Optimal Capital Income Taxation with Means-tested Benefits *
"PRELIMINARY AND INCOMPLETE"

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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 personal income taxation in a life-cycle context.

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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%.[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 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.

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

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

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-time and liquidity constraint. 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.

Our preliminary findings suggest that a means tested pension program has effects similar to personal income taxation in a life-cycle context.

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) seeks for an answer to 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 (1985)'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 the redistribution considerations. Second, in the long run, all agents prefer the 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 be zero in the long-run. In other words, their results state 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 above zero capital income taxation result might not hold if there is a market incompleteness and/or the life-cycle framework is used. Alvarez *et al.* (1992), Erosa & Gervais (2002), and Garriga (2003) show that it might be optimal to tax capital when the life-cycle framework is used. 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, 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 incorporates life-cycle framework and 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, the gain realizes 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 the life-cycle economies in which individuals have preferences over consumption and leisure, have permanent ability differences, and face idiosyncratic shocks to labor productiveness in order to analyze the implications of a revenue neutral tax reform in which labor and capital income taxes are replaced by a flat tax and shows that elimination of capital tax in this environment creates a positive effect on the 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%.

Recently, Nakajima (2008) and Conesa (2010) extend Conesa *et al.* (2009)' study by incorporating housing asset and making capital income tax labor dependent respectively. In particular, Nakajima (2008) compares whether and how the optimal capital tax rate differs between the model with housing and without housing. He showed that the optimal capital tax rate in the model with housing is 1%, which is significantly lower than the optimal capital tax rate calculated by Conesa *et al.* (2009).

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

3 The Model Economy

We use a general equilibrium OLG model economy with uninsured idiosyncratic shocks to labor productivity and mortality. Main features of our model follow those of Conesa *et al.* (2009), Conesa(2010), and Nakajima (2008). 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 $\overline{\psi} = \sum\limits_{\psi} \psi \Pi(\psi)$,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:

$$Y_t = A_t K_t^{\alpha} L_t^{1-\alpha}. \tag{2}$$

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:

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

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

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

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

where C_t is aggregate private consumption and G_t is aggregate public consumption.

3.5 The Public Sector

The government runs a public pension system that consists of universal flat rate and means-tested pension programs. Since individuals face stochastic life-span and private annuity markets are closed by assumption, a fraction of 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 pension program expenditures, the government levies taxes on capital income, labor income, and consumption.

The pension program of our model reflects the basic features of that of the UK.[3] Individuals

[3] The UK pension program consists of an almost universal flat rate Basic State Pension (BSP) and compulsory earnings-related scheme. (Individuals must enroll to either the earnings-related PAYG financed public pension

who reach retirement age receive a flat rate universal basic pension $b(x)$ and might be entitled to additional pension benefits depending on their private income.[4] Means-tested benefits are determined as follows:

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

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.

Following Conesa *et al.* (2009) and Nakajima (2008) we use the functional form introduced by Gouveia and Strauss (1994) to capture the progressiveness of the labor income tax rate:[5]

$$T(y) = \kappa_0(y - (y^{-\kappa_1} + \kappa_2)^{-1/\kappa_1}), \tag{7}$$

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. We assume that the capital income tax rate is proportional and denoted by τ_k. In this study our aim to determine the optimal level of τ_k as in Conesa *et al.* (2009) and Nakajima (2008). 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:

$$y_t = \left\{ \begin{array}{c} r_t(a_t + \eta_t) + y_t^l \text{ if } j < j^*, \\ r_t(a_t + \eta_t) + b_t(x) \text{ if } j \geq j^*, \end{array} \right\} \tag{8}$$

where $y_t^l = w_t \bar{e}_j \hat{e}_i \psi l_j$ is an individual's labor income.

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

$$\left\{ \begin{array}{c} (1 + \tau_{c,t})c + a' \leq (1 + r_t(1 - \tau_{k,t}))(a + \eta_t) + (1 - \tau_l)y_t^l \text{ when } j < j^* \\ (1 + \tau_{c,t})c + a' \leq (1 + r_t(1 - \tau_{k,t}))(a + \eta_t) + b_t(x) + b_t^*(x) \text{ when } j \geq j^* \\ (1 + \tau_{c,t})c = (1 + r_t(1 - \tau_{k,t}))(a + \eta_t) + b_t(x) + b_t^*(x) \text{ when } j = J, \end{array} \right\} \tag{9}$$

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. Pension program in our model assume away the earnings-related component.

[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 employd in the quantitative public finance literature. See for example, Castaneda et al. (1999), Rios Rull (1999), and Conesa nad Kruger (2006).

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:

$$a' \geq 0. \tag{10}$$

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:

$$V_t(x) = \max_{c,l}\{u(c, 1-l) + \beta s_j \int V_{t+1}(x')Q(\eta, d\eta')\} \tag{11}$$

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 (2008).

Definition 1 *Given sequences of government expenditures* $\{G_t\}_{t=1}^{\infty}$*, consumption tax rates* $\{t_c\}_{t=1}^{\infty}$*, basic state pension amount* $\{b_t\}_{t=1}^{\infty}$*, minimum pension income guaranteed through means-tested program* $\{b_t^*\}_{t=1}^{\infty}$*, and 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,*

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

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

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

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)].[6] 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.

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.[7] There are two ability types: $\hat{e}_1 = e^{-\sigma_{\hat{e}}}$ and $\hat{e}_2 = e^{\sigma_{\hat{e}}}$, where $E(\log(\hat{e}_i)) = 0$, $\text{var}(\log(\hat{e}_i)) = \sigma^2_{\hat{e}}$, 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 $\epsilon \sim N(0, \sigma^2_{\psi})$. 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

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

[7] 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.

UK as approximately 0.08 and 0.05 in 2003. Hence, we set $\sigma^2_{\hat{e}}$=0.08 and $\sigma^2_{\psi} = 0.05$. 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 benchmark case we use the following standard Cobb-Douglas specification:

$$u(c, 1-l) = \frac{(c^{\upsilon}(1-l)^{1-\upsilon})^{1-\sigma}}{1-\sigma}. \tag{12}$$

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.[8] We set time-discount factor $\beta = 0.97$ to generate the UK's capital-output ratio of 2.26.[9]

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

$$u(c, 1-l) = \frac{c^{1-\sigma_1}}{1-\sigma_1} + \kappa\frac{(1-l)^{1-\sigma_2}}{1-\sigma_2}. \tag{13}$$

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.[10] Following Heathcote *et al.* (2008), without loss of generality, we set the 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 BSP benefits. We assume that all individuals receive the BSP benefits (need to specify amount here). We set the value of taper rate, ϕ to 0%, 50%, and 100% respectively in our analysis. We set government expenditure G to 22% GDP.

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

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

[10] 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.

In our benchmark calibration, we set the labor income tax function's parameter (κ_0 and κ_1) equal to values estimated by Gouveia and Strauss (1994).[11] We set consumption tax rate τ_c to 0.05.

Demographics	
Maximum possible life span J	65
Obligatory retirement age j^*	45
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 $\sigma^2_{\hat{e}}$	0.08
Variance shocks σ^2_{ψ}	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	0.258
Progressivity of labor income tax κ_1	0.768
Government expenditures G	22%

Table 1: Parameter Values of The Benchmark Calibration

5 Results

5.0.1 Part A. Economy with PAYG Social Security

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 system (benchmark case). A positive CEV reflects a welfare increase due to the

[11] Conesa *et al.* (2009) use the same values in their analysis .

optimal tax program compared to the benchmark case. [12]

First we describe the optimal income tax rates when there is no means-tested pension program in the economy. This model corresponds to the model analyzed in Conesa *et al.* (2009). We calibrate a similar model to the UK data. The optimal tax system consists of 30% tax on capital income and 23% tax on labor income.[13] Table 2 presents equilibrium statistics of the status quo and optimal tax systems. In the optimal tax system, all aggregate variables decrease: the capital stock and the amount of labor supply decrease by 6.3% and 0.67% respectively. Output and consumption follows these two variables and decrease by 2.7% and 1.6% respectively. This is the natural consequence of taxing the capital income quite heavily. Note that in the status quo economy, the highest marginal tax rate is 25.8%.

Variable	Status-quo	Optimal tax system	Change in percent
Total labor supply N	22.867	22.715	−0.666
Capital stock K	124.653	116.817	−6.287
Output Y	42.106	40.958	−2.727
Aggregate consumption C	26.903	26.480	−1.573
CEV			1.06

Table 2: No Targeted Pension Program

As in Conesa *et al.* (2009), the welfare gain in the optimal system is due to a better consumption smoothing across types and states and increase in the leisure time.

Variable	Status-quo	Optimal tax system	Change in percent
Total labor supply N	22.455	22.482	0.123
Capital stock K	107.624	98.497	−8.480
Output Y	39.475	38.266	−3.064
Aggregate consumption C	24.004	23.593	−1.172
CEV			2.72

Table 3: Means-tested Pension Program I

In Table 3, we analyze an economy in which there is a means-tested pension program with 0% taper rate. In this economy, the optimal capital tax rate is 40%. The means-tested pension program benefits are paid from the general budget and the optimal labor income tax rate is still 23%. Thus it is not surprising that the optimal capital income tax rate is higher in this economy. As in the economy with no pension program, all aggregate variables except labor supply decrease. In particular, the capital stock decreases by a substantial amount and other aggregate variables output and consumption follow the fall in the capital stock. The labor

[12] In other words, we calculate welfare by using ex-ante expected utility of newborns in stataionary 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 $CEV = [\frac{W(c_*,l_*)}{W(c_*,l_*)}]^{1/(1-\gamma)} - 1$.

[13] Conesa *et al.* (2009), in a model calibrated to to the US ceonomy, 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.

supply slightly increases in the optimal scheme. Thus, in this economy, the welfare gain stems from a better consumption smoothing only.

Variable	Status-quo	Optimal tax system	Change in percent
Total labor supply N	22.449	22.302	-0.656
Capital stock K	116.023	108.322	-6.637
Output Y	40.551	39.394	-2.852
Aggregate consumption C	25.367	24.924	-1.744
CEV			2.1

Table 4: Means-tested Pension Program II

In Table 4, the taper rate is set to 50%. In this economy, 32% capital income tax rate is optimal. As in above, the slightly higher capital tax rate stems from the fact that the pension program is financed through the general budget. In this case, as a result of a lower capital income tax rate, the capital stock decreases by only 6.64%. Output and consumption follow the falls in the labor supply and aggregate capital stock and decrease by 2.9% and 1.74% respectively. The welfare gain stems from a better consumption smoothing and an increase in the labor supply.

Variable	Status-quo	Optimal tax system	Change in percent
Total labor supply N	22.504	22.310	-0.861
Capital stock K	118.345	110.930	-6.265
Output Y	40.905	39.743	-2.841
Aggregate consumption C	-25.775	25.280	-1.921
CEV			1.86

Table 5: Means-tested Pension Program III

Finally, we analyze the economy with a 100% taper rate. In this economy, the optimal capital income tax rate is 30% as in the economy without a pension program. When the taper rate is 100%, the only a small portion (lower income groups) receive pension benefits and the system does not create an additional burden on the budget. Total labor supply and capital stock decrease by 0.87% and 6.27% respectively. Consequently, output and consumption levels decrease by 2.84 and 1.92% respectively. As in the cases above, better consumption smoothing and an increase in leisure are sources of the welfare gain.

5.0.2 Part B. Economy without PAYG Social Security

In this part, there is no earnings-dependent PAYG program. In the status-quo case, we use the tax function introduced by Gouveia and Strauss (1994) as in Conesa *et al.* (2009). The results for the cases when taper rate 50% and 100% respectively are reported in tables below.

In the first (second) table of this section, we report the macroeconomic and welfare implications when the system moves from the status quo to the optimal tax system when taper rate

Variable	Status-quo	Optimal tax system	Change in percent
Total labor supply N	13.263	12.899	-2.473
Capital stock K	38.630	40.702	5.361
Output Y	18.278	18.208	-0.379
Aggregate consumption C	13.965	13.586	-2.715
Soc. Welfare	-3.763	-3.782	

Table 6: Means-tested Pension Program (taper=50%)

Variable	Status-quo	Optimal tax system	Change in percent
Total labor supply N	13.309	12.899	-3.347
Capital stock K	39.285	40.932	4.191
Output Y	18.415	18.205	-1.145
Aggregate consumption C	14.199	13.754	-3.347
Soc. Welfare	-3.712	-3.619	

Table 7: Means-tested Pension Program (taper=100%)

is 50% (100%). In the first case, in the optimal scheme labor income tax rate is 20% with 37% reduction rate (i.e. when the income is $40000,the first $14800 is tax free), and the optimal capital income tax rate is 0%. In the second case, in the optimal scheme the labor income tax rate is 20% with the reduction rate of 40% (i.e. when the average income is $40000, first $16000 is tax free).

Overall, the system with 100% taper rate, 20% marginal labor income tax rate with 40% reduction rate, and the zero capital income tax rate maximizes the social welfare.

6 Conclusion

In this paper we study the interaction between capital 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 personal income taxation in a life-cycle context.

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