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Taxation and Household Labour Supply

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We evaluate reforms to the U.S. tax system in a life cycle set-up with heterogeneous married and single households and with an operative extensive margin in labour supply. We restrict our model with observations on gender and skill premia, labour-force participation of married females across skill groups, children, and the structure of marital sorting. We concentrate on two revenue-neutral tax reforms: a proportional income tax and a reform in which married individuals file taxes separately (*separate filing*). Our findings indicate that tax reforms are accompanied by large increases in labour supply that differ across demographic groups, with the bulk of the increase coming from married females. Under a proportional income tax reform, married females account for more than 50% of the changes in hours across steady states, while under separate filing reform, married females account for all the change in hours.

Key words: Taxation, Two-earner households, Labour force participation

JEL Codes: E62, H31, J12, J22

1. INTRODUCTION

Tax reforms have been at the center of numerous debates among academic economists and policy makers. As a part of this debate, there have been calls for tax reforms that would simplify the tax code, change the tax base from income to consumption, and adopt a more uniform marginal tax rate structure.[1]

In the existing literature, the decision maker is typically an individual who decides how much to work, how much to save, and in some cases, how much human capital investments to make. Yet, current households are neither a collection of breadwinner husbands and house-maker wives nor a collection of single people. In 2000, the labour-force participation of married women

1. See Auerbach and Hassett (2005) for a review.

between ages 25 and 54 was about 69%. Furthermore, their participation rate increases markedly by educational attainment and is known to respond strongly to hourly wages. Moreover, the economic environment that these households face does not feature wages that are gender neutral. Hourly earnings of females relative to males, the gender gap, are of about 70% nowadays and have been around this value for some time.[2]

These observations have long been deemed important in discussions of tax reforms but are largely unexplored in dynamic equilibrium analyses in the macro-economic and public-finance literatures. We fill this void in this paper. We quantify the effects of tax reforms taking carefully into account the labour supply of married females as well as the current demographic structure. For these purposes, we develop a dynamic equilibrium model with an operative extensive margin in labour supply, and a structure of individual and household heterogeneity that is consistent with the current U.S. demographics.

We consider a life-cycle economy populated with males and females who differ in their labour market productivities. Individuals start economic life as either *married* or *single* and do not change their marital status as they age. Married couples and single females have children that appear exogenously along their life cycle; they can be childless or have these children early or late in their life cycle. Singles decide how much to work and how much to save out of their total after-tax income. Married households decide on the labour hours of each household member, and like singles, how much to save. A novel feature in our analysis is the explicit modelling of the participation decision of married females in two-earner households and its interplay with the structure of heterogeneity and taxation. In the model, female labour-force participation is not a trivial decision for a household. First, children are associated to fixed-time costs. Furthermore, if a female with a child decides to work, the household incurs childcare expenses. Second, her labour market productivity depreciates if she chooses not to participate. Finally, if a married female enters the labour force, the household faces a utility cost. This cost allows us to capture residual heterogeneity in labour-force participation. It represents heterogeneity in the additional difficulty of coordinating multiple household activities, taste for children and home production or any other utility cost that might arise when two adults work instead of one. As a result of these assumptions, females in married households may choose not to work at all. This is a key feature of our analysis since the structure of taxation can affect the participation decision of married females, and available evidence suggests that it does so significantly.

There are several reasons that point to the relevance of our analysis. First, in the current U.S. tax system, the household (not the individual) constitutes the basic unit of taxation, which results in high tax rates on secondary earners. When a married female considers entering the labour market, the first dollar of her earned income is taxed at her husband's current marginal rate. Second, from a conceptual standpoint, wages of each member as well as the presence of children in a two-earner household affect joint labour-supply decisions as well as the reactions to changes in the tax structure. Finally, a common view among many economists has been that tax changes may have moderate impacts on labour supply. This view is supported by empirical findings on the low or near zero labour-supply elasticities of prime-age males. Recent developments, however, started to challenge this wisdom. Tax reforms in the 1980's have been shown to affect female labour-supply behaviour significantly but have relatively small effects on males (Triest, 1990; Bosworth and Burtless, 1992; Eissa, 1995).[3] These findings are consistent with ample empirical evidence that female labour supply in general, and female labour-force participation

2. Our calculations. See Section 4.1 for details.

3. More recently, Eissa and Hoynes (2006) show that the disincentives to work embedded in the Earned Income Tax Credit (EITC) for married women are quite significant (effectively subsidizing some married women to stay at home).

in particular are quite elastic (Blundell and MaCurdy, 1999; Keane, 2010). If *households*, not individuals, react to taxes much more than previously thought, the potential effects of tax reforms can be more significant.

We use our framework to conduct two hypothetical tax reform experiments and then ask: What is the importance of the labour-supply responses of married females in these experiments? What is the importance of micro labour-supply elasticities for the long-run effects on output and the labour input?

We concentrate on two revenue-neutral tax reforms. The first one eliminates all progressivity via a *proportional* income tax. This is a prototypical reform, which allows us to highlight and quantify the forces at work within the model. In our second reform, *separate filing*, we keep the progressivity and the tax base of the current system, but married individuals file their taxes separately. This reform, which arises naturally in our environment, shifts the unit of taxation from households to *individuals*. As a result, it can drastically change marginal tax rates within married households while effectively eliminating tax penalties (and bonuses) associated to marital status built into the current tax code.

A central finding of our exercises is that the differential labour-supply behaviour of different groups is key for an understanding of the aggregate effects of tax reforms. The related finding is that married females account for a disproportionate fraction of the changes in hours and labour supply. Furthermore, the relative importance of the labour-supply responses of married females increases sharply for *low* values of the intertemporal elasticity of labour supply.

Replacing current income taxes by a proportional tax increases aggregate output by about 7·4% across steady states. This increase is accompanied by differential effects on labour supply while hours per worker increase by about 3·3%, the labour-force participation of married females increases by about 4·6% and married females increase their total hours by 8·8%, with a significant response in the participation rate of married females with children which increases by 6·8%.

Our results show that *separate filing* goes a long way in generating significant aggregate output effects. With separate filing, aggregate output goes up by nearly 4%, which is more than half of the increase from a proportional income tax reform. The increase in aggregate output mainly comes from the rise in aggregate hours by married females. The labour-force participation of married females rises more than twice as it does under a proportional income tax reform: an increase of 10·4% versus 4·6%. The rise in labour-force participation of married females with children is even stronger, increasing by about 18·1% with separate filing. In contrast, male hours per worker remains nearly constant across steady states.

We find that both reforms lead to aggregate welfare gains for the generations that are alive at the time of reforms. The welfare gains are larger under a proportional income tax than under separate filing; the consumption compensation amounts to 1·3% under a proportional income tax and 0·2% under the separate filing case. We also find that a majority of households that alive at the time of reforms benefit from them. More households benefit from a move to separate filing (about 69%) than under a proportional tax (54%).

In answering the first question posed above, "what is the importance of the labour-supply responses of married females in these experiments?", we find that married females account for a disproportionate fraction of the changes in hours and labour supply. Under proportional taxes, married females account for about 51% of the total increase in labour hours and about 48% of the aggregate increase in labour supply (efficiency units). With separate filing almost all the rise in hours and labour supply comes from married females. Hence, considering explicitly the behaviour of this group is key in assessing the effects of tax reforms on labour supply.

In answering the second question, "what is the importance of micro, labour-supply elasticities for the long-run effects on output and the labour input?", we find that when reducing the intertemporal elasticity from the benchmark value of 0·4 to 0·2, the long-run response of aggregate hours and output to tax changes is not critically affected. This occurs as while households react much less to tax changes along the intensive margin under a low elasticity parameter, they respond disproportionately via changes in labour-force participation.

1.1. *Related literature*

Our work largely builds on two main strands of literature. First, our evaluation of tax reforms using a dynamic model with heterogeneity follows the work by Ventura (1999), Altig *et al.* (2001), Castaneda, Díaz-Giménez and Ríos-Rull (2003), Diaz-Gimenez and Pijoan-Mas (2005), Nishiyama and Smetters (2005), Conesa and Krueger (2006), Erosa and Koreshkova (2007), Conesa, Kitao and Krueger (2009), and among others. In contrast to these papers, we study economies populated with married and single households, where married households can have one or two earners. In this vein, Kaygusuz (2008) studies the effects of the 1980's tax reforms on female labour-force participation in the U.S. Hong and Ríos-Rull (2007) and Kaygusuz (2010) study social security in environments with an explicit role for two-member households. Chade and Ventura (2002) study the effects of tax reforms on labour supply and assortative matching in a model with heterogenous individuals and endogenous marriage decisions. They abstract, however, from the extensive margin in labour supply, among other things. Alessina, Ichino and Karabarbounis (2011) study the Ramsey optimal taxation problem of a two-earner household within a static environment, where lower tax rates for females emerge. Kleven, Kreiner and Saez (2009) study a similar optimal taxation of problem in Mirrlessian framework, where second earner makes an explicit labour-force participation decision. Second, as Cho and Rogerson (1988), Mulligan (2001), and Chang and Kim (2006), we study the aggregate effects of changes in labour supply along the extensive margin. As Rogerson and Wallenius (2009), we differ from these papers by explicitly analysing the role of the extensive margin for public policy.

Our paper is also related to two recent literatures. First, it is related to recent work that argues that the structure of taxation can significantly affect labour choices and play a central role in accounting for cross-country differences in labour-supply behaviour. Prescott (2004), Rogerson (2006), Ohanian, Raffo and Rogerson (2008), and Olovsson (2009) are examples of papers in this group. Our paper is also related to recent work that studies female labour supply in macro-economic set-ups; Jones, Manuelli and McGrattan (2003), Greenwood, Seshadri and Yorukoglu (2005), Erosa, Fuster and Restuccia (2010), Albanesi and Olivetti (2007), Knowles (2007), Attanasio, Low and Sánchez Marcos (2008), and Greenwood and Guner (2009) are representative papers in this group.

The paper is organized as follows. Section 2 presents an example that highlights the role of taxation with two-earner households and motivates the parameterization of the model economy. Section 3 presents the model economy. Section 4 discusses the parameterization of the model and the mapping to data. Results from tax reforms are presented in Section 5. Section 6 quantifies the role of married females and the extensive margin in labour supply. Section 7 discusses the implications of a lower labour-supply elasticity. Section 8 presents some welfare results. Section 9 concludes.

2. TAXATION, TWO-EARNER HOUSEHOLDS, AND THE EXTENSIVE MARGIN

In this section, we present a simple static decision problem that illustrates how taxes affect labour-supply decisions with two-earner households with and without children, with an emphasis on the potential changes in labour-force participation. The example serves to highlight key features of our general environment and to understand some of the calibration choices we make later.

Consider a married household. The household decides whether only one or both members should work and if so, how much. Let x and z denote the labour market productivities (wage rates) of males and females, respectively. Let τ be a proportional tax on labour income. The household can be childless ($k=0$) or have children ($k=1$). Couples with children have to pay for childcare services *only* if both household members works. Taking care of children costs $d>0$ units of consumption.

2.1. *A one-earner household*

Consider first the problem if only one member (husband) works. For couples with and without children, the household problem is given by

$$\max_{l_{\mathrm{m},1}} \left\{ 2[\underbrace{\log((1-\tau)zl_{\mathrm{m},1}+T)}_{=\log(c)}] - \varphi l_{\mathrm{m},1}^{1+\frac{1}{\gamma}} \right\},$$

where $l_{\mathrm{m},1}$ is the labour choice of the primary earner (husband) and T is a transfer received from the government. The subscript 1 represents the choices of a one-earner household. The function $W \equiv \varphi l^{1+\frac{1}{\gamma}}$ stands for the disutility associated to work time.

We introduce government transfers in order to capture in a simple way the role of progressive taxation. This follows as household choices under non-linear progressive taxes are qualitatively equivalent to choices under a linear tax system that combines a proportional tax rate plus a lump-sum transfer. Under a progressive tax system, changes in marginal tax rates affect labour choices even for preferences for which income and substitution effects cancel out; the same occurs under the linear tax system that we consider.

Household utility when only one member works is given by

$$V_1(\tau) = 2[\log((1-\tau)zl^*_{\mathrm{m},1}+T)] - W(l^*_{\mathrm{m},1}),$$

where a "$*$" denotes an optimal choice.

2.2. *A two-earner household*

When both members work, the household incurs a utility cost q, drawn from a distribution with cumulative distribution function $\zeta(q)$. Then the problem is given by

$$\max_{l_{\mathrm{m},2},l_{\mathrm{f},2}} \left\{ 2[\underbrace{\log((1-\tau)(zl_{\mathrm{m},2}+xl_{\mathrm{f},2})+T-d\chi(k))}_{=\log(c)}] - \varphi l_{\mathrm{m},2}^{1+\frac{1}{\gamma}} - \varphi l_{\mathrm{f},2}^{1+\frac{1}{\gamma}} - q \right\},$$

where $\chi(k)$ is an indicator for the presence of children, d is the monetary cost of children and the subscript 2 represents the choices of a two-earner household. Let the solutions to this problem be denoted by $l^*_{\mathrm{m},2}(k=0)$ and $l^*_{\mathrm{f},2}(k=0)$. Similarly, let $l^*_{\mathrm{m},2}(k=1)$ and $l^*_{\mathrm{f},2}(k=1)$ be the optimal decisions when children are present. Household utility levels are given by

$$\begin{aligned} V_2(\tau,k) - q = {} & 2[\log((1-\tau)(zl^*_{\mathrm{m},2}(k)+xl^*_{\mathrm{f},2}(k))+T-d\chi(k))] \\ & -W(l^*_{\mathrm{m},2}(k)) - W(l^*_{\mathrm{f},2}(k)) - q. \end{aligned}$$

2.3. *Taxes and the extensive margin in labour supply*

A married household is indifferent between having one and two earners for a sufficiently high value of the utility cost. Hence, there exist values of q, $q^*(k=0)$, and $q^*(k=1)$ that obey $q^*(k=0) = V_2(\tau, k=0) - V_1(\tau)$ and $q^*(k=1) = V_2(\tau, k=1) - V_1(\tau)$. For households with a q higher than the corresponding threshold value, it is optimal to have only one earner, while for those with a q lower than the threshold it is optimal to be a two-earner household. Since children are costly, it follows that $q^*(k=0) > q^*(k=1)$. Hence, everything else the same, childless couples are more likely to have two members working in the market than couples with children.

Thresholds will change as taxes change. Using the envelope theorem, it follows that

$$\frac{\partial q^*(k)}{\partial \tau} = \frac{\partial V_2(\tau,k)}{\partial \tau} - \frac{\partial V_1(\tau)}{\partial \tau} < 0.$$

This derivative is negative if household consumption with two earners is higher than with one earner, a condition that necessarily holds in our case.[4] That is, $q^*(k=0)$ and as a result, the labour-force participation of married females without children, will be lower (higher) when taxes are high (low) if the above condition holds. This is illustrated in Figure 1. Thus, a change in tax rates affects also the *extensive* margin in labour supply. For couples with children, a similar result can be shown. Furthermore, since children are costly in terms of resources, it is possible to show that

$$\left|\frac{\partial q^*(k=1)}{\partial \tau}\right| > \left|\frac{\partial q^*(k=0)}{\partial \tau}\right|$$

Hence, the participation *response* of married couples with children to tax changes is larger than for couples without children.[5]

This example has important implications for the mapping of our model economy to the data. On the one hand, the relative size of households with and without children affects the size of labour-supply response. On the other hand, as the bottom panel of Figure 1 shows, exactly how much the labour-force participation of married females will increase depends on the shape of $\zeta(q)$. Therefore, selecting the functional form for the distribution of utility costs will be an important part of the model parameterization; the magnitude of the response along the extensive margin depends on slope $\zeta'(q)$. We capture this slope by exploiting the observed differences in female labour-force participation in response to changes in the gender gap, x/z. The key to this procedure is that an increase in x, for a given z, implies an increase in labour-force participation whose magnitude hinges precisely on the magnitude of $\zeta'(q)$.

3. THE ECONOMIC ENVIRONMENT

We study a stationary overlapping generations economy populated by a continuum of males (m) and a continuum of females (f). Let $j \in \{1, 2, \ldots, J\}$ denote the age of each individual. Population grows at rate n. For tractability, individuals differ in terms of their marital status: they are born as either single or married, and their marital status does not change over time.

4. This follows from the fact that income effects from female labour supply imply that males work less when they are in a two-earner household, that is $l^*_{m,2} < l^*_{m,1}$. Since the first-order condition for husband's hours implies that marginal disutility from work has to be equal to the marginal utility from consumption times the after-tax wage rate, household consumption with two earners must be higher than with one earner.

5. For this inequality to hold household consumption with two earners must be lower with children than without children, which follows naturally from the negative income effect of children on labour-supply decisions.

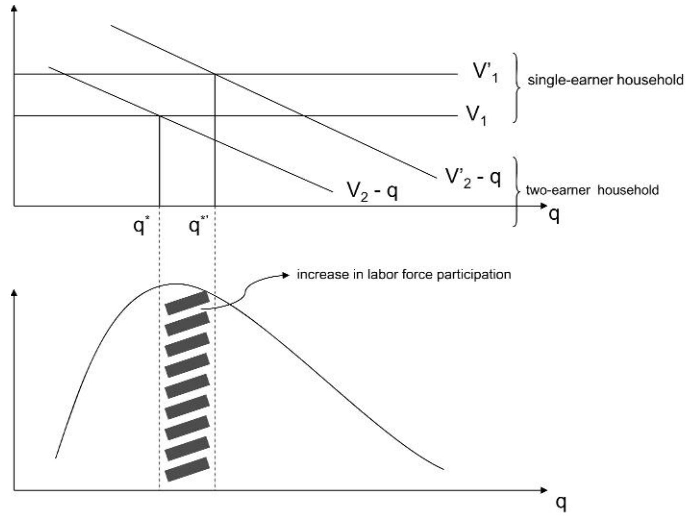

FIGURE 1
Taxes and Labour force participation of secondary earners

Married households and single females also differ in terms of the number of children attached to them. Married households and single females can be childless or endowed with two children. These children appear either *early* or *late* in the life cycle exogenously and affect the resources available to households for three periods. Children do not provide any utility.

The life cycle of agents is split into two parts. Each agent starts life as a worker and at age J_R, individuals retire and collect pension benefits until they die at age J. We assume that married households are comprised by individuals who are of the same age. As a result, members of a married household experience identical life-cycle dynamics.

Each period, working households (married or single) make labour-supply, consumption, and savings decisions. Children imply a fixed-time cost for females. If a female with children, married or single, works, then the household also has to pay childcare costs. Not working for a female is *costly*; if she does not work, she experiences losses of labour efficiency units for next period. Furthermore, if the *female* member of a married household supplies positive amounts of market work, then the household incurs a utility cost.

Heterogeneity and demographics. Individuals differ in terms of their labour efficiency units. At the start of life, each *male* is endowed with an exogenous type z, where $z \in Z$ and $Z \subset R_{++}$ is a finite set. The type of a male agent remains constant over his life cycle. Let the age-j productivity of a type-z agent be denoted by the function $\varpi_{\mathrm{m}}(z, j)$. Let $\Omega_j(z)$ denote the fraction of age-j, type-z males in male population, with $\sum_{z\in Z}\Omega_j(z) = 1$.

Each female starts her working life with a particular intrinsic type. As males, this type is fixed over time and is denoted by $x \in X$, where $X \subset R_{++}$ is a finite set. Let $\Phi_j(x)$ denote the fractions of age-j, type-x females in female population, with $\sum_{x\in X}\Phi_j(x) = 1$.

As women enter and leave the labour market, their labour market productivity levels evolve *endogenously*. Each female starts life with an initial productivity level that depends on her intrinsic type, $h_1 = \eta(x) \in H$. The next period's productivity level (h') depends on the female's intrinsic type x, her age, the current level of h, and current labour supply (l). Formally, for $j \geq 1$,

$$h' = G(x, h, l, j)$$

all $h \in H$. The function G is increasing in h and x and non-decreasing in l. It captures the combined effects of a female intrinsic type, age, and labour-supply decisions on her labour market productivity growth. We specify this function in detail in Section 4.

Let $M_j(x,z)$ denote the fraction of marriages between an age-j, type-x female and an age-j, type-z male, and let $\omega_j(z)$ and $\phi_j(x)$ be the fraction of single type-z males and the fraction of single type-x females, respectively. Then, the following accounting identity must hold:

$$\Omega_j(z) = \sum_{x \in X} M_j(x,z) + \omega_j(z). \tag{1}$$

Furthermore, since the marital status does not change, $M_j(x,z) = M(x,z)$ and $\omega_j(z) = \omega(z)$ for all j, which implies $\Omega_j(z) = \Omega(z)$. Similarly, for age-j females, we have

$$\Phi_j(x) = \sum_{z \in Z} M_j(x,z) + \phi_j(x) \tag{2}$$

Since marital status does not change $\phi_j(x) = \phi(x)$ and $\Phi_j(x) = \Phi(x)$ for all j

We assume that each cohort is $1+n$ bigger than the previous one. These demographic patterns are stationary so that age j agents are a fraction μ_j of the population at any point in time. The weights are normalized to add up to one, and obey the recursion, $\mu_{j+1} = \mu_j/(1+n)$.

Children. Children are assigned exogenously to married couples and single females at the start of life, depending on the intrinsic type of parents. Each married couple and single female can be of three types: *early* child bearers, *late* child bearers, and those *without* any children. Early and late child bearers have *two* children for three periods. Early child bearers have these children in ages $j = 1,2,3$, while late child bearers have children attached to them in ages $j = 2,3,4$.

Childcare costs. We assume that if a female with children works, married or single, then the household has to pay for childcare costs. Childcare costs depend on the age of the child (s). For a female with children of age $s \in \{1,2,3\}$, the household needs to purchase $d(s)$ units of (childcare) labour services for their two children. Since the competitive price of chilecare services is the wage rate w, the total cost of childcare services for two children equals $wd(s)$.

Utility cost of joint work. We assume that at the start of their lives married households draw a $q \in Q$, where $Q \subset R_{++}$ is a finite set. These values of q represent the *utility costs* of joint market work for married couples. For a given household, the initial draw of a utility cost depends on the intrinsic type of the husband. Let $\zeta(q|z)$ denote the probability that the cost of joint work is q, with $\sum_{q \in Q} \zeta(q|z) = 1$.

Preferences. The momentary utility function for a single female is given by

$$U_{\mathrm{f}}^{\mathrm{S}}(c,l,k_y) = \log(c) - \varphi(l + k_y \varkappa)^{1+\frac{1}{\gamma}},$$

where c is consumption, l is time devoted to market work, φ is a parameter controlling the disutility of work, $\varkappa$ is fixed-time cost having two age 1 (young) children for a female, and γ is the intertemporal elasticity of labour supply. Here, $k_y = 0$ stands for the absence of age 1 (young) children in the household, whereas $k_y = 1$ stands for young children being present. Since a single male does not have any children, his utility function is simply given by

$$U_{\mathrm{m}}^{\mathrm{S}}(c,l) = \log(c) - \varphi(l)^{1+\frac{1}{\gamma}}.$$

Married households maximize the sum of their members utilities. We assume that when the female member of a married household works, the household incurs a utility cost q. Then, the utility function for a married female is given by

$$U_{\mathrm{f}}^{\mathrm{M}}(c, l_{\mathrm{f}}, q, k_y) = \log(c) - \varphi(l_{\mathrm{f}} + k_y \varkappa)^{1+\frac{1}{\gamma}} - \frac{1}{2}\chi\{l_{\mathrm{f}}\}q,$$

while the one for a married male reads as

$$U_{\mathrm{m}}^{\mathrm{M}}(c, l_{\mathrm{m}}, l_{\mathrm{f}}, q) = \log(c) - \varphi l_{\mathrm{m}}^{1+\frac{1}{\gamma}} - \frac{1}{2}\chi\{l_{\mathrm{f}}\}q,$$

where $\chi\{\cdot\}$ denote the indicator function. Note that consumption is a public good within the household. Note also that the parameter $\gamma > 0$, the intertemporal elasticity of labour supply, and φ, the weight on disutility of work, are independent of gender and marital status.

Production and markets. There is an aggregate firm that operates a constant returns to scale technology. The firm rents capital and labour services from households at the rate R and w, respectively. Using K units of capital and L_{g} units of labour, firms produce $F(K, L_{\mathrm{g}}) = K^{\alpha} L_{\mathrm{g}}^{1-\alpha}$ units of consumption (investment) goods. We assume that capital depreciates at rate δ_k. Households save in the form of a risk-free asset that pays the competitive rate of return $r = R - \delta_k$.

Incomes, taxation, and social security. Let a stand for household's assets. Then, the total pre-tax resources of a single working male of age j and a single female worker of age j without any children are given by $a + ra + w\varpi_{\mathrm{m}}(z, j)l_{\mathrm{m}}$ and $a + ra + whl_{\mathrm{f}}$, respectively. For a single female worker with children, they amount to $a + ra + whl - wd(s)\chi\{l_{\mathrm{f}}\}$. The pre-tax total resources for a married working couple with children are given by $a + ra + w\varpi_{\mathrm{m}}(z, j)l_{\mathrm{m}} + whl_{\mathrm{f}} - wd(s)\chi\{l_{\mathrm{f}}\}$, while they are $a + ra + w\varpi_{\mathrm{m}}(z, j)l_{\mathrm{m}} + whl_{\mathrm{f}}$ for those without children.

Retired households have access to social security benefits. We assume that social security benefits depend on agents' intrinsic types, that is initially more productive agents receive larger social security benefits. This allows us to capture in a parsimonious way the positive relation between lifetime earnings and social security transfers as well as the intra-cohort redistribution built into the system. Let $p_{\mathrm{f}}^{\mathrm{S}}(x)$, $p_{\mathrm{m}}^{\mathrm{S}}(z)$, and $p^{\mathrm{M}}(x, z)$ indicate the level of social security benefits for a single female of type x, a single male of type z, and a married retired household of type (x, z), respectively. Hence, retired households pre-tax resources are simply $a + ra + p_{\mathrm{f}}^{\mathrm{S}}(x)$ and $a + ra + p_{\mathrm{m}}^{\mathrm{S}}(z)$ for singles, and $a + ra + p^{\mathrm{M}}(x, z)$ for married ones.

Income for tax purposes, I, is defined as total labour and capital income. Hence, for a single male worker, it equals $I = ra + w\varpi_{\mathrm{m}}(z, j)l_{\mathrm{m}}$, while for a single female worker, it reads as $I = ra + whl_{\mathrm{f}}$. For a married working household, taxable income equals $I = ra + w\varpi_{\mathrm{m}}(z, j)l_{\mathrm{m}} + whl_{\mathrm{f}}$. We assume that social security benefits are not taxed, so income for tax purposes is simply given by ra for retired households. The total income tax liabilities of married and single households are affected by the presence of children in the household and are represented by tax functions $T^{\mathrm{M}}(I, k)$ and $T^{\mathrm{S}}(I, k)$, respectively, where $k = 0$ stands for the absence of children in the household, whereas $k = 1$ stands for children of any age being present. These functions are continuous in I, increasing and convex. This representation captures the actual variation in tax liabilities associated to the presence of children in households.

There is also a (flat) payroll tax that taxes individual labour incomes, represented by τ_{p}, to fund social security transfers. Moreover, each household pays an additional flat capital income tax for the returns from his/her asset holdings, denoted by τ_k.

3.1. *Decision problem*

We now present the decision problem for different types of agents in the recursive language. For single males, the individual state is (a, z, j). For single females, the individual state is given by (a, h, x, b, j). For married couples, the state is given by (a, h, x, z, q, b, j). Note that the dependency of taxes on the presence of children in the household (k) is summarized by age (j) and childbearing status (b): (i) $k = 1$ if $b = \{1, 2\}$ and $j = \{b, b+1, b+2\}$ and (ii) $k = 0$ if $b = 2$ and $j = 1$, or $b = \{1, 2\}$ for all $j > b+2$, or $b = 0$ for all j. Similarly, the presence of age 1 (young) children (k_y) depends on b and j.

The problem of a single male household. Consider now the problem of a single male worker of type (a, z, j). A single worker of type-(a, z, j) decides how much to work and how much to save. His problem is given by

$$V_{\mathrm{m}}^{\mathrm{S}}(a, z, j) = \max_{a', l}\{U_{\mathrm{m}}^{\mathrm{S}}(c, l) + \beta V_{\mathrm{m}}^{\mathrm{S}}(a', z, j+1)\} \tag{3}$$

subject to

$$c + a' = \begin{cases} a(1 + r(1-\tau_k)) + w\varpi_{\mathrm{m}}(z, j)l(1-\tau_{\mathrm{p}}) - T^{\mathrm{S}}(w\varpi_{\mathrm{m}}(z, j)l + ra, 0) & \text{if } j < J_R, \\ a(1 + r(1-\tau_k)) + p_{\mathrm{m}}^{\mathrm{S}}(z) - T^{\mathrm{S}}(ra), & \text{otherwise,} \end{cases}$$

and

$$l \geq 0,\ a' \geq 0 \text{ (with strict equality if } j = J).$$

The problem of a single female household. In contrast to a single male, a single female's decisions also depends on her current human capital h and her childbearing status b. Hence, given her current state, (a, x, h, b, j), the problem of a single female is

$$V_{\mathrm{f}}^{\mathrm{S}}(a, h, x, b, j) = \max_{a', l}\{U_{\mathrm{f}}^{\mathrm{S}}(c, l, k_y) + \beta V_{\mathrm{f}}^{\mathrm{S}}(a', h', x, b, j+1)\},$$

subject to

(i) *With kids*: if $b = \{1, 2\}$, $j \in \{b, b+1, b+2\}$, then $k = 1$, and

$$c + a' = a(1 + r(1-\tau_k)) + whl(1-\tau_{\mathrm{p}}) - T^{\mathrm{S}}(whl + ra, 1) - wd(j+1-b)\chi(l).$$

Furthermore, if $b = j$, then $k_y = 1$.

(ii) *Without kids but not retired*: if $b = 0$, or $b = \{1, 2\}$ and $b + 2 < j < J_R$, or $b = 2$ and $j = 1$, then $k = 0$ and

$$c + a' = a(1 + r(1-\tau_k)) + whl(1-\tau_{\mathrm{p}}) - T^{\mathrm{S}}(whl + ra, 0).$$

(iii) *Retired*: if $j \geq J_R$, $k = 0$ and

$$c + a' = a(1 + r(1-\tau_k)) + p_{\mathrm{f}}^{\mathrm{S}}(x) - T^{\mathrm{S}}(ra, 0).$$

In addition,

$$h' = G(x, h, l, j),$$

$$l \geq 0, a' \geq 0 \quad \text{(with strict equality if } j = J).$$

Note how the cost of children depends on the age of children. If $b = 1$, the household has children at ages 1, 2, and 3, then $wd(j+1-b)$ denote cost for ages 1, 2, and 3 with $j = \{1, 2, 3\}$. If $b = 2$, the household has children at ages 2, 3, and 4, then $wd(j+1-b)$ denotes the cost for children of ages 1, 2, and 3 with $j = \{2, 3, 4\}$. A female only incurs the time cost of children if her kids are 1 year old, and this happens if $b = j = 1$ or $b = j = 2$.

3.2. *The problem of married households*

Like singles, married couples decide how much to consume, how much to save, and how much to work. They also decide whether the female member of the household should work. Their problem is given by

$$V^{\mathrm{M}}(a,h,x,z,q,b,j) = \max_{a',\, l_{\mathrm{f}},\, l_{\mathrm{m}}} \{[U_{\mathrm{f}}^{\mathrm{M}}(c,l_{\mathrm{f}},q,k_y)+U_{\mathrm{m}}^{\mathrm{M}}(c,l_{\mathrm{m}},l_{\mathrm{f}},q)] + \beta V^{\mathrm{M}}(a',h',x,z,q,b,j+1)\},$$

subject to

(i) *With kids*: if $b=\{1,2\}$, $j\in\{b,b+1,b+2\}$, then $k=1$ and

$$c+a' = a(1+r(1-\tau_k))+w(\varpi_{\mathrm{m}}(z,j)l_{\mathrm{m}}+hl_{\mathrm{f}})(1-\tau_{\mathrm{p}}) - T^{\mathrm{M}}(w\varpi_{\mathrm{m}}(z,j)l_{\mathrm{m}}+whl_{\mathrm{f}}+ra,1)-wd(j+1-b)\chi(l_{\mathrm{f}}).$$

Furthermore, if $b=j$, then $k_y=1$.

(ii) *Without kids but not retired*: if $b=0$, or $b=\{1,2\}$ and $b+2<j<J_R$, or $b=2$, $j=1$, then $k=0$ and

$$c+a' = a(1+r(1-\tau_k))+w(\varpi_{\mathrm{m}}(z,j)l_{\mathrm{m}}+hl_{\mathrm{f}})(1-\tau_{\mathrm{p}}) - T^{\mathrm{M}}(w\varpi_{\mathrm{m}}(z,j)l_{\mathrm{m}}+whl_{\mathrm{f}}+ra,0).$$

(iii) *Retired*: if $j\geq J_R$, then $k=0$ and

$$c+a'=a(1+r(1-\tau_k))+p^{\mathrm{M}}(x,z)-T^{\mathrm{M}}(ra,0).$$

In addition,

$$h'=G(x,h,l_{\mathrm{f}},j),$$
$$l_{\mathrm{m}}\geq 0,\ l_{\mathrm{f}}\geq 0, a'\geq 0 \quad \text{(with strict equality if } j=J).$$

3.3. *Stationary equilibrium*

The aggregate state of this economy consists of distribution of households over their types, asset, and human capital levels. In particular, let the function $\psi_j^{\mathrm{M}}(a,h,x,z,q,b)$ denote the number of married individuals of age j with assets a, female human capital h, when the female is of type x, the male is of type z, the household faces a utility cost q of joint work, and is of childbearing type b. The functions $\psi_{\mathrm{f},j}^{\mathrm{S}}(a,h,x,h,b)$, for single females, and $\psi_{\mathrm{m},j}^{\mathrm{S}}(a,z)$, for single males, are defined in a similar way. As we mentioned earlier, we restrict x, z, and q to take values from finite sets and b is finite by construction. In contrast, household assets, a, and female human capital levels, h, are continuous decisions. We denote by $A=[0,\overline{a}]$ and $H=[0,\overline{h}]$ the sets of possible assets and female human capital levels.

By construction, $M(x,z)$, the number married households of type (x,z), must satisfy for all ages

$$M(x,z)=\sum_{q,b}\int_{A\times H}\psi_j^{\mathrm{M}}(a,h,x,z,q,b)dh\,da.$$

Similarly, the fraction of single females and males must be consistent with the corresponding measures $\psi_{\mathrm{f},j}^{\mathrm{S}}$ and $\psi_{\mathrm{m},j}^{\mathrm{S}}$. For all ages,

$$\phi(x)=\sum_{b}\int_{A\times H}\psi_{\mathrm{f},j}^{\mathrm{S}}(a,h,x,b)dh\,da,$$

and

$$\omega(z) = \int_A \psi^{\mathrm{S}}_{\mathrm{m},j}(a,z)da.$$

In stationary equilibrium, factor markets clear. Aggregate capital (K) and aggregate labour (L) are given by

$$K = \sum_j \mu_j \left[\sum_{x,z,q,b} \int_{A\times H} a\psi^{\mathrm{M}}_j(a,h,x,z,q,b)dh\,da + \sum_z \int_A a\psi^{\mathrm{S}}_{\mathrm{m},j}(a,z)da \right. \\ \left. + \sum_{x,b} \int_{A\times H} a\psi^{\mathrm{S}}_{\mathrm{f},j}(a,h,x,b)dh\,da \right], \tag{4}$$

and

$$L = \sum_j \mu_j \left[\sum_{x,z,q,b} \int_{A\times H} (hl^{\mathrm{M}}_{\mathrm{f}}(a,h,x,z,q,b,j) + \varpi_{\mathrm{m}}(z,j) l^{\mathrm{M}}_{\mathrm{m}}(a,h,x,z,q,b,j)) \right. \\ \times \psi^{\mathrm{M}}_j(a,h,x,z,q,b)dh\,da + \sum_z \int_A \varpi_{\mathrm{m}}(z,j) l^{\mathrm{S}}_{\mathrm{m}}(a,z,j)\psi^{\mathrm{S}}_{\mathrm{m}}(a,z)da \\ \left. + \sum_{x,b} \int_{A\times H} hl^{\mathrm{S}}_{\mathrm{f}}(a,h,x,b,j)\psi^{\mathrm{S}}_{\mathrm{f},j}(a,x,b)dh\,da \right]. \tag{5}$$

Furthermore, labour used in the production of goods, L_{g}, equals

$$L_{\mathrm{g}} = L - \left[\sum_{x,z,q} \sum_{b=1,2} \sum_{j=b,b+2} \mu_j \int_{A\times H} \chi\{l^{\mathrm{M}}_{\mathrm{f}}\} d(j+1-b)\psi^{\mathrm{M}}_j(a,h,x,z,q,b)dh\,da \right. \\ \left. + \sum_x \sum_{b=1,2} \sum_{j=b,b+2} \mu_j \int_{A\times H} \chi\{l^{\mathrm{S}}_{\mathrm{f}}\} d(j+1-b)\psi^{\mathrm{S}}_{\mathrm{f},j}(a,h,x,b)dh\,da \right], \tag{6}$$

where the term in brackets is the quantity of labour used in childcare services.

In addition, factor prices are competitive so $w = F_2(K, L_{\mathrm{g}})$, $R = F_1(K, L_{\mathrm{g}})$, and $r = R - \delta_k$. In the Supplementary Appendix, we provide a formal definition of equilibria.

4. PARAMETER VALUES

We now proceed to assign parameter values to the endowment, preference, and technology parameters of our benchmark economy. To this end, we use aggregate as well as cross-sectional and demographic data from multiple sources. As a first step in this process, we start by defining the length of a period to be 5 years.

Demographics and endowments. We assume that agents start their life at age 25 as workers and work for 40 years, corresponding to ages 25–64. Hence, the first model period ($j = 1$) corresponds to ages 25–29, while the first model period of retirement ($j = J_R$) corresponds to ages 65–79. After 8 periods of working life, all agents retire at age 65 and live until age 80; that is we set $J = 11$. The population grows at the annual rate of 1·1%, the average values for the U.S. economy between 1960 and 2000.

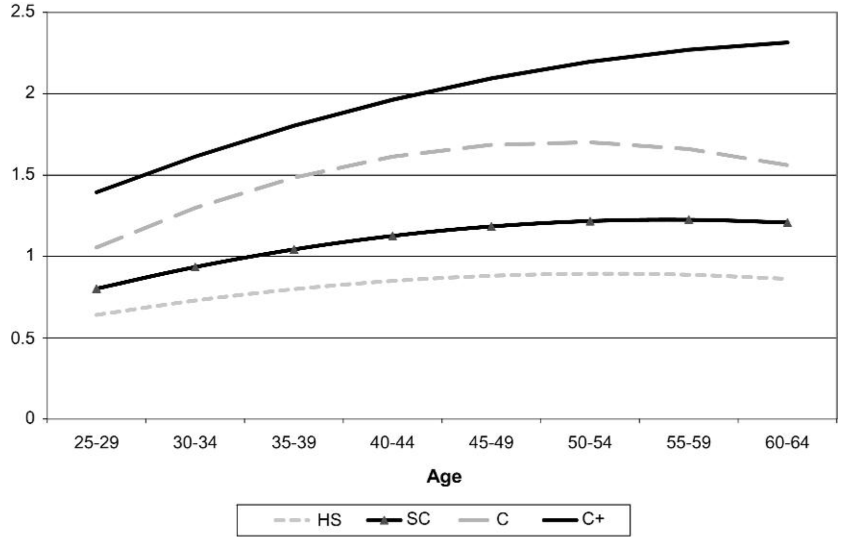

FIGURE 2
Labour productivity levels, males

We set the number of types for males to 4. Each type corresponds to an educational attainment level: *less than or equal to high school* (hs), *some college* (sc), *college* (col), and *post-college* education (col+). We use data from the March Supplement of the 2000 Current Population Survey (CPS) to calculate age-efficiency profiles for each male type. Efficiency levels correspond to mean weekly wage rates within an education group, which we construct using annual wage and salary income and weeks worked. We normalize wages by the overall mean weekly wages for all males and females between ages 25 and 64. We include in the sample the civilian adult population who worked as full-time workers last year and exclude those who are self-employed or unpaid workers or make less than half of the minimum wage.[6] Figure 2 shows the second degree polynomials that we fit to the raw wage data. In our quantitative exercises, we calibrate the male-efficiency units, $\varpi_{\rm m}(z, j)$, using these fitted values. Our estimates imply a wage growth of about 60% for college graduates from ages 25–29 to ages 45–49. The corresponding values for high school graduates are about 38%.

We assume that there are four intrinsic female types, corresponding to four education levels. Following the same procedure for males, we also calculate the initial (ages 25–29) efficiency levels for females. Table A1 in the Supplementary Tables shows initial efficiency levels for males and females and the corresponding gender wage gap. We use the initial efficiency levels for females to calibrate their initial human capital levels. After ages 25–29, the human capital level of females evolves endogenously according to

$$h' = G(x, h, l, j) = \exp[\ln h + \alpha_j^x \chi(l) - \delta(1 - \chi(l))]. \tag{7}$$

We calibrate the values for α_j^x and δ following a simple procedure.[7] First, following Mincer and Ofek (1982), we set δ to corresponds to an annual wage loss associated to non-participation of

6. Our sample restrictions are standard in the literature and follow Katz and Murphy (1992).
7. Our formulation of the human capital accumulation process follows Attanasio, Low and Sánchez Marcos (2008).

2%. Then, we select α_j^x so that if a female of a particular type x works in every period, her wage profile has exactly the same shape as males. This procedure takes the initial gender differences as given and assumes that the wage growth rate for a female who works full time will be the same as for a male worker; hence, it sets α_j^x values equal to the growth rates of male wages at each age. Table A2 in the Supplementary Tables shows the calibrated values for α_j^x.

We subsequently determine the distribution of individuals by productivity types for each gender, that is $\Omega(z)$ and $\Phi(x)$, using data from the 2000 U.S. Census. For this purpose, we consider all household heads or spouses who are between ages 30 and 39 and for each gender calculate the fraction of population in each education cell. For the same age group, we also construct $M(x,z)$, the distribution of married working couples as shown in Table A3 in the Supplementary Tables.[8]

Given the fractions of individuals in each education group, $\Phi(x)$ and $\Omega(z)$, and the fractions of married households, $M(x,z)$, in the data, we calculate the implied fractions of single households, $\omega(z)$ and $\phi(x)$, from accounting identities (1) and (2). The resulting values are reported in Table A4 in the Supplementary Tables. About 77% of households in the benchmark economy consists of married households, while the rest (about 23%) are single.

Since we assume that the distribution of individuals by marital status is independent of age, we use the 30–39 age group for our calibration purposes. This age group captures the marital status of recent cohorts during their prime-working years while being at the same time representative of older age groups.

Childbearing. Our model assumes that each single female and each married couple belong to one of three groups: *childless*, *early child bearer*, and *late child bearer*. The early child bearers have two children at ages 1, 2, and 3 corresponding to ages 25–29, 30–34, and 35–39, while late child bearers have their two children at ages 2, 3, and 4 corresponding to ages 30–34, 35–39, and 40–44. This particular structure captures two key features of the data from the 2002 CPS June supplement.[9] First, conditional on having a child, married couples tend to have two children.[10] Second, these two births occur within a short period of time, mainly between ages 25 and 29 for households with low education and between ages 30 and 34 for households with high education.[11]

For singles, we use data from the 2002 CPS June supplement and calculate the fraction of 40–44 years old single (never married or divorced) females with zero live births. We use these statistics as a measure of lifetime childlessness. Then we calculate the fraction of all single women above age 25 with a total number of two live births who were below age 30 at their last birth. This fraction gives us those who are early child bearers and the remaining fraction of assigned as late child bearers. The resulting distribution is shown in Table A5 in the Supplementary Tables.

8. Consistent with positive assortative matching by education, the largest entries in each row and column in Supplementary Table A3 are located along the diagonal. See Fernández, Guner and Knowles (2005) for a study of positive assortative matching by education.

9. The CPS June Supplement provides data on the total number of live births and the age at last birth for females, which are not available in the U.S. Census.

10. For married households in which women are above age 25, the total number of live births varies from 2·4 for those households in which both husband and wife have at most high school degrees to 2 for those households in which both husband and wife have more than a college degree. For the majority of households, the total number of children is close to 2.

11. The average age at first birth is 26·2 for those households in which both husband and wife have at most high school degrees, and 31·1 for those households in which both husband and wife have more than a college degree. For the same household types with two children, the average age at second were 26·8 and 31·3, respectively.

We follow a similar procedure for married couples, combining data from the CPS June Supplement and the U.S. Census. For childlessness, we use the large sample from the U.S. Census.[12] The Census does not provide data on total number of live births but the total number of children in the household is available. Therefore, as a measure of childlessness, we use the fraction of married couples between ages 35 and 39 who have no children at home.[13] Then, using the CPS June supplement, we look at all couples above age 25 in which the female had a total of two live births and was below age 30 at her last birth. This gives us the fraction of couples who are early child bearers, with the remaining married couples labelled as the late ones. Table A6 in the Supplementary Tables shows the resulting distributions.

Childcare costs. To calibrate childcare costs, we use the U.S. Bureau of Census data from the Survey of Income and Program Participation.[14] In 2005, the total yearly cost for employed mothers, who have children between ages 0 and 5 and who make childcare payments, was about \$6414·5. We take this figure from the Census as the childcare costs for two young children, which represents about 10% of average household income in 2005. The Census estimates of total childcare costs for children between 5 and 14 is about \$4851, which amounts to about 7·7% of average household income in 2005. We set $d(1) = d_1$ and $d(2) = d(3) = d_2$ and select d_1 and d_2 so that the total expenditure of families with children, that is wd_1 and wd_2, are about 10% and 7·7% of average household income for young (0–4) and older (5–14) children, respectively.[15] The calibrated values of d_1 and d_2 are 0·062 and 0·048.

Technology. We specify the production function as Cobb–Douglas and calibrate the capital share and the depreciation rate using a notion of capital that includes fixed private capital, land, inventories, and consumer durables. For the period 1960–2000, the resulting capital to output ratio averages 2·93 at the annual level. The capital share equals 0·343 and the (annual) depreciation rate amounts to 0·055.[16]

Taxation. To construct income tax functions for married and single individuals, we estimate *effective taxes* paid as a function of reported income, marital status, and children. For these purposes, we use tax return micro data from Internal Revenue Service for the year 2000 (Statistics of Income Public Use Tax File). For married households, we estimate tax functions corresponding

12. The CPS June Supplement is not particularly useful for the calculation of childlessness in married couples. The sample size is too small for some married household types for the calculation of the fraction of married females, aged 40–44, with no live births.

13. Since we use children at home as a proxy for childlessness, we use age 35–39 rather than 40–44. Using ages 40–44 generate more childlessness among less-educated people. This is counterfactual, and simply results from the fact that less-educated people are more likely to have kids younger, and hence these kids are less likely to be at home when their parents are between ages 40 and 44.

14. See Table 6 in http://www.census.gov/population/www/socdemo/child/tables-2006.html.

15. According to the National Association of Child Care Resource & Referral Agencies (2008a, NACCRRA), the cost of a day care for two young kids, one infant and one toddler, in Utah, the median state with respect to infant care costs, was about \$10,632 per year in 2005. However, NACCRRA (National Association of Child Care Resource & Referral Agencies 2008b) reports that about 25% of children have their grandparents and other relatives as primary caregivers. Making this adjustment, the yearly cost is \$7974. This is comparable with the Census data, which includes other cheaper types of childcare arrangements (such as family day care). Similarly, according to NACCRRA (National Association of Child Care Resource & Referral Agencies 2008a), the cost of school-age children is about 60% of infants, which is again in line with Census estimates.

16. We estimate the capital share and the capital to output ratio following the standard methodology; see Cooley and Prescott (1995). The data for capital and land are from Bureau of Economic Analysis (Fixed Asset Account Tables) and Bureau of Labor Statistics (Multi-factor Productivity Program Data).

TABLE 1
Tax function parameters

	$\widehat{\eta}_1$	$\widehat{\eta}_2$	R^2
Married (no children)	0·113	0·073	0·998
Married (two children)	0·084	0·090	0·992
Single (no children)	0·153	0·057	0·976
Single (two children)	0·094	0·092	0·947

Notes: Entries show the parameter estimates for the postulated tax function. These result from regressing effective average tax rates against household income, using 2000 micro data from the U.S. Internal Revenue Service. For singles with two children, the data used pertains to the "Head of Household" category—see text for details.

to the legal category *married filing jointly*. For singles without children, we estimate a tax function from the legal category *singles*; for singles with children, we estimate a tax function from the legal category *head of household*.[17]

We partition the sample in income brackets, and for each of these, we calculate total income taxes paid, total income earned, number of taxable returns, and the number of returns. Hence, we find the mean income and the average tax rate corresponding to every income bracket. We calculate the average tax rates as

$$\text{average tax rate} = \frac{\left\{\frac{\text{total amount of income tax paid}}{\text{number of taxable returns}}\right\}}{\left\{\frac{\text{total adjusted gross income}}{\text{number of returns}}\right\}}.$$

In each case, we fit the following equation to the data:

$$\text{average tax rate (income)} = \eta_1 + \eta_2 \log(\text{income}) + \varepsilon,$$

where average tax (income) is the average tax rate that applies when average income in an income bracket equals income. We calculate income by normalizing average income in each income bracket by the mean household income in 2000. Table 1 shows the estimates of the coefficients for married and single households, with and without children. To estimate the tax functions for household with children, we restrict our sample to households in which there are two dependent children for tax purposes. Given these estimates, we calculate the tax liabilities for each household as [average tax rate (income)] × (income × mean household income).

Figures 3 and 4 display estimated average and marginal tax rates for different multiples of household income. Our estimates imply that a single person without kids (with kids) with twice mean household income in 2000 faces an average tax rate of about 19·3 (15·8%) and a marginal tax rate equal to about 24·9% (24·9%). The corresponding rates for a married household with the same income are about 16·4% (14·6%) and 23·7% (23·6%).

Finally, we need to assign a value for the (flat) capital income tax rate τ_k, which we use to proxy the corporate income tax. We estimate this tax rate as the one that reproduces the observed level of tax collections out of corporate income taxes after the major reforms of 1986. For the period 1987–2000, such tax collections averaged about 1·92% of Gross Domestic Product (GDP). Using the technology parameters, we calibrate in conjunction with our notion of output (business GDP), we obtain $\tau_k = 0 \cdot 097$. Overall, our choices imply tax collections that amount to about 12·7% of output. The corresponding value in the data for the year 2000 was 12·3%.

17. We use the "head of household" category for singles with children since in practice, it is clearly advantageous for most unmarried individuals with dependent children to file under this category. For instance, the standard deduction is larger than for the "single" category, and a larger portion of income is subject to lower marginal tax rates.

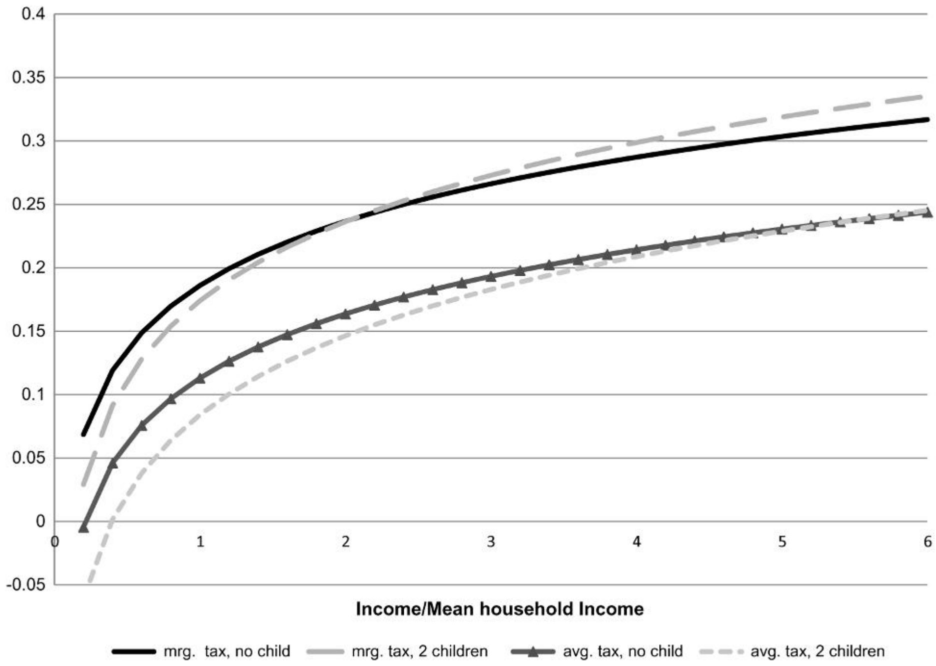

FIGURE 3
Tax Rates, Married

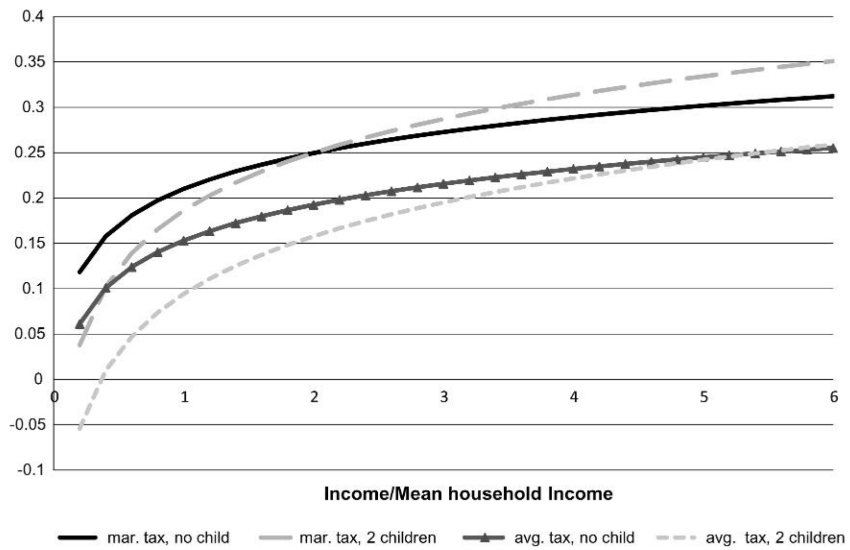

FIGURE 4
Tax rates, singles

Social security. We calculate $\tau_p = 0 \cdot 086$, as the average value of the social security contributions as a fraction of aggregate labour income for 1990–2000 period.[18] Using the 2000 U.S. Census, we calculate total Social Security income for all single and married households.[19] Tables A7 and A8 in the Supplementary Tables show Social Security benefits, normalized by the level corresponding to single males of the lowest types. Agents with higher types receive larger payments: a single male with post-college education receives about 30% more than a single male whose education is less than college, while a couple with two members with post-college education receives about 28% more than a couple with two members with less than high school education. Then, given the payroll tax rate, the value of the benefit for a single retired male of the lowest type, $p_m^S(x_1)$, balances the budget for the social security system. The value of $p_m^S(x_1)$ is about 17·8% of the average household income in the economy.

Preferences. There are three utility function parameters: the intertemporal elasticity of labour supply (γ), the parameter governing the disutility of work (φ), and the fixed-time cost of young children ($\varkappa$). We consider two values for γ: a low value of 0·2 and a higher value of 0·4. Both values are consistent with recent estimates for males. While $\gamma = 0 \cdot 2$ is in line with microeconomic evidence reviewed by Blundell and MaCurdy (1999), $\gamma = 0 \cdot 4$ is contained in the range of recent estimates by Domeij and Floden 2006, Table 5). Domeij and Floden (2006) results are based upon estimates for married males that control for the bias emerging from borrowing constraints.[20] We proceed by presenting first results when the intertemporal elasticity of substitution equals 0·4. In subsequent sections, we discuss the implications of a lower value for this parameter. Given γ, we select the parameter φ to reproduce average market hours per worker observed in the data. These average hours per worker amounted to about 40·1% of available time in 2000.[21] We set $\varkappa = 0 \cdot 141$ to match the labour-force participation of married females with young, 0–4 years old, children. From the 2000 U.S. Census, we calculate the labour-force participation of females between ages 25 and 39 who have two children and whose oldest child is less than 5 as 55·6%. We select the fixed cost such that the labour-force participation of married females with children less than 5 years (*i.e.* early child bearers between ages 25 and 29 and late child bearers between ages 30 and 34), has the same value.[22] Finally, we choose the discount factor β, so that the steady-state capital to output ratio matches the value in the data consistent with our choice of the technology parameters (2·93 in annual terms).

This leaves us with the utility cost of joint work, q, to determine. Note that even without this utility cost, married females face a non-trivial labour-force participation decision due to child-care costs and human capital accumulation. The presence of utility costs associated to joint work

18. The contributions considered are those from the Old Age, Survivors and DI programs. The data comes from the Social Security Bulletin, Annual Statistical Supplement, 2005, Tables 5.A.3.

19. Social Security income is all pre-tax income from Social Security pensions, survivors benefits, or permanent disability insurance. Since Social Security payments are reduced for those with earnings, we restrict our sample to those above age 70. For married couples, we sum the social security payments of husbands and wives.

20. Rupert, Rogerson and Wright (2000) provide estimates within a similar range in the presence of a home production margin. Heathcote, Storesletten and Violante (2009) report an estimate of 0·38, using a model with incomplete markets.

21. The numbers are for people between ages 25 and 54 and are based on data from the Consumer Population Survey. We find mean yearly hours worked by all males and females by multiplying usual hours worked in a week and number of weeks worked. We assume that each person has an available time of 5000 hours per year. Our target for hours corresponds to 2005 hours in the year 2000.

22. Our calibrated value for $\varkappa$ is in the ballpark of available estimates in the literature. Hotz and Miller (1988) estimate that the time cost of a newborn is about 660 hours per year and this cost declines at 12% per year. This would imply that parents spend about 520 hours per children, who are between ages 0 and 5. With 5000 available hours per year, this is more than 10% per child.

TABLE 2
Labour force participation of married females, 25–54

Males	Females			
	hs	sc	col	col+
hs	58·2	75·9	82·7	82·3
sc	64·6	74·8	82·9	88·4
col	61·6	68·7	73·2	83·2
col+	55·0	62·1	63·5	78·7
Total	59·7	73·4	74·8	82·1

Notes: Each entry shows the labour-force participation of married females ages 25–54, calculated from the 2000 U.S. Census. The outer row shows the weighted average for a fixed male or female type.

allows to capture residual heterogeneity among couples, beyond heterogeneity in endowments and children, that is needed to generate observed labour-supply behaviour and in particular, labour-force participation. As we explain in Section 2, all else the same, couples for which utility costs are high will have one earner, whereas those with low costs will have both members in the labour force. Public policy via taxes and transfers will affect this decision and thus the resulting degrees of labour-force participation.

We assume that the utility cost parameter is distributed according to a (flexible) gamma distribution, with parameters k_z and θ_z. Thus, conditional on the husband's type z,

$$q \sim \zeta(q|z) \equiv q^{k_z - 1} \frac{\exp(-q/\theta_z)}{\Gamma(k_z)\theta_z^{k_z}},$$

where $\Gamma(\cdot)$ is the Gamma function, which we approximate on a discrete grid. By proceeding in this way, we exploit the information contained in the *differences* in the labour-force participation of married females as their own wage rate differ with education (for a given husband type). We emphasize that this allows us to control the slope of the distribution of utility costs, which is potentially important in assessing the effects of tax changes on labour-force participation.

Using data from the 2000 U.S. census, we calculate that the employment–population ratio of married females between ages 25 and 54 for each of the educational categories defined earlier.[23] Table 2 shows the resulting distribution of the labour-force participation of married females by the productivities of husbands and wives for married households. The aggregate labour-force participation for this group is 69·3%, and it increases from 59·7% for the lowest education group to 82·1% for the highest. Our strategy is then to select the two parameters governing the gamma distribution, for every husband type, so as to reproduce each of the rows (four entries) in Table 2 as closely as possible. Altogether, this process requires estimating eight parameters (*i.e.* a pair (θ, k) for each husband educational category).

Summary. Table 3 summarizes our parameter choices. As we detailed above, n (population growth rate), γ (labour-supply elasticity), δ_k (depreciation rate of capital), α (capital share), δ (depreciation of female human capital), and α_j^x (growth factors for female human capital) are set from external estimates. We also take tax functions $T^{\mathrm{S}}(\cdot)$ and $T^{\mathrm{M}}(\cdot)$ as well as payroll taxes τ_{p} from the data. The remaining parameters are selected to match jointly several targets. First, we choose $p_{\mathrm{m}}^{\mathrm{S}}(z_1)$, the social security benefits for the lowest type male, to balance the social security budget. Second, the additional proportional tax on capital, τ_k, is selected to collect taxes

23. We consider all individuals who are not in armed forces.

TABLE 3
Parameter values

Parameter	Value	Comments
Population growth rate (n)	1·1	U.S. data—see text
Discount factor (β)	0·974	Calibrated—matches K/Y
Intertemporal elasticity (labour supply) (γ)	0·4	Literature estimates
Disutility of market work (φ)	8·03	Calibrated—matches hours per worker
Time cost of children ($\varkappa$)	0·141	Calibrated—matches LFP of married females with young (0–4) children
Childcare costs for young children (d_1)	0·062	Calibrated—matches childcare expenditure for young (0–4) children
Childcare costs for young children (d_2)	0·048	Calibrated—matches childcare expenditure for old (5–14) children
Department of human capital, females (δ)	0·02	Mincer and Ofek (1982)
Growth of human capital, females (α_j^x)	—	Calibrated—see text
Capital share (α)	0·343	Calibrated—see text
Depreciation rate (δ_k)	0·055	Calibrated—see text
Payroll tax rate ($\tau_{\rm p}$)	0·086	U.S. data—see text.
Social security income ($p_{\rm m}^{\rm S}(z_1)$) (for the lowest type single male as a % of average household income)	17·8%	Calibrated—to balance social security budget
Capital income tax rate (τ_k)	0·097	Calibrated—matches corporate income tax collections
Distribution of utility costs $\zeta(\cdot\|z)$ (Gamma distribution)	—	Calibrated—matches LFP by education conditional on husband's type

that match corporate tax collections from data. Third, d_1 and d_2, childcare time requirements for children are calibrated so that households spend the right amount of resources on childcare. Fourth, the discount factor is selected to match capital-to-output ratio. Fifth, disutility from market work, φ, is chosen to match hours per worker. Sixth, time cost of children, $\varkappa$, is used to match labour-force participation of married females with young children. Finally, eight gamma function parameters are calibrated to generate married female force participation by husbands and wives types.

Table 4 shows the performance of the benchmark model in terms of the targets we impose for φ, β, and $\varkappa$. The table also shows how well the benchmark calibration matches the labour-force participation of married females. The model has no problem in reproducing jointly these observations as the table demonstrates.

4.1. *The benchmark economy*

Before proceeding to investigate the effects of tax reforms, we report on properties of the benchmark economy and compare these with the corresponding values from data. This is critical for the questions at hand: to conduct tax reforms within our framework, we want to be confident that it offers a good model of female labour supply. We focus on different aspects of the model economy here. In particular, (i) how does female labour-force participation change by age and the presence of children? (ii) what is the gender gap in our model economy? The answer to the first question is important since the interaction between children and female labour-force participation plays a key role in our model. The answer to the second question is also critical

TABLE 4
Model and data

Statistic	Data	Model
Capital output ratio	2·93	2·95
Labour hours per worker	0·40	0·40
Labour force participation of married females with young children (%)	55·6	57·1
Participation rate of married females (%), 25–54		
Less than high school	59·7	59·9
Some college	73·4	72·4
College	74·8	79·3
More than college	82·1	81·4
Total	69·4	69·3
With children	67·4	64·4
Without children	82·5	82·9

Notes: Entries summarize the performance of the benchmark model in terms of empirical targets and key aspects of data. Total participation rates, with children and without children are not explicitly targeted.

since married females in our economy have a non-trivial labour-force participation decision that results in an endogenous gender gap. In assessing the model performance, it is important to bear in mind that the empirical targets for the model are the levels of aggregate participation rates by marriage type and the participation rates of women with young children. No age-related statistics are used, so the match between model and data in this dimension is due to the forces governing household labour supply within the model.

At the aggregate level, the model is in conformity with data. The model reproduces, by construction, the labour-force participation rate of women with young children and the economy-wide level of participation, as it targets participation rates by type. It also captures the consequences of the presence of children on participation rates. Participation rates of women with children are lower than those without children, both in the model and in the data; about 64·4% versus 67·4%. Females without children participate more, their labour-force participation are 82·9% and 82·5% in the model and in the data, respectively.

What are the female labour-supply elasticities implied by the model economy? Although there are different ways, one can measure the elasticity of female labour supply, given our model a natural one is to ask how much female labour-force participation and aggregate hours will increase if female productivity levels were increased by 1%. Our model implies an aggregate elasticity of female labour-force participation to changes in female productivity levels of about 0·72 and an aggregate elasticity of total hours worked by married females to changes in female productivity levels of about 0·95.[24] If we were to calculate the same elasticities to changes in the economy-wide wage rate, we find elasticities of 0·36 and 0·35, respectively, which are (not surprisingly) lower.[25]

Figure 5 shows married female labour-force participation by age and by the presence of children. As the figure shows, the labour-force participation of married females with children increases monotonically with age both in the model and the data, and its level is always below that for women without children. Both in the model economy and the data, those who have their

24. These elasticities are in line with estimates surveyed in Blundell and MaCurdy (1999) and Keane (2010).

25. Consistent with available empirical evidence, elasticity of male hours with respect to the wage rate is about zero.

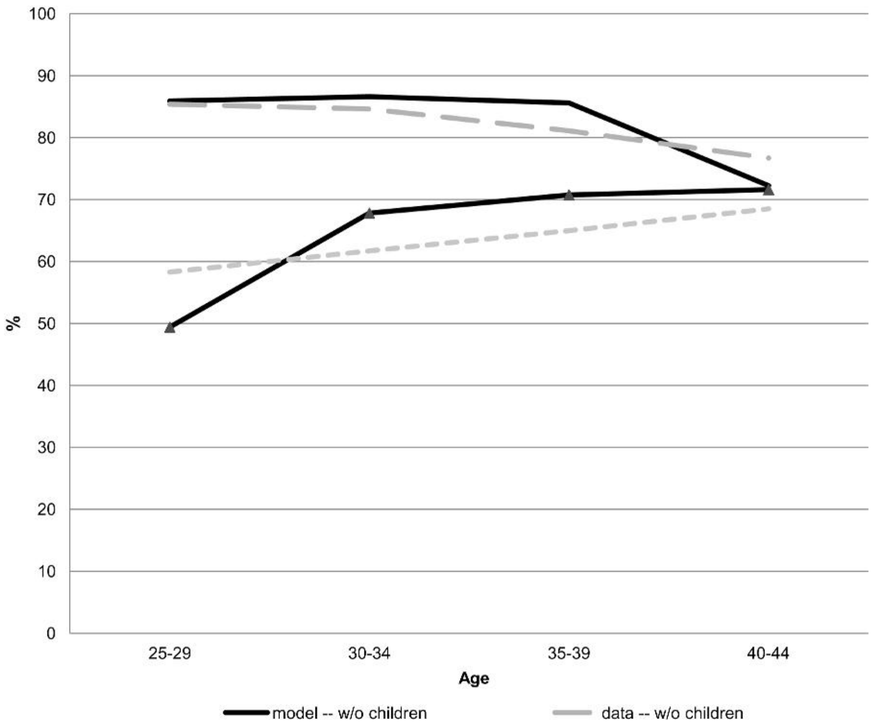

FIGURE 5
Labour force participation

children early on, at ages 25–29, are women with low levels of education; not surprisingly, their labour-force participation is low. Those who have their children in later ages tend to be skilled women, whose labour-force participation is higher. Furthermore, those who have their children early are more likely to participate in the labour market in later ages since their children age and the associated childcare costs decline. The participation rate of women without children, on the other hand, declines slightly between ages 25–29 and 40–44. The decline in later ages is mainly due to women who had their children in the first period and enter the labour-force in later ages as these children age. Since these women are mainly from lower education groups and could not accumulate human capital in the initial years, they have low labour-force participation.

Figure 6 displays the wage gender gap in the model and the data. In the model economy, we observe the labour market productivity levels for all females whether they participate in the labour market or not. Since this is a more informative statistic, we report the gender gap from the model for *all* females. In order to produce a comparable measure from the data, we have to *impute* wages for females who do not participate in the labour market. In order to do that, we estimate a standard Mincer regression with Heckman (1979) selection correction, which provides us with wage estimates for women who do not participate in the labour market. When we report data on wages, we report an average of observed wages (for women who work) and imputed wages (for women who do not work). What is critical is that Heckman's procedure allows us to assign a wage for females who do not work.[26] The model does a very good job in

26. For the *population* equation for wages, we assume that log wages of women depend on years of education, age, and age squared. For the *selection* equation, we assume that the probability of participation in the labour market

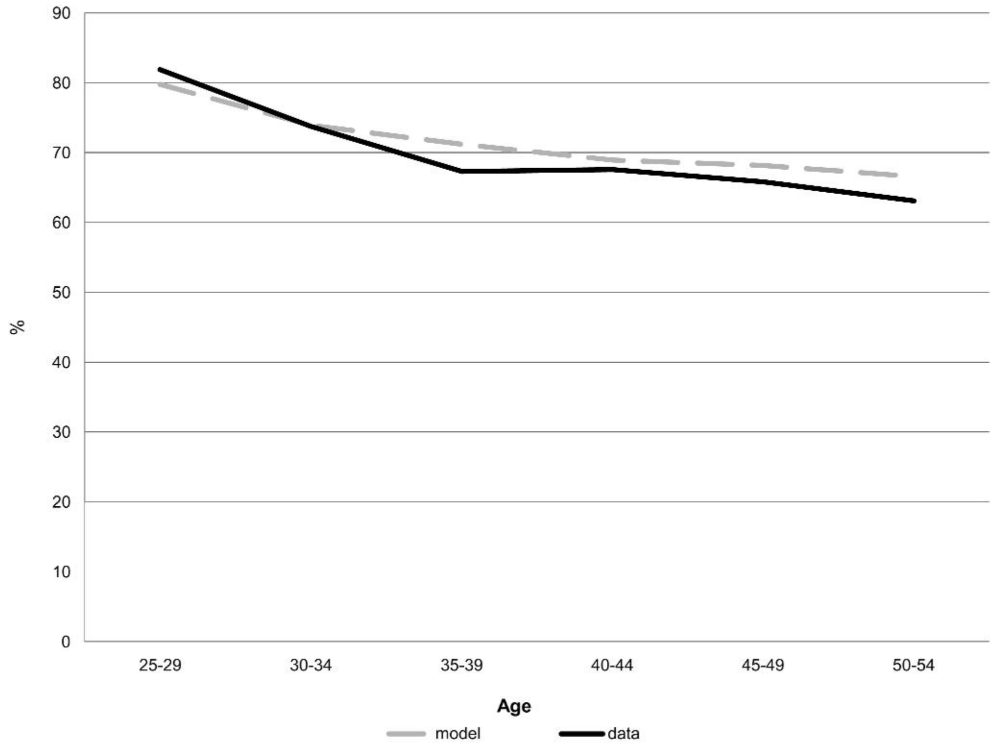

FIGURE 6
Wage gender gap

generating both the level and the age pattern of the wage gender gap. In interpreting these results, it is important to bear in mind that wage gender gap is critically determined by labour-force participation decisions. Moreover, we have selected the parameters of human capital accumulation process for females *a priori* without targeting any endogenous variables. Both in the data and the model, the ratio of female to male wages starts at about 80% and declines monotonically as women age, reaching less than 65% by age 54. The average gender gap for ages 25–54 is about 70%. As women with children decide to stay out of the labour force, their human capital declines generating endogenously a larger gender gap in later ages.[27,28]

for a female depends on her marital status, number of children younger than age 5, and the variables in the population equation. We estimate the parameters using maximum likelihood and use the corrected parameters of the Mincer equation to impute wages for women with missing wages. Our selection equation is similar to ones used by Chang and Kim (2006) and Mulligan and Rubinstein (2008).

27. Our results on the gender gap are quite similar to those by Erosa, Fuster and Restuccia (2010). They also show that differences in human capital accumulation explain the widening gender gap over the life cycle and children play a key role in determining lower human capital accumulation by females.

28. Note that in the simulations, the initial (age 25–29) human capital levels for females are set according to data in Table A1 in online Appendix. In the data, these initial productivity levels are calculated for females who participate in the labour market. In the model, females observe these initial productivity levels and then decide whether to work or not. Hence, the gender gap in the model is exactly same as the *observed* gender gap in the data (79·9%). This is almost identical to *corrected* gender gap in Figure 6 (81·7%) as selection does not play a role for this age group.

The importance of costly childbearing. What is the quantitative importance of childcare costs in the benchmark economy? To this end, and motivated by the evidence presented earlier in this section, we run two counterfactual exercises. First, we double the childcare expenses for working mothers by doubling $d(s)$ values. This has a dramatic effect on female labour-force participation. Female labour-force participation declines by about 20% (from 69·3% to 55·4%). As a result, aggregate hours and output decline by 4·1% and 5·7%, respectively. Second, we double the fixed-time cost for children. With higher time costs, married female labour-force participation declines by 8·4% (from 69·3% to 63·5%). The effect is much stronger for married females with young children, as their labour-force participation declines by 80%. As with the higher childcare costs, aggregate hours and aggregate output declines by about 1·9% and 4·1%, respectively. Hence, variation in childcare costs critically matters in the determination of participation decisions.

Participation rates and the temporal variation in wages. What are the implications for labour-force participation rates, within our model, of a wage structure consistent with observed ones in the past? The answer to this question is important in assessing whether our model generates female labour-force participation responses that are reasonable from a time-series point of view. To this end, we parameterize our economy with the wage structure of 1970, that is we take male wages for all ages and types as well as initial (age 1) wages for males from 1970 data. We keep all other parameters in their benchmark values. We find that in this scenario, female labour-force participation declines by 2·3 percentage points relative to our benchmark or about 10% of the observed change in the data.

Childcare services were more expensive in 1970 (see Attanasio, Low and Sánchez Marcos 2008). Hence, if in addition, we increase the values of child cost parameters that we get from the first experiment by 25%, aggregate labour-force participation drops by about 5·2 percentage points.[29] This indicates that the model accounts for about 21% of the observed change in the data. Given that many other factors changed from 1970 to 2000 (*i.e.* the structure of taxes as well as the marital structure of population), we conclude from these findings that the underlying elasticities in our model are sensible, as the model does not overshoot the observed decline in participation from 2000 to 1970.[30]

5. TAX REFORMS

We now consider two hypothetical reforms to the current U.S. tax structure: a proportional income tax and a move from joint to separate filing for married couples. The first reform flattens the current income tax schedule while keeping the household as unit subject to taxation. The second reform reintroduces progressivity into the system but changes the unit of taxation from households to *individuals*. The proportional income tax allows us to illustrate the effects of a rather well-studied case within the current framework and relate our results with the existing literature. The second reform, which is impossible to analyse within a standard single-earner framework, illustrates the value added of the model features of the current framework.

29. A 25% decline in childcare costs is empirically plausible. Attanasio, Low and Sánchez Marcos (2008) document that the level of childcare costs declined by 15% between 1970's and 1980's and that the decline relative to female wages was even larger. Since the 1970's, the tax treatments of childcare expenses has also become more favourable. Arguably, the availability of childcare has improved significantly as well.

30. See Kaygusuz (2010) for a decomposition of the changes in the post-1980 increase in female labour supply into parts that come from changes in taxation, wages, educational attainment, and marital structure in an environment without children.

The findings we report are based on steady-state comparisons of pre- and post-reform economies. In all cases, we keep the social security tax rate unchanged, which implies that benefits adjust with the reforms under consideration. For our benchmark set of experiments, we also keep the residual tax rate on capital income (τ_k) fixed. The exercises are in all cases *revenue neutral*.

5.1. *A proportional income tax*

Table 5 reports the key findings from this exercise. To assess these results, the reader should bear in mind that by construction, a proportional income tax makes marginal and average tax rates equal for all households. Before the reform, average and marginal tax rates covered a wide range as indicated in Figures 3 and 4; in the new steady state, the uniform tax rate that balances the budget equals 11·9%. Thus, via the removal of distortions associated with a progressive income tax, this reform leads to substantial effects on output and factor inputs. The capital-to-output ratio increases by about 5·3% across steady states, leading to changes in the wage rate of about 2·4%. Total labour supply (hours adjusted by efficiency units) increases by 4·6%. As a result of these changes, aggregate output increases substantially by about 7·4%.

Our economy allows us to identify and quantify differential responses in labour supply to tax changes that take place at the intensive margin for both males and females as well as at the *extensive* margin for married females. Recall that in the benchmark economy, the tax structure generates non-trivial disincentives to work since average and marginal tax rates increase with incomes. In addition, married females who decide to enter the labour force are taxed at their partner's current marginal tax rate. With the elimination of these disincentives, the change in labour supply of married females is substantially larger than the aggregate change in hours. The introduction of a flat-rate income tax implies that the labour-force participation of married females increases by about 4·6%, while hours per worker rise by about 3·5% for females, and about 3·1% for males. Due to changes along the intensive and the extensive margins, total hours for married females increase by about 8.8%. This is a dramatic rise and is nearly three times the changes in total male hours. These results are especially worth noting as the parameter governing

TABLE 5
Tax reforms (%)

	Proportional income			Separate filing	
	Closed economy	Closed economy ($\tau_k = 0$)	Open economy	Closed economy	Open economy
Married females LFP	4·6	4·5	5·1	10·4	11·1
Married females LFP with children	6·8	6·4	8·5	18·1	20·4
Aggregate hours	4·7	4·6	4·5	2·9	2·9
Aggregate hours (married female)	8·8	8·4	9·1	11·4	12·1
Hours per worker (female)	3·5	3·8	3·8	0·3	0·3
Hours per worker (male)	3·1	3·3	3·3	−0·2	−0·2
Aggregate labour	4·6	4·4	4·2	2·7	2·5
Capital/output	5·3	7·8	—	2·4	—
Aggregate output	7·4	8·6	4·3	3·8	2·4
Tax rate	11·9	13·8	10·8	0·1	−0·4

Notes: Entries show the steady-state effects of replacing current income taxes via the specified reforms. The values are percentage changes relative to the benchmark economy. The values for "Tax Rate" correspond to the proportional rates that are necessary to achieve budget balance. See text for details.

TABLE 6
Effects on labour force participation and human capital (%)

	Proportional income tax		Separate filing	
	LFP (increase)	Human capital (increase)	LFP (increase)	Human capital (increase)
Education				
High school	8·0	3·7	20·6	10·4
Some college	4·2	1·9	7·8	4·1
College	1·9	0·8	3·2	1·9
College +	2·1	0·9	2·7	1·3
Childbearing status				
$b=0$, childless	2·2	0·8	2·2	1·0
$b=1$, early child bearer	7·0	3·2	14·4	7·0
$b=2$, late child bearer	2·3	0·7	7·6	2·9

Notes: Entries show the steady-state effects of replacing current income taxes on labour-force participation rates the human capital. The values are percentage changes relative to the benchmark economy.

intertemporal substitution of labour is the same for males and females and take place despite the equilibrium increase in the cost of childcare (*i.e.* the wage rate goes up).

It is important to highlight three aspects of the results emerging from this experiment. First, as we show in Table 6, low-type married females increase their labour supply much more than high-type females. Over the life cycle, females with the lowest intrinsic type (those with high school education or less) increase their labour-force participation by 8·0%, while highest types (those with post-college education) increase theirs only by 2·1%. This might come as a surprise since a proportional income tax reform would likely increase marginal tax rates for lower types and reduce them for high types. There are several reasons that account for this phenomenon. Note first that the labour-force participation of high-type married females is quite large in the benchmark economy to begin with, leaving relatively little room to react to tax changes. Second, relative to the benchmark economy, marginal tax rates effectively drop or remain relatively constant for low- and middle-income households after the introduction of the proportional income tax. In the benchmark economy, the marginal tax rate on a household with an income equal to one-half average income is about 11%, little less than the rate after the reform, while the marginal rate amounts to about 17·4% for those with a mean income level. In other words, a proportional tax leads to a reduction in marginal tax rates *even* for low- and middle-income households in the new steady state.[31] Finally, the relative shapes of the distributions (cdf) of utility costs indicates the scope for a much larger reaction of less skilled types.[32]

Second, the response of married females with children is *larger* than those without children, as Table 5 and the lower panel of Table 6 demonstrate. While for married females who are

31. We abstract from means-tested welfare programs, such as food stamps and Medicaid. It is well known that such programs can generate very high marginal tax rates at low levels of income, as earning more might imply not qualifying for benefits (see Moffitt 1992 and Meghir and Phillips 2010). These programs are likely to dampen the responses by lower income households.

32. We plot in Supplementary Figure A1 the distributions for a married household with a husband with high school and more than college education levels. As it can be seen, the slopes of the distributions are much larger for a typical less-skilled couple (both with high school or less) versus a typical high-skilled couple (both with more than college education). Hence, tax changes will have larger effects for less-skilled females.

childless, the labour-force participation increases by about 2·2%, the rise is much larger, about 7·0%, for those who are early child bearers, whereas the response increases up to about 10·5% for those with young children. This phenomenon is connected with the reasons for females with children to react more strongly to tax changes (see Section 2) and to the stronger participation reaction of less-skilled females discussed above; lower types are more likely to have children as well as to have them early.

Finally, the increasing labour-force participation of married females leads to higher efficiency units (human capital) for this group, by about 1·9%. As we document in Table 6, the increase in human capital is larger for lower types and those with children, which reflects the changes in labour-force participation. It is about 3·7% for those with less than high school education in contrast to nearly 1% for those with post-college education.

Eliminating τ_k. In Table 5, we also report the results where we eliminate τ_k in a proportional income tax reform. Note that the tax rate that balances the budget is obviously higher when the capital income tax rate is included (13·8% vs. 11·9%), as larger tax collections need to be generated. The results indicate that the inclusion of the flat-rate capital income tax in the tax reforms is largely unimportant for the magnitudes of labour-supply responses. The key differences where τ_k is kept intact are in the magnitude of output changes: when the capital income tax is included in the reform, output changes amount to 8·6% versus 7·4% when the capital income tax rate is maintained.

These differences are due to the larger effects on capital accumulation that take place when the capital income tax rate is eliminated in the tax reform. This is simply accounted for by the different tax burden on capital in the two cases. When the capital income tax rate is part of the reform, the effective tax rate on capital income is simply 13·8% (*i.e.* the income tax rate), whereas it is much higher (21·6%, which is the sum of the proportional tax, 11·9% and τ_k, 9·75%) when the reform does not include the flat-rate capital income tax.

5.2. *Separate filing*

A prominent feature of the current U.S. tax system is that it treats married and single individuals differently. The problem arises since the unit subject to taxation is the *household*, not the individual, with tax schedules that differ according to marital status. This creates much discussed marriage tax penalties and bonuses, affecting the marginal tax rates that married individuals face. In particular, note that when a married female enters the labour market, the first dollar of her earned income is taxed at her husband's current marginal rate, potentially distorting her labour supply in a critical way. This reasoning motivates our second experiment, where we move from the current system to one in which each individual files his/her taxes separately. We label this hypothetical reform experiment *separate filing*.

We assume that a married person's tax liabilities consists of his/her labour income plus half of household's asset income, and each working member of a married household with children declares one of the two children for tax purposes. In particular, for a married household without children, we use the same tax function that singles without children face in the benchmark economy. For married households with children, we use a tax function from the legal category *head of household* (with one child) for each member. In addition, in order to collect the same amount of tax revenue as the benchmark economy, we assume that each individual faces an additional proportional tax (or subsidy) on his/her income.[33]

33. We estimate a tax function for heads of households with one child, resulting in parameters $\eta_1 = 0 \cdot 107$ and $\eta_2 = 0 \cdot 082$. In stationary equilibrium after the reform, a tax of 0·1% is needed to achieve revenue neutrality.

TABLE 7
Tax burden from female labour force participation, 25–34 (%)

	Benchmark economy	Separate filing
Education		
High school	15·0	3·6
Some college	15·8	4·4
College	17·6	7·8
College +	18·8	10·3
Childbearing status		
$b=0$, childless	17·2	11·2
$b=1$, early child bearer	15·4	2·7
$b=2$, late child bearer	17·1	7·2

Notes: Entries show the additional taxes associated to labour-force participation for younger females, in the benchmark economy and in the separate filing case. Additional taxes are reported as a percentage of females' earnings.

The possibility of separate filing can lower taxes on married females significantly.[34] To see this, consider a married household with kids with total income equal to twice mean household income and suppose earnings of both members are equal. Under the current system, this household faces a marginal tax rate of about 23·6%. The marginal tax rate declines to about 17·4% if the household income is split equally between husband and wife. The gain is larger for the majority of wives who earn less than their husbands.

The effects of a move from the current system to separate filing are substantial. Table 5 shows that aggregate output goes up by about 3·8% and aggregate labour by 2·7%. This is more than half of the increase associated with a proportional income tax reform. In contrast to a proportional income tax reform, however, the increase in aggregate labour is almost fully driven by the rise in aggregate hours by married females. The labour-force participation of married females rises by 10·4% (more than twice as much as it does with a proportional income tax) and aggregate hours by married females increase by about 11·4%. In contrast, hours by male workers decline slightly. As it is shown in Table 6, separate filing generates significant increases in labour-force participation and declines in gender gap for exactly the same groups that were affected by proportional taxes, married females with less education and with children, but with much larger magnitudes.

Why does married female labour-force participation react so much with separate filing? The key is that separate filing reduces the tax burden associated with female labour-force participation dramatically. Table 7 shows the *extra* taxes that a household has to pay as a fraction of the extra income that a female generates for younger households (aged 25–34). In the benchmark economy, the tax burden associated with female labour-force participation is quite similar for females with different characteristics. It is larger for females with more education and for those who do not have any children. With separate filing, the situation is radically different.[35] Now females with lower education as well as those with children face much lower tax rates associated

34. In contrast (Alessina, Ichino and Karabarbounis 2011), lower taxes on females emerge in the current framework from taxing individuals instead of households and not from an optimal taxation argument to lower taxes on females who have more elastic labour supplies. See Guner, Kaygusuz and Ventura (2011) for a quantitative analysis of gender-based taxation.

35. In the proportional tax reform case, the extra taxes associated to further labour-market participation naturally amount to the equilibrium tax rate (11·9%).

with movements along the extensive margin. Not surprisingly, their labour-force participation increases dramatically. Incidentally, these are the groups that have the largest potential response to a tax reform.

The main message from this policy experiment is quite clear. A move from the current system to one in which individuals (not households) are the basic unit of taxation goes a long way in generating significant effects on aggregate labour and output. These effects take place without eliminating tax progressivity, or the taxation of capital income, and depend critically on the response of married females. These and previous findings motivate us to explicitly quantify the relative importance of married females as a group for our results. We do this in Section 6.

5.3. *Tax reforms in an open economy*

A concern with analysis of tax reforms in equilibrium models is the (typically) large effects on capital intensity and output driven by the reduction or elimination of distortions on capital accumulation. To address this issue, we conduct tax reform exercises under the assumption of a small economy open to capital movements. We fix the before-tax rate of return on capital at the benchmark level, and thus the wage rate, and calculate stationary equilibria under the proposed tax systems.

Our main findings are summarized in Table 5, alongside the results from our main experiments. As the table shows, the effects on output are more moderate, as by construction the ratio of capital to labour in the production of goods is the same across steady states. However, a different picture emerges for the effects on labour supply. For instance, if a proportional income tax is considered, labour-force participation (aggregate hours) increases by about 5·1% (4·5%) in the small open economy case, whereas the corresponding increase is very similar, about 4·6% (4·7%) under the closed economy assumption. A similar pattern holds under a separate filing reform and for different labour-supply statistics. We conclude from these exercises that the effects of tax reforms on labour supply at multiple levels are essentially independent on whether the economy is open to capital movements or not.

5.4. *Tax reforms and within-group inequality*

Our economy is parameterized considering only heterogeneity associated to schooling levels. As a result, the benchmark economy produces less dispersion in wages and earnings than the data. We calculate, using estimates from Heathcote, Storesletten and Violante (2004) for males, that the variance of log-wages in our first (fourth) age group is about 0·177 (0·240), while it is only 0·066 (0·089) in the model for males. This implies that our model accounts for about 37·3% (37·1%) of the variance of log-wages for males at the start (middle) of the life cycle.[36] More generally, our model implies an economy-wide Gini coefficient of household earnings of about 0·283. Heathcote, Perri and Violante (2010) report a corresponding value of about 0·4 for the year 2000.

Since the model accounts for only a fraction of observed wage inequality, we assess the robustness of our results to the explicit consideration of wage heterogeneity *within* education levels. We introduce wage heterogeneity within educational groups for both males and females in a simple way at the start of the life cycle. In particular, we assume that for each education category, there are two types, high and low, and half of each education group is high type and

36. We use for these purposes the authors' estimates for the structure of fixed effects and permanent shocks to wages. We exclude temporary shocks.

the other half is low type. For males, high (low) types have Δ% higher (lower) wages than the average wage for a given education group at any point along the life cycle. For women, high (low) types imply Δ% higher (lower) wages at age 1 and female wages evolve endogenously afterwards as in the benchmark economy. Our strategy is to select Δ to generate, inside the model, the wage dispersion for males at age 1 (variance of log-wages) observed in the data according to Heathcote, Storesletten and Violante (2004) estimates. Our specification implies that required Δ is about 39·5%; that is high (low) types males and females at age 1 observe wages that are 39·5% above (below) the education-specific means. Given these estimates, we parameterize again our model economy in line with the discussion in Section 4.[37]

We find that the aggregate effects of reforms become more moderate with the inclusion of within-group inequality. Under a proportional tax (separate filing), output increases by about 6·8% (3·4%) and aggregate hours by 4·2% (2·7%). Under the benchmark specification, increases in output were 7·4% (3·8%) under a proportional tax (separate filing) reform, while aggregate hours increased by 4·7% (2·9%). At the center of the moderation in responses is the behaviour of labour-force participation rates. Under a proportional tax (separate filing), the participation rate of married females increases by about 2·8% (9·5%); the corresponding changes under our benchmark specification are 4·6% (10·4%).

The smaller changes in participation rates in the case of the proportional income tax reform are in turn driven by the behaviour of married women in poorer households. With within-group heterogeneity, taxes actually go up for a large group of women with low levels of wages. As a result, the labour supply of response of these women with is now more muted. This happens in much smaller magnitudes, however, when we consider the separate filing case (*i.e.* a progressive tax scheme); labour-force participation responses become very similar to the ones under the benchmark scenario in the absence of within-group inequality. We conclude from these exercises that the simple consideration of within-group inequality leads to moderately smaller effects on aggregates upon a reform, especially in the separate filing case. Our benchmark specification appears to capture the bulk of output and labour-supply responses upon tax reforms.

6. THE ROLE OF MARRIED FEMALES

We now discuss in more detail the impact of changes in labour supply of married females. We ask: what is the overall contribution of married females to changes in labour supply? What is the importance of labour supply changes along the extensive margin?

In answering these questions, we first note that the type of the tax reform under consideration is critical. As expected from the results in the Section 5, the role of married females is largest with a move to separate filing. Table 8 makes these points clear. In this table, we report the contribution of married females to changes in total hours and total labour supply under our benchmark calibration. For proportional income taxes, the contribution of married females to changes in total hours (labour supply) is around 51% (48%). Under separate filing, they contribute to more than 100% of the changes in total hours and labour supply, as some groups effectively reduce their hours (*e.g.* men). We conclude from these findings that the overall contribution of married females to hours and labour supply changes is substantial; they contribute disproportionately given their share of the working age population (about 37·5%).

37. We assume that childbearing status, marital status, wage growth factors for females, social security benefits depend only on agents' education level as in the benchmark economy. Within a particular education pair, couples are assumed to match randomly according to their high/low types.

TABLE 8
Role of females (%)

	Proportional income	Separate filing
Panel A: Total changes		
Δ in married female hours (% of total Δ in hours)	51·1	105·6
Δ in married female (w/children) hours (% of total Δ in hours)	20·9	57·0
Δ in Married female labour (% of Total Δ in labour)	47·9	105·7
Δ in married female (w/children) labour (% of total Δ in hours)	17·8	49·0
Panel B: Extensive margin		
Δ in married female hours (% of total Δ in hours)	25·0	86·0
Δ in married female labour (% of Total Δ in labour)	23·0	79·0

Notes: Entries show the contribution of changes in the labour supply of married females relative to total changes in labour supply, both in terms of raw hours changes as well as in terms of labour in efficiency units. The top panel shows the contribution of total changes. The bottom panel shows only the contribution of changes along the extensive margin.

In the bottom panel of Table 8, we focus on the role of the extensive margin and report its contribution to the rise in hours and total labour supply. In order to assess the role of extensive margin, we carry out the following counterfactual exercise. For each age and (x, z, q, b)-type married woman, we determine the labour-force participation status in the benchmark economy.[38] Next, we run the tax reforms in an economy where the labour-force participation decision is no longer a choice for a female. The female workers in the benchmark economy can change their hours in response to a tax reform, however, they are not allowed to drop out of the labour force. Moreover, the females who are out of the labour force in the benchmark economy are not allowed to enter the labour market. This allows us to quantify the significance of the intensive margin as well as the extensive margin in the tax reform exercises. We find that the extensive margin contributes about 25% of the changes in total hours under a proportional income tax and about 86% of the changes in hours under separate filing. For changes in labour supply, the contributions are about 23% and 79%, respectively. By this measure, these calculations suggest that the bulk of the rise in the labour supply of married females can be attributed to movements along the extensive margin.

Married females with children. How much of the increase in extensive margin and aggregates hours can be attributed to married females with children? As our results in Tables 5 and 6 show their labour supply increase more than married females without children. In order to highlight the role of females with children, we report in Table 8 the contribution of married females with children to overall changes in hours and labour supply. As the table demonstrates, the contribution of this group is substantial. Under a proportional tax, married females with children account for about 21% and 18% of the changes in hours and labour supply. In line with

38. Note that age, x, z, q, and b are exogenous characteristics of a married household.

TABLE 9
Reforms with low intertemporal elasticity (%)

	Proportional income	Separate filing
Married female LFP	6·4	11·2
Married female LFP with children	8·7	18·4
Aggregate hours	3·7	3·0
Aggregate hours (married females)	8·7	11·4
Hours per worker (female)	2·1	0
Hours per worker (male)	1·7	−0·2
Capital/output	4·9	2·2
Aggregate labour	3·4	2·7
Aggregate output	6·1	3·8
Δ in married female hours (% of total Δ in hours)	67·0	106·7
Δ in married female labour (% of total Δ in labour)	62·3	106·1

Notes: Entries show the steady-state effects of replacing current income taxes via the specified reforms under a low value of the intertemporal elasticity parameter ($\gamma = 0{\cdot}2$). The values are percentage changes relative to a benchmark economy with $\gamma = 0{\cdot}2$.

8. WELFARE EFFECTS

We report in this section some of the welfare implications associated to the tax reforms that we study, focusing on the small open-economy case under the benchmark value $\gamma = 0{\cdot}4$. To assess the welfare consequences of reforms, we compute transitional dynamics between steady states under the assumption of unanticipated tax reforms, where we compute the tax rates that balance the budget in each period. This implies that for the case of a proportional income tax, we compute the sequence of tax rates that generate the same tax revenue as in the initial steady state. For the separate filing case, we compute sequence of residual tax rates that balance the budget in each period.

For those households alive at the moment of the reform, say $t = t_0$, we calculate an aggregate measure of welfare gains in consumption terms. This corresponds to the common, proportional, per-period consumption compensation that equalizes aggregate welfare under the status quo (*i.e.* in the steady state under current taxes), with the level of aggregate welfare under the transition path implied by each reform.

We find that both reforms lead to aggregate welfare gains at $t = t_0$. The magnitude of welfare gains is *larger* under a proportional income tax than under separate filing; the consumption compensation amounts to 1·3% under a proportional income tax, whereas it is rather small (0·2%) under the separate filing case.

Heterogeneity. We find that a majority of households benefit from the reforms at $t = t_0$. More households benefit from a move to separate filing (about 69%) than under a proportional tax (54%) despite the fact that gains are larger under a proportional tax.

Not surprisingly, there is a substantial degree of heterogeneity across different ages and types in the welfare changes driven by the reforms. Table 10 reports welfare changes by age and types of newborn married households (*i.e.* born at $t = t_0$). To save space, we report results only for those married households in which both husband and wife have the same productivity type. Consider first the effects across different ages. With a proportional income tax reform, welfare gains across ages display an inverted-U shape. As very young and very old individuals, who

filing married agents lose by 0·06% and singles gain by 0·19%. Hence, both reforms make being single more attractive relative to being married.[39]

9. CONCLUDING REMARKS

Our results have clear implications for policy. First, our analysis demonstrates that reforms that change the unit of taxation from households to individuals can have substantial consequences on labour supply and output. Reforms of this sort respect the underlying nature of tax progressivity and do not rely on the elimination of taxes on capital income. They do not require large changes in other taxes to balance the budget and can be easily implemented out of existing tax schedules. As a result, such reforms could be politically easier to undertake while delivering large effects on output and labour supply.

A second implication relates to the interplay between distorting taxes and other non-tax barriers to female labour-force participation. Such barriers include the restrictive regulation of temporary work and product market distortions such as restrictions on shopping hours, that are common in several developed economies. If married females drive the bulk of hour changes associated to tax reforms, these obstacles to increasing participation can interact with changes in the tax structure and prevent the large predicted changes in labour supply to materialize. From this perspective, a more complete analysis of taxation and labour supply should study these issues. We leave this and other extensions for future work.

We conclude by commenting on two important issues we have abstracted from that might be important in future research. First, we have only considered the effects of labour-market disruptions on the skills of females but have ignored the effects of tax changes on standard human capital accumulation decisions. Recent papers have addressed this topic in economies with agent heterogeneity (*e.g.* Erosa and Koreshkova 2007), and their findings suggest that the presence of human capital decisions can amplify the effects of tax reforms. No paper has focused on the topic taking into account two-earner households with an extensive margin decision. The second issue pertains to the role of heterogeneity within educational categories and its interplay with idiosyncratic risk in two-earner households in tax reforms. Our analysis in Section 5.4 is a preliminary, first step in this direction.

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Supplementary Data

Supplementary data are available at *Review of Economic Studies* online.

39. Previous work in models with marriage decisions indicates that the effects of changes in tax rules on the equilibrium number of married and single people is small. See Chade and Ventura (2002) and Chade and Ventura (2005).

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