Contributions

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Dynamic effects of consumption tax reforms with durable consumption

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Abstract:
This paper introduces durables into a dynamic general equilibrium overlapping generation model with idiosyncratic income shocks and endogenous borrowing constraints, which depend on durables. The aim of this paper is to evaluate the welfare effects of consumption tax reforms in a richer model that captures the difference between nondurable and durable consumption. When durables are considered, the standard results that a shift to consumption taxes is welfare improving are overturned. The mechanism of this opposing result is that consumption tax makes durable consumption more expensive without relaxing the borrowing constraint. The inability of borrowing to insure against income risk deviates the economy further away from market completeness and particularly hurts young and poor households. As a result, welfare decreases, coupled with negative redistribution.

Keywords: consumption tax, durable consumption, endogenous borrowing constraint, incomplete markets, transitional dynamics, welfare

JEL classification: D52, E2, E62, H21

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1 Introduction

Given the complexity and costliness of the current tax system,[1] tax reforms have provoked heated discussion among politicians and economists. The debates favor consumption taxes over income taxes for their efficiency and fairness.[2] Replacing income taxes with a consumption tax can encourage capital formation, creating a larger economic pie to be shared by households. In a general equilibrium framework, a higher capital stock improves the return to labor and reduces the return to capital. In other words, prices (interest rates and wage rates) are adjusted in favor of households with relatively higher labor earnings than wealth. Because the economy has a higher concentration of such households, a consumption tax reform creates a welfare gain and improves redistribution (Coleman II (2000), Correia (2010)). As studied in Seidman (1984), switching to a consumption tax system favors young and old cohorts in the long run because of their stronger reliance on labor income.

In the first part of this paper, we show that, without distinguishing between durables and nondurables, a consumption tax reform that replaces income taxes with a consumption tax to finance the same amount of government spending improves efficiency, generates a long run welfare gain of 3.78%, and benefits young and old households; this finding is consistent with the literature. When taking the transition into account, we find that not only young households but also poor households experience a relatively large welfare gain. The immediate average welfare gain is 0.57%, with the redistribution component being 3.39%, which means that the reform leads to fairer distribution.

Thus far, almost all existing studies on consumption taxation focus only on nondurable consumption and neglect the importance of durables over the life cycle and the potential problems associated with durables when switching tax regimes. This omission neglects the importance of durables.

First, durables as a component of GDP are quite sizable and their share in aggregate GDP is more than 10%. As compare to nondurables, the stock of durables is roughly 2.5 times the size of the former. Second, durables play important roles in households' portfolios over the life cycle. Not only can durables provide a one-time utility flow, but they can also generate a stream of utility in subsequent periods. In addition, durables often serve as collateral. Households can borrow up to a fraction of durables to insure against income risk. For example,

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Luengo-Prado (2006) uses durables to explain the excessive smoothness and excessive sensitivity of nondurable consumption. To acquire a durable good, households usually only need to fulfill a down payment requirement, which is a fraction of the durable good. The rest of the durable good becomes collateral. Households are allowed to pay back loans against this collateral in later periods. In other words, households can also borrow against the future, while deriving utility from the durable good. This feature is particularly attractive to young households who can not afford durables in full. For example, Fernandez-Villaverde and Krueger (2011) have shown that households hold negative financial assets during the early stage of their life cycle, and the hump-shaped durable stock peaks earlier than nondurables. Due to budget constraints, households must make decisions on nondurable consumption, durable consumption and financial assets jointly. Thus, ignoring durables might bias the results when discussing the allocation of portfolios, particularly when changing tax schemes.

Before illustrating the intuition for the potential outcomes induced by durables, we have to first answer a more fundamental question of whether durables should be taxed under a consumption tax system. In this context, durables include primary residential housing and other consumer durables, such as vehicles, furniture and home appliances. Taxing vehicles and other durables seems acceptable, but whether residential housing should be taxed is rather ambiguous. Different opinions regarding taxing residential housing generally center around the debate on whether residential housing is a capital good or a durable consumption good. Linden and Gayer (2012) argues for both approaches: taxing residual housing as a capital good and as a consumption good. If residential housing were treated as a durable consumption good, then value added tax (VAT) should be levied on the first sale of all new houses. In fact, the sale of new houses is already levied with VAT in approximately two thirds of the EU member states.[3] In the "Flat Tax Reform" proposed by Hall and Rabushka,[4] though they did not provide a clear answer regarding whether residential housing should be treated as an investment or as a durable consumption good, the authors clearly state that the flat tax reform will give a "100% write-off of all business investment at the level of business enterprises". In other words, only business investment can be exempted, leaving room for the discussion on taxing residential housing.

Next we turn to the following question, if all durables (including residential housing) were taxed under a consumption tax system, would there still be any welfare gain? To address this question, we use a standard Huggett (1993) and Aiyagari (1994) type of model in a general equilibrium framework with an overlapping generation setup and endogenous labor supply. Consumption is split into nondurable consumption and durable consumption and they form aggregate consumption in a CES fashion. The borrowing constraint is endogenously determined by durable stock. Durables can serve as collateral for loans up to a fraction $(1-\theta)$, where θ corresponds to the minimum requirement, or down payment for acquiring a durable good. On the production side, we assume that there exists a neoclassical firm that utilizes capital and labor to produce output that is used for nondurable consumption, durable consumption, capital investment and government spending. The government collects its revenue from taxing households to finance a constant flow of government spending.

The aim of this paper is to evaluate the effects of consumption tax reforms in a richer model that features a difference between nondurable and durable consumption. The main finding is that moving from the current income tax system to a consumption tax scheme with equal tax rates on durables and nondurables encourages capital accumulation due to the exemption of taxation on capital. However, the reform results in a long run welfare loss of 2.65% and an immediate welfare loss of 9.69% in terms of the consumption equivalent, coupled with a negative redistribution component of -4.42%. Even with the optimal tax combination on durables and nondurables (9% on durables and 42% on nondurables), the economy on average still experiences welfare losses of 1.09% in the long run and 8.24% in the short run, coupled with worsened redistribution throughout the transition. The current young and poor households are subject to the most significant welfare loss. These results are in sharp contrast to the conventional wisdom that a consumption tax reform improves average welfare, delivers positive redistribution and benefits young and poor households.

The mechanism of these drastic changes in welfare and redistribution lies in the endogenous borrowing constraint associated with durables. A consumption tax reform imposes a tax on both nondurables and durables, making them more expensive to acquire. However, the consumption tax reform does not alter the format of borrowing constraints, meaning that the ability to borrow still depends endogenously on the value of durable stock. When the affordability of durables decreases, but the borrowing limit is not relaxed, it is in fact that the borrowing constraint becomes tightened. The inability to borrow to insure against income risk moves the economy further away from the complete market setting, leading to a welfare loss. Moreover, because a tighter borrowing constraint particularly hurts young and poor households, who are more likely to be liquidity constrained, the reform also results in negative redistribution.

We perform various of robustness checks. The main finding is that imposing tighter post-reform borrowing constraints further deteriorates welfare, whereas a relaxed borrowing limit can reduce the welfare loss from market incompleteness. Moreover, a smaller required down payment ratio makes more households subject to a tighter post-reform borrowing constraint, leading to a more substantial welfare loss.

This paper fills the void in the consumption tax literature through its inclusion of durables. The discussion of consumption taxes has a long tradition, but few work explicitly models durables. For example, Correia (2010) analytically proves in a complete market setting that a consumption tax reform could improve equity without sacrificing efficiency. The optimal combination of a consumption tax and a labor income tax is studied in Coleman II (2000) in a complete market. Seidman (1984) analyzes the welfare gain of a consumption tax reform associated with different cohorts in an OLG model without uncertainty. In a similar setup, Altig et al. (2001) compare the welfare gain of replacing the U.S. income tax code with several different forms of consumption taxes in an OLG model. A flat tax reform in stochastic version of an OLG model is discussed by Ventura (1999), but he focuses on the steady state analysis. Anagnostopoulos and Li (2013) shows that consumption tax can finance government spending without distorting capital. Moreover, Conesa and Krueger (2006) conduct a comprehensive investigation of the income tax structure and conclude that the optimal tax structure is approximately the same as the flat tax proposed by Hall and Rabushka (1995). Consumption taxes are also discussed in other frameworks, such as that of Krusell, Quadrini, and Rios-Rull (1996), who analyze a consumption tax reform from a political economics perspective.

This paper also contributes to the literature on portfolio choices over the life cycle by investigating how households allocate their resources across nondurable consumption, durable assets and financial assets when facing changing tax schemes. There is a vast literature on portfolio choices. For example, Fernandez-Villaverde and Krueger (2011) recover the hump-shaped profile of durables and nondurables over the life cycle, even after controlling for the change in family demographics. Incorporating durables, Luengo-Prado (2006) provide new perspectives to explain the excessive smoothness and the excessive sensitivity of consumption. Mankiw (1982) tests Hall's consumption hypothesis on durables and concludes that durable goods should follow an ARMA(1,1) process. Cuoco and Liu (2000) use a first-order approach to investigate the optimal stock of divisible durable goods. However, none of these studies considers changes in tax systems. The current paper is among the first to study the allocation of resources in an environment facing changing tax regimes.

The remainder of the paper is organized as follows. Section 2 describes the model and the characterization of the equilibrium. Section 3 explains the calibration strategy and model fit. The numerical results can be found in Section 4. In this part, we first show the results of a consumption tax reform in a conventional setup without durables. We then incorporate durables and show the mechanism that leads to opposing conclusions from those generated in the traditional environment. A number of robustness checks can be found in this section. Section 5 studies the the optimal consumption tax structure on durables and nondurables. Section 6 concludes the paper.

2 The model

2.1 Demographics

Time is discrete and the economy is populated by J_1 overlapping generations. In each period a continuum of new households is born, whose mass grows at a constant rate n. Each household works J_0 years and lives for J_1 years. Each household faces a positive probability of death in every period. Let $\phi_j = Prob(alive\ at\ j+1|alive\ at\ j)$ denote the conditional survival probability from age j to age $j+1$. At age J_1 households die with probability one, i.e. $\phi_{J_1} = 0$.

The probability density function of population is $\psi : A \times D \times E \times J \to \mathbb{R}_+$, where A, D, E, J are the state spaces for financial assets a, durable stock d, labor efficiency ϵ and age j. Define $\tilde{\Psi}_j : A \times D \times E \to \mathbb{R}_+$ as the conditional cumulative distribution function of financial assets, durables and labor efficiency for a given age j; and $\psi_j : J \to \mathbb{R}_+$ as the marginal density function of age.

2.2 Endowments

Households are endowed with one unit of time in each period. At working age, time is divided between work and leisure; after retirement, households enjoy leisure full-time. Households enter the market with no financial asset or durable good. Moreover, we assume that there are accidental bequests. Financial assets as well as durable stock will be equally distributed to the remaining population.

2.3 Preferences

Households derive utility from non-durable consumption c, durable stock d' and disutility from labor l. The future utility is discounted at the rate of β. The objective function of a newborn household is

$$E\sum_{j=1}^{J_1}\beta^j(\Pi_{s=1}^{j}\phi_s)u(c_j,d_{j+1},l_j).$$

2.4 Earnings

During working age, households receive a labor income consisting of a wage w, an age-dependent labor productivity e_j, an idiosyncratic shock ϵ and hours worked l.

After retirement, households receive a social security benefit pen, with a replacement ratio of b. Because we abstract from heterogeneity in permanent income,[5] the social security benefits received after retirement are the same across households.

The earning function for workers and retirees is as following:

$$y=\begin{cases}we_j\epsilon l, & j\le J_0\\ pen, & j>J_0.\end{cases}$$

2.5 Borrowing constraint

The borrowing constraint is endogenously determined by durable stock.

$$a'+(1-\theta)d'\ge 0$$

with $\theta\in[0,1]$. This constraint says that a household borrowing limit is a fraction $(1-\theta)$ of the durable stock. As discussed in Luengo-Prado (2006), this constraint implies that a household must meet a down payment requirement (θ fraction of durables) to acquire the durable goods. It also implies that when a household owns a durable good, it can serve as collateral for loans up to $(1-\theta)$ fraction of the durable stock. In general, this constraint states that the wealth in excess of the required down payment $a'+(1-\theta)d'$ is non-negative.

2.6 Adjustment cost

The change of durable stock is subject to an adjustment cost m, which takes the form of

$$m=\begin{cases}\mu(1-\delta^d)d, & \text{if } d'\ne(1-\delta^d)d\\ 0, & \text{otherwise}\end{cases}$$

where δ^d is the depreciation rate of durables. There are different ways to model adjustment costs for durables. Our functional form is the most similar to that of Luengo-Prado (2006), who follow Grossman and Laroque (1990). Luengo-Prado (2006) assumes that an adjustment cost is needed once the durable stock of the next period is different from the undepreciated durables in the current period. Moreover, she assumes that once the household has decided to adjust the durable holdings, the adjustment cost is fixed and proportional to the inherited level of the durable stock $(1-\delta^d)d$. For simplicity, our functional form follows Luengo-Prado (2006) and abstracts from Yang (2009) who assumes that there are both upward and downward adjustment costs.

2.7 Production

There is a representative firm utilizing capital K and labor L to produce output Y, which is used for nondurable consumption C, durable goods expenditure I_d, the adjustment cost of durables M, capital investment I_k, as well as government spending G. The firm's maximization problem is

$$\max_{\{K,L\}} AF(K,L) - \delta^k K - rK - wL$$

where r and w are factor prices, δ^k is the depreciation rate of capital. The law of motion of capital and durable accumulation are $K' = (1-\delta^k)K + I_k$ and $D' = (1-\delta^d)D + I_d$, respectively.

2.8 Government and fiscal policy

Each period, the government finances an exogenous stream of spending G through income taxes. This paper focuses on federal-level tax reforms, so we ignore the taxes at the state and local level. There are two categories of income taxes: capital income tax and labor income tax. The capital income tax is assumed to be proportional to the capital income ra and is taxed at the rate of τ_a. The labor income tax function is $T(\cdot)$. For working households, the taxable income includes earnings y net of one half of social security tax payments ss, where $ss = \tau^{ss}\min\{y, \bar{y}\}$ with $\bar{y}$ being the social security cap and τ_{ss} being the social security tax rate.[6] According to the current tax system, pensions and social security benefits of retirees are also taxable. In addition to the income taxes, working households have to pay a social security tax ss, described as above.

The tax payment of a household is

$$Tax = \begin{cases} \tau^a ra + T(y - 0.5ss) + ss & j \le J_0 \\ \tau^a ra + T(y) & j > J_0 \end{cases}$$

Throughout the paper, we assume that the social security system is self-financed. Therefore, the following equations hold:

$$pen = \frac{bw\sum_{j=1}^{J_0}\psi_j\int_{A\times D\times E} e_j\epsilon l\, d\tilde{\Psi}_j(a,d,\epsilon)}{\sum_{j=1}^{J_0}\psi_j\int_{A\times D\times E} d\tilde{\Psi}_j(a,d,\epsilon)}$$

$$pen\sum_{j=J_0+1}^{J_1}\psi_j\int_{A\times D\times E} d\tilde{\Psi}_j(a,d,\epsilon) = \tau_{ss}w\sum_{j=1}^{J_0}\psi_j\int_{A\times D\times E} e_j\epsilon l\, d\tilde{\Psi}_j(a,d,\epsilon)$$

2.9 Equilibrium

Definition: A steady state equilibrium is a collection of decision rules $c(a,d,\epsilon,j)$, $a'(a,d,\epsilon,j)$, $d'(a,d,\epsilon,j)$ and $l(a,d,\epsilon,j)$; taxes paid $Tax(a,d,\epsilon,j)$ and social security benefits pen; factor prices r and w; aggregate nondurable consumption C, aggregate durable stock D, aggregate capital K, aggregate labor L and aggregate adjustment cost M; government spending G, a social security tax τ_{ss}, a social security cap $\bar{y}$, a replacement ratio b and a tax regimen $\in \{benchmark, consumption\ tax\}$; and a probability density function $\psi : A\times D\times E\times J \to \mathbb{R}_+$, a conditional cumulative distribution function for a given age $\tilde{\Psi}_j : A\times D\times E \to \mathbb{R}_+$ and a marginal density function of age $\psi_j : J \to \mathbb{R}_+$ such that:

1. Given prices and tax policies, $\{c, d', a', l\}$ solve the households maximization problem:

$$
\begin{aligned}
V(a,d,\epsilon,j) &= \max_{\{c,d',a',l\}} u(c,d',l) + \beta\phi_{j+1}EV(a',d',\epsilon',j+1) \\
\text{s.t. } c + d' + a' + m &= (1+r)a + y + (1-\delta^d)d - Tax \\
y &= \begin{cases} we_j\epsilon l, & j \le J_0 \\ pen, & j > J_0 \end{cases} \\
Tax &= \begin{cases} \tau^a ra + T(we_j\epsilon l - 0.5ss) + ss, & j \le J_0 \\ \tau^a ra + T(pen), & j > J_0 \end{cases} \\
ss &= \tau^{ss}\min\{y_j, \bar{y}\} \\
m &= \begin{cases} \mu(1-\delta^d)d, & \text{if } d' \ne (1-\delta^d)d \\ 0, & \text{otherwise} \end{cases} \\
a' &\ge -(1-\theta)d' \\
c, d' &> 0, 0 < l \le 1
\end{aligned}
$$

2. The firm maximizes its profit according to

$$\max_{\{K,L\}} F(K,L) - \delta^k K - rK - wL$$

3. Markets clear:

a. The goods markets clear

$$
\begin{aligned}
C + K' - (1-\delta^k)K + D' - (1-\delta^d)D + M + G &= Y, \\
C &= \sum_{j=1}^{J_1}\psi_j \int_{A\times D\times E} c\, d\tilde{\Psi}_j(a,d,\epsilon) \\
D' &= \sum_{j=1}^{J_1}\psi_j \int_{A\times D\times E} d' d\tilde{\Psi}_j(a,d,\epsilon) \\
M &= \sum_{j=1}^{J_1}\psi_j \int_{A\times D\times E} m\, d\tilde{\Psi}_j(a,d,\epsilon)
\end{aligned}
$$

b. The capital markets clear

$$K' = \sum_{j=1}^{J_1}\psi_j \int_{A\times D\times E} a'\, d\tilde{\Psi}_j(a,d,\epsilon)$$

c. The labor markets clear

$$L = \sum_{j=1}^{J_1}\psi_j \int_{A\times D\times E} e_j\epsilon l\, d\tilde{\Psi}_j(a,d,\epsilon)$$

d. The factor markets clear

$$
\begin{aligned}
r &= F_1(K,L) - \delta^k \\
w &= F_2(K,L)
\end{aligned}
$$

4. Fiscal policy is such that:

a. The government budget is satisfied

$$G + \sum_{j=J_0+1}^{J_1} \psi_j pen = \sum_{j=1}^{J_1} \psi_j \int_{A\times D\times E} Tax \, d\tilde{\Psi}_j(a,d,\epsilon)$$

b. The social security system satisfies:

$$pen = \frac{bw \sum_{j=1}^{J_0} \psi_j \int_{A\times D\times E} e_j \epsilon l \, d\tilde{\Psi}_j(a,d,\epsilon)}{\sum_{j=1}^{J_0} \psi_j \int_{A\times D\times E} d\tilde{\Psi}_j(a,d,\epsilon)}$$

$$pen \sum_{j=J_0+1}^{J_1} \psi_j \int_{A\times D\times E} d\tilde{\Psi}_j(a,d,\epsilon) = \tau_{ss} w \sum_{j=1}^{J_0} \psi_j \int_{A\times D\times E} e_j \epsilon l \, d\tilde{\Psi}_j(a,d,\epsilon)$$

5. The law of motion is given as follows. Define $\mathscr{G}$ be a $\sigma-$algebra defined on state space $S = A \times D \times E$. A measure space is defined to be a pair $(S, \mathscr{G})$. A transition function on a measure space $(S, \mathscr{G})$ is a function $Q : S \times \mathscr{G} \to [0, 1]$, such that

(a) For each $s \in S$, $Q(s, \cdot)$ is a probability measure on $(S, \mathscr{G})$;

(b) For each $B \in \mathscr{G}$, $Q(\cdot, B)$ is a -measurable function.

Let $\Psi(S, \mathscr{G})$ be the set of probability measures on $(S, \mathscr{G})$, we define a Markov operator $\Gamma^* : \Psi(S, \mathscr{G}) \to \Psi(S, \mathscr{G})$ by

$$\psi_{j+1} = \Gamma^* \psi(B) = \int_S Q(s, B) \psi_j(ds),$$

where $\psi_{j+1} = \Gamma^* \psi$ is the probability measure next period, given that current values of the state are drawn according to the probability measure ψ_j.

3 Calibration and definitions

3.1 Data sources

The data sources include the Consumer Expenditure Survey (CEX) 2017, the Panel Study of Income Dynamics (PSID) 1968–2017, the Survey of Consumer Finances (SCF) 2016 at the household level and “GDP and Personal Income”, “Fixed Assets” and “Consumer Durable Goods” from the National Income and Product Accounts (NIPA) 1945–2017 at the aggregate level. Following Yang (2009), the capital stock is defined as private nonresidential fixed assets plus governmental nonresidential fixed assets. The durable stock includes private residential fixed assets, governmental residential fixed assets and consumer durables. For variables at the household level, the definitions will be consistent with the literature and will be presented below.

3.2 Fiscal policy

Following Heathcote and Domeij (2004), the capital income tax is set to be 39%.

The individual income tax is assumed to be proportional to taxable income, with a tax rate of 27%. This paper focuses on the difference in the welfare effects of consumption tax reforms between a case with only nondurables and a case that includes durables. As long as the reforms in the two cases are comparable, we do not pursue the perfect format for the tax functions. That is, we use proportional tax structures in the initial steady states of both cases and proportional consumption taxes in both reforms. The numerical simplification from using proportional tax functions is obvious, another rationale is as follows. If the initial income tax system is progressive, but the final consumption tax system is not, then it is highly likely that the economy will experience a welfare loss due to the deterioration in equity. From a fairness and an implementation point of view, if the original income tax system is progressive, the reformed consumption tax system should be progressive. However, the focus of the current paper is not to discuss the optimal progressivity of consumption taxes; rather, we aim to provide a fair comparison in a clean model and focus on the innate properties of durables that overturn the welfare consequences derived in an environment without durables. In fact, if we start with a progressive income tax system and move to a consumption tax regime with a certain progressivity, we might also introduce other channels that contribute to the divergence of results in the two setups (with and without durables). As long as the tax systems in the two environments are comparable, we keep the tax systems as simple as possible.

The social security tax is 12.4%. The resulting replacement ratio is 57%, such that the aggregate social security contribution by workers is equal to social security benefits claimed by retirees. This number is close to the actual replacement ratio of 60%.

3.3 Technology and timing

The model takes 2 years as one period.

The production function is assumed to be Cobb-Douglas $Y = AK^{\alpha}L^{1-\alpha}$ with the capital share of output equals 0.3. We follow the procedure described in Fernandez-Villaverde and Krueger (2011), calculating the depreciation of capital δ^k and that of durables δ^d from the NIPA data to match investment shares of output and capital to output ratios for the US economy. That is $\delta^k = \frac{I^k/Y}{K/Y}$ and $\delta^d = \frac{I^d/Y}{D/Y}$. We find that the 2-year depreciation rate of capital is 0.18 and that of durables is 0.17. These numbers imply that the annual depreciation rate of capital is 0.089 and that of durable is 0.085, which are very similar to Fernandez-Villaverde and Krueger (2011).

3.4 Adjustment cost and down payment ratio

We follow Luengo-Prado (2006), assuming $\mu = 0.05$. In the benchmark economy, the down payment ratio θ is set to be 0.2, implying that the borrowing limit is 80% of the durable stock. This is a commonly used value in durables and housing literature, for example Fernandez-Villaverde and Krueger (2011), Grossman and Laroque (1990), and Luengo-Prado (2006) among others.

3.5 Demographics

We assume that households enter the market without any financial asset or durable stock, i.e. $a_0 = 0$, $d_0 = 0$. Following Yang (2009), the annual population growth rate 1.2%, meaning that the 2-year population growth rate $n = 2.4\%$. The conditional survival rate ϕ_j is adopted from Bell and Miller (2002). In Bell and Miller (2002), they provide conditional cohort probabilities of survival at age 0, 30, 60, 65, 75 and 100. We interpolate the conditional survival probabilities at other ages with 1 year interval, then we multiply the probabilities of consecutive 2 years to get the conditional survival probabilities with a 2-year interval. Figure 1 shows the interpolated probabilities that we use in the model.

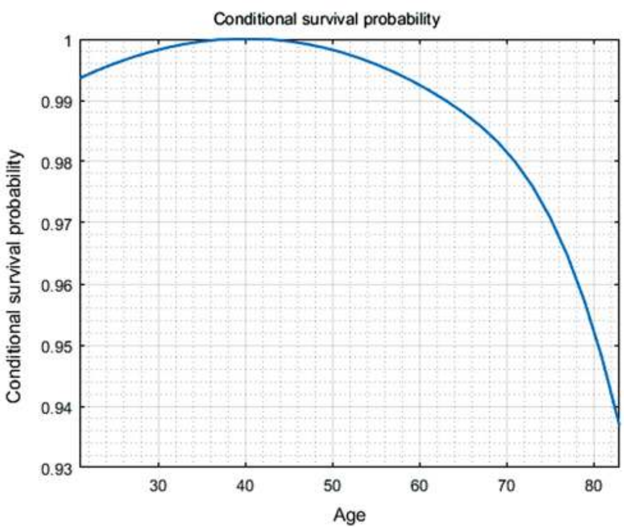

Figure 1: Conditional survival probability

3.6 Life cycle wage profile and the stochastic earning process

We assume that the logarithm hourly wage is linear in its components. Specifically, the logarithm wage by household i of at year t $\hat{y}_t^i$ is given by

$$\hat{y}_t^i = \omega_t + f(X) + \epsilon_t^i + \eta_t^i$$
$$\epsilon_t^i = \rho\epsilon_{t-1}^i + \nu_t^i$$

where ω_t is a time dummy, controlling for the time fixed effects; $f(X)$ is the life cycle wage profile, X is the set of life cycle characteristics, including age, age squared and cohort dummies; ϵ_t^i is a persistent component following an AR(1) process, η_t^i and ν_t^i are white noises, assuming to follow normal distributions with variances of σ_η^2 and σ_ν^2, respectively.

Using the PSID data from 1969 to 2016, we form an individual earnings panel.[7,8] The reason we set 2 years as one model period is that since 1997, the PSID conducts interviews every 2 years. To keep track of individuals using more recent data would require compromising on the time frame. We keep individuals who are between 21 and 65 years old and who belong to the labor force. The reason we do not adhere to the selection criteria as the literature[9] on earning processes is two-fold. One reason is that we are not trying to address the issue of how earnings evolve over the life cycle; the other reason is that we need to be consistent with the data selection criteria of other data sets that we use to test the model validity.

To obtain the life cycle wage profile, we first regress the logarithm wage rate on age, age squared, cohort dummies and year dummies (capturing the time fixed effects), shown in Figure 2. Then, we run the auto-regression of the residuals to obtain the persistent parameter $\rho = 0.92$ and the variance $\sigma_\nu^2 = 0.044$. These estimates are comparable to those in the literature. For example, Storesletten, Telmer, and Yaron (2004) estimate the annual persistence parameter to be 0.99 and the variance to be 0.017. Heathcote and Domeij (2004) summarize that the persistence ranges from 0.88 to 0.96, and the variance is between 0.12 and 0.25. The persistence and the variance are 0.98 and 0.029 in Conesa and Krueger (2006). Diaz and Luengo-Prado (2010) use 0.99 and 0.016 for the persistence and variance, respectively. Yang (2009) estimate the 5-year persistence and variance to be 0.85 and 0.30, which implies that the annual persistence is roughly 0.97 and the variance is 0.014.[10] Applying the algorithm described in Tauchen (1986), we discretize the AR(1) process into a three-state Markov process. Shown in Table 1, ϵ represents the levels of labor efficiency, the Markov transition matrix is denoted by Π, and its ergodic distribution is labeled Π^*.

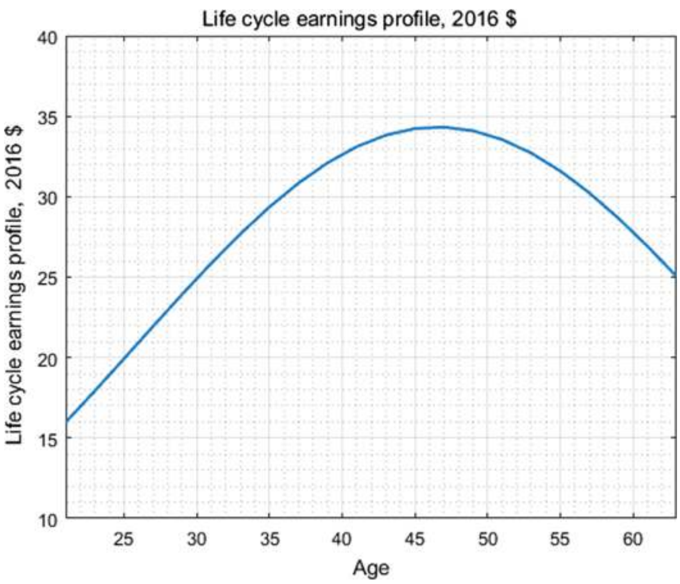

Figure 2: Life cycle wage profile, in 2016 $.

Table 1: Earning process.

			Earning process
θ	0.332	1.000	3.015
	0.975	0.025	0.000

Π	0.013	0.974	0.013
	0.000	0.025	0.975
Π*	0.256	0.447	0.256

3.7 Preferences

The benchmark utility function takes the form of $u(c,d',l) = \frac{\left((\gamma c^{\xi}+(1-\gamma)d'^{\xi})^{1/\xi}\right)^{1-\sigma}}{1-\sigma} - B\frac{l^{1+1/\chi}}{1+1/\chi}$, where σ is the risk-aversion parameter, γ captures the share of nondurable consumption in total expenditure, $\frac{1}{1-\xi}$ is the constant elasticity of substitution between nondurable consumption and durable consumption, and χ is the Frisch elasticity of labor supply. The relative risk aversion parameter σ is set to be 2. γ is calibrated to match the 2-year nondurable to durable consumption ratio of 0.82 from the NIPA data.[11] In the benchmark economy, we assume $\xi = 0$, implying a Cobb-Douglas utility. We follow Chetty et al. (2012) and set $\chi = 0.75$, and B is calibrated such that average hour worked is $1/3$. Finally, β is to target the 2-year capital to output ratio of 0.93.

The parameters associated with preferences are shown in Table 2.

Table 2: Parameters in the model.

Parameter		**Calibrations**	
		With durables (benchmark)	**w/o durables**
Preference			
β	Discount factor	0.928	0.932
γ	Share of nondurable	0.820	-
ξ	$\frac{1}{1-\xi}$ is the CES between C and D	0.000	0.000
σ	Relative risk aversion	2.000	2.000
χ	Frisher elasticity	0.750	0.750
B		16.332	14.761
Technology			
α	Capital share of output	0.300	0.300
δ^k	2-year capital depreciate rate	0.178	0.178
δ^d	2-year durable depreciate rate	0.169	0.169
μ	Adjustment cost	–	0.050
θ	Down payment	–	0.200
Government			
τ_a	Capital income tax	0.390	0.390
τ_w	Labor income tax	0.269	0.269
τ_{ss}	Social security tax	0.124	0.124
$\bar{y}$	SS contribution cap	2.46 average earnings	
b	Retired replacement ratio	0.523	0.569
Demographics			
T	Maximum life expectancy	32 (85 year-old)	32
Tr	Retirement age	22 (65 year-old)	22
n	2-year population growth rate	0.024	0.024
ϕ	2-year conditional survival rate	See text	
Earnings process			
e	Age profile	See text	
ρ	Persistence of 2-year AR(1) process	0.916	0.916
σ_ν^2	Variance of 2-year AR(1) process	0.0435	0.0435

3.8 Model validity

Table 3 presents the distribution of the benchmark economy versus the data. The cross sectional earnings distribution is calculated from the PSID 2017 data; to be consistent with the estimation of the earnings process, we focus on individuals who are between 21 and 65 year-old and who belong to the labor force. We can see that the model matches the distribution of earnings quite well, with the Gini index being 0.554 and the top quintile takes up 58.91% of the total earnings. However, because our model does not have a wide spread in labor shock realizations, the top percentiles possess much less earnings than that in the data.

Table 3: Model validation, distributions.

	Gini	Bottom			Quintiles					Top		
		Bot1	Bot1-5	Bot5-10	Q1	Q2	Q3	Q4	Q5	Top10-5	Top5-1	Top1
Earnings												
Data	0.588	0	0	0	0	5.87	12.98	22.29	58.49	11.82	14.57	15.03
Benchmark	0.554	0	0	0	0	5.24	13.78	22.07	58.91	17.68	13.62	5.58
Total wealth (financial assets + durable stock)												
Data	0.891	−0.62	−0.70	−0.33	−1.84	0.15	2.34	9.00	90.34	12.77	26.28	38.87
Benchmark	0.696	0	0.12	0.23	0.84	1.67	5.96	15.19	76.33	21.19	23.99	6.42
Finance assets												
Data	1.318	−2.76	−5.28	−4.2	−17.46	−3.98	−0.31	1.43	120.32	12.55	35.46	64.27
Benchmark	0.921	−0.67	−1.92	−1.90	−6.77	−1.47	1.09	13.73	93.42	28.83	29.347	8.23
Durable stock												
Data	0.690	0	0	0	0	0.18	9.25	22.01	68.55	15.08	19.91	13.89
Benchmark	0.431	0	0.36	0.92	3.31	10.96	13.81	22.11	49.81	14.88	12.05	2.94
Nondurable consumption												
Data	0.345	0.19	1.17	1.89	8.09	13.38	18.55	26.84	46.97	11.26	12.65	5.35
Benchmark	0.401	0.13	0.72	1.00	4.55	10.98	14.66	22.64	47.17	12.12	11.80	2.85
Hours worked												
Data	0.230	0.16	1.37	2.57	10.37	14.41	18.03	24.68	32.51	8.11	7.33	2.32
Benchmark	0.255	0	0	0	9.43	10.55	25.39	26.42	28.49	6.98	6.30	1.21

For wealth and consumption, we use adult equivalence as a unit. The adult equivalence scale is calculated according to the OECD rule: the first adult is counted as 1, the second adult has a weight of 0.7, the rest of the members in the household have a weight of 0.5 each.

The cross sectional distribution of total assets, financial assets and durable stock are derived from the SCF 2016 data.[12] The financial assets are defined as liquid assets net of all debt, the durable stock includes primary residential assets and vehicles, and the total assets are the summation of financial assets and durable stock. Comparing the SCF and CEX datasets, the SCF includes detailed information on housing but does not have information on other durables, such as home furniture, equipment and appliances. On the other hand, the CEX contains data on both housing other durables but provides only the stock value of housing and the expenditure flows of other durables. In other words, it is difficult to back out the total stock of durables from the CEX data. Thus, given its thoroughness on housing stock, we compromise on the other durables and choose the SCF data to calculate the distribution of durable stock.

The middle three panels of Table 3 present the distribution of total assets, financial assets and durable stock. The Gini indexes of these three variables are 0.89, 1.32 and 0.69, respectively. Our statistics are comparable to Diaz and Luengo-Prado (2010) who use the SCF 1998 data. In their statistics, the Gini index of financial assets is 0.94, with the fifth quintile occupying 102% of the total financial assets; housing assets have a Gini index of 0.64, with the fifth quintile taking up 63% of the total housing stock; the wealth Gini index equals 0.80, and the top quintile still has the lion's share (82%) of the total wealth. Our statistics offer a more concentrated distribution at the top in these variables than the literature. One explanation is that the inequality of wealth continues to rise over the years.

Comparing with the data, the model generates a lower Gini of and lower concentration in total wealth, financial assets and durables at the top than the data. It is well known that Aiyagari type of models, which incorporate uncertainty only in labor earnings, cannot generate as large inequality in wealth as that in data.

The cross sectional distribution of nondurable consumption is calculated from the CEX 2017 data. The main categories included in nondurable consumption are food, rent, utility, appeals, transportation (excluding the purchase of new cars and used cars), entertainments and contributions. Financial expenditures, such as mortgage interest payments and expenditures on education and insurance, are excluded from nondurable consumption. Again, the model does a fairly good job of generating a consumption distribution that is comparable to the data.

Moreover, Figure 3–Figure 5 compare the nondurable consumption, durable stock and financial assets over the life cycle between the data and the model. For the estimation of life cycle nondurable consumption, we employ six waves of the CEX data from 2007 to 2017 every other year to construct a pseudo panel with 37 cohorts. For durable stock and financial assets, four waves of the SCF data from 2007 to 2016 are used to construct a 25-cohort pseudo panel.[13] Then we follow the semi-parametric approach described in Fernandez-Villaverde and Krueger (2011) and Yang (2006) to estimate the life cycle profile of nondurables, durables and financial assets.

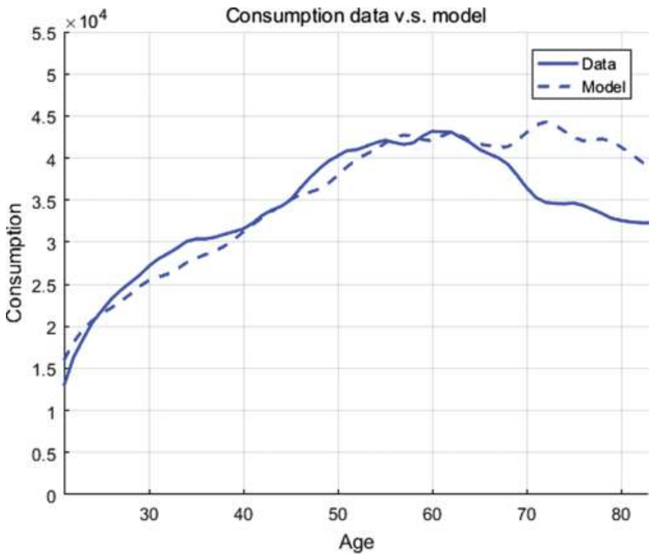

Figure 3: Life cycle nondurable consumption, data vs. model, in 2016 $.

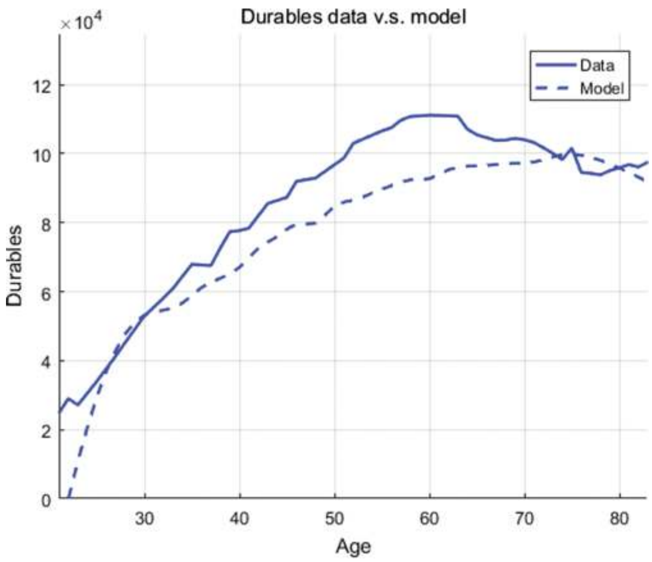

Figure 4: Life cycle durable stock, data vs. model, in 2016 $.

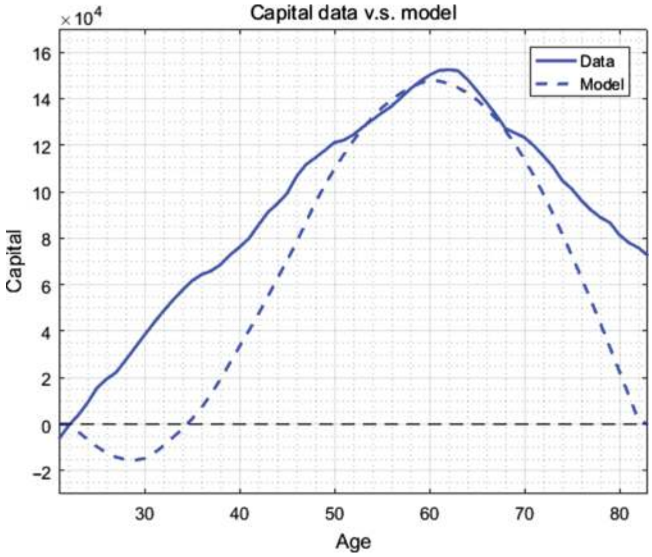

Figure 5: Life cycle finance assets, data vs. model, in 2016 $.

In general, our model matches the life cycle profile of nondurable consumption, durable stock and financial assets quite well. However, because we assume no bequest motive, all assets will be depleted before the last period. Figure 5 shows that the decrease in capital at old age occurs much more quickly in the model than in data. Due to this model specification, the model also falls short of matching the nondurable consumption pattern during late years, as shown in Figure 3.

4 Numerical experiments

The numerical experiments involve replacing the current income taxes with consumption taxes. We begin the analysis in a conventional setup without durables. In this part, we show how a consumption tax reform improves redistribution and results in a welfare gain. Next, we incorporate durables and focus on the main mechanism that leads to welfare loss and negative redistribution. In this subsection, various robustness checks are performed to help to understand the factors that matter for the welfare consequences. All the experiments replace the current income taxes with consumption taxes while holding the government revenue neutral. In addition, we keep the social security tax fixed and adjust the replacement ratio to maintain the self-financed social security system.

4.1 Results without durables

This subsection discusses the effects of a consumption tax reform in a conventional setup where only a single nondurable consumer good is considered. Households solve the maximization problem of

$$V(a,\epsilon,j) = \max_{\{c,l,a'\}} \left\{ \frac{c^{1-\sigma}}{1-\sigma} - B\frac{l^{1+1/\chi}}{1+1/\chi} + \beta\phi_{j+1}EV(a',\epsilon',j+1) \right\}$$

subject to the budget constraint and the borrowing constraint

$$\begin{aligned} c + a' &= (1+(1-\tau_a)r)a + y - Tax \\ a' &\geq 0 \end{aligned}$$

After the reform, only the social security tax τ_{ss} remains, all other income taxes are replaced by a consumption tax τ_c, and the replacement ratio b is adjusted to maintain the self-financed social security system. The budget constraint and the borrowing constraint become

$$\begin{aligned} (1+\tau_c)c + a' &= (1+r)a + y - \mathbf{1}_{\{j\leq J_0\}}ss \\ a' &\geq 0 \end{aligned}$$

where **1** is an indicator function, takes the value of 1 if $j \leq J_0$ and 0 otherwise.

The steady state results are shown in Table 4, the percentage change from the initial is also presented. As discussed in Coleman II (2000), Correia (2010), and Ventura (1999), the consumption tax reform boosts efficiency because it excludes the investment from the tax base. In particular, the aggregate capital increases by 24.84%, and the capital-to-output ratio has a 18.81% increase; consequently, the aggregate consumption also improves by 35.28%.

Table 4: Steady state comparison and short-run welfare gain.

	w/o durables			With durables					
	Initial	Reform	Δ%	Initial (Benchmark)	Equal rate Reform	Δ%	Optimal Reform	Δ%
τ_a	0.390	0	–	0.390	0	–	0	–
τ_w	0.270	0	–	0.270	0	–	0	–
τ_c	0	0.25	–	0	0.321	–	0.420	–
τ_d	–	–	–	0	0.321	–	0.089	–
b	0.523	0.524	–	0.569	0.569	–	0.570	–
r[a]	0.140	0.080	(−36.43)	0.140	0.101	(−28.28)	0.094	(−32.76)
pen	0.308	0.325	(5.52)	0.391	0.415	(6.14)	0.419	(7.16)
K	0.959	1.197	(24.84)	0.915	1.099	(20.10)	1.134	(24.00)
H[b]	0.333	0.329	(−1.31)	0.333	0.326	(−2.12)	0.321	(−3.49)
L	0.979	0.968	−1.15	1.001	0.994	(−0.75)	0.993	(−0.82)
D	–	–	–	0.627	0.596	(−4.77)	0.663	(5.98)
C	0.577	0.781	(35.28)	0.508	0.493	(−3.06)	0.459	(−9.82)
K/Y	0.930	1.105	(18.81)	0.930	1.065	(14.28)	1.097	(16.92)
C/D	–	–	–	0.810	0.827	(1.80)	0.691	(−14.90)
G/Y	0.210	0.199	(−5.68)	0.199	0.190	(−2.02)	0.188	(−5.71)
Gini_{a+d}	–	–	–	0.696	0.716	–	0.702	–
Gini_a	0.773	0.791	–	0.921	0.930	–	0.896	–
Gini_d	–	–	–	0.431	0.411	–	0.415	–
Gini_h	0.237	0.234	–	0.255	0.249	–	0.250	–
Gini_{earn}	0.550	0.551	–	0.554	0.552	–	0.552	–
Gini_c	0.387	0.383	–	0.401	0.393	–	0.397	–
$\Delta^{LR}(\%)$	–	–	3.78	–	–	−2.65	–	−1.09
$\Delta^{SR}(\%)$	–	–	0.57	–	–	−9.69	–	−8.24
$\Delta^{SR}_{agg}(\%)$	–	–	−2.73	–	–	−5.51	–	−4.71
$\Delta^{SR}_{dist}(\%)$	–	–	3.39	–	–	−4.42	–	−3.70

[a]Steady state comparison.
[b]H denote the average hours worked, it is calculated as $H = \sum_{j=1}^{J_1} \psi_j \int_{A\times D\times E} l(a,d,\epsilon,j) d\tilde{\Psi}_j(a,d,\epsilon)$.

How earnings, assets and consumption are changed over the life cycle by the consumption tax reform is presented in Figure 6– Figure 8. Figure 6 shows that due to a higher wage, households with the highest labor efficiency have the largest increase in earnings. Across age, the biggest boost to earnings appears to middle-age households because they are at the peak of the life cycle productivity. Consequently, middle-aged households with the highest labor efficiency enjoy the largest increase in assets and consumption, as shown in Figure 7 and Figure 8. For retirees, Table 4 shows that the reform increases their social security benefits by 5.52% due to the increase in earnings and thus the social security tax payments by working households.[14]

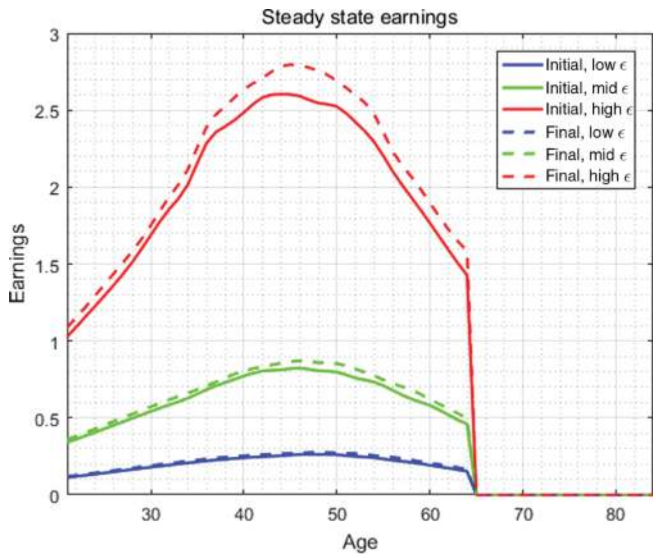

Figure 6: Steady state earnings, without durables.

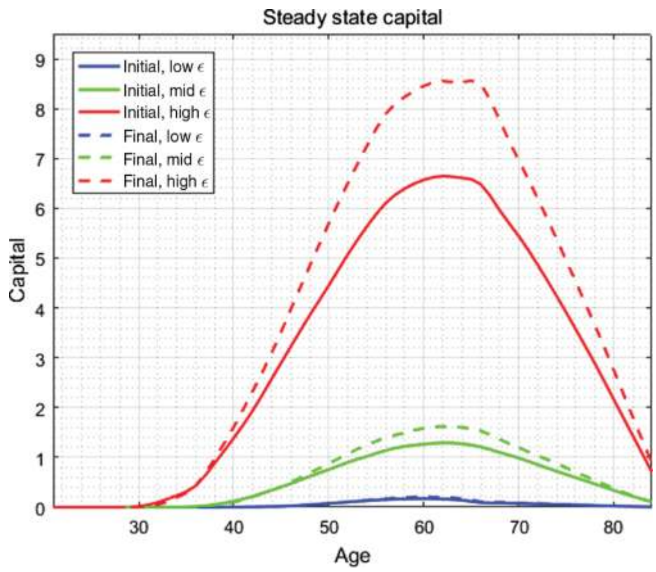

Figure 7: Steady state capital, without durables.

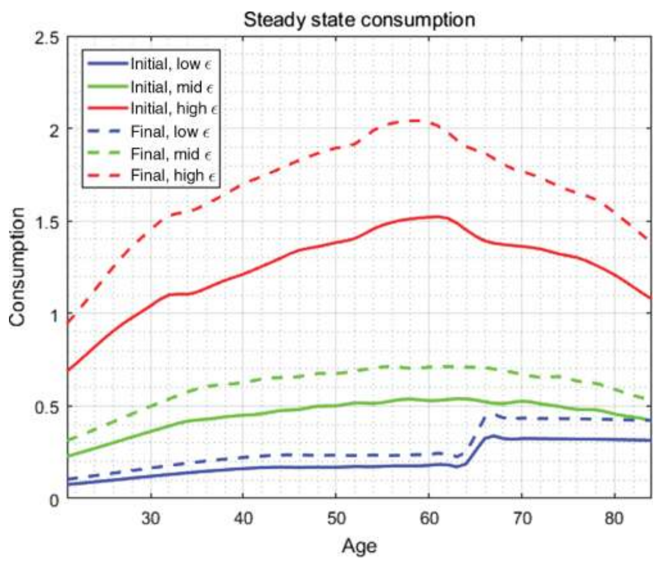

Figure 8: Steady state consumption, without durables.

Intuitively, the consumption tax reform increases capital stock, boosts wage rate and reduces interest rate. Households who are relying more on earnings and less on capital can benefit from the reform. If we consider the steady state welfare comparison, namely, comparing the welfare of the current newborns with the future newborns at different ages, then households can experience a welfare gain when they are very young or very old because of their strong reliance on earnings or social security benefits; whereas their welfare drops during the middle age due to their high accumulation of assets. The steady state welfare gains across age and labor type are shown in Figure 9 and Figure 10. Note that Figure 9 replicates Seidman (1984), who compared steady state welfare of a consumption tax reform in a complete market setting. Moreover, Figure 10 shows that high labor efficiency households experience more substantial welfare losses during middle ages, which can be explained by their more abundant asset accumulation.

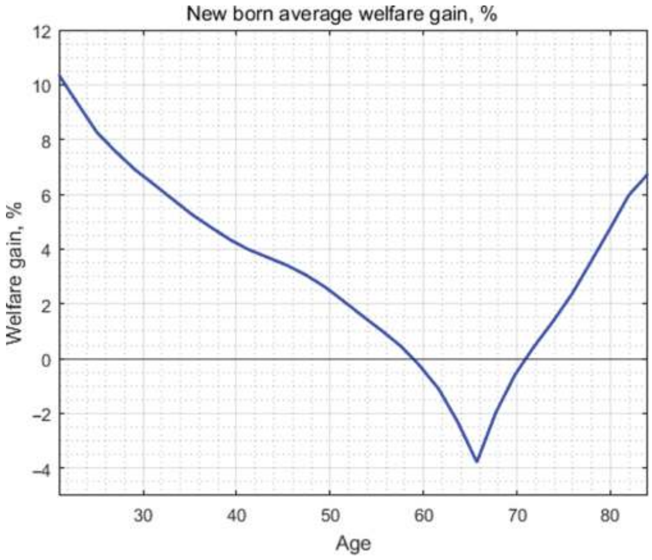

Figure 9: Long-run welfare gain by age, without durables.

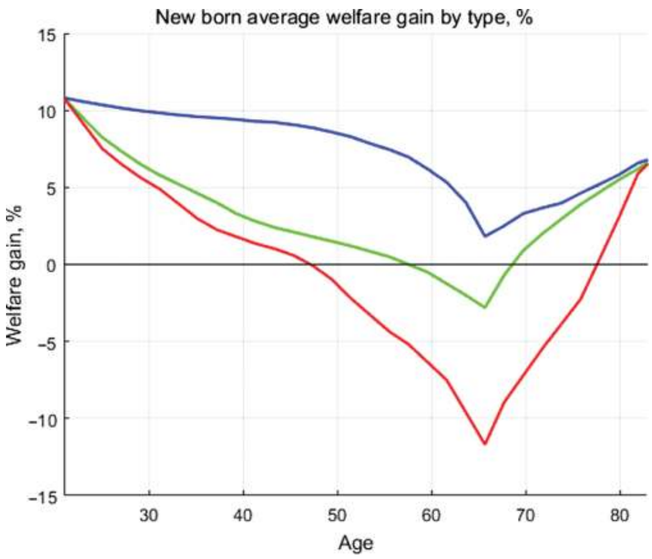

Figure 10: Long-run welfare gain by age and labor type, without durables.

The distribution in the steady state is displayed in Table 5. The reform increases the Gini index and concentration of earnings at the top because a higher wage increases earnings to a greater extent for households with high labor efficiency, namely, for households at the top end of the earnings distribution. Similarly, many households at the top end of the asset and consumption distribution also possess high labor efficiency, the relatively larger improvement in their earnings entitles these households to claim more assets and consumption from the economy. Specifically, the Gini index of assets increases due to households in the 5th quintile and top percentiles increase their shares in the aggregate. The Gini of consumption slightly drops, but top groups still expand their share in the aggregate consumption. This conclusion is consistent with Ventura (1999): a flat tax reform worsens equity at the steady state.

Table 5: Steady state distribution, without durable.

	Gini	Bottom			Quintiles					Top		
		Bot1	Bot1-5	Bot5-10	Q1	Q2	Q3	Q4	Q5	Top10-5	Top5-1	Top1
Labor supply												
Benchmark	0.237	0	0	0	0	21.41	25.54	25.81	27.24	7.32	5.29	1.67
Reform	0.234	0	0	0	0	22.01	24.09	25.72	28.18	6.23	6.25	1.67
Earnings												
Benchmark	0.550	0	0	0	0	5.52	14.40	21.45	58.63	17.18	15.18	3.18
Reform	0.551	0	0	0	0	5.49	14.40	21.37	58.74	17.60	12.58	5.70
Assets												
Benchmark	0.772	0	0	0	0	0.06	2.71	13.40	83.83	26.66	25.68	7.49
Reform	0.791	0	0	0	0	0.00	1.72	13.05	85.23	25.07	31.00	7.44
Consumption												
Benchmark	0.387	0.16	0.58	1.35	4.83	11.71	14.71	22.59	46.17	11.46	11.48	2.73
Reform	0.383	0.17	0.59	1.38	4.92	10.52	16.51	20.93	47.12	11.92	10.64	3.00

In our setup, steady state welfare refers to the welfare of newborns. A higher/lower welfare of newborns in a distant future does not translate into a higher/lower welfare for the current population. We turn to evaluate the welfare gain of the current population along the transitional dynamics. We assume that the consumption tax reform is unanticipated and that households have perfect foresight. Throughout the transition, the consumption tax and the replacement ratio are adjusted period by period to maintain the balanced government budget and the self-financed social security system.

The transition paths are shown in Figure 11. Upon the implementation of the reform, consumption drops, and the tax rate τ_c surges. As time passes, capital is gradually accumulated, which in turn causes consumption to rise. Higher consumption expands the tax base, and the tax rate falls.

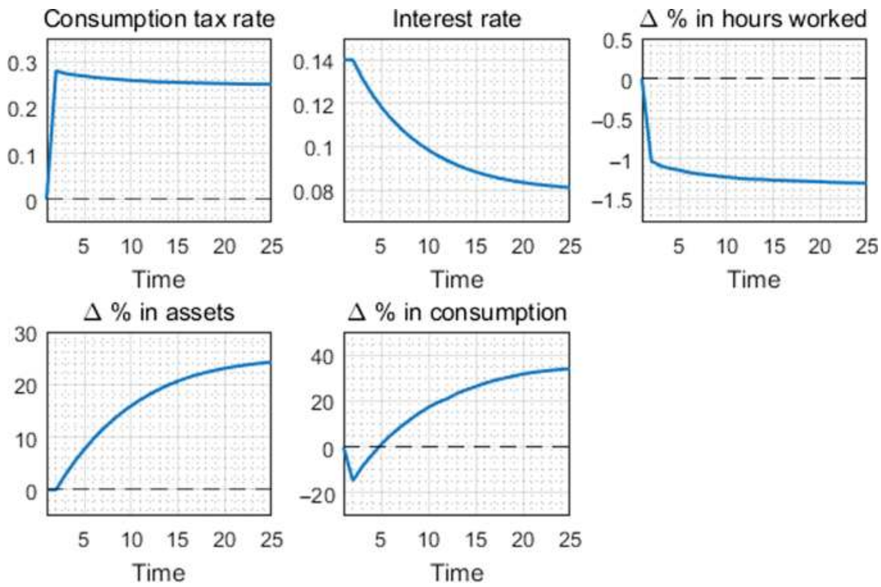

Figure 11: Transition paths, without durables.

The last three rows in Table 4 are the average welfare gain of the current population in terms of the consumption equivalent and its aggregate and redistribution components on the impact of the reform.[15] The average welfare gain is 0.57%, meaning that there is an immediate welfare improvement as a result of the reform. Because the aggregate consumption drops immediately after the reform and takes nearly 5 periods (10 years) to recover before eventually converging to the new high steady state (Figure 11), the aggregate component, which captures the welfare gain that comes from the change in efficiency, is only −2.73%. Lastly, the consumption tax reform improves equity with a redistribution component of 3.39%.

To better understand the above results and to see who is in favor of the reform, Figure 12 plots the welfare gain of the current population by age and Figure 13 further decomposes the welfare gain by labor type. The main finding is that young and poor households receive the most substantial improvement in welfare.

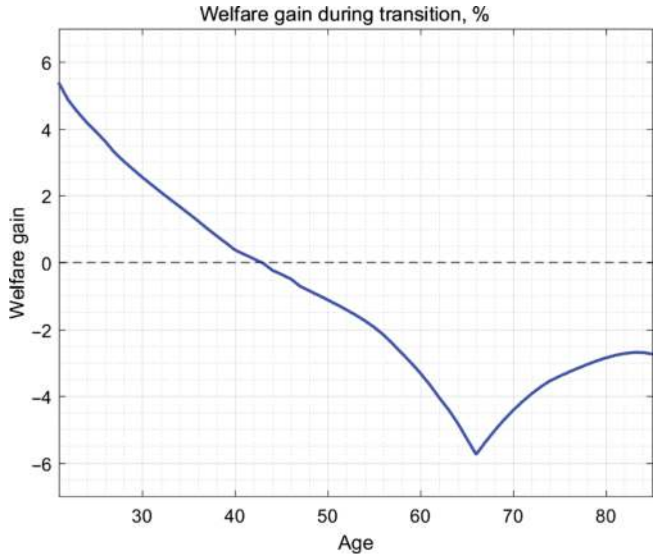

Figure 12: Short-run welfare gain by age, without durables.

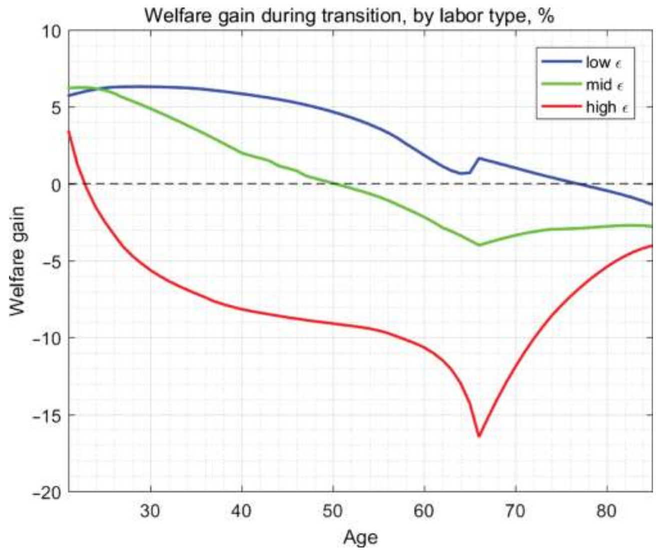

Figure 13: Short-run welfare gain by age and type, without durables.

During the transition, the interest rate gradually falls, and the wage increases accordingly; households who are more dependent on labor income than on asset income are potentially better off. Similar results have been shown and proven by Correia (2010) in an infinite horizon model at both the steady state and transition, and by Seidman (1984) in an overlapping generation model at the steady state. What is new to an OLG model with transitional dynamics is that how much time a household remains in the economy is also crucial to determining its welfare gain. For households with relatively more earnings than asset income, the younger they are, the more time they can wait for the eventual higher wage to arrive and take advantage of it. Thus, as shown in Figure 13, younger households tend to have greater welfare gain than older cohorts.

Overall, during the transition, both age and the composition of income play important roles in determining the individual welfare gain. The size of the welfare gain/loss depends on the relative strength of these two aspects. With young and poor households improving their well being, the reform delivers favorable redistribution.

4.2 Results with durables

Next, we consider the situation with consumer durables. The households solve the maximization problem described in Section 2.9. In this section, we assume that the reform imposes an equal tax rate on durables and nondurables. This experiment is labeled "Equal rate" and will be referred to as the benchmark experiment. In the next section, I allow the tax rates to differ across consumption.

The post-reform budget constraint and the borrowing constraint become:

$$(1 + \tau_c)(c + d' + m - (1 - \delta^d)d) + a' = (1 + r)a + y - \mathbf{1}_{\{j \leq J_0\}} ss \tag{1}$$

$$a' \geq -(1 - \theta)d'. \tag{2}$$

Here durables are taxed based on the difference in their stock between two periods. The borrowing constraint keeps the same format as that of pre-reform, meaning that the borrowing limit is still $(1 - \theta)$ fraction of the durable stock.

The same as before, the aggregate capital increases following the consumption tax reform, shown in Table 4; Figure 14 shows that middle-aged households experience the largest increase in capital accumulation; and earnings increase the most for more productive households, as exhibited in Figure 15.

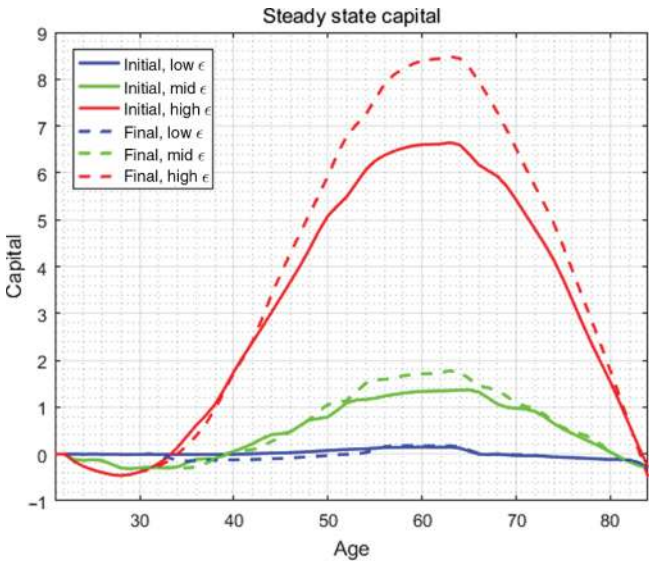

Figure 14: Steady state capital, with durables.

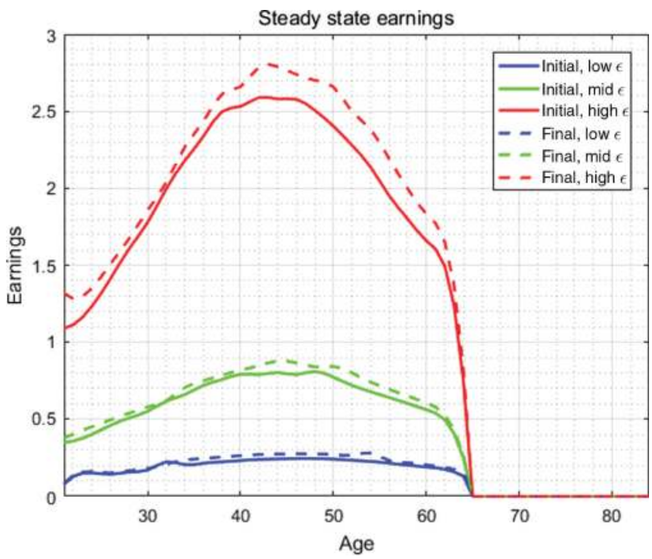

Figure 15: Steady state earnings, with durables.

What is new in this case is associated with the endogenous borrowing constraint introduced by durables. For the pre-reform economy, we rearrange the intertemporal conditions for financial assets and durables to obtain three essential conditions for c and d'[16]

$$c + a' + d' - (1 - \mathbf{1}_m \mu)(1 - \delta^d)d = (1 + r)a + y - Tax \tag{3}$$

$$a' + (1 - \theta)d' \geq 0 \tag{4}$$

$$\begin{cases} \frac{\partial u}{\partial d'} = \beta\phi'(1 + (1 - \tau_a)r - (1 - \mu)(1 - \delta^d))E\frac{\partial u}{\partial c'} + \theta\zeta, & \text{if } d' \neq (1 - \delta^d)d \\ \frac{\partial u}{\partial c} = \beta\phi'(1 + (1 - \tau_a)r)E\frac{\partial u}{\partial c'} + \zeta, & \text{if } d' = (1 - \delta^d)d \end{cases} \quad (5)$$

where ζ is the Lagrangian multiplier associated with the borrowing constraint, it is greater than 0 when households are liquidity constrained, and 0 otherwise; $\mathbf{1}_m\mu$ is an indicator function, it equals to 1 if an adjustment takes place, and 0 otherwise. Repeating the arrangement for the post-reform economy, we have:

$$(1 + \tau_c)c + a' + (1 + \tau_c)(d' - (1 - \mathbf{1}_m\mu)(1 - \delta^d)d) = (1 + r)a + y - Tax \quad (6)$$

$$a' + (1 - \theta)d' \geq 0 \quad (7)$$

$$\begin{cases} \frac{\partial u}{\partial d'} = \beta\phi'(r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c'} + (\theta + \tau_c)\zeta, & \text{if } d' \neq (1 - \delta^d)d \\ \frac{\partial u}{\partial c} = \beta\phi'(1 + r)E\frac{\partial u}{\partial c'} + (1 + \tau_c)\zeta, & \text{if } d' = (1 - \delta^d)d \end{cases} \quad (8)$$

.

The comparison between Equation (3),(4) and Equation (6),(7) implies that the reform increases the "prices" of nondurables and durables from 1 to $1 + \tau_c$ but does not alter the format of the borrowing constraint, i.e. the borrowing limit is still $(1 - \theta)$ fraction of the value of durable stock d'. Intuitively, when prices increase but the borrowing limit is unchanged, it is in fact that the borrowing constraint gets tightened. When the ability to borrow to insure against income risk decreases, the economy deviates further away from market completeness toward an incomplete market. As a result, nondurable and durable consumption fall by 3.06% and 4.77%, respectively, and the long run average welfare gain drops by 2.65%, shown in Table 4.

A tighter borrowing constraint has more adverse effects on young and poor households. In addition, young and poor households are more likely to be liquidity constrained, and thus are subject to an increased marginal cost of accumulating durables. To see this, compare Equation (5) with Equation (8); if a liquidity constrained household was to increase the durable stock, the reform would increase the additional marginal cost caused by being liquidity constrained from $\theta\zeta$ to $(\theta + \tau_c)\zeta$. Figure 16 reflects this change. Due to the unaffordability of durables, young households either postpone or downsize durable consumption.

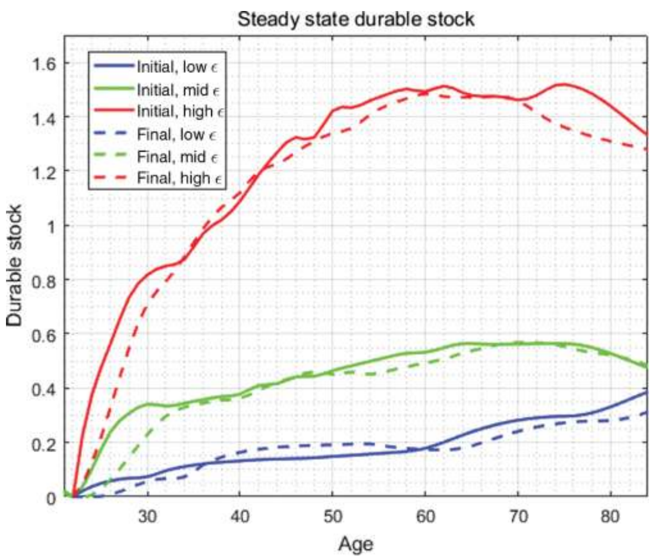

Figure 16: Steady state durables, with durables.

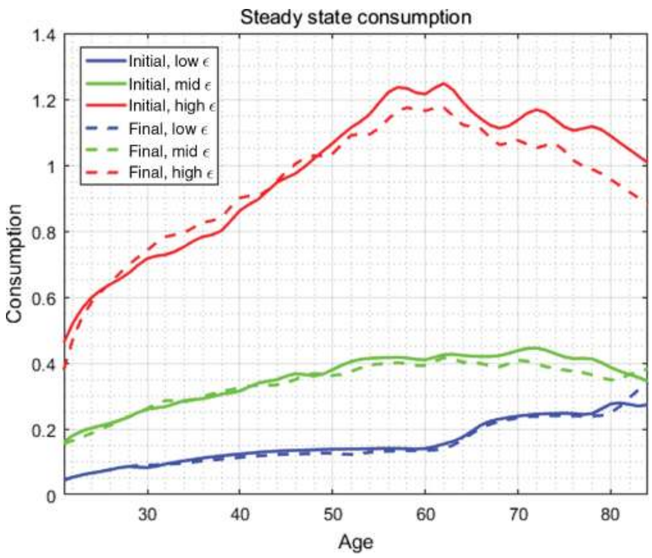

Figure 17: Steady state nondurable consumption, with durables.

One thing worth mentioning is that shifting from income taxes to consumption taxes, on the one hand, increases the "prices" of consumption; on the other hand, boosts young and poor households' income by increasing their wages. In a conventional case without durables, the increase in income outweighs the increase in tax payments, making young and poor households enjoy more consumption and be better off. However, in the current setup, the negative consequences of a tighter borrowing constraint on young and poor households outweighs the increase in their income, reducing both durable and nondurable consumption (see Figure 17) and leading to a welfare loss.

With durables being disproportionally less preferable for young and poor households, a consumption tax reform deteriorates the distribution of durables, as reflected by a more concentrated distribution at the top, as reported in Table 6. The Gini index of financial assets also increases slightly, from 0.92 to 0.930. The comparison of the distribution of financial assets before and after the reform reveals that households in the first quintile actually increase their share of aggregate capital after the reform. This is exactly because the unaffordability of durables resulted from the consumption tax reform shifts durable holdings toward financial assets. With durables and financial assets becoming more unevenly distributed post-reform, the Gini index of total assets increases from 0.70 to 0.72.

Table 6: Steady state distribution, with durable.

	Gini	Bottom			Quintiles					Top		
		Bot1	Bot1-5	Bot5-10	Q1	Q2	Q3	Q4	Q5	Top10-5	Top5-1	Top1
Labor supply												
Benchmark	0.255	0	0	0	0	19.69	25.39	26.42	28.49	6.98	6.29	1.21
Equal rate	0.249	0	0	0	0	18.87	27.02	26.10	28.00	7.33	5.89	1.45
Optimal	0.252	0	0	0	0	19.90	25.01	25.81	29.27	6.96	6.76	1.21
Earnings												
Benchmark	0.554	0	0	0	0	5.24	14.01	21.93	58.81	17.64	16.02	3.01
Equal rate	0.552	0	0	0	0	5.26	14.46	21.47	58.79	17.65	13.71	5.32
Optimal	0.552	0	0	0	0	5.22	14.15	21.91	58.71	16.90	15.13	4.49
Total wealth												
Benchmark	0.696	0	0.12	0.23	0.84	1.67	5.96	15.19	76.33	21.19	23.99	6.42
Equal rate	0.716	0	0.10	0.18	0.67	1.13	5.11	15.46	77.62	23.87	23.76	7.16
Optimal	0.702	0	0.09	0.16	0.54	1.27	5.82	15.56	76.80	21.26	24.75	6.43
Financial assets												
Benchmark	0.921	−0.67	−1.92	−1.90	−6.77	−1.47	1.09	13.73	93.42	28.83	29.347	8.23
Equal rate	0.930	−0.56	−1.81	−1.12	−6.11	−2.39	0.67	14.22	93.60	29.08	30.98	8.88
Optimal	0.896	−0.47	−1.54	−0.94	−5.18	−2.01	1.44	13.95	91.80	27.16	31.67	7.76

Durables												
Benchmark	0.431	0	0.36	0.92	4.61	10.55	14.35	21.71	48.77	12.29	11.19	3.51
Equal rate	0.411	0	0.34	0.88	3.31	10.96	13.81	22.11	49.81	14.88	12.05	2.94
Optimal	0.415	0	0.29	1.18	4.41	10.31	14.32	21.92	49.04	12.91	12.40	3.08
Nondurable consumption												
Benchmark	0.401	0.20	1.01	0.91	4.67	6.67	15.11	17.89	55.66	14.45	17.23	11.92
Equal rate	0.393	0.11	0.94	1.19	5.00	7.73	16.56	20.22	50.48	14.24	12.95	12.35
Optimal	0.397	0.24	1.05	1.29	5.56	6.63	15.29	21.48	51.03	12.18	15.56	12.38

The transition paths of the aggregate variables and prices are very similar to those in the case without durables, as shown in Figure 18. In addition, the aggregate durable stock also falls immediately following the reform due to a sudden increase in consumption taxes.

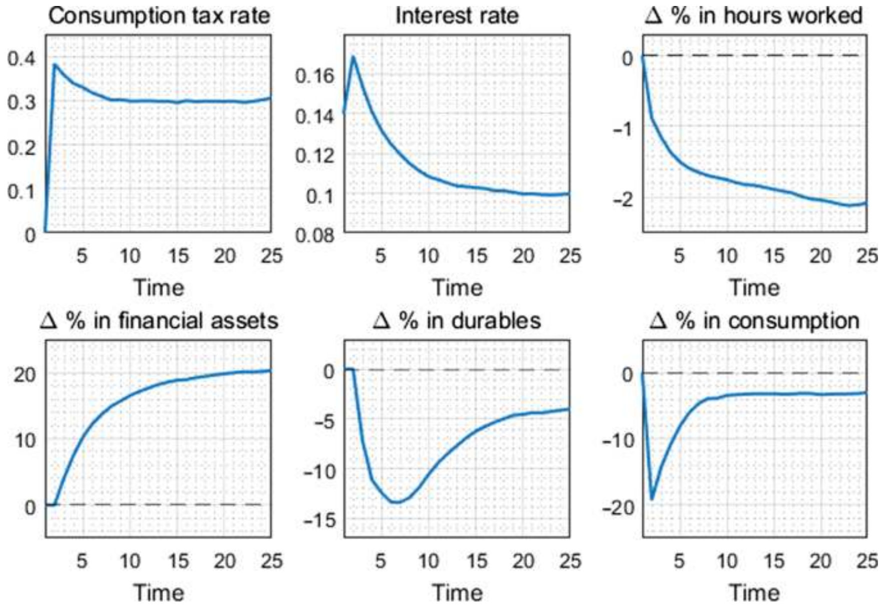

Figure 18: Transition paths, with durables.

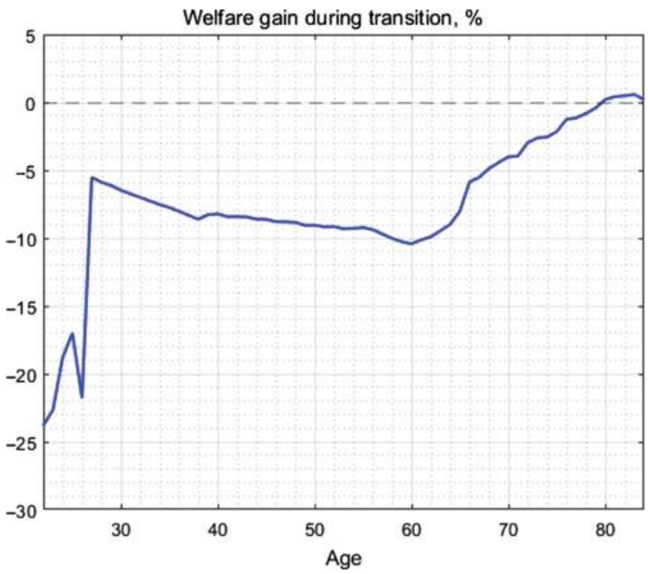

Figure 19: Short-run welfare gain by age, with durables.

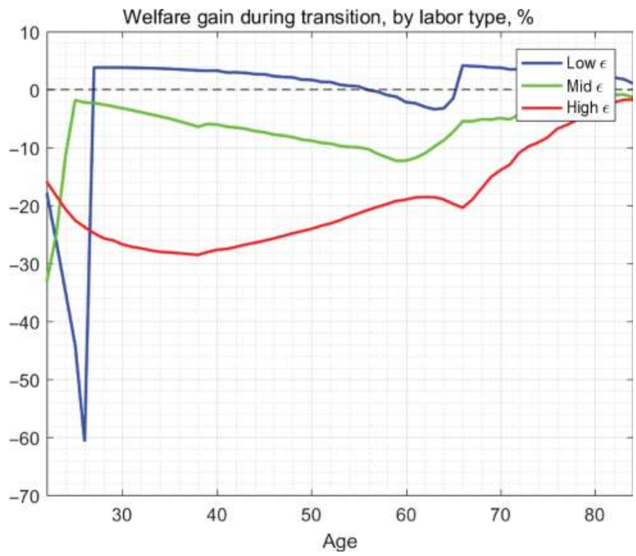

Figure 20: Short-run welfare gain by age and type, with durables.

The large drop in nondurables and durabls immediately following the tax reform and their slow recovery inevitably yields a negative aggregate component of the welfare gain Δ_{agg}^{SR} = -5.51%. As we analyzed above, the consumption tax reform hurts young and poor households most badly at steady state. This adverse effect is even stronger during the transition. At the final steady state, the wage rate has already increased, and young and poor households can fully take advantage of higher earnings; whereas during the transition, the wage remains low, current young and poor households suffer more from low wages but high consumption taxes, as shown in Figure 19 and Figure 20. As a result, the redistribution component Δ_{dist}^{SR} plunges to −4.42%. The unfavorable redistribution adds to the negative aggregate component, further dragging down the welfare gain: the average immediate welfare loss in terms of the consumption equivalent Δ^{SR} is 9.69%.

4.3 Robustness

This section performs various robustness checks to assess how the model parameterization affects the results. We change one parameter at a time, keeping the other parameters as in the benchmark economy. Table 7 presents the steady state results of experiments with different parameters. K_0, D_0 and C_0 are the aggregate capital, durables and nondurable consumption at the initial steady state, $\Delta\ K$, ΔD and ΔC corresponds to the change of these variables by the reform, K_0/Y, K_1/Y_1, C_0/D_0 and C_1/D_1 are the capital-to-output ratio, non-durable to durable ratio before and after the reform.

Table 7: Robustness, aggregate variables.

	Experiments	τ_c %	K_0[a]	ΔK[b] %	D_0	ΔD %	C_0	ΔC %	K_0/Y_0[c]	K_1/Y_1[d]	C_0/D_0	C_1/D_1	ΔWel[e] %
	Benchmark	32.05	0.91	20.10	0.63	−4.77	0.51	−3.06	0.93	1.07	0.81	0.83	−2.65
1	tighter CC	32.05	0.91	28.69	0.63	−6.57	0.51	−2.27	0.93	1.15	0.81	0.84	−2.79
2	relaxed CC	32.25	0.91	16.02	0.63	−3.76	0.51	−3.52	0.93	1.09	0.81	0.81	−2.41
3	$\theta = 0$	44.98	1.51	1.91	0.90	−40.96	0.68	−36.82	0.97	1.12	0.75	0.84	−32.63
4	$\theta = 1.0$	31.94	0.94	13.82	0.61	−0.03	0.53	−3.41	0.92	1.04	0.84	0.87	−2.42
5	$\mu = 0$	32.36	0.89	29.91	0.68	1.45	0.52	−1.57	0.93	1.18	0.75	0.73	−2.38
6	$\mu = 0.1$	30.21	0.92	15.72	0.62	−2.84	0.53	−2.81	0.94	1.11	0.84	0.88	−2.59
7	$\xi = -0.4$	32.57	0.89	31.31	0.71	0.68	0.51	−2.75	0.91	1.07	0.70	0.68	−2.92
8	$\xi = 0.4$	31.89	0.95	27.91	0.61	−0.89	0.53	−3.29	0.97	1.22	0.86	0.86	−2.28

[a] K_0, C_0 and D_0 represent the initial steady state capital, nondurable consumption and durable consumption stock, respectively.
[b] ΔK, ΔC and ΔD are the percentage changes in capital, nondurable consumption and durable consumption stock from their initial steady states.
[c] K_0/Y_0 and C_0/D_0 are the initial steady state capital to output ratio and the ratio between nondurables and durables.
[d] K_1/Y_1 and C_1/D_1 are the final steady state capital to output ratio and the ratio between nondurables and durables.
[e] ΔWel is the consumption equivalent of the welfare gain, represented in percentage.

4.3.1 Changing the post-reform borrowing constraint

In the previous subsection we understand that the welfare loss comes from a relatively tightened borrowing constraint, such that the post-reform economy moves further away from market completeness. To further analyze the extent to which the post-reform borrowing constraint affects the results, we conduct two robustness experiments in this part. The first experiment is with an even tighter post-reform borrowing constraint, i.e. a zero borrowing constraint, labeled as "Experiment 1". The other experiment, labeled as "Experiment 2", assumes that the relative tightness of the post-reform borrowing constraint remains the same as before.

In the case with a zero borrowing constraint, the post-reform budget constraint and borrowing constraint become

$$(1+\tau_c)c + a' + (1+\tau_c)(d' - (1-\mathbf{1}_m\mu)(1-\delta^d)d) = (1+r)a + y - Tax \tag{9}$$

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

Comparing with Equation (6) and Equation (7) in the previous section, the current post-reform borrowing constraint is even tighter, implying that the consumption tax reform has brought more incompleteness into the economy.

Moreover, the post-reform Euler equation corresponding to Equation (5) becomes

$$\begin{cases} \frac{\partial u}{\partial d'} = \beta\phi'(r+\mu+\delta^d-\mu\delta^d)E\frac{\partial u}{\partial c'} + (1+\tau_c)\zeta, & \text{if } d' \neq (1-\delta^d)d \\ \frac{\partial u}{\partial c} = \beta\phi'(1+r)E\frac{\partial u}{\partial c'} + (1+\tau_c)\zeta, & \text{if } d' = (1-\delta^d)d \end{cases} \tag{11}$$

If a liquidity constraint household was to increase durables, the additional marginal cost $(1+\tau_c)\zeta$ is even larger than that in the benchmark experiment $(\theta+\tau_c)\zeta$ (see Equation (8)).

Therefore, a zero post reform borrowing constraint, to a greater extent, exacerbates market incompleteness and hurts young, poor and liquidity constrained households. Table 7 and Table 8 show that durable stock drops by 6.57%, the biggest decline in this set of experiments, coupled with a higher Gini index of 0.43. Because of the unaffordability of durables, households substitute with more nondurable consumption, so nondurable consumption decreases by only 2.27%. As expected, when borrowing is not allowed, the financial assets increase with the largest magnitude of 28.69%. Overall, the tightened post-reform borrowing constraint reduces welfare by 2.79%.

Table 8: Robustness, Gini indexes.

	Experiments	$Gini_c$		$Gini_d$		$Gini_h$	
		pre[a]	post[b]	pre	post	pre	post
	Benchmark	0.401	0.393	0.431	0.411	0.255	0.249
1	tighter CC	0.401	0.388	0.431	0.433	0.255	0.251
2	relaxed CC	0.401	0.405	0.431	0.412	0.255	0.250
3	$\theta = 0$	0.249	0.389	0.267	0.427	0.318	0.252
4	$\theta = 1.0$	0.416	0.403	0.442	0.422	0.252	0.251
5	$\mu = 0$	0.409	0.406	0.439	0.417	0.257	0.253
6	$\mu = 0.1$	0.358	0.393	0.412	0.416	0.300	0.249
7	$\xi = -0.4$	0.401	0.393	0.419	0.407	0.260	0.254
8	$\xi = 0.4$	0.403	0.394	0.444	0.430	0.255	0.247

[a]"Pre" denotes the initial steady state before the reform.
[b]"Post" denotes the final steady state after the reform.

Next, we experiment on a post-reform borrowing constraint, which maintains the same tightness as that in the benchmark economy. Specifically, we have post-reform budget constraint and borrowing constraint as follows:

$$(1+\tau_c)c + a' + (1+\tau_c)(d' - (1-\mathbf{1}_m\mu)(1-\delta^d)d) = (1+r)a + y - Tax \tag{12}$$

$$a' + (1+\tau_c)(1-\theta)d' \geq 0 \tag{13}$$

When the "price" of durables increases by $(1 + \tau_c)$, the borrowing constraint is also relaxed by $(1 + \tau_c)$. In this case, the relative tightness of borrowing constraint remains unchanged.

For the liquidity constrained households, their marginal cost of accumulating durables increases to $\theta(1 + \tau_c)\zeta$, lesser than that in the benchmark experiment. This come from comparing the following post reform Euler equation with Equation (8):

$$\begin{cases} \frac{\partial u}{\partial d'} = \beta\phi'(r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c'} + \theta(1 + \tau_c)\zeta, & \text{if } d' \neq (1 - \delta^d)d \\ \frac{\partial u}{\partial c} = \beta\phi'(1 + r)E\frac{\partial u}{\partial c'} + (1 + \tau_c)\zeta, & \text{if } d' = (1 - \delta^d)d. \end{cases} \tag{14}$$

With a more relaxed post-reform borrowing constraint, the welfare loss reduces to 2.41%.

4.3.2 Changing the down payment ratio θ

The benchmark experiment shows that a consumption tax reform actually tightens borrowing constraints and results in a welfare loss. The comparison between the pre- and post-reform budget constraints, borrowing constraints and first order conditions shows that the smaller the θ, the stronger the effect.

To see this, we consider two extreme cases $\theta = 0$ and $\theta = 1$, labeled as "Experiment 3" and "Experiment 4", respectively.

When $\theta = 0$, no down payment is needed to acquire a durable good. At the initial steady state, households of any income level can own durables without a cost, as explained by a high D_0. Once the reform takes place, a consumption tax is imposed to possess durables. Without the relaxation of borrowing constraints, households with an income below a certain level can no longer afford a durable good because they cannot afford the tax payments. A lower θ makes more households subject to a tighter post-reform borrowing constraint. Consequently, the change in aggregate durable stock is sizable, the Gini index of durables also increases drastically and the aggregate welfare drops by 32.63%.

In contrast, with a 100% down payment, the borrowing constraint degenerates to $a' \geq 0$. At the initial economy, only households with a sufficient amount of income can afford durables. After the reform, some of these families can no longer afford durables due to the tax, but the percentage of such families is small. Hence, the overall impact of a consumption tax reform is milder and the welfare loss is lower.

4.3.3 Changing the adjustment cost μ

When the adjustment cost increases at the initial steady state, durables are more expensive to acquire, households shift from durable consumption to financial assets and nondurable consumption, as shown in Experiment 5 and 6 of Table 7. Because a consumption tax would also be imposed on adjustment costs, a larger adjustment cost makes durables less desirable and simultaneously crowds out nondurable consumption. Hence, increasing the adjustment cost reduces the welfare gain of the reform.

4.3.4 Changing the elasticity ξ between *C* and *D*

The elasticity of substitution between durable and nondurable consumption affects the fraction of expenditures on each good and the extent to which a consumption tax reform would have an impact. At the initial steady state, when the elasticity of substitution is high, the resources are shifted from durables toward financial assets and nondurable consumption. We experiment with the elasticity of substitution being 0.71 ($\xi = -0.4$) and 1.67 ($\xi = 0.4$), and the results are shown with labels 7 and 8 in Table 7. With the consumption tax reform being unfavorable to durable consumption, a larger elasticity of substitution mitigates the adverse effect on durables by allocating more resources to nondurables and less to durables. Thus, the welfare loss decreases with the elasticity of substitution.

5 The optimal consumption tax structure

In this section, we explore the optimal consumption tax combination of durables and nondurables. By optimal, we mean the tax code that yields the highest welfare gain of the current population. We study the reforms that involve moving from the current income tax system to a range of consumption taxes on durables between −50% and 150%, and the tax on nondurables is adjusted to balance the government budget.

The top left panel in Figure 21 describes the steady state tax rates on durables and nondurables. Let τ_c denote the tax on nondurables and τ_d be the tax on durables. When more of the tax burden is borne by durables, nondurable consumption is subject to lower tax rates.

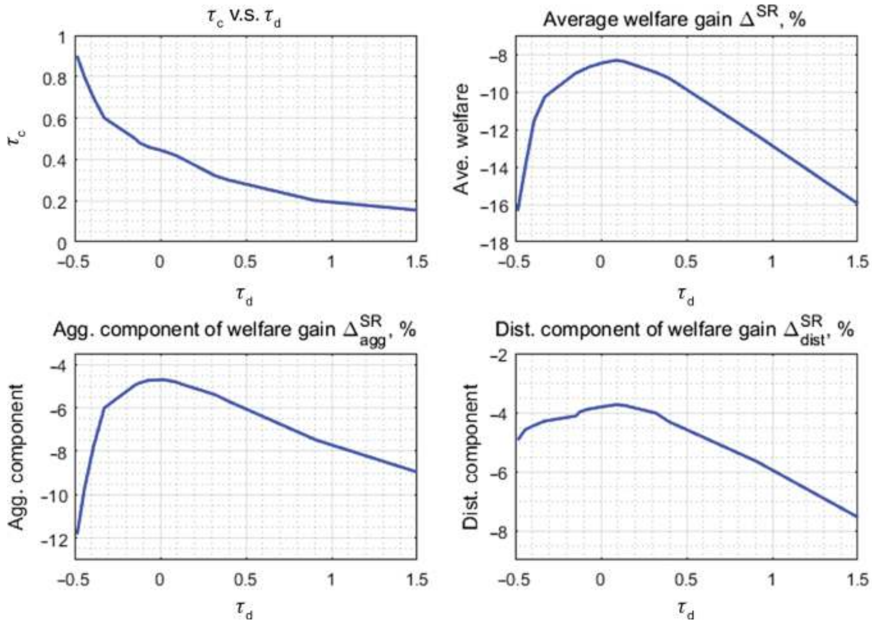

Figure 21: Short-run welfare gains with different τ_c and τ_d combinations.

With differential tax rates on durable and nondurable consumption, the post-reform equations that correspond to Equation (6), (7) and Equation (8) become

$$(1+\tau_c)c + a' + (1+\tau_d)(d' - (1-\mathbf{1}_m\mu)(1-\delta^d)d) = (1+r)a + y - Tax \tag{15}$$

$$a' \geq (1-\delta^d)d' \tag{16}$$

$$\begin{cases} \frac{\partial u}{\partial d'} = \beta\phi' \frac{1+\tau_d}{1+\tau_c}(r+\mu+\delta^d-\mu\delta^d)E\frac{\partial u}{\partial c'} + (\theta+\tau_d)\zeta, & \text{if } d' \neq (1-\delta^d)d \\ \frac{\partial u}{\partial c} = \beta\phi'(1+r)E\frac{\partial u}{\partial c'} + (1+\tau_c)\zeta, & \text{if } d' = (1-\delta^d)d \end{cases} \tag{17}$$

From the previous analysis, we know that the optimal tax structure is the one in which the post-reform borrowing constraint does not become too tight and the additional term in the marginal cost of accumulating durables for liquidity constrained households is not too large.

The remaining panels in Figure 21 present the average welfare gain and its aggregate and redistribution components on the impact of the reform. The aggregate component of the welfare gain exhibits a humped shape as the tax burden shifts between durables and nondurables. When τ_d is negative, the borrowing constraint is more relaxed and the marginal cost of accumulating durables by liquidity constrained households is reduced. However, a low τ_d is accompanied by a high τ_c, which largely discourages the consumption of nondurable goods, such that the aggregate component of the welfare gain drops. On the other hand, when τ_d becomes higher, the post reform borrowing constraint becomes tighter, depressing both durable accumulation and nondurable consumption, and the aggregate component of the welfare gain also falls. The distribution component exhibits a slight hump, with more negative redistribution at a high τ_d because it increases the cost of accumulating durables for liquidity constrained households.

Overall, the optimality occurs at τ_c = 42% and τ_d = 9%. Even with the most preferable tax combination on durables and nondurables, the economy still diliver a welfare loss of 1.09% in the long run and of 8.24% in the short run, with aggregate and redistribution components of −4.71% and −3.70%, respectively. This result implies that a conventional environment that does not distinguish between durables and nondurables overstates the welfare gain and the redistribution effects of a consumption tax reform.

Because the optimal scheme taxes nondurable consumption more heavily than durables, shown in the last two columns of Table 4, households substitute more durables for nondurables. The distribution of variables are presented in Table 6. With the optimal taxation, financial assets and total wealth are also more equally distributed.

6 Conclusion

This paper investigates the welfare effects of a consumption tax reform in an economy with durable consumption. The main message is that the conventional analysis (with a single nondurable consumption) of consumption tax reform might overstate its welfare gains and equity improvement.

The paper began with a conventional setup that does not distinguish between durables and nondurables. The experiment that replaces income taxes with consumption taxes while keeping government revenue neutral agrees with the previous literature that such reforms can improve efficiency and welfare at the steady state. When taking the transition into account, the short run welfare gain is 0.57%, with a positive redistribution component. We discover two channels through which redistribution will be affected: age and the composition of income. In general, the younger the households are, and/or the more the households rely on labor earnings, the larger the welfare gain.

Next, we incorporate durables into the model and assume that the borrowing constraint endogenously depends on durable stock. We conduct the above experiment with an equal tax rate on both durables and nondurables. Similar to the previous case, a consumption tax reform boosts capital accumulation and efficiency in the long run. However, in this new environment the consumption tax reform imposes a tax on durables without relaxing the borrowing constraint, which effectively tightens the borrowing constraint, deviating the economy further away from market completeness. The resulting welfare loss is 2.65% in the long run and 9.69% in the short run, coupled with a deteriorated distribution. In addition, in contrast with the previous case, we find that young and poor households are subject to the most substantial welfare loss.

Lastly, this paper calculated the optimal tax mix on durables and nondurables and found that when durables are subject to a 9% tax rate and nondurables 42%, the resulting welfare gain is the largest. However, on average, the economy would still experience a long run welfare loss of 1.09% and a short run welfare loss of 8.24%, coupled with a negative redistribution component of −3.70%.

We conclude that durables play important roles in households portfolios over the life cycle, thus ignoring durables while studying tax reforms will lead to biased results.

A Definition of welfare gain

A.1 Welfare gain without durables

The welfare gain and the decomposition of the welfare gain are defined in the same way as Domeij and Heathcote (2004), except that we have overlapping generations and that the long-run and short-run welfare gain take different forms.

Specifically, the long run average welfare gain is defined as how much consumption need to be given to newborns in the future in order for them to be indifferent about the reform. Let c_j^{NR} and c_j^R are pre- and post-reform consumption of a newborn household at age j, similarly, l_j^{NR} and l_j^R are the hours worked (note that hours worked becomes 0 after retirement age J_0), then the long run average welfare gain Δ^{LR} is the solution of the following equation,

$$\int_{A\times E} E\sum_{j=1}^{J} 1\beta^j(\Pi_{s=1}^{j}\phi_s)\left(\frac{(c_j^R)^{1-\sigma}}{1-\sigma} - B\frac{(l_j^R)^{1+1/\chi}}{1+1/\chi})d\hat{\Psi}_1^R(a,\epsilon\right)$$

$$= \int_{A\times E} E\sum_{j=1}^{J} 1\beta^j(\Pi_{s=1}^{j}\phi_s)\left(\frac{((1+\Delta^{LR})c_j^{NR})^{1-\sigma}}{1-\sigma} - B\frac{(l_j^{NR 1+1/\chi}}{1+1/\chi}\right)d\hat{\Psi}_1^{NR}(a,\epsilon),$$

where $\hat{\Phi}_1^{NR}(a,\epsilon)$ and $\hat{\Phi}_1^{R}(a,\epsilon)$ are the conditional cumulative distribution function over assets a and labor efficiency ϵ at age 1 pre- and post-reform. These conditional cumulative distribution functions are different from $\tilde{\Psi}_1(a,d,\epsilon)$ where durables d are also an argument.

The short-run welfare gain are in term of the consumption equivalent of the current population. Let Δ^{SR} denote the immediate average welfare gain of the current population in terms of the consumption equivalent, then it is the solution of the following equation

$$\sum_{j=1}^{J_1}\psi_j\int_{A\times E}E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j+1}^{t}\phi_s)\left(\frac{(c_t^R)^{1-\sigma}}{1-\sigma}-B\frac{(l_t^R)^{1+1/\chi}}{1+1/\chi}\right)d\hat{\Psi}_j^R(a,\epsilon)$$
$$=\sum_{j=1}^{J_1}\psi_j\int_{A\times E}E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j+1}^{t}\phi_s)\left(\frac{((1+\Delta^{LR})c_t^{NR})^{1-\sigma}}{1-\sigma}-B\frac{(l_t^{NR})^{1+1/\chi}}{1+1/\chi}\right)d\hat{\Psi}_j^{NR}(a,\epsilon)$$

Define $\hat{c}_j^R=\hat{c}_j^{NR}\frac{C^R}{C^{NR}}$, where C^{NR} and C^R are the aggregate consumption pre- and post-reform. Similarly, $\hat{l}_j^R=\hat{l}_j^{NR}\frac{H^R}{H^{NR}}$, where H^{NR} and H^R are aggregate hours worked pre- and post-reform. The aggregate component of the short run welfare gain $\Delta_{agg}^{SR}$is the solution of the following equation

$$\sum_{j=1}^{J_1}\psi_j\int_{A\times E}E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j+1}^{t}\phi_s)\left(\frac{(\hat{c}_t^R)^{1-\sigma}}{1-\sigma}-B\frac{(\hat{l}_t^R)^{1+1/\chi}}{1+1/\chi}\right)d\hat{\Psi}_j^R(a,\epsilon)$$
$$=\sum_{j=1}^{J_1}\psi_j\int_{A\times E}E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j+1}^{t}\phi_s)\left(\frac{((1+\Delta^{LR})c_t^{NR})^{1-\sigma}}{1-\sigma}-B\frac{(l_t^{NR})^{1+1/\chi}}{1+1/\chi}\right)d\hat{\Psi}_j^{NR}(a,\epsilon)$$

At last, the redistribution component Δ_{dist}^{SR} is

$$\Delta_{dist}^{SR}=(1+\Delta^{SR})/(1+\Delta_{agg}^{SR})-1.$$

A.2 Welfare gain with durables

Here the consumption equivalent is defined as how much more consumption bundle of durables and non-durable $(\gamma c_j^{\xi}+(1-\gamma)d_{j+1}^{\xi})^{1/\xi}$ should be given in order for a newborn household to be indifferent about the reform. Specifically, denote the average long run welfare gain as Δ^{LR}. It solves the following equation:

$$\int_{A\times D\times E}E\sum_{j=1}^{J_1}\beta^j(\Pi_{s=1}^{j}\phi_s)\left[\frac{\left((\gamma(c_j^R)^{\xi}+(1-\gamma)(d_{j+1}^R)^{\xi})^{1/\xi}\right)^{1-\sigma}}{1-\sigma}-B\frac{(l_j^R)^{1+1/\chi}}{1+1/\chi}\right]d\tilde{\Psi}_1^R(a,d,\epsilon)$$
$$=\int_{A\times D\times E}E\sum_{j=1}^{J_1}\beta^j(\Pi_{s=1}^{j}\phi_s)\left[\frac{\left((1+\Delta^{LR})(\gamma(c_j^{NR})^{\xi}+(1-\gamma)(d_{j+1}^{NR})^{\xi})^{1/\xi}\right)^{1-\sigma}}{1-\sigma}-B\frac{(l_j^{NR})^{1+1/\chi}}{1+1/\chi}\right]d\tilde{\Psi}_1^{NR}(a,d,\epsilon),$$

where c^{NR} and c^R are household nondurable consumption over time if there is no reform and if there is a reform. Other variables are interpreted in the same way. $\tilde{\Psi}_1$ is the conditional cumulative distribution function at age 1.

Similar to the long run welfare gain, here the consumption equivalent is defined as how much more consumption bundle of durables and nondurable $(\gamma c^{\xi}+(1-\gamma)d^{\xi})^{1/\xi}$ should be given in order for the existing households to be indifferent about the reform. Let Δ^{SR} denote the average welfare gain in the short run. It solves the following equation:

$$\sum_{j=1}^{J_1}\psi_j\int_{A\times D\times E}E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j+1}^{t}\phi_s)\left[\frac{\left((\gamma(c_t^R)^{\xi}+(1-\gamma)(d_{t+1}^R)^{\xi})^{1/\xi}\right)^{1-\sigma}}{1-\sigma}-B\frac{(l_t^R)^{1+1/\chi}}{1+1/\chi}\right]d\tilde{\Psi}_j^{NR}(a,d,\epsilon)$$
$$=\sum_{j=1}^{J_1}\psi_j\int_{A\times D\times E}E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j+1}^{t}\phi_s)\left[\frac{\left((1+\Delta^{SR})(\gamma(c_t^{NR})^{\xi}+(1-\gamma)(d_{t+1}^{NR})^{\xi})^{1/\xi}\right)^{1-\sigma}}{1-\sigma}-B\frac{(l_t^{NR})^{1+1/\chi}}{1+1/\chi}\right]d\tilde{\Psi}_j^{NR}(a,d,\epsilon),$$

because Δ^{SR} captures the immediate welfare gain of the reform, the immediate distribution post-reform remains the same as if there is no reform.

We also define the aggregate component of the welfare gain in a similar way. Define

$$(\gamma(\hat{c}_j^R)^\xi + (1-\gamma)(\hat{d}_{j+1}^R)^\xi)^{1/\xi} = \left(\gamma(\hat{c}_j^{NR}\frac{C^R}{C^{NR}})^\xi + (1-\gamma)(\hat{d}_{j+1}^{NR}\frac{D^R}{D^{NR}})^\xi\right)^{1/\xi}$$
$$\hat{l}_j^R = \hat{l}_j^{NR}\frac{H^R}{H^{NR}}$$

Denote the short run aggregate component by Δ_{agg}^{SR}, it is the solution of the following equation:

$$\sum_{j=1}^{J_1}\psi_j\int_{A\times D\times E} E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j}^t\phi_s)\left[\frac{\left(\gamma(\hat{c}_t^R)^\xi + (1-\gamma)(\hat{d}_{t+1}^R)^\xi)^{1/\xi}\right)^{1-\sigma}}{1-\sigma} - B\frac{(\hat{l}_t^R)^{1+1/\chi}}{1+1/\chi}\right]d\tilde{\Psi}_j^{NR}(a,d,\epsilon)$$
$$=\sum_{j=1}^{J_1}\psi_j\int_{A\times D\times E} E\sum_{t=j}^{J_1}\beta^{t-j}(\Pi_{s=j}^t\phi_s)\left[\frac{((1+\Delta_{agg}^{SR})(\gamma(c_t^{NR})^\xi + (1-\gamma)(d_{t+1}^{NR})^\xi)^{1/\xi})^{1-\sigma}}{1-\sigma} - B\frac{(l_t^{NR})^{1+1/\chi}}{1+1/\chi}\right]d\tilde{\Psi}_j^{NR}(a,d,\epsilon).$$

Lastly, the short run redistribution component Δ_{dist}^{SR} is

$$\Delta_{dist}^{SR} = (1+\Delta^{SR})/(1+\Delta_{agg}^{SR}) - 1$$

B FOC for model with durables

The maximization problem of the benchmark economy is

$$\max_{\{c_j,d_{j+1},a_{j+1},l_j\}} E\sum_{j=1}^{J_1}\beta^j(\Pi_{s=1}^j)u(c_j,d_{j+1},l_j)$$

subject to

$$c_j + d_{j+1} + m_j + a_{j+1} = (1+r)a_j + y_j + (1-\delta^d)d_j - Tax_j$$
$$a_{j+1} + (1-\theta)d_{j+1} \geq 0$$
$$c_j > 0, d_{j+1} > 0, 0 < l_j \leq 1.$$

Let $\beta^j(\Pi_{s=1}^j)\lambda_j$ be the multiplier of the budget constraint, $\beta^j(\Pi_{s=1}^j)\zeta_j$ be the multiplier of the borrowing constraint, the rest of the constraints are slack. Then we have the Lagrangian function

$$\begin{aligned} L =& E\sum_{j=1}^{J_1}\beta^j(\Pi_{s=1}^j)\{u(c_j,d_{j+1},l_j) \\ &-\lambda_j(c_j + d_{j+1} + m_j + a_{j+1} - (1+r)a_j - y_j - (1-\delta^d)d_j + Tax_j) \\ &+\zeta_j(a_{j+1} + (1-\theta)d_{j+1})\}. \end{aligned}$$

Taking derivatives with respective the arguments:

$$\begin{aligned} c_j &: \frac{\partial u}{\partial c_j} = \lambda_j \\ a_{j+1} &: \lambda_j = \beta\phi_{j+1}(1+(1-\tau_a)r)E\lambda_{j+1} + \zeta_j \\ d_{j+1} &: \lambda_j = \beta\phi_{j+1}(1-\mu)(1-\delta^d)E\lambda_{j+1} + \frac{\partial u}{\partial d_{j+1}} + (1-\theta)\zeta_j, \text{ if } d' \neq (1-\delta^d)d \\ l_j &: \frac{\partial u}{\partial l_j} = \lambda_j\frac{\partial(y_j - Tax_j)}{\partial l_j}, \text{ if } j \leq J_0. \end{aligned}$$

Rearranging and we get the following intratemporal and intertemporal conditions:

$$\begin{aligned}
\frac{\partial u/\partial c_j}{\partial u/\partial l_j} &= \frac{1}{\partial(y_j - Tax_j)/\partial l_j}, \text{ if } j \le J_0 \\
\frac{\partial u}{\partial d_{j+1}} &= \beta\phi_{j+1}((1-\tau_a)r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c_{j+1}} + \theta\zeta_j, \text{ if } d' \neq (1-\delta^d)d \\
\frac{\partial u}{\partial c_j} &= \beta\phi_{j+1}(1 + (1-\tau_a)r)E\frac{\partial u}{\partial c_{j+1}} + \zeta_j, \text{ if } d' = (1-\delta^d)d.
\end{aligned}$$

Because our conclusion rests on the relative tightness of the post-reform borrowing constraint, we write the post-reform borrowing constraint in a more general way, $a' \geq B(d')$, where $B(\cdot)$ is a function of d'. Denote the tax rates of nondurables and durables as τ_c and τ_d, then the first order conditions become

$$\begin{aligned}
\frac{\partial u/\partial c_j}{\partial u/\partial l_j} &= \frac{1+\tau_c}{\partial y_j/\partial l_j}, \text{ if } j \le J_0 \\
\frac{\partial u}{\partial d_{j+1}} &= \beta\phi_{j+1}\frac{1+\tau_d}{1+\tau_c}(r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c_{j+1}} + (1 + \tau_c + B'(d'))\zeta_j, \text{ if } d' \neq (1-\delta^d)d \\
\frac{\partial u}{\partial c_j} &= \beta\phi_{j+1}(1+r)E\frac{\partial u}{\partial c_{j+1}} + (1+\tau_c)\zeta_j, \text{ if } d' = (1-\delta^d)d.
\end{aligned}$$

In Section 4.2, when equal tax rates on nondurables and durables $\tau_c = \tau_d$, and function $B(d')$ takes the form of $B(d') = -(1-\theta)d'$, the intertemporal condition of adjusting d' is

$$\frac{\partial u}{\partial d_{j+1}} = \beta\phi_{j+1}(r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c_{j+1}} + (\theta + \tau_c)\zeta_j.$$

With equal tax rates but a zero borrowing constraint $B(d') = 0$ as in Section 4.3.1, the intertemporal condition of adjusting d' is

$$\frac{\partial u}{\partial d_{j+1}} = \beta\phi_{j+1}(r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c_{j+1}} + (1 + \tau_c)\zeta_j.$$

For the more relaxed borrowing constraint in Section 4.3.1 $B(d') = -(1-\theta)(1+\tau_c)d'$, the above first order condition becomes

$$\frac{\partial u}{\partial d_{j+1}} = \beta\phi_{j+1}(r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c_{j+1}} + \theta(1 + \tau_c)\zeta_j.$$

At last, in the section that explores the optimal tax mix, we have $\tau_c \neq \tau_d$, but $B(d') = -(1-\theta)d'$, the first order condition corresponding to changing durable stock is

$$\frac{\partial u}{\partial d_{j+1}} = \beta\phi_{j+1}\frac{1+\tau_d}{1+\tau_c}(r + \mu + \delta^d - \mu\delta^d)E\frac{\partial u}{\partial c_{j+1}} + (\theta + \tau_c)\zeta_j.$$

Notes

1 Hall and Rabushka (1995): "The federal income tax imposes two huge costs on the American people: direct compliance cost (record keeping, learning about tax requirement, preparing, copying, and sending forms, commercial tax preparation fees, audits and correspondence, penalties, errors in processing, litigation, tax court cases, enforcement and collection) and indirect economic losses from disincentives" [...] "– deadweight losses, excess burdens, welfare cost – " [...] "due to the reduction in output incurred by the complicated, high-rate federal income tax) [...].

2 Hall and Rabushka (1995), Bradford (2004), Gruber (2015), and Correia (2010), etc.

3 Cyprus, 19% in general and 5% for first-time buyer and the area is of smaller footage. Hungary, 27% for the first sale. Spain, 10% on new residential properties. Latvia, 21% on newly built. Macedonia, 18% on first turnover within 5 years. Montenegro, 19% on newly constructed. Slovak Republic, 20%. France, 20% on newly built Netherlands, 21% on newly constructed (less than 2 years). Romania, 24%. Slovenia, Real estate transfer tax of 2% is charged for purchase of second-hand properties, otherwise, VAT is levied. Austria, VAT is payable for newly-built properties. Germany, VAT is levied at a flat rate of 19%. Ireland, VAT is levied at a standard rate of 23%. Lithuania, 24% on newly built (sold within 24 months). Croatia, 25%. Italy, ranging from 4% to 22% on new properties. Canada, for newly constructed and substantially renovated homes, 5% Goods and Services Tax (GST) is applied on the purchase price. Chile, VAT is levied at a flat rate of 19% on the first sale of houses that are built by a construction company. Japan, sales of buildings are subject to consumption tax, which is levied at a flat rate of 5%. Korean, 10%. Poland, 23%.

4 Besides cash-flow expenditure tax, sales tax, the VAT, a flat tax is essentially a consumption tax. In the book by Hall and Rabushka (1995), they state that "it [the Flat tax] is a consumption tax because it removes al investment spending from the tax base". Likewise, Ventura (1999) also makes the statement that "Flat tax is a form of consumption taxation that removes the distribution of capital income".

5 For instance, studies such as Castaneda, Diaz-Gimene, and Rios-Rull (2003) and Conesa, Kitao, and Krueger (2009) among others introduce two ability levels in the model. Different abilities correspond to different levels of permanent income.

6 Here, we abstract from the double taxation problem of capital income and summarize the capital taxes paid by households and by the firm into the tax on the net return of capital. Ventura (1999) features that an individual taxable income should contain a capital income, a labor income net of half of social security contribution and transfers.

7 Throughout the paper, we use adult equivalence as a unit, namely our households refer to households in terms of adult equivalence. For earnings, we use individual level data; for consumption and wealth, we use household level data scaled by the numbers of adult equivalence.

8 Earnings include salary/wage income, bonus, overtime income, tips, commission income, professional income, extra job income, the labor part of business income and a partial of the farm income.

9 For example, Guvenen (2009), Heathcote, Storesletten, and Violante (2010), etc, require individual or households to be between 20 and 64 (60) year-old, whose earnings are not completely from self-employment, whose annual hours worked are between 260 (520) and 5110 hours, and whose hourly wage is more than a half of the minimum wage, etc.

10 If the persistence component follows an AR(1) process, and its error term is *i.i.d.*, then

$$\epsilon_t^i = \rho\epsilon_{t-1}^i + \nu = \rho(\rho\epsilon_{t-2}^i + \nu) + \nu = \rho^5\epsilon_{t-5}^i + (\rho^4 + \rho^3 + \rho^2 + \rho + 1)\nu$$

Thus, the 5-year persistence $\rho_{5year} = \rho_{1year}^5$, and $\sigma_{5year}^2 = (\rho^4 + \rho^3 + \rho^2 + \rho + 1)^2\sigma_{1year}^2$.

11 This implies that the annual ratio of nondurables to durables is 0.41. Similarly, the annual capital to output ratio is 1.96, which imply that the capital to output ratio is 0.93 in our model. For more options of parameterization, see Fang, Hu, and Yang (2019).

12 The latest dataset of the SCF.

13 The SCF data releases every 3 years, so one cohort is defined as three consecutive ages. Thus, 84 year-old group (84, 85 and 86 years of age) in 2007 is defined as the first cohort, 81 year-old group (81, 82 and 83 years of age) in 2007 is defined as the second cohort, so on and so forth. The 21 year-old group (21, 22, and 23 year-old) in 2016 becomes the 25th cohort.

14 The aggregate social security benefits received by retirees are equal to the aggregate social security taxes payments by workers. When the earnings increases, so do the social security tax payments, and therefore social security benefits increases as well. Because there are more working households than retirees, the replacement ratio also changes with the reform.

15 See the appendix for the definitions of welfare gain in the long run and short run, without durables and with durables.

16 See appendix for the derivation.

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