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Labor-dependent capital income taxation

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ABSTRACT

Capital taxation which is negatively correlated with labor supply is proposed. This paper uses a life-cycle model of heterogeneous agents that face idiosyncratic productivity shocks and shows that the tax scheme provides a strong work incentive when households possess large assets and high productivity later in the life-cycle, when they otherwise would work less. The system also adds to the saving motive of prime-age households and raises aggregate capital. The increased economic activities expand the tax base and the revenue neutral reform results in a lower average tax rate. The negative cross-dependence generates a sizable welfare gain in the long-run relative to the tax system that treats labor and capital income separately as a tax base. The reform, however, can hurt the elderly during the transition with a high marginal tax on their capital income.

1. Introduction

How capital income should be taxed is a question that never ceases to interest economists. Ever since the seminal work of Judd (1985) and Chamley (1986) that demonstrated the optimality of zero capital income tax using a neoclassical growth model populated by infinitely lived agents, numerous papers followed and explored the topic, while reaching a variety of conclusions. On the one hand, authors including Lucas (1990), Atkeson et al. (1999) and Jones et al. (1993) concur with Chamley and Judd and demonstrate robustness of the zero capital tax result in extended models. On the other hand, Hubbard and Judd (1986), Aiyagari (1995) and İmrohoroğlu (1998) argue that a departure from the complete market assumption calls for the role of a positive capital tax in a model with uninsurable idiosyncratic income risk and borrowing constraints. More recently, Erosa and Gervais (2002) and Garriga (2003) show theoretically that in a life-cycle model of overlapping generations non-zero capital income tax is in general optimal at least if the tax rates cannot be conditioned on the age of households. Conesa et al. (2009) quantitatively characterize the optimal combination of capital and labor income tax using a flexible form of taxation and find the optimal capital income tax rate is significantly positive at 36%.

What is common across the existing studies in the tradition of the Ramsey approach is that the rate of capital income taxation is assumed to be either a constant (i.e. proportional taxation) in most cases or some progressive function of capital income or total income.[1] This paper proposes a simple form of interaction between capital taxation and labor supply, in which the rate of capital tax falls in labor supply through its negative dependence on observed labor income. Our goal is to demonstrate that introducing labor-dependence in capital taxation can induce more efficient intertemporal allocation of labor supply over the life-cycle, stimulate economic activities, raising labor productivity, capital, output and consumption, and improve the overall welfare in the long-run.

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[1] Non-linear income taxation had not been studied extensively until recently. See, for example, Bohacek and Kejak (2005), Conesa and Krueger (2006), Conesa et al. (2009) and Gervais (2009), who study non-linear taxation and optimal progressivity of income taxation.

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In theoretical studies, Atkeson et al. (1999), Erosa and Gervais (2002) and Garriga (2003) show that the optimal tax rates on capital and labor vary by age in general in a model where the optimal consumption-work profile over the life-cycle is not constant. In the absence of age-dependent taxation, Conesa et al. (2009) show the optimality of a positive capital tax, arguing that it can mimic the role of optimal age-dependent labor taxes. This paper shows that the labor-dependent capital taxes can approximate the optimal age-dependent taxation in both labor and capital income and also circumvent negative consequences on aggregates, in particular on capital accumulation, implied by a high proportional capital tax under the optimal system of Conesa et al. (2009). In our proposed tax system, the reward for an additional work effort is not only the wage net of a labor tax, but also a reduction in capital taxes as a result of the negative labor-dependence. This creates a profile of *effective* wage rates that vary by age as the amount of saving changes, inducing more work effort at middle to old ages when households possess more wealth on average, in the same way as the optimal age-dependent labor taxes, or high capital taxes in the absence of age-dependent taxes, would do. The rise in the capital tax when labor income falls makes the future consumption increasingly more costly and raises the opportunity cost of leisure, which approximates the shape of optimal age-dependent capital taxes that increase in age.

Our study is also related to the recent literature referenced as the New Dynamic Public Finance (NDPF), which extends the static study of Mirrlees (1971) on the equity-efficiency trade-off involved in the optimal taxation into dynamic settings.[2] The optimal allocations under private information are shown to exhibit non-separability between asset and labor income and imply a negative covariance between capital taxes and labor income (Kocherlakota, 2005; Albanesi and Sleet, 2006; Golosov and Tsyvinski, 2006; Fukushima, 2010), analogous to the sign of the cross-partial in the tax function that we find as optimal. The system implies that accumulated savings can be used as a device to encourage work efforts, which otherwise would serve as a hedge against labor income risks and dampen work incentives.

In our calibrated life-cycle model, the tax system with a negative cross-partial implies low capital taxes for middle-age households with high labor income. They have strong saving motives for retirement, which are intensified by the higher after-tax return from savings. More saving, again, will reinforce work incentives since doing so will raise the effective wage rate. There are, however, possible counter effects in equilibrium that may offset the positive effects. First, the higher level of saving and consumption generates the income effect and may discourage work effort. Second, price changes through general equilibrium effects could reduce the saving or work incentives. For example, an increase in labor supply that dominates a rise in aggregate capital would lower the wage and offset the effect of a decline in an effective labor income taxes. Third, providing work incentives through reduction in capital taxes may negatively affect the fiscal balance and call for more taxes on other sources of income.

Therefore, understanding the net incentive effects of the reform and quantifying the strength of various forces as a result of labor-dependence require a quantitative general equilibrium analysis that incorporates these channels and their interactions within a model. This paper follows the tradition of a life-cycle model of Auerbach and Kotlikoff (1987), which is one of the workhorse models in macroeconomic policy analysis and has been extensively used in quantitative studies of fiscal policies including Altig et al. (2001), Ventura (1999), Domeij and Heathcote (2004) and Nishiyama and Smetters (2005), to name a few. A model is built and calibrated to match key features of the U.S. economy, and it is used as a benchmark to run policy experiments. As in Conesa et al. (2009), we make a parametric assumption on the tax schedule and optimize over the parameters that define the tax function to maximize the welfare, which is defined as the expected lifetime utility of a new-born agent in a stationary equilibrium. The function allows the government to choose the optimal degree of negative dependence of capital taxes on labor income as well as progressivity of labor taxes by accommodating a deductible in the tax base.

After analyzing long-run effects of the proposed reform by comparing two steady state economies, the transition dynamics between the two steady states are studied and welfare and economic effects of a reform in a short-run are quantified. Aggregate capital and labor are shown to rise by 2.1% and 6.3% in the long-run. Most of the increase in labor supply comes from the additional work provided by middle to old-age households with high labor productivity, therefore raising the average labor productivity of the economy. Given the increased economic activities, the tax base will significantly expand, resulting in a lower average income tax rate. The system generates a sizable long-run welfare gain of 3.7% in consumption equivalent variation relative to the benchmark that is calibrated to the U.S. economy. In the short-run, however, the reform brings a welfare loss to about half of the population at the time of the reform announcement. Old-age households, in particular retirees, will face a significant welfare loss due to the rise in the marginal taxes on their capital income.

The rest of the paper is organized as follows. Section 2 presents the model. Section 3 outlines the calibration, with the results presented in Section 4. Section 5 discusses interpretation of the results and sensitivity analysis. Section 6 concludes.

2. Model

This section describes the details of the model, households' problem and equilibrium definition.

[2] See, for example, Golosov et al. (2003) and Kocherlakota (2005) for earlier studies. See Golosov et al. (2006) and Kocherlakota (2010) for reviews of the literature.

2.1. Demographics

In each period the economy is populated by overlapping generations of households at age $j=1,2,\ldots J$. A new cohort is larger than the previous one by a fraction n. Lifetime is uncertain and agents of age j face a conditional probability s_j to survive until the next period. Accidental bequests are distributed in a lump-sum fashion across households that are currently alive and denoted by b. Households retire at an exogenous retirement age j_R and start to receive social security benefits ss.

2.2. Technology

A representative firm produces output according to a constant returns to scale technology: $Y=F(K,L)=AK^{\alpha}L^{1-\alpha}$, where K and L are aggregate capital and labor and α is the capital share. The constant A normalizes units in our economy. Capital depreciates at rate δ. The firm rents capital and labor efficiency from households in competitive markets, where factor prices r and w are equated to the marginal productivities.

2.3. Endowment and preference

Every period agents are endowed with one unit of time, which they can spend supplying labor in a competitive market or consuming leisure. New households enter the economy with no assets, besides a lump-sum transfer from accidental bequests.

Labor income is given as $\varepsilon_j elw$. ε_j captures age-dependent deterministic labor productivity with $\varepsilon_j=0$ for $j\geq j_R$. e represents an idiosyncratic productivity shock, which follows a Markov process. l denotes hours of work that agents choose optimally.

Preferences over the sequence of consumption and leisure $\{c_j,(1-l_j)\}_{j=1}^{J}$ are represented by a time-separable utility function $E\{\sum_{j=1}^{J}\beta^{j-1}u(c_j,1-l_j)\}$, where β is the time discount factor. Expectations are with respect to the stochastic process governing idiosyncratic labor productivity and mortality risks.

2.4. Government

The government taxes consumption and income from labor and capital in order to finance an exogenous amount of public expenditures G. The consumption tax is proportional at rate τ_c and the income tax is given by a function $\mathcal{T}(y_L,y_K)$, where y_L and y_K represent labor and capital income, respectively. A balanced budget is imposed every period. The government also operates a self-financed pay-as-you-go social security system, represented by a payroll tax τ_{ss} on labor income and a benefit ss for each retiree.

2.5. Market structure

There is no market for state-contingent assets. Households can only purchase and accumulate a positive amount of one-period riskless asset that pays at the market interest rate.

2.6. Household problem

The households' problem is computed recursively. Households are heterogeneous in three dimensions in terms of age j, assets at the beginning of a period a and idiosyncratic labor productivity e. A household's problem is to solve

$$V_j(a,e)=\max_{c,l,a'}\{u(c,1-l)+\beta EV_{j+1}(a',e')\}, \tag{1}$$

subject to

$$c+a'=(1+r)(a+b)+\varepsilon_j elw+T, \quad a'\geq 0, \;\; l\in[0,1], \tag{2}$$

where T represents the net transfer from the government.

$$T=-\tau_c c-\mathcal{T}(y_L,y_K)-\tau_{ss}y_L \quad \text{if } j<j_R, \tag{3}$$

$$T=-\tau_c c-\mathcal{T}(0,y_K)+ss \quad \text{if } j\geq j_R. \tag{4}$$

The labor income and capital income are given as $y_L=\varepsilon_j elw$ and $y_K=r(a+b)$.

Table 1
Benchmark calibration.

Demographics		
Maximum age	J	81 (100 years old)
Retirement age	j_R	46 (65 years old)
Population growth rate	n	0.011
Conditional survival rates	s_j	Bell and Miller (2002)
Labor productivity		
Age-specific efficiency	ε_j	Hansen (1993)
Idiosyncratic risk: AR(1) process	ρ	0.97
	σ_e^2	0.02
Technology		
Capital share parameter	α	0.36
Depreciation rate	δ	0.083
TFP	A	Normalization
Preference		
Discount factor	β	0.991
Preference weight on consumption	v	0.373
Curvature parameter	σ	4.0
Government		
Consumption tax	τ_c	0.05
Income tax function	$\{\kappa_0,\kappa_1\}$	{0.258,0.768}
Social security tax	τ_{ss}	0.106
Social security benefit	ss	45% of average labor income
Government expenditures	G	17% of aggregate output

Note: The table contains the list of calibrated parameters and the parameter values.

2.7. *Competitive equilibrium*

A competitive stationary equilibrium, for a given set of fiscal variables $\{G,\tau_c,\tau_{ss}\}$, is households' decision rules $\{c,l,a'\}$ in each state (j,a,e), factor prices $\{r,w\}$, income tax function $\mathcal{T}$, social security benefit $\{ss\}$, a lump-sum transfer of accidental bequests $\{b\}$ and distribution of households $\{\mu_j(a,e)\}$ over the state space that satisfy the following conditions: (i) households' allocation rules solve the optimization problems defined in Section 2.6, (ii) factor prices are determined competitively; $r=F_K(K,L)-\delta$ and $w=F_L(K,L)$, (iii) the labor and capital markets clear; $L=\sum_j\sum_a\sum_e\varepsilon_j el_j(a,e)\mu_j(a,e)$ and $K=\sum_j\sum_a\sum_e[a_j(a,e)+b]\mu_j(a,e)$, (iv) the income tax function satisfies the government budget constraint,[3] $G=\sum_j\sum_a\sum_e[\tau_c c_j(a,e)+\mathcal{T}(y_{L,j}(a,e),y_{K,j}(a,e))]\mu_j(a,e)$, (v) the social security system is self-financed; $ss\sum_{j\geq j_R}\sum_a\sum_e\mu_j(a,e)=\sum_{j<j_R}\sum_a\sum_e\tau_{ss}\varepsilon_j el_j(a,e)w\mu_j(a,e)$, (vi) the final good market clears; $C+K'+G=Y+(1-\delta)K$, where K' denotes aggregate capital in the next period and C aggregate consumption, and (vii) the lump-sum bequest transfer is consistent with the amount of assets left by the deceased: $b=\sum_j\sum_a\sum_e a_j'(a,e)(1-s_{j-1})\mu_j(a,e)$. (viii) The distribution $\mu_j(a,e)$ is time-invariant. The law of motion for the distribution of households over the state space satisfies $\mu_j(a,e)=R_\mu[\mu_j(a,e)]$, where R_μ is a one-period transition operator on the distribution.

3. Calibration

This section presents the parametrization of the model. The values of calibrated parameters are summarized in Table 1.

Demographics: The model period is one year. Agents enter the economy at age 20 and live up to the maximum age of 100. Age-specific surviving rates are based on Bell and Miller (2002). The population grows at 1.1%.

Preferences: Households rank a bundle of consumption and leisure according to the period utility function defined as

$$u(c,1-l)=\frac{[c^{v}(1-l)^{1-v}]^{1-\sigma}}{1-\sigma}. \tag{5}$$

The parameter v determines the weight on utility from consumption relative to that from leisure, which is calibrated, so that one-third of disposable time is spent on the market work on average. σ is set at 4, which implies the intertemporal elasticity of substitution of about 0.5, in the middle of the range of micro-estimates (see Attanasio, 1999, for a survey).[4] The subjective discount factor β is set at 0.991, so that the model generates a capital-output ratio of 2.7.

[3] To satisfy the government budget constraint, at least one of the parameters that define the income tax function must adjust. This parameter depends on the form of the tax schedule in the benchmark and reformed tax system. More details are provided in Sections 3 and 4.

[4] Note that the coefficient of relative risk aversion is given as $1-v(1-\sigma)=2.1$ with calibrated $v=0.373$.

Endowment: Age-dependent labor productivity ε_j is based on the estimates of Hansen (1993). The idiosyncratic component e is specified as a first-order autoregressive process with a persistence parameter $\rho = 0.97$ and a variance of the white noise $\sigma_e^2 = 0.02$, which lie in the range of estimates in the literature (see, for example, Heathcote et al., 2010). The process is approximated by a transition matrix defined over five grid points, using the method of Tauchen (1986). Agents make a random draw of e from its stationary distribution as they enter the economy.

Technology: The capital share is set at 0.36 and the depreciation rate δ at 8.3%, implied by the law of motion for the capital in the steady state, $\delta = (X/Y)/(K/Y) - n$ with the target investment-output ratio X/Y of 25.5% and capital-output ratio K/Y of 2.7. The TFP parameter A is normalized, so that the average per-capita income is 1.0.

Government: The government finances an exogenous stream of expenditures by taxation of consumption and income. Public expenditures are set at 17% of the total output in the benchmark economy, as in Conesa et al. (2009). The level of expenditures G is kept constant across tax experiments. The consumption tax rate is set at 5%.

In the benchmark economy, the income tax is given by a non-linear function of total income, $y = y_L + y_K$. The function approximates the progressive income tax schedule in the U.S. following the functional form estimated by Gouveia and Strauss (1994):

$$\mathcal{T}(y) = \kappa_0\{y - (y^{-\kappa_1} + \kappa_2)^{-1/\kappa_1}\}. \tag{6}$$

Parameter κ_0 is the limit of marginal taxes as income goes to infinity, κ_1 determines the curvature of marginal taxes and κ_2 is a scaling parameter. To preserve the shape of the tax function estimated by Gouveia and Strauss, their parameter estimates $\{\kappa_0, \kappa_1\} = \{0.258, 0.768\}$ are used and the scaling parameter κ_2 is chosen so that the government budget is balanced.

The social security tax τ_{ss} is set at 10.6%. The pension benefit ss is determined to balance the social security budget and it is 45% of the average earnings in the benchmark economy, close to the average replacement rate of the U.S. social security system.

4. Numerical results

This section will investigate the effect of labor-dependent capital income taxation.

4.1. Computational experiment

The following form of income taxation is considered:

$$\mathcal{T}(y_L, y_K) = \phi_0 y_K + \phi_1 y_L y_K + \phi_2 (y_L - d_L), \tag{7}$$

where $\{\phi_1, \phi_1, \phi_2, d_L\}$ are the policy parameters to be specified.[5] The marginal tax on capital income is given as

$$\mathcal{T}_{y_K}(y_L, y_K) = \phi_0 + \phi_1 y_L, \tag{8}$$

where $\phi_1 < 0$ implies negative dependence of capital income taxes on labor income. Conesa et al. (2009) searched the optimal tax schedule for labor and capital income taxes using the function of Gouveia and Strauss in (6) and found that the optimal scheme is well-approximated by a combination of a progressive labor tax, summarized by a flat tax with a sizable deduction, and a high proportional tax on capital income. We denote such a tax function that approximates the optimal of Conesa et al. (2009) as

$$\mathcal{T}^{CKK}(y_L, y_K) = \phi_0 y_K + \phi_2 (y_L - d_L). \tag{9}$$

The function (7) allows for at least the same degree of flexibility as the function (9) and adds an additional degree of freedom by the extra term $\phi_1 y_L y_K$, which represents the cross-dependence of capital taxes on labor income. In order to quantify the gains associated with the non-zero cross-partial, in Section 5.2 the optimal tax parameters are computed under the functional form of (9) and the results are compared.

The social welfare function is defined as the discounted lifetime utility of a new-born agent in a stationary equilibrium, which is indexed by the income tax function $\mathcal{T}(y_L, y_K)$. We search for the combination of tax parameters that maximizes the value of the social welfare function. The tax reform is revenue neutral, that is, the amount of expenditures that need to be raised through the tax system remains the same.

The optimal tax system that maximizes the value of social welfare function is given by the set of parameter values; $\phi_0 = 0.67$, $\phi_1 = -0.39$, $\phi_2 = 0.23$ and $d_L = 0.28$.[6] The capital income tax rates as a function of labor income under the optimal system are displayed in Fig. 1. The tax function implies much higher taxes on capital income than in the benchmark economy in general. The highest marginal tax rate when agents do not work at all is 67%. However, with the negative cross-partial of $\phi_1 = -0.39$, the capital tax falls sharply as the labor income increases and when the labor income

[5] The deduction d_L is bounded above by the labor income y_L of a household.

[6] If labor income is normalized and expressed in terms of the average labor income in the benchmark economy, the coefficient ϕ_2 would be − 0.32. It implies that under the optimal tax system, the capital income tax rate will be 35% (=0.67 − 0.32) if the labor income is at the average of the benchmark, as mentioned in the text, and 3% (=0.67 − 0.32 × 2) if the labor income is twice as large as the average.

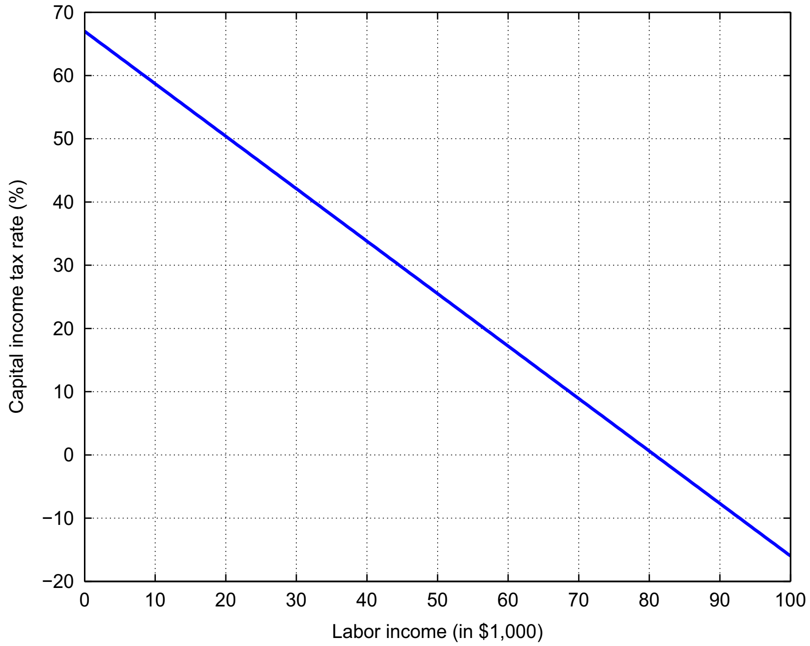

Fig. 1. Capital income tax function under the reform. *Note*: The figure shows the capital income tax rate in percentage as a function of labor income under the optimal tax system.

Table 2
Aggregate effects of the optimal tax system.

	Benchmark (%)	Reform (%)
Output *Y*	–	+4.8
Capital *K*	–	+2.1
Labor *L*	–	+6.3
Work hours	–	+3.7
Consumption *C*	–	+7.3
Wage	–	−1.4
Interest rate	5.0	5.3
Average income tax rate	18.2	17.0
Workers	18.5	15.4
Retirees	11.2	67.0
CEV	–	+3.7

Note: The table summarizes the changes in aggregate variables, average income tax rates and welfare effects under the optimal tax system.

is at the average level of the benchmark economy, the capital tax rate is about 35%. For given capital income, the labor tax is progressive, with a deduction of d_L=0.28, or about $13,000, relative to the average income of $47,000 in 2008. The following three subsections will investigate the features of the economy under the optimal system and changes from the benchmark in terms of aggregate variables and life-cycle profiles as well as the transitional dynamics to the reform economy.

4.2. Aggregate effects

The effects of the tax reform on aggregate variables are summarized in Table 2. The negative dependence of the tax schedule provides incentives for more work and saving. Aggregate capital and labor supply increase by 2.1% and 6.3%, respectively, and aggregate consumption rises by 7.3%. The rise in labor supply dominates the rise in capital and the interest rate increases from 5.0% to 5.3% given the lower capital–labor ratio.

One may be concerned that the reform can negatively affect tax revenues by generating incentives through tax rewards and require a hike in the average taxes to finance given government expenditures. It turns out, however, that the average income tax rate defined as the total tax payment divided by the sum of total labor and capital income, declines by 1.2 percentage points in the reform economy, because increased economic activities significantly expand the income tax base. Note that the tax function is anonymous and everyone in the economy is assumed to face the same tax schedule. The tax rate on retirees' capital income stands at 67%, the highest marginal tax on capital income since their labor income is zero by assumption. Section 5.3 considers a reform in which the tax function for retirees is excluded from the optimization and remains the same as the benchmark tax function.

The last row of Table 2 shows the long-run welfare effect of a reform, which is expressed in terms of consumption equivalent variation from a perspective of a new-born agent under the veil of ignorance on the evolution of states over the life-cycle. It is a percentage change in consumption across all possible states in the benchmark economy that is required to make a new-born agent as well off as in the reform economy. A positive number implies a welfare improvement by the reform. The large increase in consumption while being offset by the added disutility from more work leads to a net welfare gain of 3.7%. The direct benefit of the reform falls on households with the realization of high labor productivity and labor income who enjoy higher after-tax return from savings. It is, however, not just the households in states of high productivity and large assets that benefit from the reform and those with a low level of assets and productivity may also gain due to the progressive labor taxes with a sizable deduction. The analysis of who gains and loses among the currently alive generations requires computation of transition dynamics, which is discussed in Section 4.4.

4.3. *Effects on life-cycle profiles*

Fig. 2 displays the average profile of work hours, consumption and wealth over the entire life-cycle in the benchmark and the reform economy. Fig. 3 displays the average of the total income tax rates by age among working-age households in the two economies as well as the decomposition of the tax rates in the reform economy, distinguishing between the capital and labor income tax rates.[7] As Fig. 2(a) shows, the effect on work hours is not uniform across ages and a large increase in aggregate labor supply comes from the additional efforts of workers in middle to old ages. The heterogeneous effects can be explained by a combination of different factors. First, households have a stronger incentive to increase labor supply when the gain is larger (or the loss is smaller) by doing so. This happens when they have more wealth and higher capital income given the negative cross-partial in the tax function.[8] Second, after the peak of labor income, the capital tax starts to rise as shown in 3(b). The shape of the capital tax rates is the mirror image of the labor income profile, because of the negative dependence in the tax function. It implies an increasingly higher cost of future consumption and rising opportunity cost of leisure as households age, generating additional work incentives that increase in age. As discussed further in Section 5.1, the shape of the capital taxes after the peak of labor income resembles the optimal profile of age-dependent capital income taxes when the government is allowed to condition tax rates on age, as shown in Erosa and Gervais (2002) and Garriga (2003) under non-separable preference of the form used in this paper. Lastly, average labor taxes are lower for older households. Marginal labor taxes decline in capital income in the same way as capital taxes fall in labor income and the labor tax rates faced by middle to old-age households who have accumulated wealth (as shown in Fig. 2(c)) are lower, which further increases the benefit of work as they age.

Consumption and assets will reach their peaks at around age 55–60 under the reform and the peak levels are much higher than in the benchmark. After retirement, however, both consumption and assets start to fall more rapidly and lie below the level of the benchmark after age 70 s due to the high capital taxes faced by retirees.[9]

Because of the non-uniform change in labor supply across age groups and the decomposition effect, the average labor productivity is higher. As shown in Table 2, the aggregate labor supply increases by 6.3%, which is greater than the rise in work hours of 3.7%.

4.4. *Transition to the reform economy*

The results so far are based on the comparison of two steady states, one implied by the benchmark that approximates the U.S. economy and the tax system ('initial steady state') and the other implied by the optimal reformed tax system ('final steady state'). This section studies how the economy responds to the reform and makes a transition from the initial steady state to the final steady state. The economy is assumed to be in the initial steady state in period 0, and at the beginning of period 1, the tax reform is announced and implemented. The government will implement the new tax schedule of the form (7) with the values of the parameters that are found as optimal in a stationary equilibrium. During the transition the proportional tax rate ϕ_2 on labor income net of deduction will adjust to balance the government budget and to fill any gap between the revenues and spendings.

Fig. 4 displays how the aggregate labor, capital, consumption, the budget-balancing tax parameter ϕ_2 and factor prices evolve over time. The two circles in each plot at the first and last period represent the levels in the initial and final steady state respectively. Upon the implementation of the new tax policy, labor supply immediately jumps up by more than 6%, while the capital moves only gradually. The aggregate capital falls slightly in the initial years of the transition,

[7] The tax rate for retirees is constant at 67% and not displayed in the figure. Also note that the decomposition analysis cannot be done for the benchmark since the income tax function does not distinguish sources of income.

[8] These age-dependent effects approximate the role of optimal age-dependent labor taxes. See Section 5.1 for more details on the relation to the literature of age-dependent optimal income taxation in a life-cycle model.

[9] As discussed in Section 5.3, this 'reversal' does not occur if we assume an alternative tax function for retirees and use the same tax schedule as in the benchmark for them.

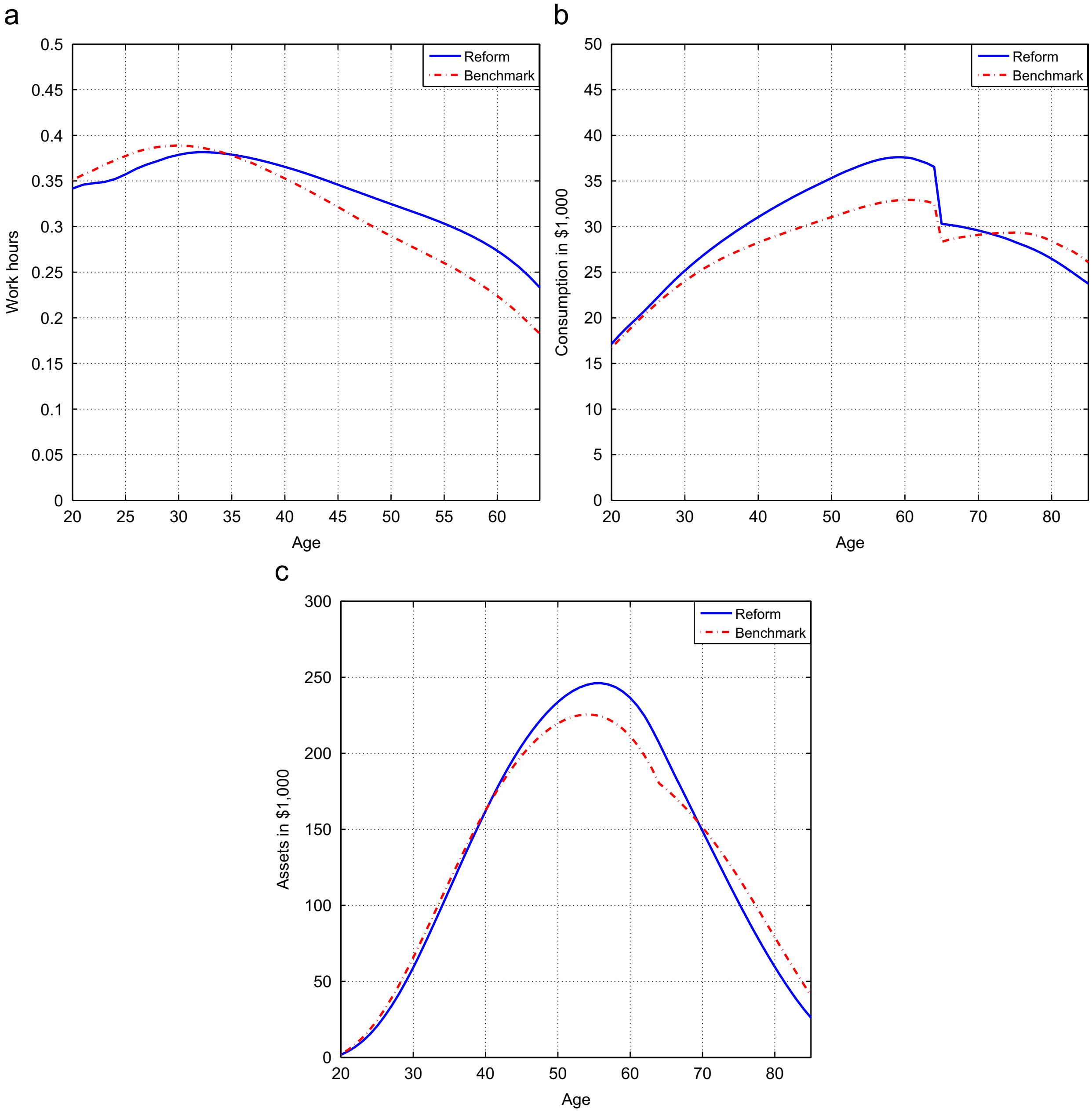

Fig. 2. Life-cycle profiles in benchmark and reform. *Note*: The figures compare the life-cycle profiles of work hours, consumption and assets in the benchmark and the reform economy: (a) work hours, (b) consumption and (c) assets.

which is driven by the decumulation of capital by retirees, who face a sudden and significant increase in the capital taxes from the average of 11.2% in the benchmark economy to a flat 67%.[10] As a result, capital-labor ratio drops immediately, reducing the wage rate by more than 2% and raising the interest rate from 5% to above 5.5% in the first period of the reform. The tax base will start to decline due to the initial drop in capital income as well as the fall in labor supply after its immediate upward jump in response to the policy reform. As a result, the tax rate ϕ_2 on labor income will rise gradually over the first 15 years of the transition from 0.22 to slightly below 0.24. Thereafter, the income tax base will start to expand steadily driven by the accumulation of the capital stock and the tax rate will fall and converge to the long-run level of 0.232.

[10] If the tax function remains the same as in the benchmark for retirees, which is considered in Section 5.3, the aggregate capital will monotonically rise during the transition and there is no initial drop.

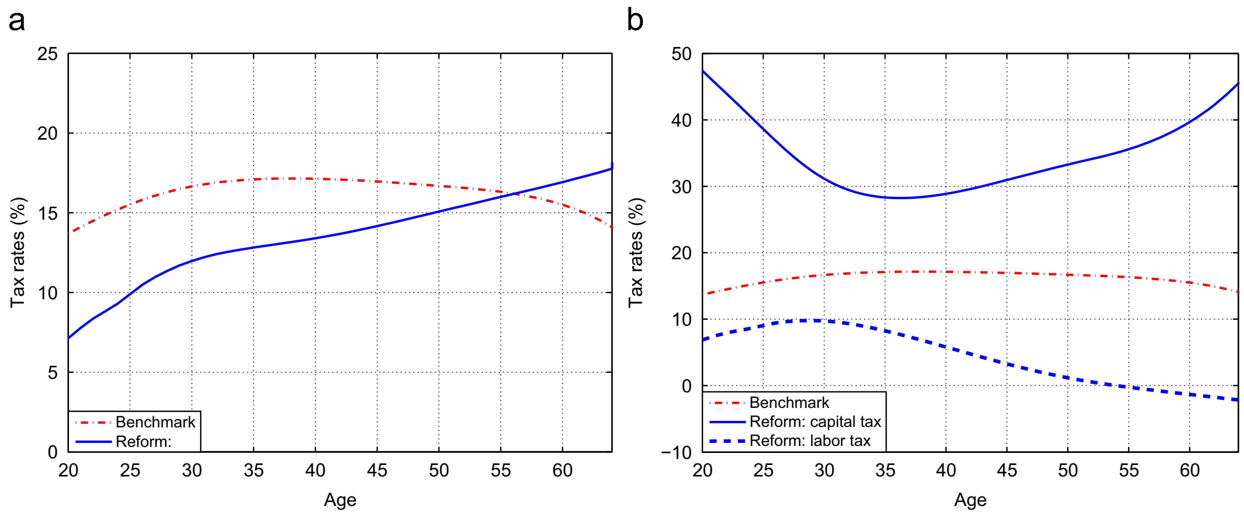

Fig. 3. Tax rates by age. *Note*: The figures compare the tax rates conditional on age in the benchmark and reform economy: (a) total income tax rates and (b) total income tax rates in benchmark and capital and labor income tax rates in reform.

The computation of the transition dynamics also enables us to analyze welfare effects of the tax reform on generations that are currently alive and study if the reform can bring a welfare gain for the majority. We compute consumption equivalent variation of households in different states when the reform is implemented in period 1. It measures the percentage change in consumption in all the possible states for the remainder of each household's life that would make the household indifferent between the benchmark and the reform economy.

Fig. 5 displays the average welfare effect of the transition for workers across the dimension of age and assets. Fig. 5(a) shows the welfare effect by age, which monotonically declines from above 2.0% to less than −4.0% in consumption equivalent variation. New-born agents (those at age 20) benefit from the reform, but the size of the average welfare gain is only 2.4% in consumption equivalence, much lower than the long-run gain of 3.7%. The wage rate is lower than in the final steady state during the first decades of transition and they will also face a higher tax rate ϕ_2 during most of their working years than in the final steady state. Those negative effects, however, faced by the very young agents during the initial years of the reform are offset by the gain they enjoy as they reach middle-ages and most of them prefer the reform to the status-quo. Young households with low labor income will face a sudden increase in the capital income tax, but the effect is relatively small since they do not own many assets. As shown in Fig. 5(b), the welfare gain declines in wealth due to the unexpected and significant rise in capital taxes. As a result of the heavy taxation on capital income, the reform has more negative welfare effects on older households, who have accumulated assets than on younger households during the transition. About one half of the population (52.6%) at the time of the reform announcement will experience a welfare loss from the transition, mostly due to the rise in capital taxes and the average welfare effect across households is −0.6% in consumption equivalence. The reform will most severely hurt retired households at the time of the policy change, who experience a large welfare loss at the magnitude of 2.1% in consumption equivalent variation on average. One possibility to mitigate such a transitional cost, in particular on the elderly, would be to raise the capital tax only gradually and spread the transitional burden across generations or to provide an alternative tax treatment for retirees. Section 5.3 considers such an alternative, where the tax function is the same as in the benchmark for retirees. In that case, the average welfare effect from the transition will be positive at 1.2% in consumption equivalence and retirees will experience a welfare gain of 2.8% consumption equivalent variation from the transition, with most of the gains originating from the rise in the interest rate and the higher retirement benefit due to the increase in the average labor income.

5. Interpretation of results and sensitivity analysis

This section will first discuss how our results relate to the existing theoretical and quantitative work on optimal income taxation in life-cycle models. It also presents sensitivity analysis of the assumed tax function for the optimization and preference parameters of the model.

5.1. Theories of optimal income taxation and interpretation of results

Atkeson et al. (1999), Erosa and Gervais (2002) and Garriga (2003) study theoretically the optimal income taxation in a life-cycle model with potentially age-dependent labor and capital income taxes. They show that in a typical overlapping generations model, in which optimal labor supply is never constant, the optimal labor income tax is also non-constant.

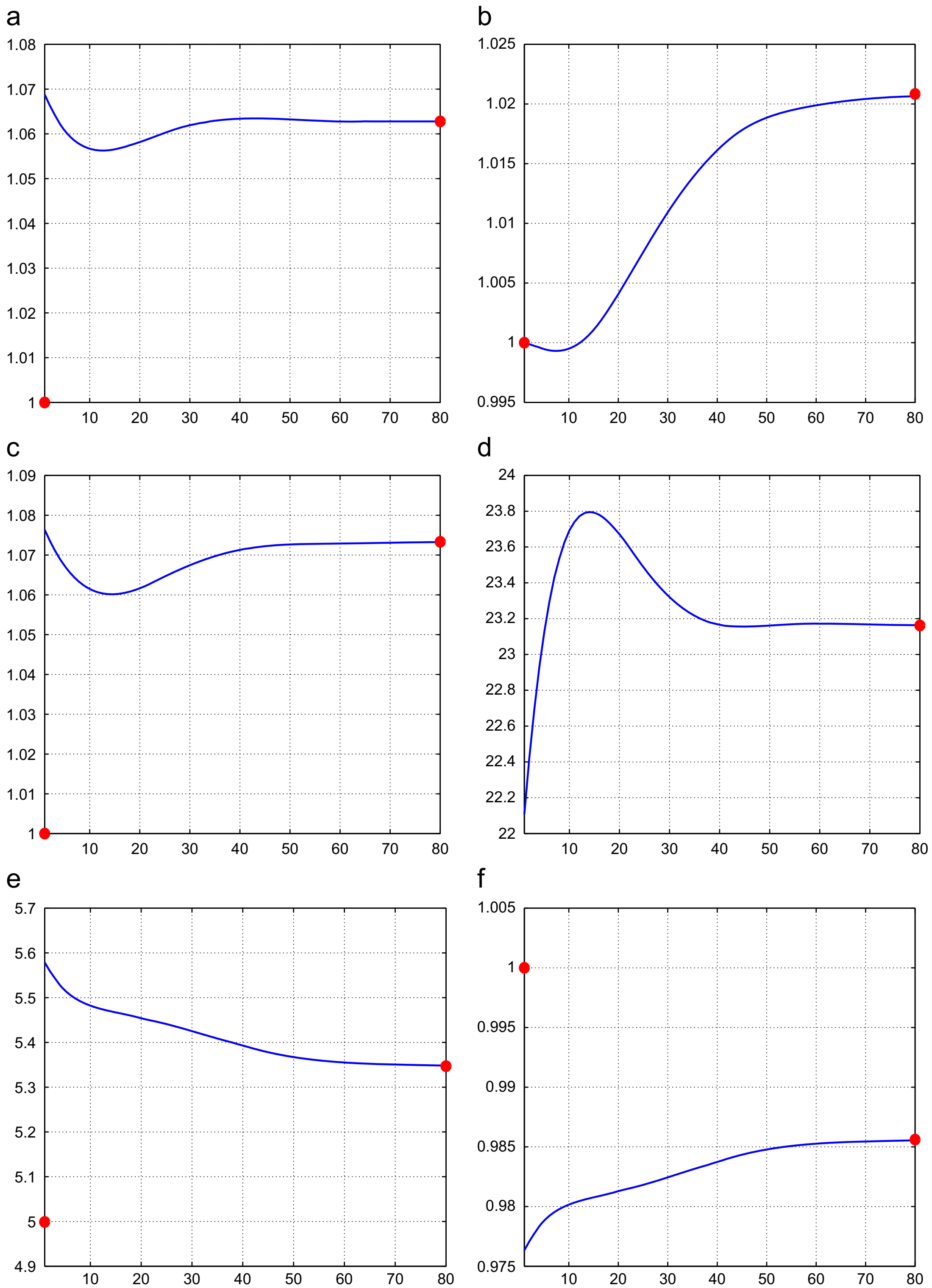

Fig. 4. Transition of aggregate variables. *Note*: Two circles at the first and last periods denote the levels in the initial and final steady states, except for the tax rate that does not have an equivalent value in the initial steady state. The level variables (L, K, C and w) are normalized, so that they take the value of unity in the initial steady state. The interest rates are in percentage and the tax rates are the values of tax parameter ϕ_2 that adjusts during the transition. On horizontal axes are the years since the reform announcement: (a) labor L, (b) capital K, (c) consumption C, (d) tax rate ϕ_2, (e) interest rate r and (f) wage w.

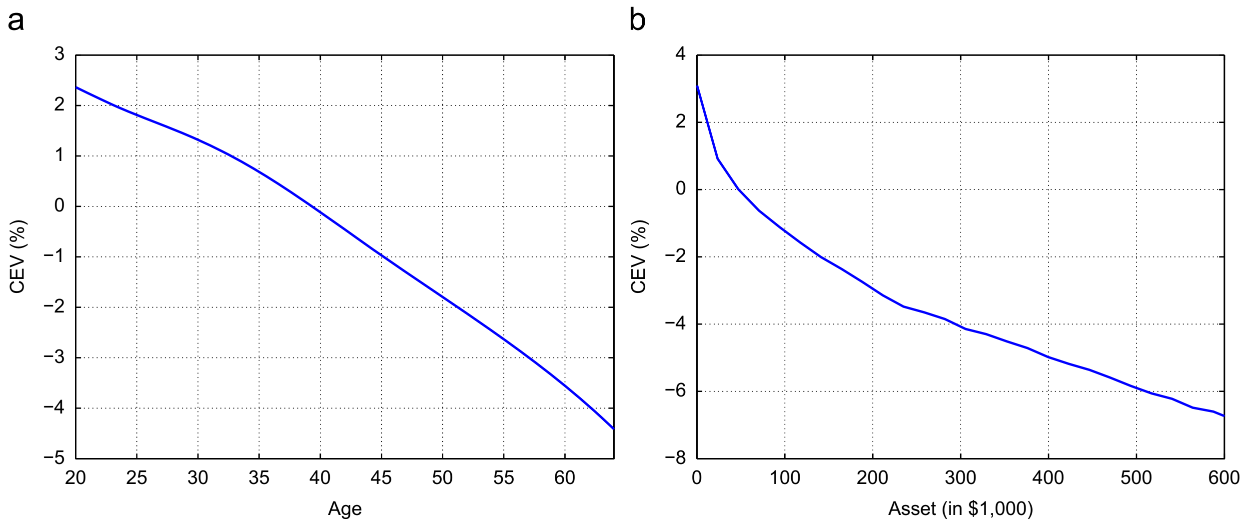

Fig. 5. Welfare effect of the transition. *Note*: The figures display the welfare effects on workers evaluated in terms of consumption equivalent variation (CEV) across ages and asset levels: (a) welfare effect across ages and (b) welfare effect across assets.

When the labor supply falls, the optimal labor tax is shown to decline as well. Conesa et al. (2009) take a quantitative approach and demonstrate the optimality of a positive and large capital income tax in a Bewley-type life-cycle model, when taxes are restricted to be age-independent. They emphasize the role of capital taxation to approximate the age-dependent labor taxation and affect the intertemporal allocation of labor supply.

The optimal profile of capital income taxes differs by the preference specification. Under the non-separable preference of the form in (5) considered above, optimal age-dependent capital taxes are also non-constant over the life-cycle. Erosa and Gervais (2002) and Garriga (2003) show that the optimal capital taxes rise from negative to positive over the life-cycle in a model that exhibits a hump-shaped labor supply profile. When labor taxes cannot be conditioned on age, age-dependent capital taxation can mimic the role of age-dependent labor taxation. This result holds under general preference.[11]

Labor-dependent capital taxation that is proposed in this paper can approximate the profiles of age-dependent taxation of both labor and capital income. In order to highlight the intuition, consider a simple stationary model in which a household of age j chooses consumption c_j, saving a_{j+1} and labor supply l_j to maximize the present discounted value of utility, $U(c_j, l_j)$, satisfying regular conditions. Ignore any uncertainty or borrowing constraint. Denote the interest rate as r and normalize the wage to 1. Denoting proportional labor and capital income taxes at each age as τ_{l_j} and τ_{k_j} and labor productivity as ε_j, the intertemporal optimality condition with respect to labor supply is given as

$$\frac{\varepsilon_{j+1}}{\varepsilon_j}\frac{U_{l_j}}{U_{l_{j+1}}} = \beta[1+r(1-\tau_{k_{j+1}})]\frac{1-\tau_{l_j}}{1-\tau_{l_{j+1}}}. \tag{10}$$

Consider the case where the optimal labor tax falls in age, that is, $\tau_{l_j} > \tau_{l_{j+1}}$. In the absence of age-dependence in labor taxes, a positive capital income tax can generate the same intertemporal wedge created by the age-dependent labor taxation.[12] Now suppose that the optimal labor tax falls at an increasing rate and the optimal *wedge* defined as $\omega_j = (1-\tau_{l_j})/(1-\tau_{l_{j+1}})$ falls in age. In such a case, age-dependent capital taxes that increase in age can mimic the role of non-constant wedges generated by the age-dependent labor taxes. A constant age-independent capital tax can only generate a single wedge.

Now consider labor-dependent capital taxation of the form proposed in this paper, that is, the capital income tax is a decreasing function of labor income, denoted as $\tau_k(\varepsilon_j l_j)$ with $\tau_k' < 0$. Intertemporal optimality conditions read as

$$\frac{\varepsilon_{j+1}}{\varepsilon_j}\frac{U_{l_j}}{U_{l_{j+1}}} = \beta[1+r(1-\tau_k(\varepsilon_{j+1}l_{j+1}))]\frac{(1-\tau_{l_j})-r\tau_k'(\varepsilon_j l_j)a_j}{(1-\tau_{l_{j+1}})-r\tau_k'(\varepsilon_{j+1}l_{j+1})a_{j+1}}, \tag{11}$$

$$\frac{U_{c_j}}{U_{c_{j+1}}} = \beta[1+r(1-\tau_k(\varepsilon_{j+1}l_{j+1}))]. \tag{12}$$

[11] A separate appendix that contains details of these results is available as supplemental material in Science Direct and at http://sites.google.com/site/sagirikitao/research3. The appendix uses simple two and three-period models with separable and non-separable preference specifications and provides all the algebra and more detailed description of the results presented in this section.

[12] This is the intuition for the optimality of a positive and high capital tax in Conesa et al. (2009).

The additional terms $(-r\tau_k' a) > 0$ on the RHS of (11) reflect the reduction in capital tax payment by an additional work effort, which is added to the after-tax wage $(1-\tau_l)$ to constitute an effective wage rate at each age. In the part of the life-cycle where households accumulate more wealth, this additional benefit of work will increase as well, generating a profile of rising effective wage rates and the intertemporal wedge $(-r\tau_{k,j}' a_j)/(-r\tau_{k,j+1}' a_{j+1})$. In addition, when labor income starts to decline, the capital tax begins to rise, making the future consumption increasingly more costly and raising the opportunity cost of leisure as households age. Therefore these two effects of labor-dependent capital taxation on intertemporal allocation of labor supply approximate the role of age-dependent labor taxes that decline in age, first through the increasing effective wage rates due to the accumulation of wealth, and second through the rise in capital taxes due to a decline in labor income. Essentially, both age-dependent taxes and labor-dependent taxes in the absence of age-dependence generate a profile of increasing net benefit of work and induce more work effort at older ages. We also note that the optimal age-dependent capital taxes increase in age and the implied profile of capital taxes with labor-dependence mimics such a profile in the part of the life-cycle where labor income declines.[13]

We have argued that in the absence of age-dependence, labor-dependent capital taxation can mimic age-dependent labor taxes through two channels, one through the rising capital tax rates and the other through the rising effective wages. It does not have to rely solely on a single flat capital tax to approximate the intertemporal wedge implied by the optimal age-dependent labor taxes. Conesa et al. (2009) find that the optimal capital tax rate is positive and significantly high at 36%. The degree of capital taxation involves a trade-off between the role to approximate age-dependent labor taxes and the distortions on households' saving decision. The high constant capital tax significantly discourages the saving and the aggregate capital falls by as much as 7% under the optimal tax system of Conesa et al. (2009). Introducing the labor-dependence provides a possibility of mitigating the negative general equilibrium consequence on aggregate capital and output.[14] Additional saving will not only increase future consumption but also effective wage rates in future since the extra benefit of work due to the reduction in capital taxes $(-r\tau_k' a)$ increases in wealth.

We also point that the tax schedule considered in this paper, namely a tax system with a negative cross-partial, can potentially offer benefits that are not available under proportional age-dependent taxes. Recent studies in the New Dynamic Public Finance (NDPF) literature extend the classic Mirrlees' trade-off on equity and efficiency to dynamic settings and examine the optimal taxation of income that is allowed to be an arbitrary function of current and past incomes. In the presence of private information on idiosyncratic productivities, studies show that the optimal tax calls for a negative covariance between marginal taxes on capital income and current labor income (Kocherlakota, 2005; Albanesi and Sleet, 2006; Golosov and Tsyvinski, 2006; Fukushima, 2010). The result is analogous to our quantitative finding that the coefficient on the cross-term of the tax function is negative and that the extra term generates a sizable welfare gain relative to the tax system without such dependence, as discussed further in Section 5.2. The negative cross-partial would dampen the work disincentive that accumulated wealth would provide otherwise. On the contrary, it would serve as a device to encourage more effort, especially from households with large assets, since an additional hour of work will raise the after-tax return on their wealth. The negative dependence allows the government to distinguish between agents of the same age and same current earnings by the amount of assets and to provide different work incentives. Insofar as labor income and wealth are positively correlated, the system implicitly provides those with a history of good productivity shocks with additional incentives to work since that would raise the after-tax return on their large assets. To the extent that the unconstrained optimal labor tax would depend on the history of productivity shocks and that the accumulated savings covary with them, the proposed tax system with a negative cross-partial may generate benefits that proportional age-dependent taxes are not able to deliver.[15]

5.2. Optimal tax system without non-zero cross-partial

As discussed in Section 4.1, this section considers a reform under the tax function of the form in (9) without the cross-partial term. The same social welfare function will be used for the optimization, that is, the ex-ante welfare of a new-born household in the economy. The aggregate effects are summarized in the column labeled as Reform A in Table 3. The tax function that maximizes the social welfare is defined by the set of parameters; $\phi_0 = 0.43$, $\phi_2 = 0.18$ and d_L=0.26, or a deduction of \$12,000 in 2008\$. The optimal function is similar to what Conesa et al. (2009) found, which is a combination of a proportional capital tax at 36% and progressive labor tax summarized by a flat tax of 23% with a deduction of \$7,200.[16] The capital tax rate of 43% in the optimal is significantly higher than the capital tax rate under the baseline optimization for most of the households, as seen in Fig. 3(b). Aggregate capital declines significantly by nearly 8% relative to the benchmark

[13] In the initial years of the life-cycle in which earnings start to grow from a low level, the capital tax is very high under our proposed tax system. The welfare effect, however, of high capital taxes during this period is relatively small since very young households do not own many assets.

[14] A positive capital tax and labor-dependent capital tax are not the only ways to approximate the optimal age-dependent labor taxation. In a recent work, Gervais (2009) focuses on the progressivity imbedded in the U.S. tax system and its role to mimic the role of age-dependent taxation.

[15] Recent work by Golosov et al. (2010) considers a novel tax system, in which the marginal labor tax depends on 'consolidated income accounts (CIA)' which track the history of past labor income. The optimal tax system has the feature that the total tax bill is lower for agents with a higher balance in the CIA. The tax system enables the government to have marginal taxes as an implicit function of history in a similar way as the tax system with a negative cross-partial studied in this paper.

[16] As discussed in Section 4.1, Conesa et al. (2009) use Gouveia and Strauss's non-linear function for labor income taxes in the baseline optimization. They also derive the optimal using a simpler function of a flat tax plus a deduction that is used in this section and find that the optimal is a combination of a proportional capital tax of 43% and a labor tax of 20% with a deduction of \$10,200 (see Table 6 in Conesa et al., 2009).

Table 3
Aggregate effects of the optimal tax system: alternative tax functions.

	Benchmark (%)	Reform A (%)	Reform B (%)
Output Y	–	−1.6	+3.6
Capital K	–	−7.8	+1.0
Labor L	–	+2.1	+5.0
Work hours	–	+1.5	+1.9
Consumption C	–	+0.7	+5.7
Wage	–	−3.6	−1.4
Interest rate	5.0	5.9	5.3
Average income tax rate	18.2	18.2	17.3
Workers	18.5	17.3	17.4
Retirees	11.2	43.0	13.0
CEV	–	+2.3	+ 2.9

Note: The column labeled Reform A indicates the effects of the optimal tax system under the tax function without non-zero cross-partial. The column labeled Reform B indicates the effects the optimal tax system when using the benchmark tax function for retirees.

Table 4
Sensitivity to preference specifications.

	Benchmark (%)	Reform (%)
Output Y	–	+1.8
Capital K	–	+3.5
Labor L	–	+0.8
Work hours	–	−1.7
Consumption C	–	+1.5
Wage	–	+1.0
Interest rate	5.0	4.8
Average income tax rate	18.2	17.9
Workers	18.5	16.0
Retirees	11.2	75.0
CEV	–	+2.9

Note: The table summarizes aggregate effects of the optimal tax system under separable preference with lower elasticity of labor supply.

economy, in the same magnitude as what Conesa et al. (2009) found under their optimal system. Although the average work hours and aggregate labor supply will both rise by about 2%, the output declines by 1.6% and consumption increases only marginally by 0.7% in the reform economy. The long-run average welfare gain of the reform is 2.3% in consumption equivalent variation, much lower than the 3.7% gain when the cross-partial term is allowed to be non-zero.

5.3. *Alternative tax function for retirees*

In the baseline case, it is assumed that everyone in the economy faces the same tax function. Retirees with no labor income are imposed the highest marginal tax rate of 67% on their capital income, since their earnings are zero. As shown in Sections 4.3 and 4.4, the reform will reduce consumption and saving of many retirees and they face a significant welfare loss from the transition. This section considers an alternative tax treatment of retirees, by assuming the same tax function as in the benchmark so that they do not face a sudden and significant rise in capital taxation. Workers face the same tax function (7) and the optimization is over the same set of tax parameters to maximize the same welfare function.

The optimal tax function is similar to that of the baseline case, with the highest capital tax rate of $\phi_0 = 0.68$ and the coefficient on the cross-term $\phi_1 = -0.41$, compared to the baseline optimal of $\phi_0 = 0.67$ and $\phi_1 = -0.39$.[17] The aggregate effects are summarized in the last column of Table 3. The long-run welfare gain is 2.9% in consumption equivalence, in a similar magnitude, though lower than the 3.7% gain in the baseline case. The short-run welfare, however, shows a very different picture. In the baseline, retirees suffered from a large welfare loss of -2.1% in consumption equivalence on average, but under this reform, they enjoy the average welfare gain of 2.8%. The interest rate on their retirement wealth is much higher during the transition due to the lower capital-labor ratio and the retirement benefit will rise as well since the economy's overall earnings rise. The average welfare effect from the transition across the entire population is positive at 1.2% in consumption equivalence and the majority (62%) will experience a welfare gain.

[17] For the part of progressive labor tax, $\phi_2 = 0.26$ and d_L=0.26, also similar to the baseline optimal.

5.4. Sensitivity to preference parameters

This subsection will study sensitivity of our results to the degree of labor supply elasticity. In the baseline calibration the preference is assumed to be non-separable in consumption and leisure, with the implied average intertemporal elasticity of labor supply of about 1.1. In order to quantify the sensitivity to the labor supply elasticity, we consider a preference that is separable in consumption and leisure, which allows us to pin down the value of labor supply elasticity:

$$\frac{c^{1-\sigma_1}}{1-\sigma_1}+\chi\frac{(1-l)^{1-\sigma_2}}{1-\sigma_2}. \tag{13}$$

Under this alternative preference specification, parameters of the model are recalibrated to match the same aggregate statistics that are used as calibration targets, namely, the value of the subjective discount factor β, preference parameter ν and TFP parameter A. The value of σ_1 in (13) is set at 2, which implies the degree of relative risk aversion equivalent to the

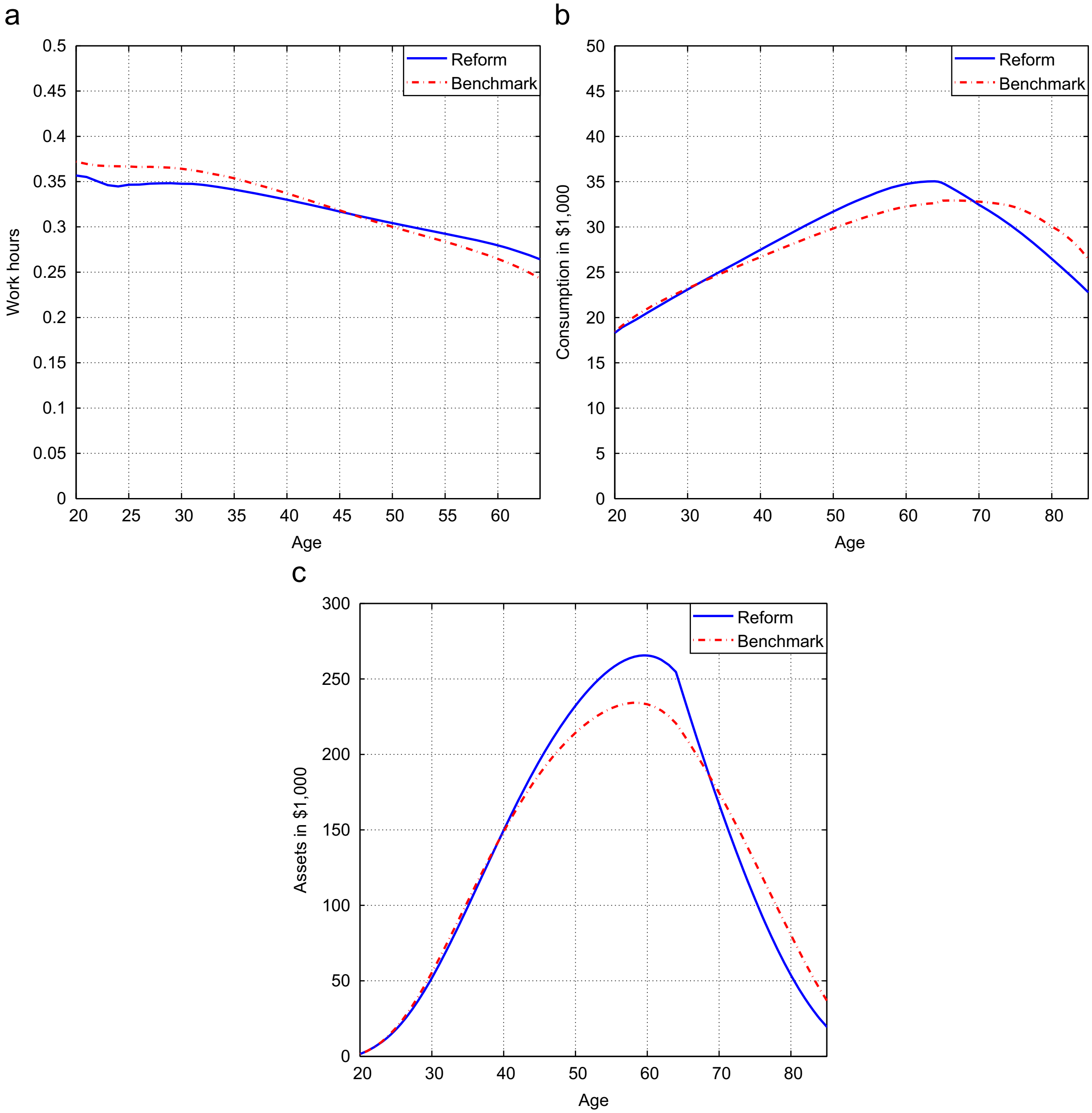

Fig. 6. Life-cycle profiles in benchmark and reform. *Note*: The figures compare the life-cycle profiles of work hours, consumption and assets in the benchmark and the reform economy under the separable preference with lower labor supply elasticity: (a) work hours, (b) consumption and (c) assets.

baseline model. σ_2 is set at the value of 4, which implies the average Frisch elasticity of 0.5, about half of the value in the baseline calibration.

The optimal tax function is given as $\phi_0 = 0.75$, $\phi_1 = -0.74$, $\phi_2 = 0.35$ and $d_L = 0.35$, or a deduction of $16,000 in 2008$. Results are summarized in Table 4. The proportional labor tax rate ϕ_2 is 0.35, significantly higher than in the baseline case of 0.23, given that the labor is supplied more inelastically and the tax will be less distortionary. The effect on the profile of work hours is subdued, as shown in Fig. 6(a), and the higher taxes depress average work hours by 1.7%. The high marginal tax on capital income and the significantly more negative coefficient on the cross-term raise the opportunity cost of leisure as households age, which together with the decline in the interest rate make the hours profile flatter. Work hours increase for middle to old age household while they decline for the young households. As a result, the aggregate labor supply marginally increases by 0.8% despite a drop in average work hours, raising the economy's labor productivity. The coefficient on the cross-term is much more negative than in the baseline optimal and generates a somewhat larger increase in aggregate capital by 3.5% relative to the increase of 2.1% in the baseline. The long-run welfare gain of the reform is in a similar magnitude at 2.9% in consumption equivalence, compared to the 3.7% gain in the baseline.

6. Conclusion

The paper studied a capital income tax that declines in labor supply through its negative dependence on labor income. It is shown that such a system provides an ample incentive to work harder and save more, especially for households of middle to old ages who possess high labor productivity and wealth and induces more efficient allocation of labor supply over the life-cycle. The reform brings a sizable welfare gain in the long-run in the magnitude of 3.7% in consumption equivalent variation. In the short-run, however, the reform will hurt the elderly, in particular retirees, who face a significant increase in taxes on income from their accumulated wealth.

There are several extensions that future research should investigate. Existing studies on income taxation in life-cycle models focus on labor supply responses on the intensive margin and it is less well known how allowing for endogenous labor participation and retirement decision will impact the quantitative analysis. Also, extending the model to incorporate additional heterogeneity among households due to factors such as education levels or unemployment risks will be a natural extension and searching for the optimal tax schedule in such a model will be worth exploring despite a computational challenge.

As a final remark, one may question practicality of such a reform in light of its apparent complexity. The tax authority, however, only needs the information on capital and labor income, nothing more than what the existing U.S. tax system asks for. What is critical in generating various incentive effects is the simple mechanism in which additional work effort increases the net return from savings. The tax function considered in this paper is one of the possibilities. We believe that the system may indeed have a merit in its simplicity relative to the existing intricate tax system.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jmoneco.2010.09.004.

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