ARC Centre of Excellence in Population Ageing Research

Working Paper 2012/13

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Optimal Capital Income Taxation with Means-tested Benefits [*]

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20th May 2012

Abstract

This paper studies the interaction between capital income taxation and a means tested age pension in the context of an overlapping generations model, calibrated to the UK economy. Recent literature has suggested a rehabilitation of capital income taxation (Conesa *et al.* (2009)), predicated on the idea that capital is a complement with retirement leisure. This leads naturally to the conjecture that a publicly funded age pension contingent upon holdings of capital or capital income may have a similar effect. We formalize this using a stochastic OLG model with multiple individuals differentiated by labour productivity and pension entitlement. Our preliminary findings suggest that a means tested pension has effects similar to capital income taxation in a life-cycle context.

JEL Classification: E21, E62, H55

Keywords: Dynamic general equilibrium, taxation, welfare.

1   Introduction

Over the last decade or so, the 1980s results of Judd and Chamley (Judd (1985) & Chamley (1986)) that a zero capital income tax rate is optimal, have been severely qualified. There are two major explanations. The first relates to restrictions on instruments. When consumer preference is placed in a life-cycle framework, individuals vary their optimal consumption-work plan over the cycle, and age specific taxation is not available, capital income tax may be a second best solution. Secondly, if markets are incomplete, resulting in liquidity constraints and/or uninsurable idiosyncratic income risk, then a non-zero capital income tax may dominate a zero capital tax environment, because higher net-of-tax labour earnings relax liquidity constraints and/or provide more opportunity for self-insurance. Conesa *et al.* (2009) show that when these features of preferences, policy restrictions and markets are represented in overlapping generations (OLG) models of incomplete economies, then the optimal capital income tax rate is 36% for the US economy.[1]

This paper revisits the optimal capital income tax question. A motivating feature of second best taxation policy relates to the non-taxation of leisure. In a life-cycle framework, the most important non-taxable good is leisure, and an enormous literature has been devoted to optimizing tax design in the face of this constraint, based fundamentally upon the idea that if a good is non-taxable, then a second best solution will involve taxing its complement. Perhaps the most important consumption of leisure is related to the retirement decision - leisure taken after retirement has been the target of successive attempts to induce workers to delay retirement, by raising the access age to social security and/or tax preferred private pensions, or through other means. Life cycle capital accumulation is a natural complement to retirement leisure, and if it could be targeted as separately taxable, then this may lead to an allocation of resources which is welfare-superior to a tax on all capital.

Taking the above observation as a point of departure, we study the impact of resource-testing (means-testing) public pensions, a feasible policy action equivalent to introducing a capital income tax on retirement capital. We incorporate this into an incomplete market OLG model, loosely stylized to the UK economy. The UK runs a means tested pension program and is thus suitable to our analytic purposes. The UK reformed its means-tested pension benefits by reducing the taper rate on private income from 100% (pre-refom rate) to 40% (post-reform rate). The means-tested social insurance program provides an old age pension income subject to a means testing of income and asset holdings. The macroeconomic and welfare implications of various social security arrangements including Pay As You Go (PAYG) and means-tested pension programs are well analyzed in the literature. For instance, Sefton *et al.* (2008) and Kumru & Piggott (2009) analyze the welfare and aggregate effects of changes in the generosity of means-tested social pension programs showing that generous programs have a big negative impact on social welfare. This is because they create distortions on individuals' labor supply and saving decisions.

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[1]See Conesa *et al.* (2009) and the next section for a detailed literature review on the issues discussed above.

This paper contributes to the literature from the two angles. First, it extends Conesa *et al.* (2009) that analyzes the optimal capital income tax rate by adding an additional factor that interacts with the capital income tax rate. Second, it carries Sefton & van de Ven (2009)'s study on the relation between means-tested benefits and taxation to a richer modeling environment so that we can quantify the optimal income tax rates a lá Conesa *et al.* (2009) for the UK.

We use an incomplete market stochastic general equilibrium OLG model economy. It is populated by overlapping generations of individuals who can live up to 81-periods (real age of 100). During the course of life, individuals face idiosyncratic income risk, uncertain life-times and liquidity constraints. After retirement individuals receive means-tested pension benefits. The aggregate technology is represented by a Cobb-Douglas production function. Factor prices are derived from the representative firm's maximization problem. The government levies taxes to finance its expenditures and pension program.

We show that the optimal tax capital income tax rates in both pre-and post-reform economies in the UK is significantly positive at 33% and 34% respectively. Our results are in line with those of the previous studies that show that the significantly positive capital income tax rate is optimal. In addition, we show the negative relation between higher taper rates and the optimal capital income tax rate: the higher the benefit reduction rate is, the lower the optimal capital income tax rate is. This result highlights the role of a means-tested pension program as a non-linear capital income tax.

2   Related Literature

In their seminal papers, by using the Ramsey approach in the one-sector growth model with complete markets, Judd (1985) and Chamley (1986) show that it is not optimal for the government to tax capital income in the long run. In particular, Judd (1985) asks the following question: how much will the disincentive effects of capital income taxation on savings and the associated loss in wages reduce the amount of redistribution to the employees? Judd's findings can be summarized as follows. First, since the short-run supply of capital is inelastic, unexpected increases in the tax rate on capital income might be favored by a relatively poor majority because of redistribution considerations. Second, in the long run, all agents prefer a zero percent capital income tax rate. Chamley (1986) uses a general form utility function and shows that the optimal tax rate on capital income tends to zero in the long-run. In other words, their results indicate that a tax on capital income is not an efficient way of redistributing income. Judd and Chamley's zero capital income taxation result is robust to changes in the assumptions they made [see Conesa *et al.* (2009)].

However, the zero capital income taxation result might not hold if there is a market incompleteness and/or the life-cycle framework is used [see Alvarez *et al.* (1992), Erosa & Gervais (2002), and Garriga (2003)]. In particular, Erosa & Gervais (2002) prove that it is optimal for a government to tax or subsidize interest income by using a standard life-cycle model. The reason is simple. Individuals' optimal consumption-work plan is not constant over the life-cycle. As a

result, the government always wants to use age varying capital and income tax rates. If it is not possible to condition tax rates on age, a non-zero capital income tax rate can be a substitute for age-conditioned consumption and labor income taxes. Similarly, Hubbard & Judd (1986) and Aiyagari (1995), show that if there are incomplete credit and/or insurance markets, i.e. individuals are liquidity constrained and/or face uninsurable idiosyncratic income risk, then the optimal capital tax rate can't be zero.

There is also a strand of the optimal-tax literature which incorporates a life-cycle framework and an incomplete market setting to analyze aggregate and welfare effects of various tax schemes (see Auerbach & Kotlikoff (1987), Imrohoroglu (1998), Ventura (1999), Fuster *et al.* (2007), and Conesa *et al.* (2009)). In a seminal work, by using a deterministic OLG model with complete markets, Auerbach & Kotlikoff (1987) find that the aggregate capital stock increases when the tax base is changed from a 15% capital income tax to a 20.1% wage tax or a 17.6% consumption tax. Their results show that while replacing the capital income tax with the wage tax reduces efficiency, a welfare gain is realized when the capital income tax is replaced with the consumption tax. Imrohoroglu (1998) studies aggregate and welfare implications of eliminating capital income taxation by using an incomplete market stochastic OLG model and shows that the capital income tax is not desirable because it negatively affects the private saving decision.[2] In the model the labor supply is inelastic and hence, the labor income tax does not create any distortions on individuals' labor supply decisions. Yet, the labor income tax is still undesirable because it hinders individuals' ability to self-insure. Replacing the capital income tax with the labor income tax causes reallocation of resources from the years of old age to middle age. In other words, while a decrease in the capital tax rate increases the capital stock, it creates a negative consumption profile effect. Imrohoroglu (1998) concludes that there is a positive capital income tax rate that maximizes the social welfare. Ventura (1999) studies life-cycle economies in which individuals have preferences over consumption and leisure, have permanent ability differences, and face idiosyncratic shocks to labor productivity, to analyze the implications of a revenue neutral tax reform in which labor and capital income taxes are replaced by a flat tax. He shows that elimination of the capital tax in this environment creates a positive effect on capital accumulation. Fuster *et al.* (2007) use a dynastic framework to analyze the welfare effects of different revenue-neutral tax reforms. They find that the reform that eliminates all income taxation and increases the consumption taxation to 35% creates the largest welfare gain. They show that the majority of the population alive at the time of the reform benefit from it in the dynastic framework although the same reform would benefit only a small percentage of population in a pure-life cycle model. Finally, Conesa *et al.* (2009) quantitatively characterize the optimal capital and labor income tax by using an OLG model in which individuals face uninsurable idiosyncratic income shocks and permanent productivity differences. They find that the optimal capital income tax rate is significantly positive at 36%.

There is a number of recent studies that extend Conesa *et al.* (2009) from various directions. Nakajima (2010) incorporates housing asset into a model similar to that of Conesa *et al.* (2009)

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[2]This, in turn creates distortions on the aggregate capital stock, output, and consumption.

and shows that the optimal capital income tax rate in the model with housing is 1%. Kuklik (2011) extends Conesa *et al.* (2009)'s model by adding two additional elements: a non-linear mapping between hours worked and wages and inter-vivos transfers and shows that the optimal capital income tax rate in the US is 7.4%. These results suggest that changes in the model structure affect the optimal capital income tax rate quite substantially. Kitao (2010) studies the implications of the reform proposal that replaces the current US income tax system with a system that includes a labor-dependent capital income taxation and shows that the reform proposal creates a significant welfare gain. Similarly, Fukushima (2010) sets up a model similar to that of Conesa *et al.* (2009) and study the implications of a policy reform which replaces an optimal flat tax with an optimal nonlinear tax that is age and history dependent and shows that welfare increases substantially.

Although social insurance benefits have been means-tested for a long time, these policies have recently entered into the economists' interests. By using a partial equilibrium model with a binary labor-leisure choice Sefton *et al.* (2008) and Sefton & van de Ven (2009) analyzed the welfare implications of the means-testing of pension benefits and the interactions between various tax schemes and means-tested benefits respectively. Kumru & Piggott (2009) extend Sefton *et al.* (2008)'s model to analyze the implications of means-tested benefits in a general equilibrium framework. Both studies report that means-testing increases welfare. Golosov & Tsyvinski (2006) analyze the implications of the asset testing of disability insurance system and find significant welfare gains from asset testing. In a recent paper, Kitao (2012) analyzes various social security reform proposals including means-testing of benefits and shows that means-testing is a desirable policy.

We extend this canonical framework by explicitly incorporating resource testing into the public retirement transfer system, so that we can analyze the interactions between resource testing and capital income taxation. This allows us to study the impacts of alternative withdrawal, or taper rates of the transfer system on the optimal capital and labour income tax rates. We hypothesize that because a taper rate operates as a de facto capital income tax rate on retirement assets, the optimal capital income tax rate will be lower, the higher the taper rate. Further, the taper rate directly impacts upon retirement assets, rather than capital as it accumulated throughout the life cycle, and this extended structure allows us to explore the implications of this age-based policy.

3 The Model Economy

We use a general equilibrium OLG model economy with uninsured idiosyncratic shocks to labor productivity and mortality. The main features of our model follow those of Conesa *et al.* (2009), Kitao (2010), and Nakajima (2010). In terms of modeling the public sector we follow Sefton *et al.* (2008) and Sefton & van de Ven (2009).

3.1 Demographics

Time is discrete. Each period a new generation is born. Individuals live a maximum of J periods. The population grows at a constant rate n. All individuals face a probability (s_j) of surviving from age j to $j + 1$ conditional on surviving up to age j. Individuals retire at exogenously determined retirement age j^* and receive relevant pension benefits.

3.2 Endowments

Let $j \in \hat{J} = \{1, 2, ...J\}$ denotes age. An individual's labor productivity in a given period depends on age, permanent differences in productivity due to differences in education or abilities, and an idiosyncratic productivity shock to the individual's labor productivity. In other words, agents are heterogenous in terms of labor productivity. Age-dependent labor productivity is denoted by $\bar{e}_j$. Each individual is born with a permanent ability type $\hat{e}_i \in \hat{E} = \{\hat{e}_1, \hat{e}_2, ..., \hat{e}_m\}$ with probability $p_i > 0$. Individuals face idiosyncratic shock $\psi \in \Psi = \{\psi_1, \psi_2, ..., \psi_n\}$ to labor productivity. The stochastic process for ψ is identical and independent across individuals and follows a finite-state Markov process with a stationary distribution over time: $Q(\psi, \Psi) = \Pr(\psi' \in \Psi | \psi)$. We assume that Q consists of only strictly positive entries and hence, Π is the unique, strictly positive, invariant distribution associated with Q. Initially each individual has the same average stochastic productivity given by $\overline{\psi} = \sum_{\psi} \psi \Pi(\psi)$, where $\Pi(\psi)$ is the probability of ψ. Hence, an ability type $\hat{e}_i$ individual's labor supply at age j in terms of efficiency units are written as $\bar{e}_j \hat{e}_i \psi l_j$, where l_j is hours of work. Let $a \in A \subset \mathbb{R}^+$, where a denotes asset holdings. A is a compact set. Its upper bound never binds and its lower bound is equal to zero. We define the space of individuals' state variables as follows: $X = \hat{J} \times A \times \hat{E} \times \Psi$. Note that at any time t, an individual is characterized by the state set $x = (j, a, \hat{e}_i, \psi) \in X$. Let M be the Borel σ-algebra generated by X and let $B \in M$. Define μ as the probability measure over M. Hence, we can represent individuals' type distribution by the probability space (X, M, μ).

3.3 Preferences

Individuals have preferences over consumption and leisure sequence $\{c_j, (1-l_j)\}_{j=1}^{J}$ represented by a standard time separable utility function:

$$E\left[\sum_{j=1}^{J} \beta^{j-1} u(c_j, 1 - l_j)\right],\tag{1}$$

where E is the expectation operator and β is the time-discount factor. Expectations are taken over the stochastic processes that govern the idiosyncratic labor productivity risk and longevity.

3.4 Technology

A representative firm produces output Y at time t by using aggregate labor input measured in efficiency units (L) and aggregate capital stock (K). The technology is represented by a Cobb-Douglas constant returns to scale production function:

$$Y_t = A_t K_t^\alpha L_t^{1-\alpha}. \qquad (2)$$

A_t is the level of total factor productivity. Output shares of capital stock and labor input are given by α and $(1-\alpha)$ respectively. The capital stock depreciates at a constant rate $\delta \in (0,1)$. The representative firm maximizes its profit by setting wage and rental rates equal to the marginal products of labor and capital respectively:

$$w_t = A_t(1-\alpha)(\frac{K_t}{L_t}), \qquad (3)$$

$$r_t = A_t\alpha(\frac{K_t}{L_t})^{\alpha-1}. \qquad (4)$$

The aggregate resource constraint in this economy is given by the following equation:

$$C_t + G_t + Pen_t + K_{t+1} + (1-\delta)K_t = Y_t, \qquad (5)$$

where C_t is aggregate private consumption, G_t is aggregate public consumption, and Pen_t is aggregate means-tested pension benefit payments.

3.5 The Public Sector

The government runs a public pension system comprising a means-tested pension and an earnings-dependent, self-financed Pay As You Go (PAYG) pension (so called State Second Pension) programs. Since individuals face stochastic life-span and private annuity markets are closed by assumption, a fraction of the population will leave accidental bequests. The government confiscates all accidental bequests and delivers them to the remaining population in a lump-sum manner. We denote these transfers by η_t. Finally, the government faces a sequence of exogenously given consumption expenditures $\{G_t\}_{t=1}^\infty$. To finance its consumption and means-tested pension program expenditures, the government levies taxes on capital income, labor income, and consumption. State Second Pension expenditures are financed through payroll tax collections.

The pension program of our model reflects the basic features of that of the UK.[3] Individuals who reach retirement age receive a state second pension benefit $b(x)$ and might be entitled

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[3]The UK pension program consists of an almost universal flat rate Basic State Pension (BSP) and compulsory earnings-related scheme (State Second Pension). Individuals must enroll in either the earnings-related PAYG financed public pension program or make contributions to private pension funds. In addition, at retirement, individuals may receive means-tested pension benefits subject to the asset and income tests. See Sefton *et al.* (2008) for a detailed exposition of the UK public pension program. The pension program in our model assumes away the universal (BSP) component.

to additional pension benefits depending on their private income.[4] Means-tested benefits are determined as follows:

$$b_t^*(x) = \max[b_t^{\min} - \phi y_t, 0],\tag{6}$$

where $b_t^*(x)$ is the means-tested benefit received by a j year old individual; $b_t^{\min}$ is the minimum pension income guaranteed by the government; ϕ is the taper (benefit reduction) rate; and y_t is the individual's gross income. State second pension program is self-financing and benefits are calculated as follows:

$$b_t(x) = \theta \frac{\sum_{j=1}^{j^*-1} y_t^l}{j^* - 1},\tag{7}$$

where $y_t^l = w_t \bar{e}_j \hat{e}_i \psi l_j$ is an individual's labor income and θ is the state second pension replacement rate.

Following Conesa *et al.* (2009) and Nakajima (2010) we use the functional form introduced by Gouveia & Strauss (1994) to capture the progressiveness of the income tax rate in our baseline economies:[5]

$$T(y) = \kappa_0(y - (y^{-\kappa_1} + \kappa_2)^{-1/\kappa_1}),\tag{8}$$

where κ_0, κ_1, and κ_2 are parameters. In this specification, while the level of average tax rate is controlled by κ_0, the progressiveness of the tax code is controlled by κ_1. The parameter κ_2 ensures that the balanced budget condition holds.[6] In our calculation of the optimal tax rates, we assume that the capital income tax rate is proportional and denoted by τ_k and the labor income tax rate is determined by the same Gouveia and Strauss tax function. In this study our aim to determine the optimal level of τ_k as in Conesa *et al.* (2009) and Nakajima (2010). In addition to taxes on capital and labor incomes, the government taxes consumption expenditures at an exogenously given proportional rate τ_c.

3.6 An Individual's Decision Problem

A j year old individual's gross income at time t is given as follows:

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[4]In our model individuals can receive the means-tested benefits only after they reach the exogenously determined retirement age (equivalent to the state pension age). However, in the UK, individuals might be entitled to means-tested benefits before they reach the state pension age. The actual means-tested benefits are also subject to asset tests. Individuals receive the minimum retirement benefits determined by asset and income tests.

[5]This functional form has been extensively employed in the quantitative public finance literature. See for example, Castaneda *et al.* (1999), Rios-Rull (1999), and Conesa & Kruger (2006).

[6]Gouveia and Strauss tax function comprises an array of progressive, proportional, and regressive tax schedules: The limiting values of marginal and average tax rates are equal to κ_0 ($\lim_{y\to\infty} \frac{T(y)}{y} = \lim_{y\to\infty} T'(y) = \kappa_0$); when $\kappa_1 = -1$, the amount of tax paid does not depend on income ($T(y) = -\kappa_0\kappa_1$); when $\kappa_1 \to 0$, the tax system is propostional ($T(y) = \kappa_0 y$); and when $\kappa_1 > 1$, the tax system is progressive since aveage and marginal taxes are strictly increasing function of income ($\frac{T(y)}{y} = \kappa_0(1 - (1 + \kappa_2 y^{\kappa_1})^{-\frac{1}{\kappa_1}}$ and $T'(y) = \kappa_0(1 - (1 + \kappa_2 y^{\kappa_1})^{-\frac{1}{\kappa_1}-1}))$.

$$y_t = \left\{ \begin{array}{l} r_t(a_t + \eta_t) + y_t^l \text{ if } j < j^*, \\ r_t(a_t + \eta_t) + b_t(x) + b_t^*(x) \text{ if } j \geq j^*. \end{array} \right\} \tag{9}$$

Hence, the individual's budget constraint can be written as

$$\left\{ \begin{array}{l} (1 + \tau_{c,t})c + a' \leq (1 + r_t(1 - \tau_{k,t}))(a + \eta_t) + (1 - \tau_l)y_t^l \text{ when } j < j^* \\ (1 + \tau_{c,t})c + a' \leq (1 + r_t(1 - \tau_{k,t}))(a + \eta_t) + b_t(x) + \text{ when } j \geq j^* \\ (1 + \tau_{c,t})c = (1 + r_t(1 - \tau_{k,t}))(a + \eta_t) + b_t(x) + b_t^*(x) \text{ when } j = J, \end{array} \right\} \tag{10}$$

where the next period's variables are denoted by a prime. For instance, a' denotes the next period's asset holdings.

Individuals also face the following borrowing constraint:

$$a' \geq 0. \tag{11}$$

The decision problem of an individual in our model economy can be written as a dynamic programming problem. Denoting the value function of the individual at time t by V_t, the decision problem is represented by the following problem:

$$V_t(x) = \max_{c,l}\{u(c, 1 - l) + \beta s_j \int V_{t+1}(x')Q(\eta, d\eta')\} \tag{12}$$

subject to the aforementioned budget and borrowing constraints.

3.7 Equilibrium

Our competitive and stationary competitive equilibrium definition follows Auerbach & Kotlikoff (1987), Conesa *et al.* (2009), and Nakajima (2010).

Definition 1 *Given sequences of government expenditures $\{G_t\}_{t=1}^{\infty}$, consumption tax rates $\{t_c\}_{t=1}^{\infty}$, payroll tax rate $\{\tau_p\}_{t=1}^{\infty}$, minimum pension income guaranteed through means-tested program $\{b_t^*\}_{t=1}^{\infty}$, taper rate $\{\phi\}_{t=1}^{\infty}$ and initial conditions K_1 and Φ_1, a competitive equilibrium is a sequence of value functions $\{V_t\}_{t=1}^{\infty}$ and optimal decision rules $\{c_t, a_t', l_t\}_{t=1}^{\infty}$, measures $\{\Phi_t\}_{t=1}^{\infty}$, aggregate stock of capital and aggregate labor supply $\{K_t, L_t\}_{t=1}^{\infty}$, prices $\{r_t, w_t\}_{t=1}^{\infty}$, transfers $\{\eta_t\}_{t=1}^{\infty}$, and tax policies $\{\tau_{k,t}, T_t(.)\}_{t=1}^{\infty}$ such that*

1. *$\{V_t\}_{t=1}^{\infty}$ is a solution to the maximization problem defined above. Associated optimal decision rules are given by the sequence $\{c_t, a_t', l_t\}_{t=1}^{\infty}$.*

2. *The representative firm maximizes its profit according to the equations 3 and 4.*

3. *All markets clear:*

   (a) *$K_t = \int a\Phi_t(dj \times da \times d\hat{e}_i \times d\psi)$,*

   (b) *$L_t = \int \bar{e}_j \hat{e}_i \psi l_j(j, a, \hat{e}_i, \psi)\Phi_t(dj \times da \times d\hat{e}_i \times d\psi)$,*

(c) $\int c_t(j, a, \hat{e}, \psi)\Phi_t(dj \times da \times d\hat{e}_i \times d\psi) + K_{t+1} + G_t = Y_t + (1 - \delta)K_t.$

4. *Law of motion*

   (a) *for all $\hat{J}$ such that $1 \notin \hat{J}$ is given by $\Phi_{t+1}(\hat{J} \times A \times \hat{E} \times \Psi) = \int P_t((j, a, \hat{e}_i, \psi); \hat{J} \times A \times \hat{E} \times \Psi)\Phi_t(dj \times da \times d\hat{e}_i \times d\psi)$ where,*

   $$P_t((j, a, \hat{e}_i, \psi); \hat{J} \times A \times \hat{E} \times \Psi) = \begin{cases} Q(\psi, \Psi)s_j \ \text{if } j+1 \in J, a'_t(j, a, \hat{e}_i, \psi) \in A, \hat{e}_i \in \hat{E} \\ \qquad\qquad 0 \ \text{else} \end{cases}$$

   (b) *for $\hat{J} = \{1\}$:* $\Phi_{t+1}(\{1\} \times A \times \hat{E} \times \Psi) = (1 + n)^t \begin{cases} \sum_{\hat{e}_i \in \hat{E}} p_{\hat{e}_i} \ \text{if } 0 \in A, \overline{\psi} \in \Psi \\ \qquad\quad 0 \ \text{else} \end{cases}$

5. *Transfers are given by $\eta_{t+1} \int \Phi_{t+1}(dj \times da \times d\hat{e}_i \times d\psi) = \int (1 - s_j)a'_t(j, a, \hat{e}_i, \psi)\Phi_t(dj \times da \times d\hat{e}_i \times d\psi).$*

6. *State second pension program is self financing: $\tau_{p,t} \int y^l_t \Phi_t(\{j^*, ..., J\} \times da \times d\hat{e}_i \times d\psi) = \theta_t \int \Phi_t(\{j^*, ..., J\} \times da \times d\hat{e}_i \times d\psi).$*

7. *Means-tested pension payments given by $Pen_t = \int (b_t + b^*_t)(dj \times da \times d\hat{e}_i \times d\psi).$*

8. *Government runs a balanced budget: $G_t + Pen_t = \int T_t[y^l_t]\Phi_t(dj \times da \times d\hat{e}_i \times d\psi) + \int \tau_{k,t} r_t(a + \eta_t)\Phi_t(dj \times da \times d\hat{e}_i \times d\psi) + \tau_{c,t} \int c_t \Phi_t(dj \times da \times d\hat{e}_i \times d\psi)$*

Definition 2 *A stationary equilibrium is a competitive equilibrium in which per capita variables and functions, prices, and policies are constant. Aggregate variables grow at the constant rate n.*

4 Calibration

This section defines the parameter values of our model. The values of calibrated parameters for the benchmark economy is presented in Table 1.

Demographics Each model period corresponds to a year. Individuals are born at a real age of 20 (model age of 1) and they can live up to a maximum real life age of 100 (model age of 81). The population growth rate is assumed to be equal to the long-term average growth rate of the UK's population i.e. $n = 0.5\%$ [National Statistics (2009a)].[7] The sequence of conditional survival probabilities in the model, s_j is set equal to the sequence of conditional survival probabilities of men in the UK using $2002 - 2004$ data [National Statistics (2009b)]. The mandatory retirement age is 65 (model age of 46), which is equal to the UK's state pension age for men.

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[7]It is the average annual population growth rate between 2001 and 2007.

Endowment An individual's wage income at time t in the natural natural logarithm is given by $\log(w_t) + \log(\bar{e}_j) + \log(\hat{e}_i) + \log(\psi)$. The age dependent efficiency index, $\bar{e}_j$ is set as follows: Robinson (2003) estimates age-earnings profiles for different educational levels by using various specifications. We take her estimates of weekly earnings for different levels of experience, normalize the data by setting the value of weekly earnings for a man with one year' experience to 1 and interpolate the normalized data by using the spline method for missing values.[8] There are two ability types: $\hat{e}_1 = e^{-\sigma_{\hat{e}}}$ and $\hat{e}_2 = e^{\sigma_{\hat{e}}}$, where $E(\log(\hat{e}_i)) = 0$, $\text{var}(\log(\hat{e}_i)) = \sigma_{\hat{e}}^2$, and population mass, $p_i = 1/2$. The stochastic component of idiosyncratic part of wages follows $AR(1)$ process, $\log(\psi') = \rho \log(\psi) + \epsilon$, where $\epsilon \sim N(0, \sigma_\psi^2)$. $AR(1)$ process is approximated by using a finite-state first order Markov process with seven states. Blundell & Etheridge (2008) calculate the variance of permanent and temporary shocks to earnings in the UK as approximately 0.08 and 0.05 in 2003. Hence, we set $\sigma_{\hat{e}}^2 = 0.08$ and $\sigma_\psi^2 = 0.05$. Following Sefton *et al.* (2008), we set the persistence parameter, $\rho = 0.990$.

Preferences Individuals have time-separable preferences over consumption and leisure. In our main exercises we use the following standard Cobb-Douglas specification:

$$u(c, 1 - l) = \frac{(c^\upsilon(1 - l)^{1-\upsilon})^{1-\sigma}}{1 - \sigma}. \tag{13}$$

The value of parameter υ determines the importance of consumption relative to leisure and the value of parameter σ determines the level of risk aversion. Intertemporal elasticity of substitution in consumption (IES) is equal to $\frac{1}{1+\sigma\upsilon-\upsilon}$. We set $\sigma = 4$ and pin down $\upsilon = 0.377$ by setting IES=0.5, which is commonly accepted value for IES in the literature. By setting $\upsilon = 0.377$ we make sure that average hours worked is $1/3$ of the disposable time endowment.[9] We set time-discount factor $\beta = 0.97$ to generate the UK's capital-output ratio of 2.26.[10]

We conduct sensitivity analysis by using a separable utility function in the following form that generates a lower labor supply elasticity:

$$u(c, 1 - l) = \frac{c^{1-\sigma_1}}{1 - \sigma_1} + \kappa \frac{(1 - l)^{1-\sigma_2}}{1 - \sigma_2}. \tag{14}$$

In this case IES in consumption is equal to $\frac{1}{\sigma_1}$. We set $\sigma_1 = 2$ in order to make IES= 0.5 as in above. We set $\sigma_2 = 3$ to generate a value for the Frisch Elasticity that is in the range of various estimates.[11] Following Heathcote *et al.* (2008), without loss of generality, we set the

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[8] Robinson (2003) estimates weekly earnings for both men and women according to whether they have attained a low, medium, or high educational level. She uses quadratic, cubic, and quartic specifications. We use the values of her estimates for men in the group with the least amount of education which is calculated using a quadratic specification.

[9] The Frisch Elasticity=$\frac{1-l}{l}[\frac{1-\gamma(1-\sigma)}{\sigma}]$, which is equal to 1 under our parameter value choices.

[10] Weale (2004) states that the UK's capital-output ratio in 2002 is 2.26.

[11] The Frisch Elasticity=$\frac{1-l}{l}\frac{1}{\sigma_2} = 2/3$ under our parameter value choices. There is no consensus on the values of the Frisch elasticities of labor supply and leisure. Domeij & Flodén (2006) estimate the value of the Frisch elasticity of labor supply to be between 0.1 and 0.3. However, they show that these values are downward-biased and claim that unbiased estimates are larger.

value of κ to 1. We set $\beta = 0.97$ to generate the UK's capital-output ratio of 2.26 in this case as well.

Technology Batini *et al.* (2000) report the values of labor's share of income $(1 - \alpha)$ in the UK between 1970 and 1995. The values fluctuate between 68% and 74% and their average is approximately 70%. Hence, we set the value of labor income share to 0.70. Weale (2004) estimates the capital depreciation rate in the UK in 2002 to be 4.82%. We use the same value for δ. The technology level, A can be chosen freely and we set it to 1.

Government Policy We set the maximum value of means-tested pension income, b^* to its actual yearly value for single individuals in 2003 ($b^* = £5309$). This benefit is reduced by taper (phase-out) rate applied to any private income including state second pension benefits. We set the value of taper rate, ϕ to 100%, 40%, and 0% respectively in our analysis. We set government expenditure G to 22% GDP.

We estimate the parameters of the Gouveia and Strauss tax function by using the UK data as $(\kappa_0, \kappa_1, \kappa_2) = (.521, .701, .317)$. In our baseline calibrations, we set the income tax function's parameters' κ_0 and κ_1 equal to our estimated values and κ_2 is determined endogenously. In our search for optimal tax system we set the values of the labor income tax function's parameters κ_1 and κ_2 equal to those of the baseline's income tax function (i.e. we keep the level of progressivity constant) and κ_0 is determined endogenously. We set consumption tax rate τ_c to 5%.

5 Results

5.1 Computational Experiment and Welfare Measures

As we explained earlier, in a baseline case, total taxes are given by

$$T(y) = \kappa_0(y - (y^{-\kappa_1} + \kappa_2)^{-1/\kappa_1}),$$

where y stands for total disposable income that is the sum of capital income (y_K) and labor income (y_L). In the baseline case, κ_2 is determined by the budget balance condition. In our experiments, as in Conesa *et al.* (2009) and Nakajima (2010), the government maximizes over two tax functions:

$$
\begin{aligned}
T_K(y_K) &= \tau_K y_K \text{ and} \\
T_L(y_L) &= \kappa_0(y_L - (y_L^{-\kappa_1} + \kappa_2)^{-1/\kappa_1}).
\end{aligned}
$$

In our search for an optimal tax scheme, we use the same functional form for the labor income tax as in the baseline case but restrict capital taxes to be proportional. In contrast to the baseline case, κ_0 is determined by the balanced budget condition while we set the values of

Demographics	
Maximum possible life span J	81 (real age of 100)
Obligatory retirement age j^*	46 (real age of 65)
Growth rate of population n	0.5%
Conditional survival probabilities $\{s_j\}_{j=1}^J$	UK $2002-2004$
Endowments	
Age efficiency profile $\{\bar{e}_j\}_{j=1}^{j^*-1}$	Robinson (2003)
Variance types $\sigma_{\hat{e}}^2$	0.08
Variance shocks σ_ψ^2	0.05
Persistence ρ	0.990
Preferences	
Annual discount factor of utility β	0.97
Risk aversion σ	4
Consumption share υ	0.377
Production	
Capital share of the GDP α	0.30
Annual depreciation of capital stock δ	4.82%
Scale parameter A	1
Government	
BSP value	$2003-2004$ tax year values
Minimum guaranteed pension income b^*	$2003-2004$ tax year value for a single individual
Taper rate ϕ	100%
Consumption tax rate τ_c	5%
Marginal tax rate κ_0	0.521
Progressivity of labor income tax κ_1	0.701
Government expenditures G	22%

Table 1: Parameter Values of The Benchmark Calibration

the progressivity parameters κ_0 and κ_1 equal to their baseline values.[12] It is important to note that the tax reform is revenue neutral i.e. the total tax revenue required to be raised in order to finance government expenditures is the same across optimal and baseline tax cases.

In order to compare welfare across economies with different tax programs, following Conesa *et al.* (2009), we compute the consumption equivalent variation (CEV) which is simply the uniform percentage decrease in consumption required to make an agent indifferent between being born under the optimal tax program (comparison case) relative to being born under the status quo tax system (baseline case). A positive CEV reflects a welfare increase due to the optimal tax program compared to the baseline case.[13] Our CEV measure can be decomposed into two components: one part that captures the changes in CEV due to changes in consumption from c_0 to c_* and the other part captures the changes in leisure from $(1 - l_0)$ to $(1 - l_*)$. Each

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[12] In our model, as in Nakajima (2010), marginal tax rate parameter κ_0 balances the government budget. In contrast, in Conesa *et al.* (2009), a progressivity parameter, κ_2 balances the budget.

[13] In other words, we calculate welfare by using ex-ante expected utility of newborns in stationary equilibrium [denoted by $W(c,l)$] and transform into consumption units. The welfare consequences of switching from a steady-state allocation (c_0, l_0) to (c_*, l_*) is given by $CEV = [\frac{W(c_*, l_*)}{W(c_*, l_*)}]^{1/(1-\gamma)} - 1$.

component then can be divided further to capture changes in average consumption (leisure) and distribution of consumption (leisure). In other words, $CEV \approx CEV_C + CEV_L$, where CEV_C and CEV_L denote the changes in CEV due to consumption and leisure respectively. $CEV_C \approx CEV_{CL} + CEV_{CD}$ and $CEV_L \approx CEV_{LL} + CEV_{LD}$, where CEV_{CL} and CEV_{LL} denote changes in CEV due to changes in the level of consumption and leisure respectively and CEV_{CD} and CEV_{LD} denote changes in CEV due to changes in the distribution of consumption and leisure respectively. It can be shown that $CEV_{CL} = (C_*/C_0) - 1$ and $CEV_{LL} = (L_*/L_0) - 1$, where C and L stand for aggregate amounts of consumption and leisure.[14]

In our benchmark economy, we set the taper rate to 100%, which is the pre-reform rate in 2003 in the UK, and calculate total taxes paid by using the baseline tax function. Then we calculate the optimal tax rates for this economy. To explore the implications of a means-tested pension program with capital income taxation, we vary the taper rate by keeping the baseline tax function constant and calculate the optimal tax rates for those economies as well.

5.2   Benchmark Model

First we describe the features of the benchmark economy and the implications of the optimal tax program in this economy. In the baseline case, income tax system is characterized by (κ_0, κ_1, κ_2)=(0.521, 0.701, 0.819) which reflects the progressive income tax system in the UK. In contrast, the optimal tax system is 33% tax rate on capital income (τ_k) and a labor income tax characterized by (κ_0, κ_1, κ_2)=(0.454, 0.701, 0.819) implying the labor income tax is a flat tax with marginal rate of 45.4% and a deduction of about £17396 relative to the average income of £26970. As in Conesa *et al.* (2009) and Nakajima (2010), the significantly positive tax on capital income maximizes welfare.[15] The intuition behind taxing capital income with a significantly higher rate is similar to those given in Conesa *et al.* (2009) and Nakajima (2010): Individuals' saving decisions are not strongly elastic to the changes in after tax interest rate when a model incorporates the strong life-cycle saving motives. Relative inelasticity of the saving compared to labor supply is the main reason behind the optimality of a higher capital income tax rate. When life-cycle effects are not present, on the other hand, taxing capital income is not optimal.

Table 2 presents equilibrium statistics of the baseline and optimal tax systems and welfare consequences of switching from the baseline tax system to the optimal one. As a consequence of switching from the baseline to the optimal system, all economic aggregates increase significantly. The optimal system's positive effects on saving and labor supply decisions are reflected in higher aggregate output and consumption levels. Interestingly, the effects of the optimal system on aggregate labor supply and capital stock differ from those documented in Conesa *et al.* (2009) and Nakajima (2010). In Conesa *et al.* (2009) the optimal tax system decreases all economic aggregates to a certain degree. In particular, capital stock and labor supply decrease by 6.64%

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[14]Details of welfare compositon are given in Conesa *et al.* (2009).

[15]Conesa *et al.* (2009), in a model calibrated to the US economy, find that the optimal tax system is given by a 36% capital income tax rate and 23% labor income tax rate with a deduction of $7200. In a similar model, Nakajima (2010) finds that the optimal capital income tax rate is 31%.

Economic Aggregates	Status-quo	Optimal tax system	Change in percent
Average hours worked	0.316	0.330	4.28
Labor supply N	12.452	12.957	3.90
Capital stock K	52.928	53.823	1.66
Output Y	19.221	19.863	3.23
Consumption C	12.511	13.207	5.27

Welfare			Change in percent
CEV			1.34
CEV_C			5.59
CEV_{CL}			5.27
CEV_{CD}			0.32
CEV_L			-4.26
CEV_{LL}			-4.28
CEV_{LD}			0.02

Table 2: 100% Taper

and 0.11% respectively. In Nakajima (2010), on the other hand, capital stock increases by 2.3% while labor supply declines by 1.5%.[16]

Total welfare gain is equivalent to 1.34% increase in consumption at all ages and all states of the world. This value is quite close to the one calculated by Conesa *et al.* (2009).[17] Yet, the sources of welfare gain is different. In Conesa *et al.* (2009), the improvement in the life-cycle distribution of the consumption and the increase in the level of the amount of leisure taken are the main driving forces behind the total increase in welfare despite the fact that the level of consumption decreases substantially. In our case, however, the main source behind the welfare improvement is increase in the level of consumption. Improvements in distribution of consumption and leisure play a minor positive role while decrease in the level of leisure creates a substantial negative effect on welfare.

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[16]Note that the baseline tax system in Nakajima (2010) is slightly different from the baseline tax system in Conesa *et al.* (2009) and this paper. In Nakajima (2010), the baseline case tax system consists of 40% proportional tax on capital income and tax on labor income defined by the Gouveia-Strauss tax function.

[17]They find that percentage change in CEV is equal to 1.33%. In contrast, Nakajima (2010) calculates a quite smaller gain, i.e. CEV increases by 0.1% only. This is most likely due to their choice of baseline tax function.
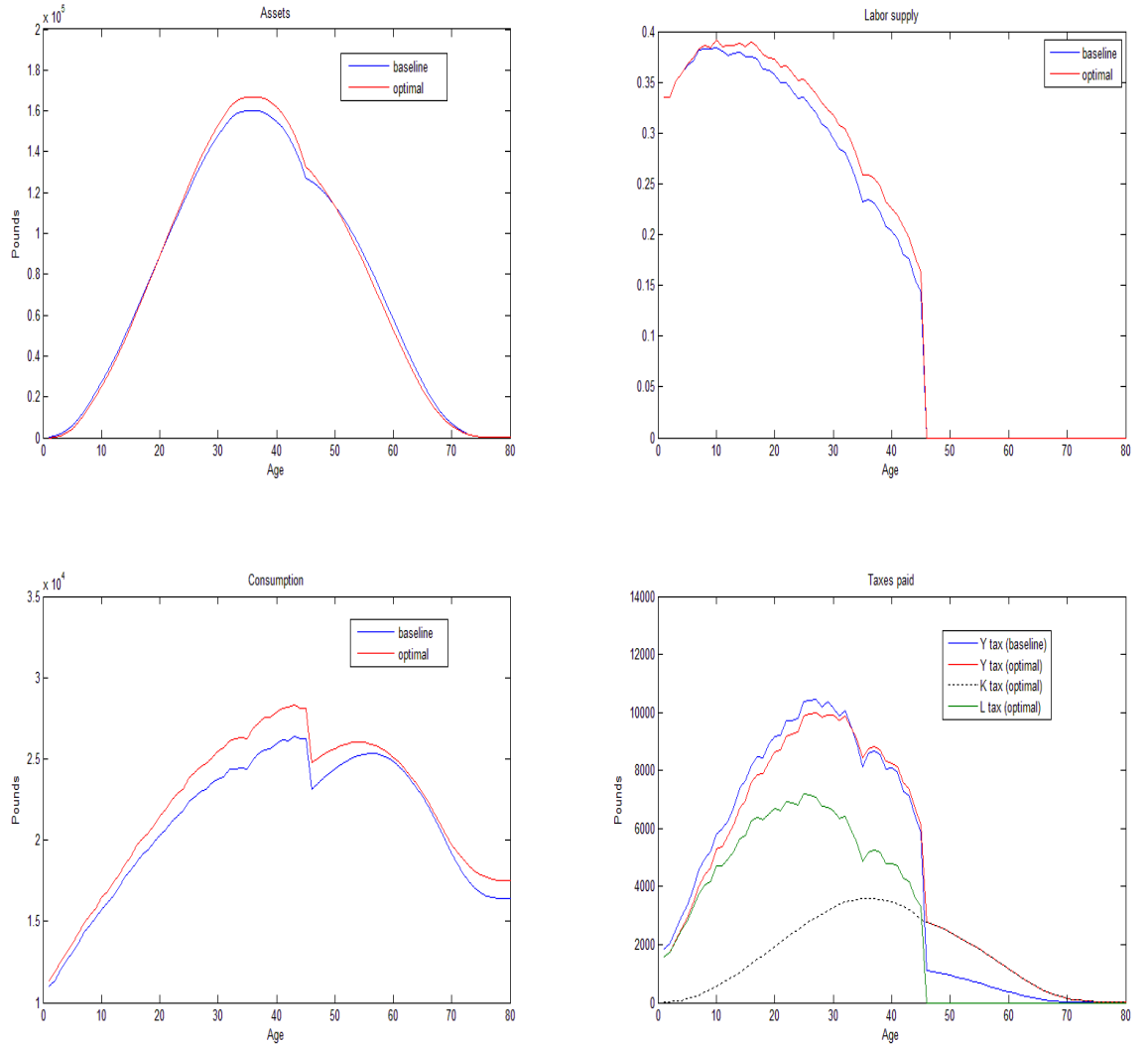
Figure 1. Life-cycle profiles of assets, labor supply, consumption, and taxes

In Figure 1 we document the life-cycle profiles of the average type in the baseline and optimal tax system economies when the taper rate is set at 100%. We delegate the life-cycle profiles of different productivity types to Appendix A. Figure 1(a) shows the average asset holdings (the relevant tax base for the capital income tax) by age. As in earlier studies, life-cycle asset holdings are hump-shaped and individuals between age 40 to 70 bear the main burden of the capital income tax. The positive effect of the optimal tax system on asset holdings is can be easily seen in the figure: In younger ages (approximately from age 20 to age 40) asset holdings are identical in both systems; life-cycle asset holdings in the optimal system exceed that of the base line during middle age (approximately from age 40 to 70); and the life-cycle asset holdings in the baseline system is slightly higher at old ages (approximately from age 70 to 100). This in turn reflects a significantly higher capital stock in the optimal system. While in Conesa

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et al. (2009) life-cycle asset holdings in the optimal system lie below the baseline, in Nakajima (2010) life-cycle asset holdings in baseline and optimal cases follow a similar path to those of the benchmark case. The optimal system in our model mitigates some of the burden from the shoulders of the middle aged individuals and hence, this group's asset holdings increase. Figure 1(b) demonstrates the average life-cycle pattern of hours worked. Labor supply increases in early 20s up to early 30s and declines after that until retirement age independently from the tax regime. Individuals prefer to postpone leisure to old age as a consequence of a higher time discount rate and positive after tax return on asset holdings. As is clear from the figure, the optimal tax system results in a higher labor supply in almost all ages. This result is in contrast with that of Conesa *et al.* (2009) in which the optimal system induces individuals to work more at more productive ages. In Figure 1(c) we document the empirically plausible hump-shaped life-cycle consumption profiles for both tax systems. It also documents a discrete fall in the retirement as a result of non-seperability of consumption and leisure. As is clear from the figure, the optimal tax system increases the level of consumption at all ages without changing the pattern much. In contrast, in Conesa *et al.* (2009), the optimal tax system smooths the distribution but decreases the level especially after retirement. Finally, Figure 1(d) documents the life-cycle profiles of taxes paid. Note that in the optimal system, we are able to seperate the amount of taxes paid from capital and labor incomes. In the baseline case, until retirement, individuals pay more taxes. After retirement, the amount of taxes paid at each age is lower than that of the optimal tax system, which prescribes a hevaier tax on capital income.

5.3 Effects of Resources Testing

We now turn to explore the interaction between resource testing of retirement income and the capital income tax. Our computational strategy is the same as above except we set the taper rate to the post-reform rate of 40% now. In the baseline case the income tax system is characterized by $(\kappa_0, \kappa_1, \kappa_2)=(0.521, 0.701, 0.905)$. In the baseline economies κ_2 is determined endogenously. As a natural consequence of this, κ_2 across two baseline economies slightly differ. Yet, this small difference affects the progressivity of the tax system minimally. The optimal tax system in this case is 34% tax rate on capital income (τ_k) and a labor income tax characterized by $(\kappa_0, \kappa_1, \kappa_2)=(0.457, 0.701, 0.905)$ implying the labor income tax is a flat tax with marginal rate of 45.7% and a deduction of about £17396 relative to the average income of £26970.

A quick comparison of optimal tax systems reveals that when the taper rate is low, slightly higher capital income tax rate maximizes welfare. Lower taper rate causes an increase in the government's revenue requirement. This additional increase on revenue can be either financed by an increase on the labor income or the capital income tax rates. Our result shows that the additional revenue requirement is financed by an increase in both labor and capital income tax rates. One can interpret resource-testing of retirement income as a form of non-linear capital income tax since it reduces the effective return of private retirement savings for people who are eligible for benefits relative to those who are not (Sefton & van de Ven (2009)). When the taper rate is decreased the effective tax on capital income decreases. This in turn implies a slightly

Variable	Status-quo	Optimal tax system	Change in percent
Average hours worked	0.314	0.329	4.67
Labor supply N	12.536	12.895	4.18
Capital stock K	51.129	52.298	2.23
Output Y	18.919	19.627	3.60
Consumption C	12.216	12.922	5.46
Welfare			Change in percent
CEV			1.51
CEV_C			5.73
CEV_{CL}			5.46
CEV_{CD}			0.27
CEV_L			-4.22
CEV_{LL}			-4.67
CEV_{LD}			0.45

Table 3: 40% Taper

higher optimal capital income tax rate in addition to an increase in the revenue requirement.

As in above, Table 3 presents equilibrium statistics of the baseline and optimal tax systems and welfare consequences of switching from the baseline tax system to the optimal one. Similar to the benchmark case all economic aggregates grow. Yet, the growth rates of economic aggregates are larger. This implies that when taper rate is low switching from the baseline tax system to the optimal tax system creates a larger improvements in economic aggregates. We see a similar trend in the welfare measure as well. In an economy with a lower taper rate, the optimal tax system increases welfare relatively more. The intuition is simple. When the taper rate is high, the effective tax on capital income is relatively closer to the its optimal value but when the taper rate is low the effective tax on capital income is relatively far away from the optimal value. Hence, the optimal tax system prescribes a higher capital income tax rate and improves welfare even more when the taper rate is relatively low.
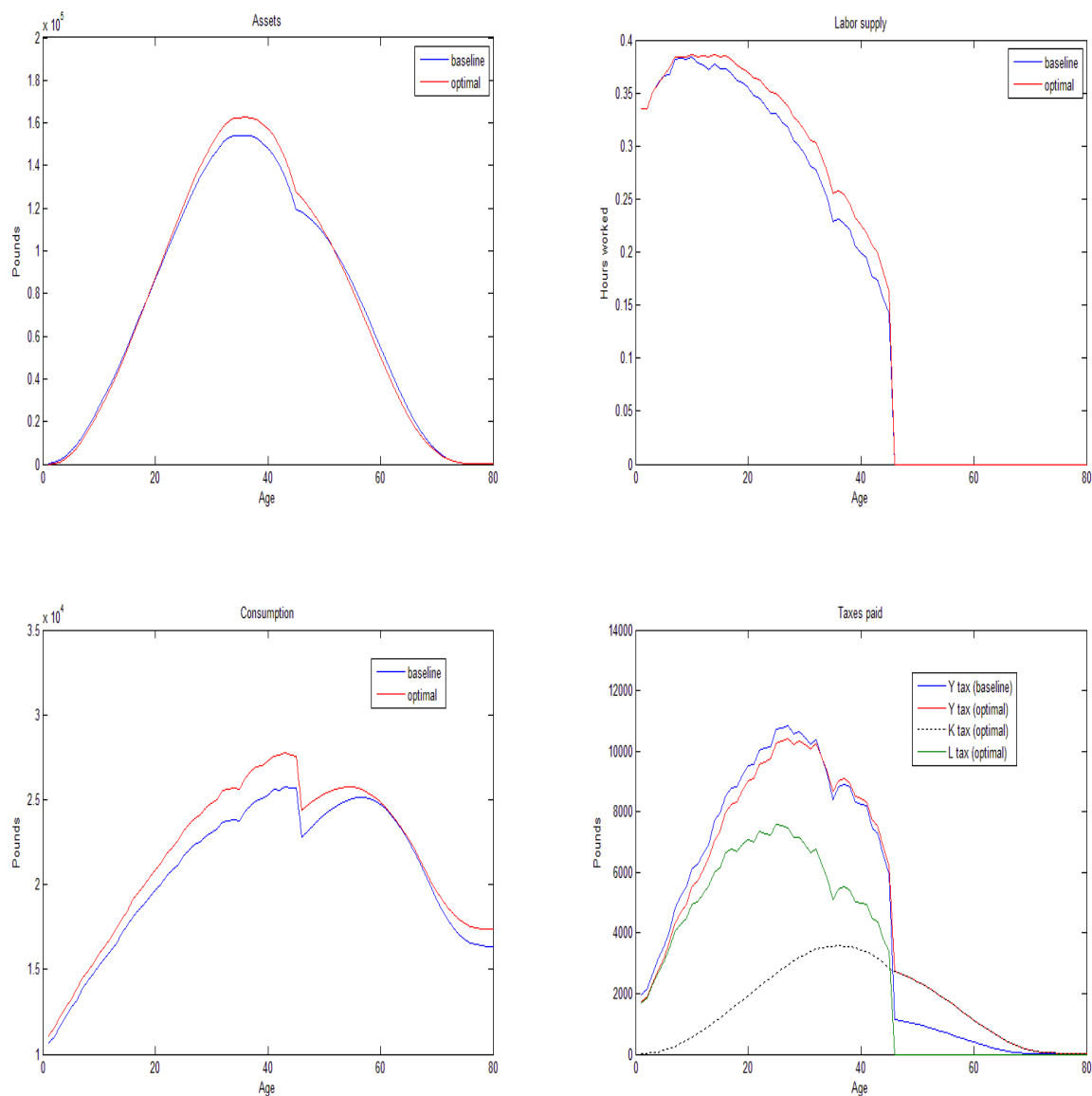
Figure 2. Life-cycle profiles of assets, labor supply, consumption, and taxes

Figure 2 documents the life-cycle profiles of the average type in the baseline and optimal tax system economies when taper rate is 40%. We delegate the life-cycle profiles of different productivity types to Appendix A. A comparison of Figure 1 and Figure 2 reveals that although the optimal tax system in both cases create similar distributional effects on the life-cycle profiles, the level effect is larger when taper rate is 40%. This is also reflected in higher percentage changes in economic aggregates when taper rate is 40%.

Now we go further and reduce the taper to 0%. We can call the pension program in this case as an universal pension program since all individuals receive the benefits without any reduction.

In the baseline case the income tax system is characterized by $(\kappa_0, \kappa_1, \kappa_2)$=(0.521, 0.701, 1.427). The optimal tax system in this case is 37% tax rate on capital income (τ_k) and a labor income tax characterized by $(\kappa_0, \kappa_1, \kappa_2)$=(0.465, 0.701, 1.427) implying the labor income tax is a flat tax with marginal rate of 46.5% and a deduction of about £17396 relative to the average income of £26970. Our aforementioned claims regarding with the relationship between means-testing and optimal capital income tax rate is further strengthened here: When the taper rate is low, the optimal capital income tax rate is relatively higher. Taper rate of 0% means a form of non-linear tax on capital income in old ages is absent. Hence, the capital income tax is needed to be higher in order to make the effective tax on capital income reaches its optimal value in addition to the higher revenue financing requirements.

Variable	Status-quo	Optimal tax system	Change in percent
Average hours worked	0.307	0.324	5.34
Labor supply N	12.109	12.705	4.69
Capital stock K	43.933	46.909	6.24
Output Y	17.825	18.800	5.19
Consumption C	10.974	11.842	7.33
Welfare			Change in percent
CEV			3.47
CEV_C			7.93
CEV_{CL}			7.33
CEV_{CD}			0.60
CEV_L			−4.46
CEV_{LL}			−5.34
CEV_{LD}			0.88

Table 4: 0% Taper

Table 4 presents equilibrium statistics of the baseline and optimal tax systems and welfare consequences of switching from the baseline tax system to the optimal one. Similar to the earlier cases all economic aggregates grow. Yet, the rates of growth of economic aggregates are significantly larger. This implies that when taper rate is 0% switching from the baseline tax system to the optimal tax system is creates substantial improvements in economic aggregates. We see a similar trend in the welfare measure as well. Welfare improvement is stunningly higher than the previous cases. This has important policy implications: In the existence of the universal pension program, reforming the tax system can improve the welfare significantly. We delegate the figures of life-cycle profiles for this case to Appendix A (see Figure A1). In terms of the distribution, the life-cycle profiles do not differ form those of the previous profiles yet it is apparent that the level effects are much larger in this case. This significant level effect is also reflected in CEV_{CL} measure which is significantly higher than the previous ones.
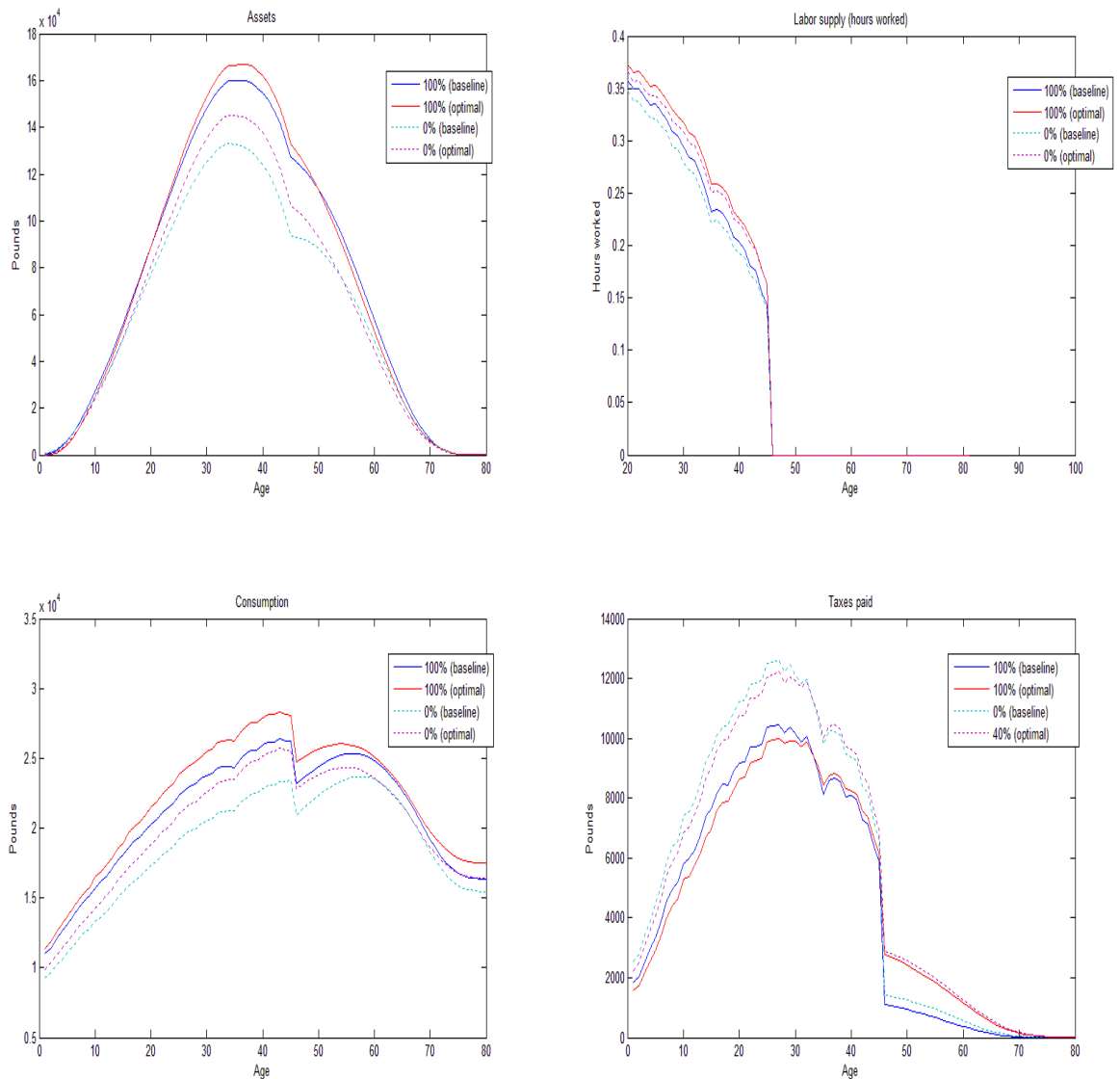
Figure 3. Comparison

In order to make a comparison across economies with different taper rates we created Figure 3 in which we combined the life-cycle profiles of the cases when the taper is 100% and 0% respectively. This figure reveals the quasi complementarity between the optimal tax system and the resource testing program. More precisely, the asset distribution in the economy with 0% taper rate and baseline tax system can be improved either switching from the baseline tax system to the optimal one keeping the taper rate intact or be improved by switching from 0% taper rate to 100% taper rate keeping the baseline tax system intact. All the level of improvements differ across these two policies, the complementarity across them enhances the government's choice set.

Variable	Status-quo	Optimal tax system	Change in percent
Average hours worked	0.323	0.337	4.03
Labor supply N	12.969	13.219	3.95
Capital stock K	55.878	57.384	2.62
Output Y	19.804	20.534	3.56
Consumption C	13.074	13.888	5.87

Welfare			Change in pecent
CEV			1.67
CEV_C			6.13
CEV_{CL}			5.87
CEV_{CD}			0.26
CEV_L			-4.46
CEV_{LL}			-4.03
CEV_{LD}			-0.43

Table 5: No Means-test

Finally, we analyze the economy with no resource tested pension program. In the baseline case the income tax system is characterized by $(\kappa_0, \kappa_1, \kappa_2)=(0.521, 0.701, 0.691)$. The optimal tax system in this case is 31% tax rate on capital income (τ_k) and a labor income tax characterized by $(\kappa_0, \kappa_1, \kappa_2)=(0.437, 0.701, 0.691)$ implying the labor income tax is a flat tax with marginal rate of 43.7% and a deduction of about £17396 relative to the average income of £26970. Notice that when there is no means-tested pension program, the government's revenue requirement is relatively lower. This in turn implies lower optimal tax rates on labor and capital incomes. Interesting point is that, although higher taper rates implicate higher effective tax rate on capital income, higher revenue requirement due to the existence of means-tested pension program dominates and cause a relatively higher capital income tax rate. The implications of the optimal system on economic aggregates and welfare is quite similar to that of the benchmark case. Welfare improvement as a result of switching from the baseline to the optimal system is larger than that of the benchmark (100% taper rate) and the post-refrom cases (40% taper rate). This result is interesting in a sense that it highlights the complementarity between optimal income tax rate and taper rate once again. From the distributional point of view, the life-cycle profiles are similar to the previous ones (see Figure A2).

In a different model setting, Sefton & van de Ven (2009) analyze the implications of the various tax reforms with the means-testing without searching for the optimal tax system. Our paper differs from that of Sefton & van de Ven (2009) not only form the modelling perspective as explained earlier, it also differ in terms of searching for a optimal tax system a lá Conesa *et al.* (2009) and establishing a degree of the complementarity between the capital income tax and means-testing.

6   Conclusion

In this paper we study the interaction between capital income taxation and resource tested retirement transfer in the context of an overlapping generations model, calibrated to the UK economy. Recent literature has suggested a rehabilitation of capital income taxation (Conesa *et al.* (2009)), predicated on the idea that capital is a complement with retirement leisure. This leads naturally to the conjecture that a publicly funded age pension contingent upon holdings of capital or capital income may have a similar effect. We formalize this using a stochastic OLG model with multiple individuals differentiated by labour productivity and pension entitlement.

Our results confirm recent analyses suggesting that a significantly positive capital income tax rate may be optimal (Conesa *et al.* (2009)). But our extended model reverses the dynamics of this result reported in earlier studies. In our model, the source of welfare improvement largely depends upon increased aggregate consumption, in contrast to improvement in the inter-temporal spread of consumption highlighted in earlier work.

The policy value of our work lies in including an additional policy instrument in the model – the retirement transfer withdrawal rate. We find that higher taper rates are associated with lower optimal capital income tax rates. The lower the taper rate, the higher the welfare improvement relative to the baseline case. We infer that welfare improvements in our economy may also result from the age-targeting of retirement capital income. In specifications with low taper rate, much greater reliance is placed upon capital income taxes to generate welfare improvements.

This model assumes a closed economy, and steady population growth on which population structure does not change. It does not accommodate sub-household agents – implicitly, all tax and withdrawal rates are assumed to be household rates. We plan to relax these simplifying assumptions in further work.
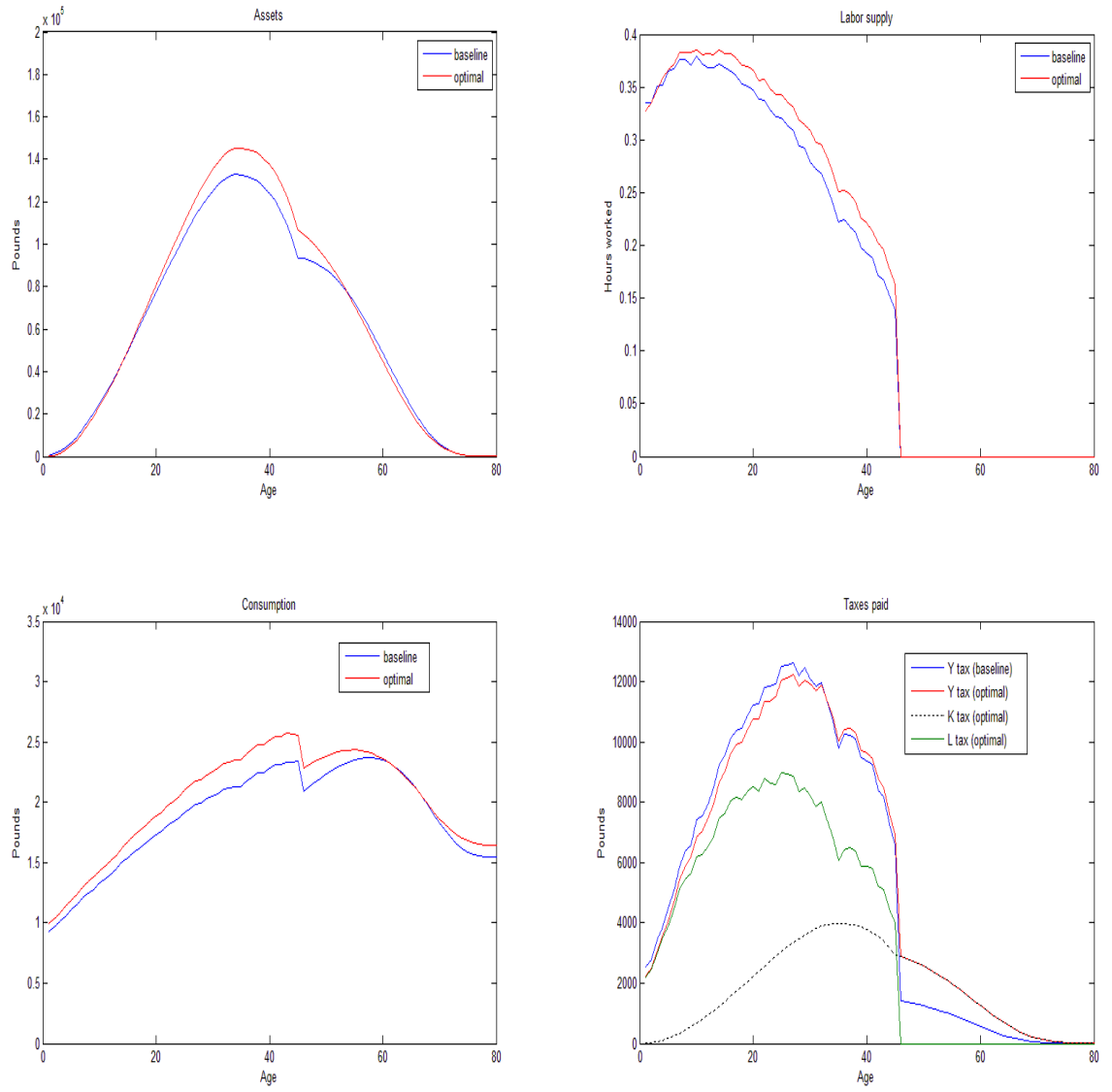
7 Appendix

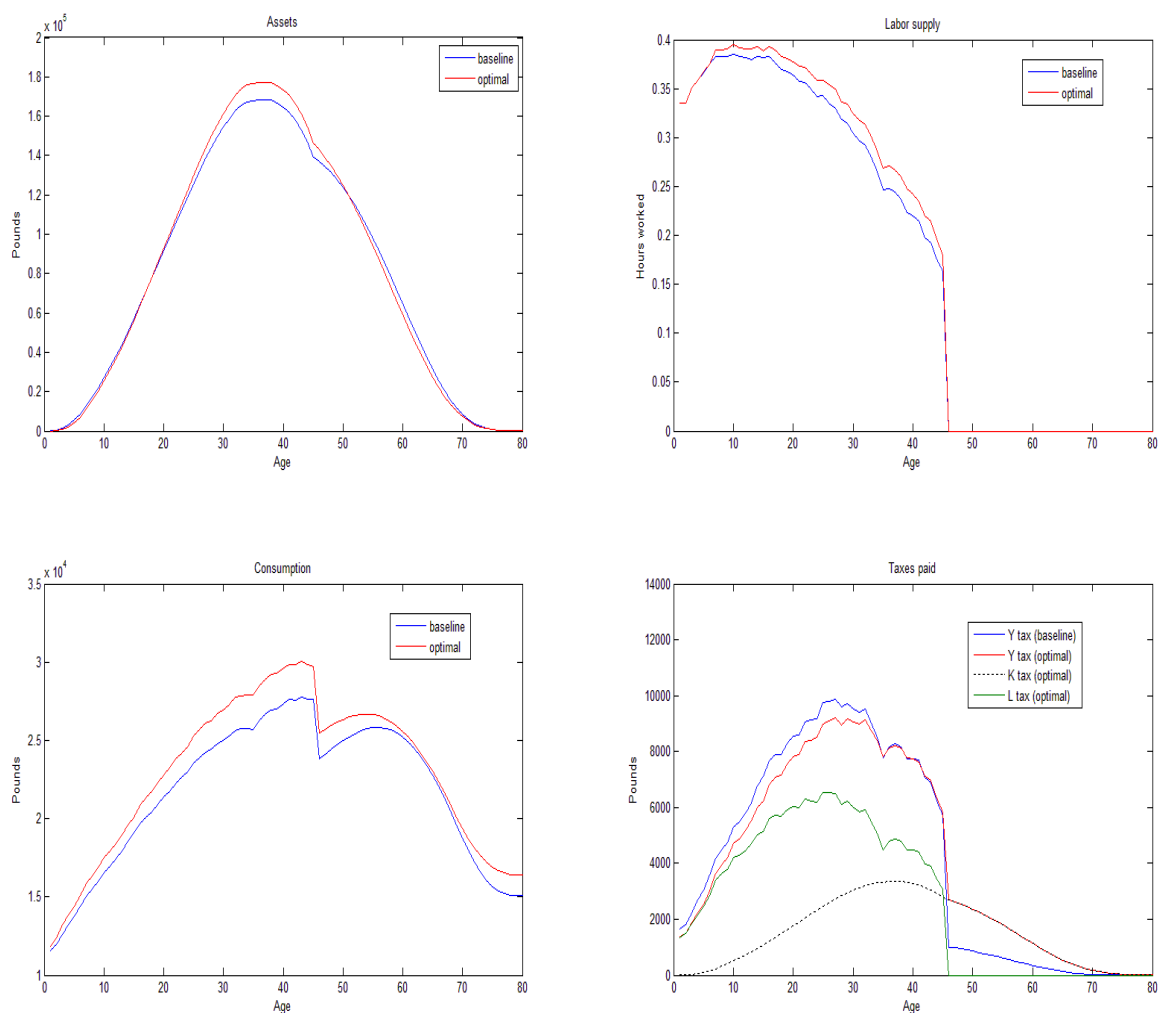Figure A1. Life-cycle profiles of assets, labor supply, consumption, and taxes

Figure A2. Life-cycle profiles of assets, labor supply, consumption, and taxes

References

Aiyagari, S. Rao. 1995. Optimal Capital Income Taxation with Incomplete Markets, Borrowing Constraints, and Constant Discounting. *Journal of Poliitcal Economy*, **103**, 1158–1175.

Alvarez, Y., J. Burbidge, T. Farrell, & Palmer, L. 1992. Optimal taxation in a life-cycle model. *Canadian Journal of Economics*, **25**, 111–22.

Auerbach, A. J., & Kotlikoff, L. J. 1987. *Dynamic Fiscal Policy.* New York, NY, USA: Cambridge University Press.

Batini, N., Jackson, B., & Nickell, S. 2000. Inflation Dynamics and the Labour Share in the UK. *Bank of England Discussion Paper.*

Blundell, R., & Etheridge, B. 2008. Consumption, Income and Earnings Inequality in the UK. *Working Paper.*

Castaneda, Ana, Diaz-Gimenez, Javier, & Rios-Rull, Jose-Victor. 1999. Earnings and Wealth Inequality and Income Taxation: Quantifying the Trade-offs of Switching to a Proportional Income Tax in the US.

Chamley, C. 1986. Optimal taxation of capital income in general equilibrium with infinite lives. *Econometrica*, **54**, 607–622.

Conesa, J. C., Kitao, S., & Krueger, D. 2009. Taxing capital? Not a bad idea after all! *American Economic Review*, **99**, 25–48.

Conesa, Juan Carlos, & Kruger, Dirk. 2006. On the Optimal Progressivity of the Income Tax Code. *Journal of Monetary Economics*, **53**, 1425–1450.

Domeij, D., & Flodén, M. 2006. The labor-supply elasticity and borrowing constraints: Why estimates are biased. *Review of Economic Dynamics*, **9**, 242–262.

Erosa, A., & Gervais, M. 2002. Optimal taxation in life-cycle economies. *Journal of Economic Theory*, **105**, 338–369.

Fukushima, Kenichi. 2010. Quantifying the Welfare Gains From Flexible Dynamic Income Tax Systems. *Working paper.*

Fuster, L., Imrohoroglu, A., & Imrohoroglu, S. 2007. Altrusim, Incomplete Markets and Tax Reform. *Working Paper.*

Garriga, C. 2003. Optimal Fiscal Policy in Overlapping Generations Models. *Working Paper.*

Golosov, Mikhail, & Tsyvinski, Aleh. 2006. Designing Optimal Disability Insurance: A Case for Asset Testing. *Journal of Political Economy*, **114**, 257–279.

Gouveia, M., & Strauss, R. 1994. Effective Federal Individual Income Tax Functions: An Exploratory Empirical Analysis. *National Tax Journal*, **47**, 317–339.

Heathcote, J., Storesletten, K., & Violante, G. L. 2008. Insurance and opportunities: A welfare analysis of labor market risk. *Journal of Monetary Economics*, **55**, 501–525.

Hubbard, R. Glenn, & Judd, K. L. 1986. Liquidity constraints, fiscal policy, and consumption. *Brookings Papers on Economic Activity*, **1**, 1–50.

Imrohoroglu, S. 1998. A quantitative analysis of capital income taxation. *International Economic Review*, **39**, 307–28.

Judd, K. 1985. Redistributive Taxation in a Simple Perfect Foresight Model. *Journal of Public Economics*, **28**, 59–83.

Kitao, Sagiri. 2010. Labor-dependent Capital Income Taxation. *Journal of Monetary Economics*, **57**, 959–974.

Kitao, Sagiri. 2012. Sustainable Social Security: Four Options. *Working Paper*.

Kuklik, Michael. 2011. Optima Taxation and Labor Supply. *Working paper*.

Kumru, Cagri S, & Piggott, John. 2009. Should Public Retirement Provision Be Means-tested? *Australian School of Business Research Paper No. 2009 AIPAR 01*.

Nakajima, Makoto. 2010. Optimal Capital Income Taxation with Housing. *Working Paper*.

National Statistics. 2009a. *Population Change: UK population increases by 388000.* <http://www.statistics.gov.uk/CCI/nugget.asp?ID=950&Pos=5&ColRank=2&Rank=1000>.

National Statistics. 2009b. *United Kingdom Interim Life Tables 1980-82 to 2005-07.* <http://www.statistics.gov.uk/StatBase/Product.asp?vlnk=14459&Pos=&ColRank=1&Rank=422>.

Rios-Rull, Jose-Victor. 1999. Computation of Equilibria in Heterogenous-agent Models. *Chap. 11 of:* Marimon, R, & Scott, A. (eds), *Computational Methods for the Study of Economic Dynamics*. Oxford: Oxfor University Press.

Robinson, H. 2003. Are you experienced? British evidence on age-earnings profiles. *Applied Economics*, **35**, 1101–1115.

Sefton, J., van de Ven, J., & Weale, M. 2008. Means testing retirement benefits: Fostering Equity or Discouraging Savings? *Economic Journal*, **118**, 556–590.

Sefton, James, & van de Ven, Justin. 2009. Optimal Design of Means Tested Retirement Benefits. *Economic Journal*, **119**, 461–481.

Ventura, G. 1999. Flat tax reform: A quantitative exploration. *Journal of Economic Dynamics and Control*, **23**, 1425–1458.

Weale, M. 2004. *UK Productivity: its failings and outlook*. Presented by Martin Weale, CBE, Director, NIESR at the Society of Business Economists Annual Conference.