_0, e^t) \lambda(dx_0) + \sum_{t=0}^{\infty} \beta^t \log \left(\frac{C_t^R}{C_t^{NR}}\right)$$

$$= \int_X \sum_{t=0}^{\infty} \sum_{e^t \in E^t} \beta^t \log \left(c_t^{NR}(e^t; x_0)\right) \mu^t(x_0, e^t) \lambda(dx_0) + \sum_{t=0}^{\infty} \beta^t \log(1 + \Delta^a)$$

Comparing Equations (A.27) and (A.29) we see that

$$(A.30) \qquad \sum_{t=0}^{\infty} \beta^t \log \left(1 + \Delta_{x_0}^a\right) = \sum_{t=0}^{\infty} \beta^t \log(1 + \Delta^a)$$

Thus for all x_0, $\Delta_{x_0}^a = \Delta^a$.

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