REVENUE NEUTRAL TAX REFORMS IN A DSGE MODEL WITH HOME PRODUCTION AND INFINITELY LIVED AGENTS

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Thesis Abstract

İbrahim Demir, "Revenue Neutral Tax Reforms in a DSGE Model with Home Production and Infinitely Lived Agents"

The subject of this thesis is to explore the effects of two revenue neutral tax reforms on equity, efficieny and welfare of the society. In order to do this a DSGE model with infinitely lived agents and uninsurable idiosycnratic productivity shocks is constructed. This model is calibrated to match the macroeconomic aggregates and distributional statistics of the US economy in the period 2001-2008. In the benchmark model a progressive tax on income and a flat tax on consumption is levied.

Next the first tax reform is applied to the model economy. With the first tax reform progressive income taxation is replaced with a revenue neutral flat income tax and the flat consumption tax is kept in place. This tax reform causes macroeconomic aggregates to increase, however due to the largely inequitable income distribution of agents in the model, total welfare of households decreases. As expected wealth distribution of the society becomes less equitable.

Finally the effects of the second revenue neutral tax reform are investigated. In this tax reform, income taxation is abolished and the flat tax rate on consumption is increased to a higher rate which ensures revenue neutrality. This tax reform increases macroeconomic aggregates and total welfare of the society. As a result of this tax reform, wealth distribution of the society becomes slightly more equitable.

Tez Özeti

İbrahim Demir, "Ev Üretimi ve Sonsuz Yaşamlı Ekonomik Aktörleri olan bir DSGD Modelinde Eşit Hasılatlı Vergi Reformları"

Bu tezin amacı eşit hasılatlı iki vergi reformunun ekonomik eşitlik, etkinlik ve toplumun refahı üzerindeki etkilerini incelemektir. Bu amaçla sonsuz yaşamlı ekonomik aktörleri ve sigortalanamayan bireye özel üretkenlik şokları olan bir DSGD modeli kurulmuştur. Model Birleşik Devletler ekonomisinin 2001-2008 dönemindeki makroekonomik verileri ve dağılım istatistikleri yakalanmaya çalışılarak kalibre edilmiştir. Ana modelde gelir üzerinden artan oranlarda (progresif), tüketim üzerinden sabit bir vergi alınmaktadır.

Bir sonraki aşamada model ekonomiye birinci vergi reformu uygulanmıştır. İlk vergi reformunda progresif gelir vergisinin yerine aynı mikarda gelir vergisi hasılatı olan bir sabit gelir vergisi uygulanmakta ve sabit tüketim vergisi yerinde bırakılmaktadır. Bu vergi reformu makroekonomik değişkenleri artırmakta, ancak modeldeki ekonomik aktörlerin gelir dağılımındaki adaletsizlikten dolayı toplam refah seviyesi azalmaktadır. Beklendiği üzere toplumun servet dağılımı daha adaletsiz hale gelmiştir.

Son olarak ikinci vergi reformunun sonuçları incelenmiştir. Bu reformda gelirin vergilendirilmesi kaldırılmakta ve tüketimden alınan sabit vergi ana modeldeki toplam vergi hasılatı toplanacak derecede arttırılmaktadır. Bu reform makroekonomik değişkenleri ve ekonomik aktörlerin toplam refah düzeyini arttırmaktadır. Ayrıca servet dağılımı az miktarda daha adaletli hale gelmektedir.

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CHAPTER 1

INTRODUCTION

The subject of this thesis is the quantitative exploration of the effects of two revenue neutral income tax reforms on efficiency, equity and welfare of the society. In the first tax reform the progressive income taxation scheme of the benchmark model is replaced with a revenue neutral flat income tax. In the second tax reform income taxation is replaced by a revenue neutral flat tax on consumption. A brief history of recent tax reform proposals and the motivation behind this study is given below.

Although they have recently made a strong comeback, income tax reform proposals (especially flat income tax reform proposals) have been around since as early as 1962 in the Western world. In his seminal 1962 book "Capitalism and Freedom", Milton Freedman proposes a negative income tax (NIT) which is a flat income tax that turns into a subsidy for poor households when deductions exceed household income.

Later on in 1985 Robert Hall and Alvin Rabushka have devised the Hall-Rabushka tax reform proposal at the Hoover Institute in the United States which is basically a flat tax on consumption. This proposal directly influenced the Tax Reform Act of 1986 which greatly simplified the US income tax code.

After the Soviet Union collapsed in 1991, Estonia, Latvia and Lithuania who had newly gained their freedoms embraced flat taxation as a policy tool to increase economic growth. Starting from the early 2000's several other countries in Eastern Europe followed their example. Russia in 2001, Slovakia in 2004, Romania in 2005, Ukraine and Macedonia in 2007 and Albania and Bulgaria in 2008 have each adopted flat taxation regimes.

These developments have by no means gone unnoticed in the Western world. As early as 2001 Paul Kirschhof (who was suggested as the next finance minister of Germany in 2005) proposed a flat tax reform for the German economy. In 2004 elections, flat tax reforms were also proposed by the center left in Spain. The Dutch Council of Economic Advisors suggested adopting flat taxation in Netherlands in 2005. Although ultimately rejected by Gordon Brown in 2007, flat taxation was brought into discussion by the Conservative Party in UK.

As is evident by all these examples, income tax reform proposals are in no way just theoretical curiosities to be explored by economists. Since they have recently often become the subject of political debate in the Western world, I believe it's extremely crucial to quantify and understand their possible effects on equity, efficiency and welfare of the society by setting up quantitative models. This has been the main motivation behind the choice of income tax reform as the subject of my thesis. The model economy which has been used in this study is discussed briefly below.

The model economy has infinitely lived agents which are subject to periodical idiosyncratic productivity shocks and borrowing constraints. Therefore the asset markets are not complete and in order to insure themselves against possible negative productivity shocks and smooth their consumption in the future, the agents accumulate extra capital. The labor supply levels of the agents in the model are endogenously determined. The model economy includes a home production mechanism and the agents allocate their available time between three activities: working in the market sector, working at home and leisure. Welfare is measured as the average lifetime utility of agents in the model.

The model economy has also a government which levies taxes on income and consumption. The government uses the tax revenue to finance its non-productive consumption which is a constant proportion of the economy's output each period and pays out benefits to the unemployed. In the benchmark case the government levies a progressive tax on income and a flat tax on consumption (i.e., people in the higher income brackets pay a higher proportion of their income as tax but a constant tax rate applies for consumption expenditure). As mentioned earlier, the first tax reform replaces progressive income taxation with a revenue neutral flat income tax and the second tax reform replaces income taxation with a revenue neutral flat tax on consumption.

Unfortunately the effects of these tax reforms on equity, efficiency and welfare are not straightforward. First of all, regarding the first reform proposal, there exists a trade-off between efficiency and equity when a flat taxation scheme is adopted. On the one hand, a progressive tax acts as a disincentive against saving more and working longer for more productive members of the society and thus has a negative impact on capital accumulation, aggregate labor supply and ultimately aggregate output. In addition when various loopholes and exemptions in tax codes are taken into account progressive taxes are much harder to accurately calculate and file than flat taxes and this by itself imposes a cost that can easily be avoided by adopting flat taxation. Therefore flat taxation has a positive impact on economic efficiency.

On the other hand, progressive taxation helps ensure that a more equitable distribution of income is achieved in the society, and therefore theoretically also leads to a more equitable distribution of wealth and consumption. Also according to Conesa and Krueger (2006) in the absence of complete insurance markets (as is the

case in our model economy), progressive taxation acts as “a partial substitute for these missing markets and therefore may lead to less volatile household consumption over time” (p. 1426). So progressive taxation leads to more equitable economic allocations. (However at this point the reader must also be aware that exemption levels can be used with flat taxation schemes to introduce a desired level of progressivity into a flat taxation system as well.)

Therefore the effects of a revenue neutral income tax reform are by no means trivial and more importantly they are not analytically tractable either; there are no closed form solutions that will enable us to see the effects of this policy suggestion. Instead the methods of numerical analysis must be utilized to explore these effects.

The same situation also holds when exploring the effects of the second tax reform proposal (i.e., abandoning income taxation and adopting a flat consumption tax as the sole source of tax revenue and doing this in a revenue neutral manner.) Abandoning flat taxation means incentivizing agents to work longer hours and save more, since labor income and return on capital investment are no longer being taxed. However since consumption is now being taxed at a higher rate people are also incentivized to replace consumption with leisure, so they are in this way more likely to spend less time working in the market sector. The net effect on consumption, leisure and the time spent working in the market sector are by no means analytically tractable. Again the methods of numerical analysis must be utilized to explore these effects.

Before closing this chapter, it should be noted here that this thesis aims only to explore the steady state effects of the proposed tax reforms; the transitional dynamics that take place after the regime change until the new steady state is achieved is beyond the scope of this study.

CHAPTER 2

LITERATURE REVIEW

In this chapter previous studies that have dealt with the subjects of progressive taxation, tax reform proposals and home production (which is the unique ingredient of the model economy in this study) are discussed. The literature reviews on these subjects will be given in two subsections: literature review on progressive taxation and tax reform and the literature review on home production.

Literature Review on Progressive Taxation and Tax Reform

Questions regarding taxation have been the subject of several academic papers since the early 1970's. The early seminal papers in this field paved the way for a satisfactory quantitative analysis of the issues regarding a progressive taxation system such as the optimal progressivity of the tax system and flat tax reforms that can replace it. So in order to better understand how the literature progressed in this field, one should initially examine these early works.

The earliest work on progressive taxation goes back to the papers by Mirrlees (1971) and Varian (1980). Mirrlees (1971) explores the shape of the optimum earned income tax schedule and concludes that its shape depends on the distribution of skills within the population and to the labor-leisure preferences. He offers an approximately linear income tax schedule but also advises that taxes complementary to this income tax should be devised. Varian (1980) concludes that if income

contains a random component (such as the idiosyncratic productivity shocks on labor income in our model economy) then a system of redistributive taxation (i.e., a more progressive tax system) will contribute to reducing the variance of after tax income.

The next great step in the literature of taxation takes place with Aiyagari's seminal papers in 1994 (Aiyagari, 1994a , Aiyagari, 1994b). Aiyagari (1994a) uses a model economy with incomplete asset markets and infinitely lived agents to investigate the effects of idiosyncratic productivity shocks on aggregate saving. He concludes that the consumption smoothing behavior in the presence of these shocks lead to greater capital accumulation and lower interest rates. In addition by using his model, Aiyagari (1994a) achieves empirically plausible relative degrees of inequality for the distribution of income and wealth, even though his model cannot capture the observed Gini coefficients for income and wealth distributions.

Although not directly linked with progressive taxation, Aiyagari (1994b) uses the same model to determine the optimal capital income taxation and arrives at the conclusion that the optimal capital income tax rate is positive in the presence of uninsured idiosyncratic uncertainty. In this model taxing capital income prevents over accumulation of capital due to self-insurance. This conclusion contradicts the zero capital income tax result separately arrived at by Judd (1985) and Chamley (1986). Judd (1985) uses a representative agent model with infinitely lived agents to investigate the redistributive potential of capital taxation. Chamley (1986) uses a similar model to determine the optimal capital tax.

From the mid-1990's onward several important papers that deal with progressive taxation and tax reform proposals have been published. The common point of almost all these papers is that they all use an OLG model and following Aiyagari's seminal papers in 1994, they all include uninsured productivity shocks.

The reason behind the use of OLG models is that OLG models incorporate the life-cycle saving motive and can even include the bequest motive and therefore are much better in capturing wealth and income distributions than models with infinitely lived agents. The reason behind the use of uninsured productivity shocks is to introduce the precautionary saving incentive and better capture the level of aggregate capital stock. Important contributions to the literature in this period include the following.

Altig et al. (1997) use an OLG model with exogenous age dependent productivity values for the agents to compare the equity, efficiency and macroeconomic effects of five alternative flat tax reform proposals. Ventura (1999) also uses an OLG model to explore the effects of a revenue neutral flat tax reform; the agents in his model are faced with age dependent but individual specific productivity shocks. Retirement is mandatory after a certain age and agents leave behind accidental bequests that are confiscated by the government. His model is particularly successful in capturing the observed Gini coefficient of income of the US economy.

Castaneda et al. (1999) utilize almost the same model as Ventura (1999) with one crucial difference. In order to obtain the discrete productivity values, transition probabilites and the stationary distribution of agents associated with the idiosyncratic productivity shocks, they do not assume an underlying exogenous stochastic process. Instead they obtain their calibrated values directly from the Lorenz curves of the observed income and wealth distributions of the US economy. Therefore this paper's calibration results match the Gini coefficients of the US income and wealth distributions perfectly.

Heer and Trede (2003) use a model economy with infinitely lived agents and uninsured idiosyncratic productivity shocks to examine the effects of two revenue

neutral income tax reforms for the German economy. They use the empirical distribution of hourly wages in Germany in 1995 to estimate the five productivity types that are available to the agents in their model economy. In order to estimate the transition probabilities between these productivity types, they use the observed quartile transition probabilities between 1995 and 1996. Their data source is the 1995 and 1996 editions of the Socio Economic Panel for Germany (GSOEP). The model economy and the tax reform proposals of this thesis are closest in spirit to this study, even though their model economy does not include home production and the calibration strategies that have been adopted are different.

Conesa and Krueger (2006) use the OLG setup with productivity shocks, borrowing constraints and accidental bequests to determine the optimal progressivity of the income tax code for the US. Diaz-Gimenez and Pijoan-Mas (2006) use the same model as Castaneda et al. (1999) to evaluate the effects of two revenue neutral flat tax reform proposals for the US economy. Conesa at al. (2007) characterize the optimal capital and labor income taxes in an OLG model with idiosyncratic uninsurable income shocks. They arrive at the conclusion that a system which taxes capital income heavily and taxes labor income at a flat rate (but with deductions) is optimal in the long run.

More recently Imrohoroglu et al. (2008) investigate the welfare effects of abolishing capital income taxation and replacing it with five different revenue neutral tax reforms. They end up deciding that eliminating all income taxation and taxing consumption at a flat rate of 35% will increase the welfare most among these five tax reform proposals. Finally, Kitao (2010) uses an OLG model, in which agents' productivities depend on their ages and idiosyncratic labor productivity shocks, to investigate a capital income tax that declines with increasing labor supply. The

author demonstrates that such a tax provides an incentive for agents to work longer and save more.

Literature Review On Home Production

As mentioned in the introduction, the model economy of my thesis includes a home production mechanism. Home production is the activity of using time spent at home and goods produced in the market sector to produce goods and services that are consumed in the household. In order to understand why a model of taxation should include home production, one should investigate the literature about how people allocate their time between market work, leisure and home production, the literature about the scale of home production sector relative to the aggregate output of the economy and the literature about how including home production in a model economy improves its predictions about aggregate variables and distributions of wealth and income. The following is a concise summary of the seminal works in these strands of literature.

The earliest investigations regarding the question of allocation of time go as far back as Becker (1965). Becker (1965), unlike several prior studies in the literature, sets a distinction between time spent as leisure and time devoted to home production. He allows households to use their time and the market produced goods that they purchase to produce home produced goods. In his own words households are "small factories, which combine capital goods, raw material and labour to clean, feed, procreate and produce useful commodities" (p. 496). He analyzes the effects of changes in earnings, goods' prices and the productivity of households in the market

sector on households' allocation of time and puts special emphasis on the forgone resources (time and income) due to home production.

Building on Becker's groundbreaking work, Reuben Granau published another seminal paper on the question of allocation of time in 1977. However unlike Becker (1965), his households use only time to produce home produced goods through a strictly convex home production function. His justification for using a strictly convex home production function is two fold: As time spent working at home increases, its marginal productivity falls due to fatigue and the home production begins shifting to goods that have a cheaper market substitute. He investigates the effects of a change in the market wage rate and income on the trichotomy of time allocation of households.

Graham and Carole (1984) estimate the parameters of a home production function of Cobb-Douglas specification where the inputs are time spent at home by the husband and the wife. After estimating these parameters by using the data from the ninth wave of Panel Study of Income Dynamics (PSID), they estimate that the imputed value of home production in 1976 US dollars was as much as $17,669 per household.

During early 1990's several studies investigating real business cycles have focused on home production and the question of allocation of time. Greenwood and Hercowitz (1991) built a model which includes a home production function of Cobb-Douglas type where the inputs are home capital and time spent at home. Market capital which is used in the market sector's production function is distinct from home capital and both home and market capital are produced in the market sector. This paper investigates the investment on home and market capital stocks during business

cycles. One crucial point of this paper is that it does not set a distinction between leisure and time spent working at home.

Aiyagari (1993) uses a simple two generation OLG model with skill acquisition and home production to explain trends over time in the allocation of time and the variance of time spent working at home and time spent working in the market sector. In his model the market produced good can only be produced in the market sector whereas home produced good can be produced both in the home and market sector, which imply substitutability between the two goods. There's also again a trichotomy in the allocation of time.

Greenwood et al. (1993) point out that for the US economy estimates of the relative size of the household sector relative to GDP are between 20% - 50 %. These figures clearly indicate that the household sector in the US economy quite large. Including home production in the standard RBC model of Kydland and Prescott (1992), they're able to improve the predictions of the model on several dimensions such as volatilities of market output, consumption and investment.

McGrattan et al. (1997) introduce a home production function of CES type, which uses home capital and time spent working at home as inputs, into a dynamic general equilibrium model of the US economy. Labor income and return on market capital investment are taxed at flat rates. By using this model they can provide better predictions of the standard deviations and correlations with respect to GDP of various aggregates of the US economy such as market consumption, total investment, home and market capital stocks etc. Finally, they conduct three simple tax reform experiments: i) eliminating all taxation, ii) setting capital tax to zero while increasing

the income tax so that the reform is revenue neutral and iii) introducing a tax on home capital and investigate the results.

Campbell and Ludvigson (1998) inspect the intertemporal elasticity of substitution of market good consumption and the intra-temporal elasticity of substitution between the consumptions of home and market produced goods with a model economy which has infinitely lived agents, home and market production functions of Cobb-Douglas specification and separate home and market capital goods. There is no leisure in this model; all available time is allocated to either work at home or work in the market. Their main conclusion is that by using a model with an intertemporal elasticity of substitution which is significantly below unity the cyclical variation of hours worked in the market and the variation of market consumption are better captured.

Beginning from the early 2000's the concept of home production has been widely incorporated into both RBC and growth models to answer a variety of questions. Gomme et al. (2000) integrates "time to build capital" technology, i.e. capital building projects that are begun at period t require J periods to complete, into an RBC model to resolve two important problems that have plagued other RBC models with home production function: 1) Investment in home capital leads investment in market capital in business cycles. 2) There's a positive correlation between home and business investments.

Parente et al. (2000) introduce a home production function of Cobb-Douglas type which has aggregate productivity shocks into the neoclassical growth model. The aim of this paper is to study the extent to which cross-country differences in income are created by policy differences that distort capital accumulation. In the

standard neoclassical growth model, extraordinarily large distortions are required to explain the differences in income across countries; however introducing a home production technology improves the model's ability to account for the income differences. With home production, required distortions are much smaller.

Ragan (2006) develops a household production model with publicly provided goods that are close substitutes to home produced goods. The benchmark model of the paper also includes flat taxation on market good consumption and market sector labor income. The government rebates the collected taxes as lump-sum transfers to households. Both publicly provided goods and taxation influence the households' decisions to allocate their time between market work, home work and leisure in the face of distortions such as changes in taxation regimes and lump-sum transfers.

Finally Aguiar (2007) uses five decades of time-use surveys, Current Population Survey (CPS) and PSID data, to investigate the trends in time spent working at home, time spent working in the market and time devoted to leisure in the US.

CHAPTER 3

THE MODEL

The model economy consists of 3 sectors: households, firms and the government. Detailed activities undertaken by these 3 sectors are as follows.

Households

Households are infinitely lived and are heterogeneous with respect to their productivites and their beginning of period wealth. We assume that the total measure of all households in the economy is 1. Each period every household draws an idiosyncratic productivity value from a finite set $\mathcal{E} = \{\epsilon^1, \epsilon^2, \epsilon^3, \epsilon^4\}$ and it's assumed that these productivity draws follow a four state Markov chain with conditional transition probabilities given by $\pi(\epsilon'|\epsilon) = \Pr\{\epsilon_{t+1} = \epsilon'|\epsilon_t = \epsilon\}$ where $\epsilon, \epsilon' \in \mathcal{E}$. There's no aggregate uncertainity in the model.

Households can spend their time in three different activities. They can spend their time working at home and produce a home produced good by using a strictly concave home production function which has the functional form ${e_{Ht}}^{1/\eta}$where $1/\eta \in (0,1)$. This home produced good can not be traded for either capital or the consumption good produced in the market sector, so each household consumes whatever home produced good it produces, which means $c_{Ht} = {e_{Ht}}^{1/\eta}$ where c_{Ht} is the amount of home produced good consumed. Households can also spend their time working in a perfectly competitive labor market, which means that the amount of

labor income received by a household is $\epsilon_t w_t e_{Mt}$ where w_t is the wage level in period t and e_{Mt} is the amount of time spent working in the market place. Finally a household can choose to devote it's time to leisure, L_t .

If a household chooses not to work in the market sector, it gets an unemployment benefit UB_t which is equal to $(repl)\epsilon^1\bar{n}^1{}_t$ where *repl* is the replacement ratio of the unemployment benefit and $\bar{n}^1{}_t$ is the average time worked in the market sector by those agents of the first productivity type who actually choose to work. So each period unemployment benefit equals replacement ratio times the average labor income of the working agents who belong to the first productivity type in that period.

The instantaneous utility received by a household in period t depends on the consumption level of a composite consumption good which is a composite of c_{Ht}, c_{Mt} and L_t. The composite consumption good in period t has the functional form $C_t = {c_{Ht}}^{\mu}{c_{Mt}}^{\lambda}{L_t}^{\kappa}$ and the instantenous utility received in period t when C_t is consumed is $U(C_t) = \frac{{C_t}^{1-\sigma}-1}{1-\sigma}$ where σ is the coefficient of relative risk aversion.

A household chooses infinite sequences $\{L_t\}$, $\{e_{Ht}\}$, $\{c_{Mt}\}$ and $\{k_{t+1}\}$ to maximize its sum of discounted utilities conditioned on it's information set at time t. So a household's problem is:

$$\max E_0\left[\sum_{t=0}^{\infty}\beta^t U(C_t)\right] \qquad \text{s.t:} \tag{1}$$

$$r_t k_t + \epsilon_t w_t e_{Mt} + UB_t(e_{Mt} == 0) - k_{t+1} + k_t - (1+\tau_c)c_{Mt} - \tau(y) \geq 0 \tag{2}$$

$$e_{Mt} + e_{Ht} + L_t = 1 \tag{3}$$

$$k_t \geq 0\,, \forall t \tag{4}$$

where τ_c is the flat tax on consumption charged by the government in the benchmark model and $\tau(y)$ is the progressive income tax. Its functional form is given and explained in the calibration section. $(e_{Mt} == 0)$ is a signal function which takes the value 1 if the household chooses not to work $(e_{Mt} == 0)$ and 0 otherwise. k_t is the beginning of period capital stock and k_{t+1} is the amount of capital which is chosen to be held in the next period.

In the constrained maximization problem above, equation (2) is the budget constraint of the household and equation (3) is its time allocation constraint. (Notice in equation (3) that a household's total available time is equal to 1.) By inspecting equation (2), it's seen that a household's sources of income are return on capital, labor income from the market sector and, if the household chooses not to work in the market sector, the unemployment benefit it receives from the government. The household spends its income on investment on capital $(k_{t+1} - k_t)$, on purchasing the market produced consumption good and paying the associated consumption tax $(1 + \tau_c)c_{Mt}$ and on progressive income tax, $\tau(y)$. Equation (4) simply states that households can not hold negative assets at any given time; so households in the model economy are borrowing constrained.

Solving the constrained utility maximization problem given above yields an important intra-temporal Euler equation regarding each household's optimal time allocation scheme that will be used in the calibration section. So that equation will now be derived.

Let us first write the Lagrangian function and the maximization problem:

$\max E_0 [\sum_{t=0}^{\infty} \beta^t U(C_t)] + \sum_{t=0}^{\infty} \lambda_t [r_t k_t + \epsilon_t w_t e_{Mt} + UB_t(e_{Mt} == 0) - k_{t+1} + k_t - (1+\tau_c)c_{Mt} - \tau(y)] + \sum_{t=0}^{\infty} \Gamma_t [1 - e_{Mt} - e_{Ht} - L_t]$

with respect to $\{L_t\}$, $\{e_{Ht}\}$, $\{c_{Mt}\}$ and $\{k_{t+1}\}$.

To get our crucial intra-temporal Euler equation, we will use the first order derivatives of the Lagrangian function with respect to L_t and e_{Ht}. The first order conditions with respect to L_t and e_{Ht} are:

$$L_t: \qquad \beta^t U'(C_t)\left(\kappa {L_t}^{\kappa-1} {e_{Ht}}^{\mu/\eta} {c_{Mt}}^{\lambda}\right) = \Gamma_t \tag{5}$$

$$e_{Ht}: \qquad \beta^t U'(C_t)\left(\frac{\mu}{\eta} {L_t}^{\kappa} {e_{Ht}}^{\frac{\mu}{\eta}-1} {c_{Mt}}^{\lambda}\right) = \Gamma_t \tag{6}$$

Please notice here that in equations (5) and (6) , home production function ${c_{Ht}} = {e_{Ht}}^{1/\eta}$ has been used.

Dividing equation (5) by equation (6) yields:

$$\frac{e_{Ht}}{L_t} = \frac{\mu}{\eta\kappa} \tag{7}$$

Using equations (2) and (7), it is easily seen that:

$$e_{Ht} = (1 - e_{Mt})(\mu / (\mu + \eta\kappa)) \tag{8}$$

$$L_t = (1 - e_{Mt})(\eta\kappa/(\mu + \eta\kappa)) \tag{9}$$

Firms

The firms in our model economy use a standard neo-classical production function:

$$F(K_t, N_t) = K_t^{\alpha} N_t^{1-\alpha} \quad (10)$$

where α is the income share of capital. We assume that both factor markets are perfectly competitive, thus households are simple price takers in the labor and capital markets.

Due to the neo-classical assumptions, rent and wage in each period are respectively equal to the market value of the marginal products of aggregate capital stock and aggregate effective labor supply:

$$r_t = \alpha \left(\frac{N_t}{K_t}\right)^{1-\alpha} - \delta \quad (11)$$

$$w_t = (1-\alpha) \left(\frac{K_t}{N_t}\right)^{\alpha} \quad (12)$$

where δ is the depreciation rate of the capital stock.

Government

The government in the benchmark model levies a flat tax on consumption and a progressive income tax to finance government consumption, which is non-productive, and unemployment benefits. So government's budget equation is:

$$(1 - workPop)(UB_t) + G_t = \left(\sum C_{m_t}\right)(\tau_c) + \tau(y) \quad (13)$$

where $workPop$ is the total population in the model economy that chooses to work, $\sum C_{m_t}$ is the total amount of market produced consumption good that is bought and $\tau(y)$ is the total amount of income tax that is collected. Also unemployment benefits are exempt form income taxation.

Stationary Equilibrium

Before stating the set of rules which characterize a stationary equilibrium of the model economy, a bit of elaboration on the notation that shall be used in this section will be in order.

There are two state variables associated with the utility maximization problem of households in the model: productivity ϵ and beginning of period capital stock k. I denote the state space $\{\epsilon^1, \epsilon^2, \epsilon^3, \epsilon^4\}\ x\ [kmin, kmax]$ as $\mathbb{S}$. Aiyagari (1994a) notes that as long as the after tax return on savings (i.e., the interest rate, r) is less than the households' common rate of time preference $1/(1-\beta)$, then there will be an upper bound on the amount of asset holdings households choose to own. Since this is the case as explained in Aiyagari (1994a) for model economies with heterogeneous agents and uninsured productivity shocks, we have the upper bound on asset holdings $kmax$. On the other hand due to the borrowing constraint, $kmin = 0$. I also let ψ denote the stationary measure of households.

The value function $V(\epsilon, k)$ is the solution to the constrained dynamic utility maximization problem defined by (1), (2), (3) and (4):

$$V(\epsilon, k) = \max[\, U(C) + \beta\ E\ \{V(\epsilon', k')\}] \tag{14}$$

A stationary equilibrium of the model economy is a collection of a value function $V\ (\epsilon, k)$, individual policy rules $c_m(\epsilon, k)$, $k'(\epsilon, k)$, $L\ (\epsilon, k)$ and $e_h(\epsilon, k)$, a stationary distribution of state variables, stationary relative prices of factors of production (r, w) aggregate variables $(K, N_m, N_h, C_m, C_h, T)$ and tax policies that satisfy the following set of rules:

1) Aggregate capital stock, aggregate effective labor supply in the market sector and at home, aggregate consumption of market and home produced goods and tax revenues are also consistent with the individual choices of households. (i.e., aggregate consistency holds.) So we have:

$$K' = \int_{\mathbb{S}} k'(\epsilon, k)\, d\psi \tag{15}$$

$$N_m = \int_{\mathbb{S}} \epsilon e_m(\epsilon, k)\, d\,\psi \tag{16}$$

$$N_h = \int_{\mathbb{S}} \epsilon e_h(\epsilon, k)\, d\,\psi \tag{17}$$

$$C_m = \int_{\mathbb{S}} c_m(\epsilon, k)\, d\psi \tag{18}$$

$$C_h = \int_{\mathbb{S}} c_h(\epsilon, k)\, d\psi \tag{19}$$

$$T = \int_{\mathbb{S}} \tau\big(y(\epsilon, k)\big) d\psi + \tau_c C_m \tag{20}$$

2) $c_m(\epsilon, k)$, $k'(\epsilon, k)$, $L\ (\epsilon, k)$ and $e_h(\epsilon, k)$ are optimal decision rules and solve the household's utility maximization problem described in (1), (2), (3) and (4).

3) Factor prices are equal to the market value of the factors' marginal products, as described in (11) and (12).

4) The goods market clears both in the market and home sectors.

$$F(K, N_m) + \ (1 - \delta)K = \ K' + C_m \ + G \tag{21}$$

$$F_h\ (N_h) = C_h \tag{22}$$

5) The government's budget is balanced. So equation (13) holds each period.

6) The measure of households is stationary: $\psi = \int_{\mathbb{S}} \pi\ (\epsilon' | \epsilon)\ d\psi$ (23)

CHAPTER 4

CALIBRATION

In this chapter I calibrate the benchmark economy by using empirical observations and econometric estimates of various aspects of the US economy between years 2001-2008. The goal in this chapter is to achieve as high a degree of consistency as possible between the simulated results of our calibrated benchmark model and the actual calibration targets that are obtained from empirical observations and the literature.

The explanations will proceed step by step, elaborating on why a particular value has been chosen for calibrating the parameter in question.

Calibrating the Discount Factor, Income Share of Capital and Depreciation Rate of Capital

The value of the discount factor (β) mainly affects the capital/ output ratio (K/Y) in the stationary equilibrium of the economy. Following Kitao (2010), I set a K/Y ratio of 2.7 as my calibration target. A discount factor of β = 0.95 yields a simulated value of 2.73 for K/Y ratio in our benchmark model.

As for the income share of capital, I follow the literature and use the commonly used value of α = 0.36 that captures the US income share of capital in the post-WWII era.

The depreciation rate of capital (δ) mainly affects the investment/capital ratio of the economy. Although a value as high as 0.08 has been used in Aiyagari (1994a), the common range for δ used in the literature is between 0.06-0.07. Following Castaneda et al. (2003), I set $\delta = 0.06$.

Replacement Ratio of Unemployment Benefit and Government Expenditure to Output Ratio

I obtain the average net replacement rates of unemployment benefits over sixty months of unemployment for the US economy in the period 2001-2008 from OECD's Main Tax / Benefit Indicators for the period 2001-2008 (OECD, Directorate for labor, employment and social affairs, 2001-2008). This data yields an average of 0.32 as the replacement rate.

As for the government expenditure to output ratio, the share of government consumption and gross investment excluding transfers (at the federal, state and local levels) to output should be computed. I again use the data provided by the OECD (OECD, Stat extracts web page, 2001-2008) and come up with a ratio of 0.19.

Weights of $C_{ht,}$ C_{mt} and L_t in the Composite Consumption Good

Recall that the functional form of the composite consumption good was as follows: $C_t = {c_{Ht}}^{\mu} {c_{Mt}}^{\lambda} {L_t}^{\kappa}$. The parameters μ and κ determine the ratio of time spent working at home and time devoted to leisure according to the intratemporal Euler equation that was derived in equations (5), (6) and (7) of Chapter 3. In order to calibrate these

three parameters (μ, κ, λ), I obtain the average proportion of time dedicated to home production, market work and leisure by the average American in the period 2003-2008 by inspecting American Time Use Surveys that are conducted by the Bureau of Labor Statistics of the US Department of Labor (Bureau of Labor Statistics, American Time Use Survey archive, 2003-2008). Please note that the Bureau of Labor Statistics have been conducting the American Time Use Survey since 2003, so data for 2001 and 2002 are not available.

The average proportion of time that is dedicated to home work in this period is 0.231, proportion of time dedicated to market work is 0.254 and the remaining amount (0.515) is dedicated to leisure and personal care activities.[1] Since the model economy does not explicitly include personal care activities, I simply assume that the ratio of time spent working at home to time devoted to leisure is 0.231/0.515 = 0.45. Unfortunately this number although useful, is not by itself enough to determine μ, κ, λ in a unique manner. So I use the parameter values provided by Gomme and Rupert (2007) who have used a time spent working at home to time devoted to leisure ratio of 0.475 that is quite close to my own calculation of 0.45. As a result, these parameters are set as μ =0.4862, λ = 0.5138 and κ = 0.5043.

Exponent of Time Spent Working at Home in the Home Production Function

Recall that the home production function was strictly convex and had the functional form $C_{ht} = e_{ht}^{1/\eta}$ where $1/\eta \in [0,1]$. Although initially $\eta = 2$ is used in the

[1] Time devoted to sleeping is excluded from these calculations.

benchmark economy so that $1/\eta$ is 0.5, a sensitivity analysis is conducted in Appendix B by setting η to 5 and 1.25 so that $1/\eta$ becomes 0.2 and 0.8.

The Functional Form of the Utility Function and Coefficient of Relative Risk Aversion

The chosen utility function is of the CRRA (constant relative risk aversion) type and has the functional form $U(C_t) = \frac{{C_t}^{1-\sigma}-1}{1-\sigma}$ where C_t is the amount of composite consumption good consumed at time t and σ is the coefficient of relative risk aversion which is estimated to be between 1 and 4 in the literature. For the benchmark economy I set σ to 2, however a sensitivity analysis is conducted for σ in Appendix B where it is set to 1 and 4 seperately.

Before proceeding further I'd like to point out that the functional form that was chosen for the utility function is a direct byproduct of the functional form that was chosen for the composite consumption good. The more general form that could have been used for the composite consumption good (of market and home produced goods) is:

$$C\left(C_{mt,}C_{ht}\right) = \left[\psi\, {C_{mt}}^{z} + (1-\psi){C_{ht}}^{z}\right]^{\frac{1}{z}} \quad \text{if } z < 0 \; or \; 0 < z < 1 \qquad (24)$$

which is a CES type aggregator. In the benchmark model, the limiting case of this aggregator when $z = 0$ is used:

$$C\left(C_{mt,}C_{ht}\right) = {C_{mt}}^{\psi}\ {C_{ht}}^{1-\psi} \text{ if } z = 0 \qquad (25)$$

Coupling this limiting case of the CES aggregator of market and home produced goods with leisure, which is another good that gives utility to the households, the following utility function is obtained: (if $\gamma \epsilon (0,1)\ U\ (1,\infty).$)

$$U\left(C\left(C_{mt,}C_{ht}\right),e_{ht},e_{mt}\right)=\frac{[C\left(C_{mt,}C_{ht}\right)*(1-e_{ht}-e_{mt})^{\omega}]^{1-\gamma}}{1-\gamma} \qquad (26)$$

Inserting (25) into (26) yields the particular form of the utility function that has been chosen for this model. The particular advantage of this functional form is that it enables the derivation of the simple intratemporal Euler equation of time allocation that was derived in Chapter 3. If the more general case of the CES aggregator had been used, the intratemporal Euler equation of time allocation in any period t would have depended on the quantity of composite consumption good consumed in that period and the model would have taken much longer to solve numerically.

Income and Consumption Taxation in the Benchmark Model

In the benchmark model an exogenous progressive income taxation scheme is being used whereas consumption expenditure on market produced good is being taxed at a flat rate which is computed endogenously to ensure that the government's budget is balanced in the stationary equilibrium.

The literature on progressive taxation and tax reform proposals commonly uses the functional form given by Gouveia and Strauss (1994) to formulate the progressive income taxation scheme of the US. This functional form is as follows:

$$\tau(y)=\ a_0\left[y-\left(y^{-a_1}+a_2\right)^{-\frac{1}{a_1}}\right]$$

where y is taxable income and $\tau(y)$ is the amount of income tax payment. (Recall once again that unemployment benefits are tax exempt.) The parameters a_0 and $a_1$are unit independent and I use the values given by Gouveia and Strauss (1994) for a_0 and a_1. So $a_0 = 0.258$ and $a_1 = 0.768$. The parameter a_2 is obtained by setting the tax rate levied on average household in the model economy to the effective tax rate on per household GDP in US. For a_2 values around 0.45 are commonly used in the literature, so I set $a_2 = 0.45$. By using these numbers, an average tax rate of 15.2 % is obtained which is equal to the empirically observed average income tax rate in the US in year 2003. [2]

Exogenous Idiosyncratic Productivity Values, Transition Probabilities and Stationary Distribution of Agents

As mentioned in the literature review on progressive taxation section of Chapter 2, unlike other studies in this field, Castaneda et al (2003) do not assume an underlying exogenous stochastic process in order to obtain the discrete productivity values, transition probabilities and the stationary distribution associated with the idiosyncratic productivity shocks. Instead they obtain their calibrated values directly from the Lorenz curves of the observed income and wealth distributions of the US economy. Therefore they are able to capture exactly the Gini coefficients of income and wealth distributions of the US economy which makes their methodology highly desirable.

The latest study to date that has used the same strategy is Diaz-Gimenez and Pijoan-Mas (2006). Therefore in order to achieve a higher accuracy when simulating

[2] This figure has been obtained from NBER's webpage: <http://www.nber.org/~taxsim/>

income and wealth distributions, I use the productivity types, transition probabilities and stationary distribution of agents given in Diaz-Gimenez and Pijoan-Mas (2006) after slightly modifying transition probabilities and stationary distributions. The reason behind these alterations is that Diaz-Gimenez and Pijoan-Mas (2006) use an OLG model with a constant retirement probability of 0.0222. However since my benchmark model has infinitely lived agents, there's no retirement in my model, therefore the transition probabilities and the stationary distribution of agents must be accordingly adjusted.

After this slight modification, the productivity types and stationary distributions that are used in the benchmark model are as follows:

Table 1. Stochastic Productivity Types of Agents and their Stationary Distributions in the Benchmark Model

	s=1	s=2	s=3	s=4
$\epsilon\ (s)$ - Productivities	1.00	3.17	9.91	634.98
γ^*_{ϵ} – Stationary dist.	0.4778	0.3724	0.1491	0.0007

Table 2. Transition Probabilities of Agents

To state s'				
From state s	s'=1	s'=2	s'=3	s'=4
s=1	96.15	1.39	0.23	0.009
s=2	1.60	96.00	0.18	0.000
s=3	1.19	0.00	96.56	0.028
s=4	6.63	0.45	6.52	84.18

Table 3. Summary of Calibrated Parameter Values

Name of the Parameter	Symbol and Value used for Calibration
Discount factor	$\beta = 0.95$
Income share of capital	$\alpha = 0.36$
Depreciation rate	$\delta = 0.06$
Replacement rate of unemployment benefit	$repl = 0.32$
Government expenditure to output ratio	$G/\ Y = 0.19$
Weights in the composite consumption good	$\lambda = 0.5138\ \mu = 0.4862\ \kappa = 0.5043$
Parameters of the progressive income tax function	$a0 = 0.258\ a1 = 0.768\ a2 = 0.45$
Coefficient of relative risk aversion	$\sigma = \{1, 2, 4\}$
Parameter of the home production function	$\eta = \{1.25, 2, 5\}$

Table 4. Empirical Observations and Simulation Results

	Empirical Observations	Simulation Results
Capital/Output – K/Y	2.7	2.73
Consumption/Output – C/Y	0.65	0.6557
Coefficient of variation of hours worked in the market sector	0.316 – 0.342	0.29
Gini coefficient of wealth distribution	0.8	0.69
Gini coefficient of gross income distribution	0.47	0.54
Unemployment rate	5.27%	2.4%
Time worked at home	0.231	0.255
Time worked in the market sector	0.254	0.307
Time devoted to leisure	0.515	0.468

Comments on Simulation Results

As the values in Table 4 indicate, calibrated benchmark model economy's simulation results closely resemble the calibration targets. The model economy is highly successful in capturing K/Y and C/Y ratios. As mentioned previously, the target for K/Y ratio was obtained from Kitao (2010). The empirical observation regarding C/Y ratio comes from Castaneda et al. (1999).

The model is also moderately successful in capturing the Gini coefficient of the gross income distribution and the coefficient of variation of time spent working in the market. The empirically observed Gini coefficient for gross income distribution reported in Table 4 has been obtained by averaging the values stated in the Current Population Reports prepared by the US Census Bureau for the period 2001-2008. For the coefficient of variation of hours worked in the market, Jones and Manuelli (2000) uses 0.342 and Freeman and Schettkat (2005) uses 0.316. So the value that I seek to match is between 0.316-0.342.

The model economy fails to achieve the same level of inequality of the wealth distribution as found in empirical observations. As discussed in the literature review section, this is mainly due to the fact that there is no life cycle saving motive in the benchmark model since agents are infinitely lived. Nonetheless the model economy is able to predict a large share of the inequality in wealth distribution that is observed in reality, which is by itself no small deed. The Gini coefficient of wealth that I am trying to match comes from Kennickel (2009) which reports a value of 0.8.

Perhaps the greatest shortcoming of the model economy is it's incapacity to predict empirically observed unemployment rates; however this is not one of the main objectives of the constructed model and by building a more realistic

unemployment benefit mechanism, this rate can be better matched. The unemployment rate that has been given as the empirically observed value has been obtained by using the data provided by the US Census Bureau (US Census Bureau, Current Population Reports, 2001-2008).

Finally since personal care activities are not explicitly included in the model economy, but rather included in time devoted to leisure, the model is only moderately successful in predicting proportions of time which are spent working in the market and working at home and time devoted to leisure. The empirical proportions of time that are allocated to these three activities have been obtained averaging the values reported in 2003-2008 editions of American Time Use Surveys.

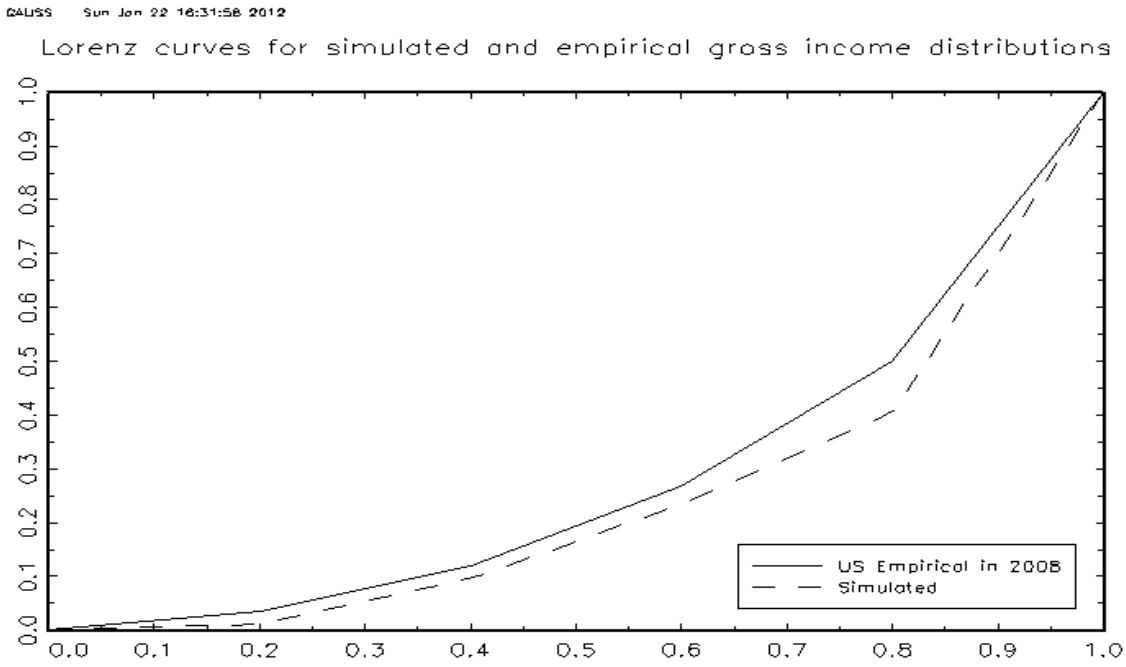


Fig. 1 Lorenz curves for simulated and empirical gross income distributions

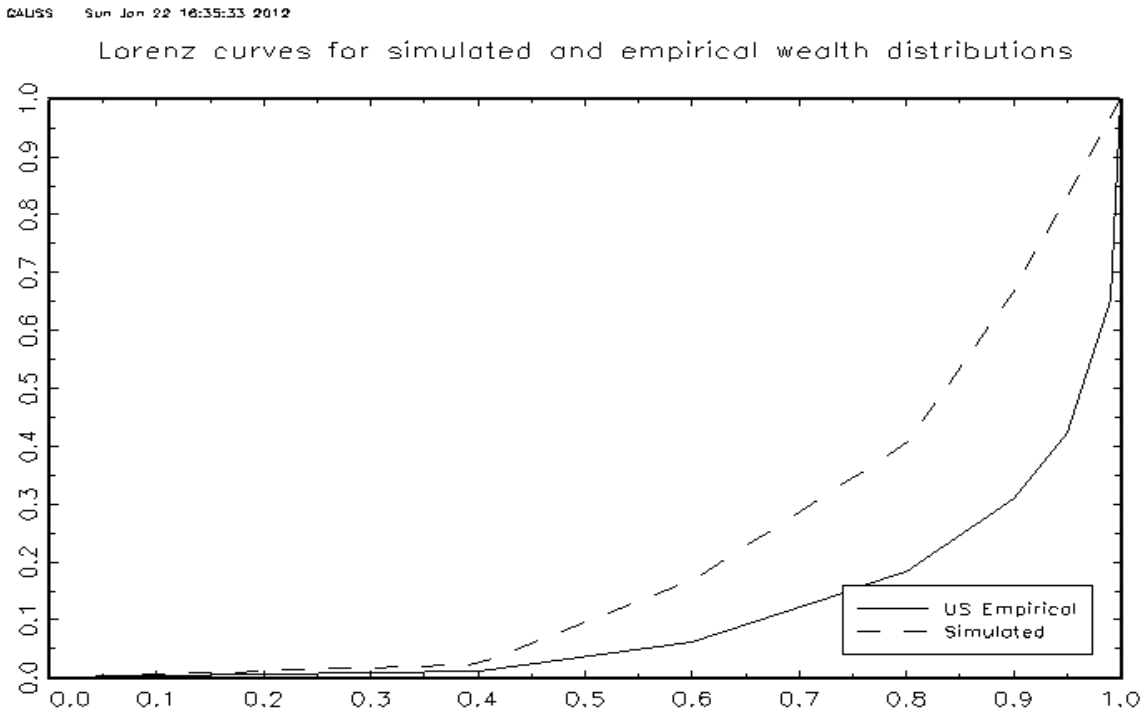


Fig. 2 Lorenz curves for simulated and empirical wealth distributions

CHAPTER 5

TAX REFORM PROPOSALS

In this chapter the equity, efficiency and welfare effects of two revenue neutral tax reform proposals are examined. The first reform proposal is to replace the progressive income taxation scheme in the benchmark model with a flat income tax that will be revenue neutral in income tax revenue. The second reform proposal is to abolish the income tax and increase the flat consumption tax so that by itself the tax revenue from taxing consumption will equal the entire tax revenue of the benchmark model. The results of these two reform proposals are discussed below and summarized in Table 7. The government expenditure to output ratio is kept at the constant level of 0.19 in both of these tax reforms and the flat consumption tax is solved endogenously so that the government's budget is balanced in the steady state.

Revenue Neutral Flat Income Tax Reform

The flat tax rate which ensures a revenue neutral income tax reform is 14.65% in our model economy. Adopting a flat income taxation scheme has two opposing effects on the labor-leisure choice of both high and low productivity agents. On the one hand, since they now face a lower marginal tax rate on their labor income, high productivity workers choose to work longer hours. The opposite is true for low productivity workers; since flat taxation means a higher marginal tax rate on their labor income, they choose to work less. This is the substitution effect due to the change in income taxation.

On the other hand, flat taxation means that high productivity workers face a lower tax rate on all previously earned labor income, so they can afford to work less with the new tax scheme. The opposite is true for low productivity workers, they need to work longer just to be able to maintain their previous levels of labor income. This is the wealth effect due to the change in income taxation. These are the two opposing effects on aggregate effective labor supply of a flat income tax reform.

It turns out that the net effect of adopting flat taxation on the aggregate effective labor supply of the model economy is positive. By inspecting Table 7, it is seen that the aggregate effective labor supply goes up by 2.06%. Aggregate labor supply, i.e., total time worked in the market sector by all agents, also goes up from 0.331 to 0.350. Other statistics regarding labor in the market sector change as follows: Coefficient of variation of hours worked in the market sector decreases from 0.287 to 0.265. Gini coefficient of labor income distribution hardly changes at all. The proportion of time spent working in the market sector increases from 0.307 to 0.320, whereas the proportion of time spent working at home and the proportion of time devoted to leisure decreases.

Savings behavior of households is also subject to the income and substitution effects mentioned above. High productivity households with high levels of wealth face a lower marginal tax rate on the return on their capital investments with flat taxation, which gives them an incentive to save more. However flat taxation also means a lower tax rate on the return on their previously made capital investments, which incentivizes them to decrease their savings. The opposite is true for households characterized by low productivity and low levels of wealth.

Again it turns out that the net effect on aggregate capital stock of adopting

flat taxation is positive. Aggregate capital stock increases from 4.904 to 5.387, which means an almost 10% increase. Capital to output ratio increases from 2.73 to 2.851. Gross return on capital investments (*r)* decreases from 0.140 to 0.133 (a fall of 5%) due to the increase in the aggregate capital stock. Gini coefficient of the wealth distribution increases from 0.694 to 0.729, so the wealth distribution of the society becomes less equitable with flat taxation.

Aggregate market good consumption of the society increases from 1.282 to 1.338, however due to the simultaneous increase in output, aggregate market good consumption to output ratio hardly changes at all.

To determine the effect on welfare of the flat tax reform, I use the consumption equivalent change (Δc) formulation as proposed by McGrattan (1994) and used by Heer and Trede (2003):

$$1-(1+\Delta c)^{1-\sigma}=\frac{W(\Omega')-W(\Omega)}{\int_{\mathbb{S}} E_0[\sum_{t=0}^{\infty}\beta^t\frac{C_t{}^{1-\sigma}}{1-\sigma}]\ d\Psi(\Omega)} \qquad (27)$$

where: Ω is the taxation scheme of the benchmark model and Ω' is the new taxation scheme. $\Psi(\Omega)$ is the stationary measure of households which depends on the taxation scheme.

The change in welfare following the switch to flat income taxation is negative for the society as a whole. Total welfare of the society falls by 6.78%. Although this result is contrary to the findings of many previous studies in the literature, it is not that surprising, since the same conclusion has been arrived at and justified in two of the seminal papers mentioned in Chapter 2. In Diaz-Gimenez and Pijoan-Mas (2006), after the less progressive flat tax reform has been adopted, aggregate welfare falls by

-0.17% of consumption. Moreover Conesa and Krueger (2006) show that a purely proportional income tax reduces social welfare in spite of increasing aggregate output and consumption. As stated in the introduction, a progressive tax system acts as a partial substitute for missing insurance markets and therefore enhances aggregate welfare, however it also distorts endogenous labor supply and capital accumulation decisions of agents and tends to decrease welfare on that account. So the net effect on welfare of moving from progressive to flat taxation depends on which one of these effects is more influential.

To be able to see quantitatively why total welfare falls with flat taxation, I order the states households can be in according to their implied gross incomes and then divide these ordered states into five equal groups. So the households in these five groups have incomes in the following ranges:

Group I households: *Income between 0 and 0.2*ymax*

Group II households: *Income between 0.2 and 0.4*ymax*

Group III households: *Income between 0.4 and 0.6*ymax*

Group IV households: *Income between 0.6 and 0.8*ymax*

Group V households: *Income greater than 0.8*ymax*

where *ymax* is the maximum possible gross income in the model. The proportions of households who are in each of these five groups in the steady state have been given in Table 5. The consumption equivalent changes of welfare that households in each group experience after the tax reforms have been given in Table 6. Examining the output given in Table 6 shows us that agents in the lowest first and second gross

income groups are actually hurt by flat taxation. This is mainly due to the fact that these lowest earning households face higher marginal tax rates when flat taxation is adopted. The opposite situation exists for households in the other higher income groups. They face a lower marginal tax rate following the switch to flat taxation and all of them benefit from flat taxation. Actually the highest earning households who are in the top income group benefit so much that their total welfare increases by almost 20%.

Total welfare of the society falls after a switch to flat taxation, because the households in the first and second gross income groups who are hurt by flat taxation constitute up to almost 85% of the society. Therefore for a society where the gross income distribution is more equitable, it can safely be said that a switch to flat taxation may very well increase total welfare.

Revenue Neutral Consumption Tax Reform

As mentioned previously, in this tax reform proposal income taxation is altogether abandoned and consumption is being taxed at a flat rate which ensures revenue neutrality. The consumption tax rate that fits this criterion is 25.17% for our model economy (compared to 8.06% that endogenously solved the benchmark model with progressive income and flat consumption taxation.)

As neither labor income nor return on capital investment is being taxed anymore, both aggregate effective labor supply in the market sector and aggregate capital stock increases after a switch to consumption taxation. Aggregate effective labor supply increases from 1.165 to 1.217 and aggregate capital stock increases

from 4.904 to 5.772 (an increase of 17.7%). Associated with these changes, there is a fall in the gross return on capital investment *(r)* from 0.140 to 0.131 (6.43% decrease). Capital to output ratio increases from 2.73 to 2.929.

Aggregate market good consumption increases from 1.282 to 1.407. Aggregate market good consumption to output ratio slightly increases from 0.6557 to 0.660.

On the side of the labor in the market sector statistics, coefficient of variation of hours worked in the market sector increases moderately from 0.287 to 0.312. This change is due to higher productivity workers working longer and lower productivity workers working less in the market sector following the switch to consumption taxation. Average proportion of time that is spent working in the market sector increases and the proportion of time spent working at home and the proportion of time devoted to leisure decreases.

The Gini coefficient of the capital distribution falls a bit from 0.694 to 0.624 which implies that the capital distribution becomes slightly more equitable with taxing consumption alone. Recalling that the interest rate falls simultaneously after the switch to consumption taxation due to the substantial increase in aggregate capital stock, it is seen that this result is in accordance with economic theory. Capital market models with moral hazard predict that the wealth distribution should become more equitable as the interest rates fall. Moreover this prediction has also been validated by Grüner (2001) who conducts an econometric analysis to show a positive correlation between interest rates and inequality of the wealth distribution for the US economy.

Gini coefficient of the gross income distribution remains almost unchanged after the switch to consumption taxation . This situation can be understood by examining the changes in the wealth and labor income distributions. The wealth distribution as explained in the previous paragraph becomes more equitable following the fall in the interest rate. Labor income distribution on the other hand becomes less equitable. Gini coefficient of the labor income distribution rises from 0.441 to 0.447. Examining the numerical results show us that the substitution effect proves to be more dominant for high productivity agents and the wealth effect proves to be more dominant for low productivity agents when the tax on labor income is lifted. So following the increase in the wage rate that comes with consumption taxation, high productivity agents choose to work more than low productivity agents in the market sector and the labor income distribution becomes less equitable. These changes in the wealth and labor income distributions counteract each other and the Gini coefficient of the gross income distribution remains almost unchanged.

Total welfare of the society increases by 2.07% by the consumption equivalent change criterion. The households who are in the third income group and who constitute 16.6% of the population in the steady state with consumption taxation are hurt the most after consumption taxation is adopted. Their consumption equivalent change of welfare is almost -45%. Households in the poorest income group are almost unaffected and households in the second, fourth and fifth income groups benefit from the tax reform.

Table 5. Stationary Distribution of Agents with respect to their Gross Income

	Group-I	Group-II	Group-III	Group-IV	Group-V
Benchmark model	46.26%	38.12%	14.72%	0.91%	$4.66x10^{-5}$
Flat tax reform	46.49%	38.02%	14.72%	0.78%	$4.59x10^{-5}$
Consumption tax reform	46.57%	36.25%	16.60%	0.55%	$4.50x10^{-5}$

Table 6. Consumption Equivalent Change of Tax Reforms for Income Groups - $\Delta C\%$

	Group-I	Group-II	Group-III	Group-IV	Group-V
Flat tax reform	-9.41	-3.44	5.39	16.81	19.37
Consumption tax reform	-0.87	10.95	-44.73	3.28	3.98

Table 7. Summary of the Effects of Tax Reforms

	Benchmark model	Flat income tax	Consumption tax
Aggregate capital stock *K*	4.904	5.387	5.772
Aggregate raw labor supply in the market sector – *N*	0.331	0.350	0.333
Aggregate effective labor supply – *Neff*	1.165	1.189	1.217
Aggregate market good consumption – *C*	1.282	1.338	1.407
Aggregate output – *Y*	1.955	2.048	2.131
Capital to output ratio - *K/Y*	2.730	2.851	2.929
Aggregate market good consumption to output ratio – *C/Y*	0.6557	0.6530	0.660
Interest rate – *r*	0.140	0.133	0.131
Wage – *w*	1.088	1.122	1.133
Coefficient of variation of hours worked in the market – *lcoeff*	0.287	0.265	0.312
Gini coefficient of the wealth distribution *wgini*	0.694	0.729	0.624
Gini coefficient of the labor income distribution - *lgini*	0.441	0.439	0.447
Gini coefficient of the gross income distribution - *ygini*	0.544	0.549	0.545
Proportion of time worked at home	0.225	0.221	0.218
Proportion of time worked in the market sector	0.307	0.320	0.330
Proportion of time devoted to leisure	0.468	0.459	0.452
Total welfare – *W*	-18.758	-20.029	-18.359
Consumption equivalent change - ΔC %	0	-7.270	2.070

CHAPTER 6

CONCLUSION

The subject of this thesis was to quantitatively explore the effects of adopting two revenue neutral tax reforms on equity, efficiency and welfare of the society. In order to do this, a DSGE model with heterogeneous, infinitely lived agents who faced uninsured idiosyncratic productivity shocks has been constructed. The model has been calibrated to match the aggregate macroeconomic quantities and distributional characteristics of the US economy in the period 2001-2008. The simulation exercise has achieved different levels of success in matching empirical observations, however other than the simulated rate of unemployment, no great discrepancy has risen between the simulated results and empirical observations.

Next the model economy has been used to investigate the effects of the proposed revenue neutral tax reforms. The first of the reforms was to replace progressive income taxation with flat income taxation and the second one was to abolish income taxation altogether and adopt a flat consumption tax. To summarize the results, both of the tax reforms had a positive impact on efficiency, savings increased by 10% and 17.7% and aggregate effective labor supply increased by 2.06% and 4.47% respectively for the flat tax and consumption tax regimes. Due to the increase in savings, interest rate fell in both reforms. Equity of the labor income and total income distributions as measured by the Gini coefficient almost did not change. The distribution of wealth became significantly less equitable with the flat

taxation regime and slightly more equitable with the consumption tax regime. In terms of welfare, after the switch to flat taxation agents in the model economy became worse-off as a whole, because the great majority of agents in the model were in the first and second income groups and these groups were negatively affected. Since other income groups were positively affected, I reasoned that adopting flat taxation for a society with even a moderately more equitable income distribution may very well increase welfare. In the case of consumption tax reform, agents as a whole became slightly better off, even though agents in the third income group were very negatively affected.

To comment on whether these results are in accordance with previous seminal works in the field, economic theory and intuition, I can summarize my findings and thoughts as follows. The result that with flat taxation total welfare in the model economy decreases is by no means unique and it has been discussed in detail in the previous chapter why such a result has been arrived at. Again the result that consumption taxation causes a slight increase in the Gini coefficient of the wealth distribution is in accordance with economic theory, since consumption taxation causes a substantial increase in aggregate capital stock and therefore a significant decrease in the interest rate. As mentioned previously such a change should indeed produces a more equitable wealth distribution according to capital market models with moral hazard.

Other than these two important results, both tax reforms led to more efficiency and flat taxation created a less equitable wealth distribution. These results are not contrary to the conclusions which have been arrived at in previous seminal papers in this field. Also neither labor income nor total income distributions were

greatly affected by either reform. Again in none of the seminal studies that were mentioned in Chapter 2, a contrary result has been obtained.

To self-criticize the study that has been conducted in this thesis, I imagine that one of the issues that can be raised is why the home production mechanism in the model economy does not include home capital. Although my initial intention was to include home capital in the model economy and I modified the computer code which solves the model to include home capital, the computation times were too long to be feasible with the kind of computers I had access to. In the future if I can gain access to more powerful computers, I intend to extend this study and include home capital in the home production mechanism.

Another criticism can be why an OLG model has not been used. The reason is that OLG models that solve labor supplies endogenously are much harder to solve numerically. Since this is a master's thesis, it is only reasonable to take the first logical step and learn how to solve numerically a model with infinitely lived agents first and then try my hand on an OLG model in the future.

These possible criticisms of course point the way for future studies. A sensible extension to this study would be to solve the same model with finitely lived agents, i.e., use an OLG model, and include home capital in the home production mechanism. As mentioned in Chapter 2, using an OLG model would enable the agents to have a life-cycle saving motive. In addition a bequest mechanism can be added to an OLG model. Both the life-cycle saving motive and the bequest motive would enable the model to better match the empirically observed Gini coefficient of the wealth distribution. One other addition I would like to make to this model in the future is to include a more elaborate unemployment benefit scheme which will

enable the model's simulated result for the unemployment rate to match the empirically oberved one.

Also as part of future works based on this study, the same model should be constructed and solved without home production and the results should be compared with the results that have been obtained in this study to better understand the effects of including home production in this model.

APPENDIX A

COMPUTATIONAL METHOD

The computational method that has been used to solve the benchmark model can be summarized as follows:

Step 1) Initial guesses are made for aggregate capital stock, aggregate effective labor supply in the market sector and the flat consumption tax rate (τ_c) which will be solved endogenously in the model. The wage rate, *w*, gross return on capital, *r* and unemployment benefit *b* that are implied by these initial guesses are computed.

Step 2) Through value function iteration, the optimal combination of control variables for agents in each state are calculated.

Step 3) Using households' optimal decisions' on how much capital stock to hold in the next period, stationary distribution of agents over the state space is calculated through iteration.

Step 4) Once the stationary distribution of agents and their optimal control variable decisions are obtained, aggregate capital stock, aggregate effective labor supply in the market sector, aggregate labor supply in the home sector, aggregate consumption that solve aggregate consistency equations are calculated. Tax revenue from income taxation and total tax revenue are also calculated.

Step 5) Using government's budget equation, the flat consumption tax rate τ_c that balances the government's budget is calculated.

Step 6) Aggregate capital stock, aggregate effective labor supply in the market sector, aggregate labor supply in the home sector, unemployment benefit and flat consumption tax rate are updated using the values that have been obtained in steps four and five.

Step 7) Steps one to six are repeated until convergence over aggregate capital stock is obtained or until a total of fifty iterations over aggregate capital stock are completed.

Some important details of the computation method that has been employed, is given below.

Before any of the steps explained here are taken, a two dimensional state space is created to keep track of the agents in each state. (Recall that the agents in the model economy were heterogeneous with respect to their productivities and beginning of period capital stocks. Thus the state space is two dimensional. If the home production function were to contain home capital, the state space would be three dimensional; because the households would also be heterogeneous with respect to their beginning of period home capital stocks.) The amount of capital that can be held by any agent at any given period is between $kmin = 0$ and $kmax$. (Following Heer and Trede (2003), I set $kmax = 12$.) A capital grid with 1000 grid points that lies between $kmin$ and $kmax$ is also created. Since there are four productivity types, the state space has 4000 grid points. (1000 possible beginning of period capital stock values for agents in each productivity type.)

In step two, to prevent the algorithm from checking every single control variable combination that is available to agents in each state, the following facts are exploited: i) Value function is a monotone increasing function of capital,

ii) Consumption is strictly positive and monotone increasing with capital, iii) Labor supply decision in the market sector is monotonely decreasing with capital. Using these facts reduces the computation time significantly.

In step two, following the example set by Heer and Trede (2003), in the first ten iterations over the aggregate capital stock, value function iteration is done only ten times since in these first iterations a high accuracy for the optimal values of control variables is not required. Starting from the eleventh iteration over the aggregate capital stock, value function iteration is done twenty times to achieve a higher accuracy when calculating optimal control variable values.

The same strategy is also pursued in step three when calculating the stationary distribution of agents over the state space. In the first ten iterations over the aggregate capital stock, only five hundred iterations are conducted to compute the stationary distribution; however after the eleventh iteration over the aggregate capital stock, five thousand iterations are conducted in each iteration.

APPENDIX B

SENSITIVITY ANALYSIS RESULTS

In this section the effects of decreasing and increasing the coefficient of relative risk aversion (σ) and the home production function parameter (η) are analyzed.

As can be seen by inspecting Table B1, decreasing the coefficient of relative risk aversion decreases the aggregate capital stock and aggregate effective labor supply of the economy. As a result aggregate output of the economy decreases and gross return on capital investment increases. Agents also increase their consumptions of the market produced good and consequently total welfare increases. Consumption to output ratio increases and aggregate capital to output ratio decreases. These results can be explained as follows.

Since decreasing the coefficient of relative risk aversion makes agents less risk averse, they are less inclined to accumulate extra capital due to the precautionary saving motive and this decreases the aggregate capital stock and increases the interest rate in the new steady state.

Decreasing the coefficient of relative risk aversion decreases the coefficient of variation of hours worked in the market sector (except for the benchmark case) and increases the Gini coefficient of the wealth distribution. (Recalling the positive correlation between the interest rate and the Gini coefficient of the wealth distribution this result is in line with the predictions of the economic theory). Gini coefficients of the labor income and gross income distributions are almost

unaffected. The proportion of time that is devoted to leisure and the proportions of time that are dedicated to working in the home and market sectors are not that much affected either.

By inspecting Table B2, it can be seen that increasing the coefficient of relative risk aversion causes the opposite effects that have been explained above.

The results of decreasing and increasing the home production function parameter (η) have been reported in Tables B3 and B4. Decreasing this parameter implies that the marginal productivity of time spent working at home increases and this should mean that time spent at home increases as η increases.

Investigating Tables B3 and B4 shows us that, indeed, when η decreases, the proportion of time that is spent working at home increases and time spent working in the market sector and time devoted to leisure decrease. Also when η decreases, aggregate effective labor supply, aggregate capital stock, aggregate consumption of the market produced good and aggregate output increase and total welfare decreases. The opposite effects are obtained if η is increased.

Consumption to output ratio seems only slightly affected (except for the consumption tax reform) when η is either increased or decreased. Also increasing or decreasing η causes the interest rate to fall, the wage level to increase slightly, the coefficient of variation of hours spent working in the market sector to increase and the Gini coefficient of the wealth distribution to decrease. The Gini coefficients of the labor income and gross income distributions are almost unchanged.

Table B1. Sensitivity Analysis Results for $\sigma = 1$

	Benchmark model	Flat income tax	Consumption tax
Aggregate capital stock *K*	3.884	4.715	5.465
Aggregate raw labor supply in the market sector – *N*	0.330	0.358	0.345
Aggregate effective labor supply – *Neff*	1.003	1.149	1.210
Aggregate market good consumption – *C*	1.289	1.377	1.525
Aggregate output – *Y*	1.633	1.911	2.083
Capital to output ratio - *K/Y*	2.378	2.468	2.624
Aggregate market good consumption to output ratio – *C/Y*	0.789	0.721	0.732
Interest rate – *r*	0.149	0.140	0.134
Wage – *w*	1.052	1.090	1.17
Coefficient of variation of hours worked in the market – *lcoeff*	0.335	0.224	0.288
Gini coefficient of the wealth distribution *wgini*	0.761	0.857	0.693
Gini coefficient of the labor income distribution - *lgini*	0.442	0.429	0.445
Gini coefficient of the gross income distribution - *ygini*	0.545	0.544	0.550
Proportion of time worked at home	0.225	0.230	0.221
Proportion of time worked in the market sector	0.309	0.292	0.320
Proportion of time devoted to leisure	0.466	0.478	0.459
Total welfare – *W*	-10.607	-11.017	-10.481
Consumption equivalent change - ΔC % [3]	0	-33.635	13.428

[3] As σ approaches 1, our utility function converges assymptotically to the $ln\, c$ utility function. Using the consumption equivalent change formula given in page 37 for the $ln\, c$ utility function seems to yield rather large percentage changes. I have not been able to figure out the reason behind the large magnitude of these changes. I intend to explore this issue futher in the future.

Table B2. Sensitivity Analysis Results for $\sigma = 4$

	Benchmark model	Flat income tax	Consumption tax
Aggregate capital stock *K*	6.783	7.366	7.751
Aggregate raw labor supply in the market sector – *N*	0.310	0.300	0.311
Aggregate effective labor supply – *Neff*	1.246	1.287	1.319
Aggregate market good consumption – *C*	1.379	1.435	1.550
Aggregate output – *Y*	2.293	2.412	2.495
Capital to output ratio - *K/Y*	2.958	3.053	3.107
Aggregate market good consumption to output ratio – *C/Y*	0.601	0.595	0.621
Interest rate – *r*	0.122	0.117	0.115
Wage – *w*	1.178	1.199	1.211
Coefficient of variation of hours worked in the market – *lcoeff*	0.335	0.409	0.361
Gini coefficient of the wealth distribution *wgini*	0.433	0.389	0.383
Gini coefficient of the labor income distribution - *lgini*	0.451	0.456	0.453
Gini coefficient of the gross income distribution - *ygini*	0.541	0.534	0.537
Proportion of time worked at home	0.213	0.210	0.206
Proportion of time worked in the market sector	0.344	0.354	0.366
Proportion of time devoted to leisure	0.443	0.436	0.428
Total welfare – *W*	-82.022	-85.849	-77.952
Consumption equivalent change - ΔC %	0	-1.611	1.601

Table B3. Sensitivity Analysis Results for $\eta = 1.25$

	Benchmark model	Flat income tax	Consumption tax
Aggregate capital stock *K*	4.717	5.084	5.324
Aggregate raw labor supply in the market sector – *N*	0.289	0.273	0.285
Aggregate effective labor supply – *Neff*	1.040	1.049	0.964
Aggregate market good consumption – *C*	1.192	1.232	1.305
Aggregate output – *Y*	1.792	1.851	1.783
Capital to output ratio - *K/Y*	2.632	2.746	2.986
Aggregate market good consumption to output ratio – *C/Y*	0.665	0.666	0.732
Interest rate – *r*	0.137	0.131	0.119
Wage – *w*	1.103	1.132	1.191
Coefficient of variation of hours worked in the market – *lcoeff*	0.316	0.409	0.367
Gini coefficient of the wealth distribution *wgini*	0.466	0.472	0.463
Gini coefficient of the labor income distribution - *lgini*	0.436	0.442	0.442
Gini coefficient of the gross income distribution – *ygini*	0.545	0.536	0.539
Proportion of time worked at home	0.313	0.308	0.303
Proportion of time worked in the market sector	0.282	0.292	0.304
Proportion of time devoted to leisure	0.405	0.400	0.393
Total welfare – *W*	-28.297	-28.377	-27.830
Consumption equivalent change - ΔC %	0	-0.283	1.624

Table B4. Sensitivity Analysis Results for $\eta = 5$

	Benchmark model	Flat income tax	Consumption tax
Aggregate capital stock *K*	6.386	6.845	7.059
Aggregate raw labor supply in the market sector – *N*	0.384	0.379	0.370
Aggregate effective labor supply – *Neff*	1.346	1.387	1.185
Aggregate market good consumption – *C*	1.503	1.581	1.730
Aggregate output – *Y*	2.358	2.465	2.253
Capital to output ratio - *K/Y*	2.709	2.777	3.133
Aggregate market good consumption to output ratio – *C/Y*	0.638	0.642	0.768
Interest rate – *r*	0.129	0.127	0.115
Wage – *w*	1.139	1.149	1.217
Coefficient of variation of hours worked in the market – *lcoeff*	0.260	0.315	0.324
Gini coefficient of the wealth distribution *wgini*	0.592	0.691	0.429
Gini coefficient of the labor income distribution - *lgini*	0.453	0.462	0.465
Gini coefficient of the gross income distribution – *ygini*	0.542	0.542	0.529
Proportion of time worked at home	0.101	0.099	0.097
Proportion of time worked in the market sector	0.375	0.390	0.402
Proportion of time devoted to leisure	0.524	0.511	0.501
Total welfare – *W*	-12.408	-12.503	-10.954
Consumption equivalent change - ΔC %	0	-0.772	10.489

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