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**Essays in Dynamic Political Economics**

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# Essays in Dynamic Political Economics

by

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# Essays in Dynamic Political Economics

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The focus of my research is dynamic political economy in macroeconomics. The first chapter of my dissertation studies the fact that Countries in the Organization of Economic Co-operation and Development (OECD) vary widely in their ratio of capital tax rates to labor tax rates. This chapter's motivation is the strong negative correlation between the capital/labor tax ratio and old dependency ratio (defined as the ratio of population older than 65 years old to population between 20 and 65 years old) among 21 OECD countries. I study a parsimonious overlapping generations (OLG) majority voting model. In equilibrium, the retired households and relatively old working households hold a large amount of capital and vote for a low capital tax rate (implying a high labor tax rate), while relatively young working households hold a small amount of capital and vote for a high capital tax rate (implying a low labor tax rate). As a result, the model implies that countries with more old people have relatively lower capital taxes. The model takes the old dependency ratio as given and delivers a capital/labor tax ratio chosen by the median voter. The calibrated model presented here can generate not only this negative correlation, but also the tax ratios for the 21 OECD countries studied. In the second chapter, I extend the first chapter and study the Japanese economy and taxation for the past three decades. Population aging is a serious social issue in Japan. This chapter also shows that demographics is an important variable to explain the time series data of capital and labor tax rates. Interestingly, the model predicts that a benevolent or utilitarian government would set a capital tax rate to be zero as in many standard tax models. This result emphasizes the importance of modeling a political economy, as opposed to a standard social planning economy that has been extensively used previously. Finally, the third chapter focuses on US immigration policy. Illegal immigration from Mexico to the United States has been a hot topic to academic researchers and policy makers. This study quantitatively investigates the welfare effects of illegal immigration to native households in the US. More specifically, I simulate the model economy when the government deports every illegal immigrant. The simulation shows that the social welfare increases by 0.01 percent on average, and the poorest households' welfare increases by 0.1%. Although, initially, there is a decrease in the interest rate and the unemployment rate as well as an increase in the wage, these variables in the no-illegal-immigrant steady state are almost identical to the initial steady state which is calibrated to the US economy.

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# Chapter 1

# Demographics and Effective Capital/Labor Taxes in OECD Countries

## 1.1 Introduction

This chapter uses a parsimonious overlapping generations (OLG) dynamic majority voting model to explain a wide variation in the ratio of capital tax rates to labor tax rates among OECD countries, by linking the capital/labor tax ratios to the demographics of the countries. The data from 21 OECD countries show that a country with an older population has a capital tax rate that is relatively low in comparison to its labor tax rate. A country with a younger population has a labor tax rate that is relatively high compared to its capital tax rate. In the model, retired households and relatively old working households depend more on income from wealth accumulated during their working years (and hence prefer a lower capital tax rate to a lower labor tax rate), whereas relatively young working households depend more on labor income (and hence prefer a lower labor tax rate to a lower capital tax rate). The intergenerational conflict is modeled by developing a dynamic majority voting model in a small open economy. A political economy model is well-suited to capture such generational conflicts in tax preferences. I calibrate the model to match properties of each OECD country, and then evaluate the response of the tax policies to the observed difference in demographics. The model is successful in explaining the relationship between the tax ratio and demographics, both quantitatively and qualitatively.

Figure 1 displays the facts to be explained in this study. First, there is a strong negative correlation between the capital/labor tax ratio and old dependency ratio (defined as the ratio of population older than 65 years old to population between 20 and 65 years old) among 21 OECD countries. Second, the tax ratios vary between 0.3 and 1.5. Third, there is a nonlinear relationship between the tax ratios and old dependency ratios. Once the old dependency ratio reaches a certain level, the tax ratios become insensitive to changes in the old dependency ratios. Thus, the relationship between the old dependency ratios and tax ratios is nonlinear.

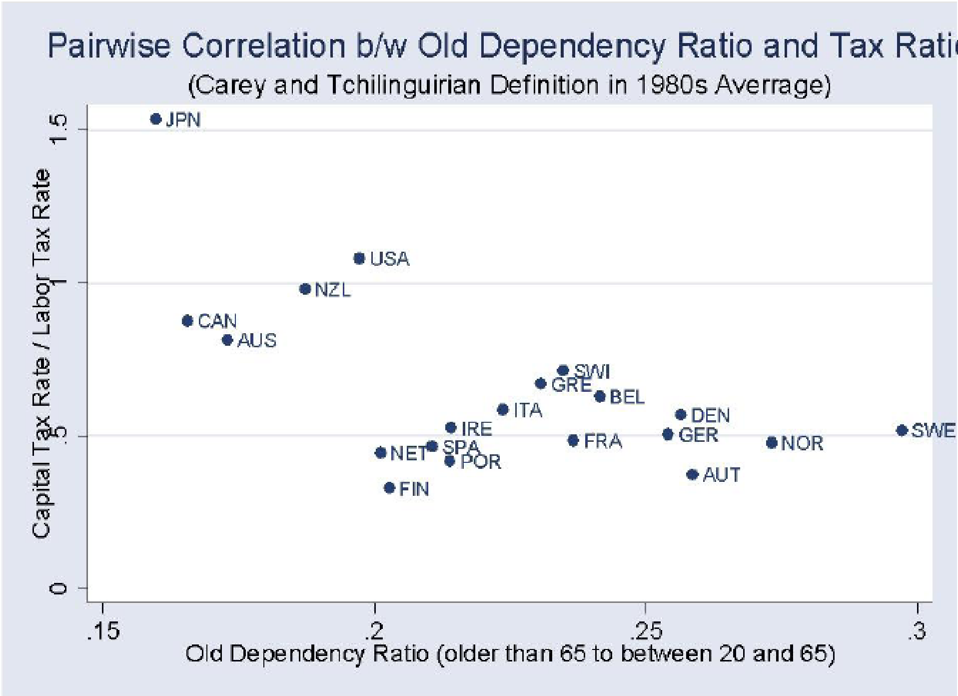
Retired households do not have any labor income and thus, do not pay any labor income tax. Therefore, they desire a low capital tax rate. Among working households, there is a wealth distribution. Typically, the younger the household is, the smaller amount of assets it holds. Working households with a large amount of assets desire a low capital tax rate since a large proportion of their income comes from capital income. Working households with a small amount of assets may prefer a low labor tax rate. However, their tax preferences are not as intuitive as the retired households, especially when the tax policy is sticky in a sense that the tax rates do not significantly change year to year. The reason that working households with few assets may prefer low tax rates is that they accumulate assets over time and start paying more and more capital taxes. Two typical assumptions in the heterogeneous agent model literature help us to understand why working households may prefer a low labor tax rate: credit constraint and risk aversion. Consider a risk-averse young household who has just entered a labor market without any assets. She wants to smooth her consumption over her lifecycle, but she is credit-constrained. A low labor tax rate gives her more after-tax labor income so that she can consume more today, and potentially save more for her retirement days. Therefore, under these conditions, young working households may prefer a low labor tax rate.

To link the old dependency ratio to the tax ratio and to capture the mechanism described in the previous paragraph, I use a parsimonious OLG model with uninsurable, idiosyncratic retirement shocks and death shocks, similar to Gertler (1999). A reasonably parameterized model can generate an old dependency ratio that is comparable to the observed old dependency ratio in the data. Further more, with incomplete markets, the model is able to generate a reasonable asset distribution that mimics the fact that people accumulate more capital over time until they retire. I also use a political recursive competitive commitment equilibrium concept developed by Krusell and Rios-Rull (1999), and extended by Corbae, D'Erasmo, and Kususcu (2008) (henceforth, CDK). Specifically, tax rates are endogenously determined by a median voter with commitment.

Since the basic idea and intuition of this study are simple, one may question why we need such a complicated infinite-horizon political economy model. Developing a dynamic model, as opposed to a static model, is necessary because capital is a dynamic variable by definition and households' dynamic asset accumulation behaviors affect their tax preference as well. For example, workers younger than 30 years old and workers older than 50 years old hold a different amount of assets and make different saving decisions. Therefore, their tax preferences are different as well. Ideally, one can develop an infinite-horizon OLG model in which each agent lives for as many as 65 years. However, this is computationally too time-intensive. The main question in this chapter is not only qualitative (the correlation being negative), but also quantitative (I measure the success of my model by looking at the level of predicted tax ratio as well). A simple two or three period OLG model or infinite-horizon OLG model in which agents live only for two periods cannot be easily taken to the data. My model is simple enough to compute, and at the same time, rich enough to capture the important mechanisms and generate heterogenous tax preferences among households.

The specific experiment this chapter considers is to calibrate the economy from a standard real business cycle (RBC)/growth model as well as the old dependency ratio data in Figure 1. Only heterogeneity across countries considered here is heterogeneity in the old dependency ratio, leading to heterogeneity in the retirement probability and the death probability. I compute the equilibrium tax ratio for each country. The calibrated model generates a strong negative correlation between the old dependency ratio and the capital/labor tax ratio. The model not only generates the right negative correlation, but also matches the level of tax ratio. Further more, the model generates a non-linear relationship, such that the tax ratio becomes less sensitive to the changes in the demographics when the old dependency ratio is high as in the data.

*Figure* 1.1 (Pairwise Correlation)




x axis - old dependency ratio, y axis - $\tau_k/\tau_l$

There exists a large volume of the literature on capital and labor taxation (Chamley, 1986). However, most quantitative work has been done exclusively for the US economy (Klein and Rios-Rull, 2003; Conesa, Kitao, and Krueger, 2006; Domeij and Heathcote, 2004). The studies that come closest to a discussion of cross-country differences in the effective capital and labor tax rates are Klein, Quadrini, and Rios-Rull (2005), and Mendoza and Tesar (2005).

Klein, Quardini, and Rios-Rull explain why the US government taxes capital income more heavily than all major EU countries except the United Kingdom. In their two country model, (exogenous) differences in population and government expenditure as a share of GDP play an important role. Time-consistency also plays an important part in determining equilibrium tax rates. Mendoza and Tesar investigate the role that international tax competition among EU countries may play. Their two country models are successful in explaining the fact that the United Kingdom taxes capital income more than continental EU countries such as Germany. However, their models are still limited to only two country settings. In summary, the previous literature focuses heavily on the US economy, and the cross-country comparison of tax rates has not been explored extensively. What distinguishes this study from these previous studies is that, first, it studies 21 countries for two different time periods in a small open economy model, and, second, it links demographics and tax rates using a political mechanism. This study develops a theoretical model to explain this relationship and also successfully replicates the tax ratios of a large set of countries.

The rest of this study is organized as the following: Section 2 presents the facts about the tax ratio of OECD countries. Section 3 describes the model.

Section 4 presents the calibration and numerical results. Section 5 concludes.

### 1.2 Facts

To measure the relationship between demographics and tax rates, some moments to capture demographics and tax rates need to be defined and incorporated into the model. Statistics such as the median age, the total fertility rate, the population growth rate, and the old dependency ratio can be used to capture demographics or age distribution of population. The old dependency ratio measures the important demographics in this study. The old dependency ratio is the ratio of people older than 65 to those between 20 and 65 years old. Age 65 is chosen as the cutoff line because in many OECD countries people retire at the age of 65 and retired households have a different mix of capital and labor income than working (young) households. Thus, retired households and working households may vary in their preference of capital and labor taxes.

This study adopts the definition of Carey and Tchilinguirian (2000), which is a revision of Mendoza, Razin, and Tesar (1996), commonly used in the literature. The tax rates reported in these studies are similar, and highly correlated. Their methodology of estimating capital, labor, and consumption tax rates, is to carefully categorize tax revenues and incomes into capital tax revenue, capital income, labor tax revenue, labor income, and consumption tax revenue. Labor tax revenue, labor income, and consumption tax revenue are easily identified in the data. If tax revenue is not from a labor tax or a consumption tax, it is classified as capital tax revenue. Similarly, if income is not from labor income, it is classified as capital income. In other words, capital tax revenue and capital income are residuals. Once the tax revenue and income are categorized, the tax rates are simply defined as the ratio of each tax revenue to each income. Not only are the US effective tax rates different from other OECD countries, but also countries vary widely in their effective capital and labor tax rates. This large variation motivates the extension of tax analysis from only the US economy to multiple economies in the OECD countries, though these studies do not address reasons for the variation in tax rates among them.

This study also uses tax ratios to summarize the capital and labor tax rates across countries. The tax ratio is defined as capital tax rate divided by labor tax rate ($\tau^k/\tau^l$). $\tau^l$ is defined as

$$\tau^l = 1 - \frac{1 - \widetilde{\tau}^l}{1 + \tau^c},$$

where $\widetilde{\tau}^l$ is the tax rate on labor income and $\tau^c$ is the consumption tax. This definition of labor tax rate is standard in the literature since both labor income taxes and consumption taxes distort labor supply decisions.

One caveat of the definition used by Mendoza, Razin, and Tesar, and Carey and Tchilinguirian is that the tax rates reported are technically average effective tax rates, not marginal tax rates. Economists are more interested in marginal tax rates since they determine household consumption, saving, and labor supply decisions. In practice, (income) tax rates are typically not flat, but progressive. However, it is hard to create a comparable progressive tax data for many countries. Progressive taxes also complicate a structure of the model significantly. In addition, many optimal or political taxation studies in macroeconomics only have flat tax rates (Chamley, 1986). The model presented here also has flat tax rates, and in this class of model, the average and marginal tax rates are equivalent.

Using the variables defined above, I investigate the relationships between the old dependency ratio and tax ratio. Figure 1 shows a pair-wise correlation between the capital/labor tax ratio and the old dependency ratio. Data from 21 OECD countries for the 1980s are reported in this figure. The intention of this model is to replicate the negative correlation, the level of tax ratios, and the non-linear relationship, presented in Figure 1. The pair-wise correlation results for the 90s is very similar, and without Japan being at the very top-left corner, the correlation is significantly negative. United Kingdom is excluded from the sample for their unique tax structure. In UK, the government taxes oil usage by firms, which increases the capital tax rate. In addition, the firms also pay taxes for wages that the firms pay to the employees, instead of employees paying the labor income tax. This increases the corporate tax rate, which is a part of capital tax rate, and decreases the labor income tax rate. Therefore, although UK has a relatively high old dependency ratio, the capital/labor tax ratio is high.

To check the robustness of this negative correlation, I use the panel structure of the data set, to estimate some reduced form relationships. Carey and Tchilinguirian report the capital and labor tax rates for three different periods; 1980-1985, 1986-1990, and 1991-1997. The demographics do not change significantly within a few years. At the same time, to control for fixed country effects, I need a panel structure. Therefore, I take the average of the entire 1980s so that I have two different time periods with a large enough variation in the old dependency ratios within countries. The dependent variable is the tax ratio. The panel data allows me to include country specific fixed effects, and to measure within country variation in the old dependency ratio and tax ratio. The independent variables include the old dependency ratio, the size of government consumption, the size of social security replacement rate, and the size of population relative to the rest of the world. Klein, Quadrini, and Rios-Rull (2005) consider the size of government consumption and population as important variables. Social security may also play a role since demographics and social security are often linked together. In the model of Phelan and Stacchetti (2001) and Klein and Rios-Rull (2003), the level of government commitment is negatively correlated with the tax ratio. However, in the data there seems to be no correlation between frequency of national elections and the tax ratio. The frequency of an election is a measure of the level of government commitment that is excluded because it exhibits almost no variation across time and is captured by the country fixed effects. Table 1 summarizes the results of the regression analysis. The relationship between the old dependency ratio and the tax ratio is significantly negative, and interestingly, not linear. After introducing a quadratic term for the old dependency ratio, the negative relationship still holds even in the fixed effects panel regression. From the above analysis, one can see that the negative correlation between the old dependency ratio and tax ratio is robust to various model specifications and the inclusion of country specific fixed effects, even though the data has only 21 countries for two different time periods. This correlation needs to be explained in a more theoretical, structural model.

*Table* 1.1 : OLS and Fixed Effect Regression Analysis ($Y = \tau_k/\tau_l$)

| | OLS | | Fixed Effects | |
|---|---|---|---|---|
| Old Dependency Ratio | -3.44*** | -42.38*** | -2.84 | -26.59** |
| | (1.05) | (8.90) | (2.39) | (10.25) |
| (Old Dependency Ratio)$^2$ | | 83.24*** | | 54.44** |
| | | (18.94) | | (23.01) |
| Social Security Replacement Rate | -0.25 | 0.24 | 0.47 | 0.46 |
| | (0.29) | (0.26) | (0.39) | (0.34) |
| (Government Consumption)/(GDP) | -0.45 | -2.01 | -0.57 | 0.38 |
| | (1.55) | (1.29) | (4.10) | (3.59) |
| Relative Population Size | 1.69*** | 1.63*** | 31.58 | 39.38 |
| | (0.45) | (0.36) | (22.67) | (19.94) |

Standard errors in parentheses

*** - statistically significant in 1% level

** - statistically significant in 5% level

The statistical analyses above cannot conclude that differences in the old dependency ratio cause the differences in the tax ratio. One counter argument is as follows: since labor taxes include social security tax by definition, one may suspect that this negative correlation is simply driven by the difference in the social security tax rate. However, the fixed effects estimations show that the coefficient on the social security replacement rate is not significant and is actually positive, not negative. Thus, the estimation results show that the negative correlation between the old dependency ratio and the tax ratio is not simply driven by the difference in the social security tax rate. The reduced form estimations also indicate that size of government consumption as a share of GDP is not significantly correlated with the tax ratio. This insignificant correlation for government consumption helps us understand why a high social security tax may not directly imply a low capital/labor tax ratio. For example, even when social security benefits are large and social security tax rate needs to be high in order to finance social security, the government still has a choice to subsidize labor income and tax capital heavily to finance the government expenditure. This point is further discussed when the government budget constraint is defined in the model section.

## 1.3 Parsimonious Small Open Economy Dynamic OLG Majority Voting Model

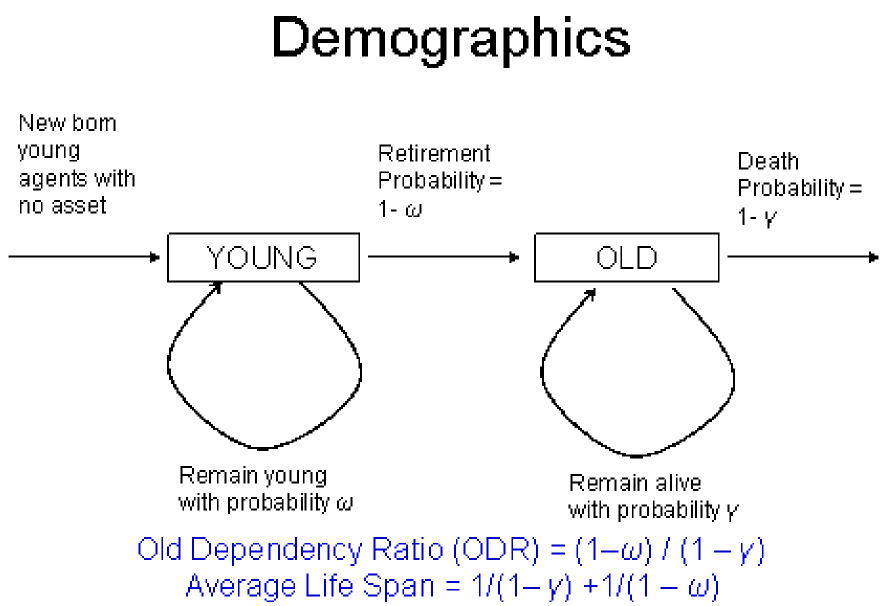
Young, working agents depend more on labor income than capital income, and prefer a low labor tax rate to a low capital tax rate, whereas retired agents depend mainly on capital income, and prefer a low capital tax rate to a low labor tax rate. To formally model the idea and quantify the effect of the difference in demographics on the tax rates, this study develops an OLG, political economy model of capital and labor taxation in a small open economy context.[1]

### 1.3.1 Demographics

A model economy consists of a unit-measure continuum of households without access to private insurance markets. Households go through two stages, but not necessarily two model periods, of life: a working/young stage and a retirement/old stage. A young, working household faces a country specific constant probability of retiring during each period, $1-\omega_i$, and a retired household faces a country specific constant probability of dying during each period $1-\gamma_i$. Young households without any asset replace the old households when they die. This implies that the average working period is $1/(1-\omega_i)$ and the average retirement period is $1/(1-\gamma_i)$. Therefore, the average lifespan is,

[1] Mateos-Planas (2007) develops a different model with the same idea and explains a decrease in the capital tax rate in the US in the past 50 years.

$1/(1-\omega_i)+1/(1-\gamma_i)$.




If appropriately parameterized, this framework generates realistic average lengths of the working period, the retirement period, and the total lifespan. Let $N_t$ be the number of young working households at $t$. Then, $(1-\omega_i)N_t$ of young agents are born at $t$. The ratio of the retired to the working, $\varphi_i$, is thus

$$\varphi_i \equiv \frac{1-\omega_i}{1-\gamma_i}.$$

This model may look non-standard. However, it actually nests both a standard infinitely lived agent model and a standard OLG model in which agents live for only two periods. When $\omega = 1$, the model becomes an infinitely lived agent model, since the young never retire or die, and there is no retired household. When $\omega = 0$ and $\gamma = 0$, the model becomes a standard infinite-horizon OLG model in which agents live only for two periods, since the young become old with probability one and the old die with probability one.

### 1.3.2 Households

Households maximize their expected lifetime utility. I assume that the period utility function has the form introduced by Greenwood, Hercowtiz and Huffman (1988), and the households' preferences are given by:

$$E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \frac{1}{1-\sigma} \left[ \left( c_t - \psi \frac{l_t^{1+1/\varepsilon}}{1+1/\varepsilon} \right)^{1-\sigma} - 1 \right] \right\}, \tag{1}$$

where $\sigma$ is the coefficient of relative risk aversion, $\varepsilon$ is the intertemporal (Frisch) elasticity of labor supply, $c_t$ is consumption, and $l_t$ denotes labor supply in period $t$. As described above, each young household faces an uninsurable, idiosyncratic retirement shock. An individual household can self-insure by holding $a_t$ units of asset which pays a risk free rate of return $r^*$. Following Gertler (1999), I assume that there is an annuity market for the retired households. All the assets that newly deceased retired agents have remaining is collected and redistributed, proportionally, to the rest of the surviving retired households. The existence of an annuity market simplifies the model by eliminating any accidental bequest. This assumption also helps the model to capture the fact that retired households do not dissave as much as a standard model predicts. There exists a borrowing constraint. Since dying with a negative amount of assets creates a problem, following Cagetti and De Nardi (2004), I assume no borrowing.

This utility specification has been widely used (Heathcote, 2005, and Corbae, D'Erasmo, and Kuruscu, 2008, are recent examples in a similar class of the model). Heathcote (2005) uses this preference specification to investigate Ricardian equivalence in a heterogenous agent economy with aggregate uncertainty. In this specification, the labor supply is independent of household's asset level. Researchers have not been able to find any strong effects of changes in the wealth level to the labor supply. This utility specification is consistent with that observation.[2]

### 1.3.3 Firms

There also exists a continuum of identical firms in the economy. I assume that the market is perfectly competitive and the production function is constant returns to scale. Thus, the number of firms can be normalized to one in equilibrium. A firm uses labor and capital as inputs and maximizes the

[2] See Heathcote (2005) for more discussions of this utility specification.

profit.

$$\max_{\{K_t, L_t\}} K_t^{\alpha} L_t^{1-\alpha} - W_t L_t - R_t K_t, \tag{2}$$

where capital letters denote aggregates. $L_t$ denotes aggregate effective labor supply. I assume that production takes place with constant returns to scale function. Capital depreciates at the rate, $\delta$. Capital can be traded freely across countries. Perfect competition in factor markets implies

$$\begin{aligned} R_t &= r^* = \alpha \left( \frac{K_t}{L_t} \right)^{\alpha - 1} - \delta, &(3) \\ W_t &= w^* = (1 - \alpha) \left( \frac{K_t}{L_t} \right)^{\alpha} &(4) \end{aligned}$$

where $r^*$ is the world real interest rate.

### 1.3.4 Government

The government collects tax revenue from capital income and labor income, and finances exogenous government expenditure $G$ and social security benefits. I also assume the budget constraint,

$$G_t + b_t w^* L_t \frac{1 - \omega_i}{1 - \gamma_i} = \tau_t^k r^* A_t + \tau_t^l w^* L_t, \tag{5}$$

is balanced in every period, where $A_t$ is the aggregate asset holding, which may be different from the aggregate capital stock, $K_t$. For many OECD countries, there is a separate social security budget and tax that is specifically levied to finance social security benefits. Since the social security tax is a part of labor income tax, whether or not the government has a separate budget constraint does not matter in my analysis.[3] Large social security benefits apparently induce a high labor tax rate. However, this is not always the case. I can rewrite the budget constraint as

$$G_t = \tau_t^k r^* A_t + \overline{\tau}_t^l w^* L_t, \tag{6}$$

$$b_t w^* L_t \frac{1-\omega_i}{1-\gamma_i} = \tau_t^b w^* L_t, \tag{7}$$

$$\tau_t^l = \overline{\tau}_t^l + \tau_t^b \tag{8}$$

Larger $b_t$ leads to a higher $\tau_t^b$. However, the government (or the median voter) could choose $\overline{\tau}_t^l$ to be very low or even negative, such that $\tau_t^l$ does not necessarily increase as $b_t$ increases. The reduced form analysis in the introduction also shows that $b$ and $\tau^k/\tau^l$ are not significantly correlated.

In this budget constraint, I implicitly assume that the capital tax rate is residence-based instead of source-based. Among the OECD countries, individual taxes are typically residence-based and corporate taxes are often

[3] I computed the model with one government budget constraint and with two separate budget constraints for the government consumption and social security benefits and got exactly the same quantitative results.

source-based. However, there are treaties and tax-deductibles where even the corporate tax rates can be approximated to be residence-based (Frenkel, Razin, and Sadka, 1991). For the model to be constrained to one political parameter ($\tau_k$ in my model), I cannot allow the government to issue debts. Later in my voting case, households vote over the future permanent capital tax rate $\tau^{k\prime}$, and this government budget constraint pins down labor income tax, $\{\tau_t^l\}_{t\geq 1}$, since $G_t$ and $b_t$ are exogenously given to the government.

### 1.3.5 Recursive Formation of the Problem

Let the distribution of capital for the young and old be denoted as $\Gamma_t^y(a_t)$ and $\Gamma_t^o(a_t)$, and the joint distribution of capital be denoted as $\Gamma(a_t, s) \equiv [\Gamma_t^y(a_t), \Gamma_t^o(a_t)]$, where $s \in \{y, o\}$ Let the law of motion be $\Gamma_{t+1} = H(\Gamma_t, \tau_t^k)$. Note that since I assume a balanced budget, so once $\tau^k$ is determined, $\tau^l$ is also determined by the government budget constraint. Then the aggregate asset holding is given by

$$A_t = \int a_t d\Gamma_t(a_t, s), \tag{9}$$

and the total population is normalized to one.

I write my problem using dynamic programing. An old household solves

$$v(a, o; \Gamma, \tau^k) = \max_{\{c, a', l\}} u(c, l) + \beta\gamma_i v(a', o; \Gamma', \tau^{k\prime}), \tag{10}$$

subject to

$$c + a' = \frac{1 + r^*(1 - \tau^k)}{\gamma_i} a + bw^* \bar{l}, \tag{11}$$

$$\Gamma' = H(\Gamma, \tau^k), \tag{12}$$

$$\tau^{k\prime} = \Psi(\Gamma, \tau^k). \tag{13}$$

where the law of motion for the asset distribution and capital tax rate is $H$ and $\Psi$, respectively, and $\bar{l}$ is the average labor supply of the young. Since the government provides an annuity market, old households who survive receive a higher return than just $r^*$. A young household solves

$$v(a, y; \Gamma, \tau^k) = \max_{\{c,l,a'\}} u(c, l) + \beta \left[\omega_i v(a', y; \Gamma', \tau^{k\prime}) + (1 - \omega_i) v(a', o; \Gamma', \tau^{k\prime})\right], \tag{14}$$

subject to

$$c + a' = \left(1 + r^*(1 - \tau^k)\right) a + w^* l (1 - \tau^l), \tag{15}$$

$$\Gamma' = H(\Gamma, \tau^k), \tag{16}$$

$$\tau^{k\prime} = \Psi(\Gamma, \tau^k). \tag{17}$$

The only sources of uncertainty or risk are the retirement shocks and death shocks. The death shock is insured by the annuity market. The retirement shocks are only partially insured by social security. This retirement shock with incomplete markets plays an important role in mimicking the fact that older working households have more savings than younger working households in the data.

It is worth noting that there is no wage inequality in the model. In the introduction, the rational for using the flat tax system as opposed to more practical, realistic progressive tax system was discussed. The model is written such that there is no need for introducing the progressive tax system, since every working household has the same labor income. In the real world, the social security benefit depends on the labor income level before the retirement. The model is also consistent in this dimension due to no wage heterogeneity among the young. The solution to the individual's problem generates decision rules which I denote as

$$
\begin{aligned}
c &= \phi_c(a, s; \Gamma, \tau^k), && (18)\\
a' &= \phi_{a'}(a, s; \Gamma, \tau^k) && (19)\\
l &= \phi_l(a, s; \Gamma, \tau^k) && (20)
\end{aligned}
$$

The utility function has the convenient property that the labor supply choice,

$$
\begin{aligned}
\phi_l(a, y; \Gamma, \tau^k) &= \left[\frac{w^*(1-\tau^l)}{\psi}\right]^{\varepsilon}, && (21)\\
\phi_l(a, o; \Gamma, \tau^k) &= 0, && (22)
\end{aligned}
$$

is independent of the consumption/savings choice. Thus, the aggregate labor supply is simply $N\left[\frac{w^*(1-\tau^l)}{\psi}\right]^{\varepsilon}$. Before moving to the endogenous determination of tax rate via a majority vote, it is useful to state a competitive equilibrium with all the political parameters given.

*Definition (RCE). Given* $\Psi(\Gamma,\tau^k)$, *a Recursive Competitive Equilibrium is a set of functions* $\{v,\phi_c,\phi_l,\phi_{a'},\Gamma,H,w,\tau^l\}$ *such that:*

*(i) given* $(\Gamma,\tau^k,H,\Psi)$, *the function* $v(.),\phi_c(.),\phi_l(.)$, *and* $\phi_{a'}(.)$ *solve the household's problem in (10) and (14).*

*(ii) Prices are competitively determined as in (3) and (4).*

*(iii) The government budget constraint (5) is satisfied.*

*(iv)* $H(\Gamma,\tau^k)$ *is given by*

$$\Gamma'(a',y) = \left[\omega_i \int I_{\{\phi_{a'}(a,y;\Gamma,\tau^k)=a'\}} d\Gamma(a,y) + \Upsilon_{new} 1_{\{a'=0\}}\right], \tag{23}$$

$$\Gamma'(a',o) = \left[(1-\omega_i)\int I_{\{\phi_{a'}(a,y;\Gamma,\tau^k)=a'\}} d\Gamma(a,y) + \gamma_i \int I_{\{\phi_{a'}(a,o;\Gamma,\tau^k)=a'\}} d\Gamma(a,o)\right]. \tag{24}$$

*where* $\Upsilon_{new}$ *is the measure of new young agents and I is an indicator function.*

### 1.3.6 Politico Economic Recursive Competitive Equilibrium (Time Zero Voting with Commitment)

In this section, I endogenize the tax choice to households. In particular, I allow households to vote for a future permanent tax rate, $\tau^{k\prime}$. It is as if the government can commit to the future tax rate. In a recursive form, $\tau^{k\prime\prime} = \Psi(\Gamma', \tau^{k\prime}) = \tau^{k\prime}$ for all $\Gamma'$ and $\tau^{k\prime}$. The future labor tax rate adjusts such that the government budget constraint is balanced every period. Since households are rational and forward-looking, they evaluate the equilibrium effects of a tax rate they vote for, calculate the expected discounted utility associated with each $\tau^{k\prime}$, and choose the permanent future tax rate that gives them the highest utility. Since households are heterogenous in two dimensions ($a$ and $\{y, o\}$), I do not know who the median voter is until I construct the distribution of "most preferred" tax rates. However, since the model has only one political parameter to vote for, each household's derived utility can be numerically shown to be single peaked. Then, the median of the most preferred tax rates is chosen.

To choose the most preferred tax rate for each household, the household must choose among alternatives. Suppose that the household starts with state vector as before $(a, s, \Gamma, \tau^k)$ and consider a permanent deviation for an arbitrary future permanent tax rate, $\tau^{k\prime}$. The old household's problem is given by

$$\widetilde{v}(a, o, \Gamma, \tau^k, \tau^{k\prime}) = \max_{\{c, a'\}} u(c, l) + \beta\gamma_i v(a', o; \Gamma', \tau^{k\prime}), \tag{25}$$

subject to

$$
\begin{aligned}
c + a' &= \frac{1 + r^*(1 - \tau^k)}{\gamma_i} a + bw\bar{l}, && (26) \\
\Gamma' &= \widetilde{H}(\Gamma, \tau^k), && (27) \\
\tau^{k\prime\prime} &= \widetilde{\Psi}(\Gamma', \tau^{k\prime}) = \tau^{k\prime} \forall \{\Gamma', \tau^{k\prime}\}. && (28)
\end{aligned}
$$

A young household solves

$$
\widetilde{v}(a, y; \Gamma, \tau^k, \tau^{k\prime}) = \max_{\{c, a', l\}} u(c, l) + \beta \left[ \omega_i v(a', y; \Gamma', \tau^{k\prime}) + (1 - \omega_i) v(a', o; \Gamma', \tau^{k\prime}) \right], \tag{29}
$$

subject to

$$
\begin{aligned}
c + a' &= \left(1 + r^*(1 - \tau^k)\right) a + w^*(1 - \tau^l) l. && (30) \\
\Gamma' &= \widetilde{H}(\Gamma, \tau^k), && (31) \\
\tau^{k\prime\prime} &= \widetilde{\Psi}(\Gamma', \tau^{k\prime}) = \tau^{k\prime} \forall \{\Gamma', \tau^{k\prime}\}. && (32)
\end{aligned}
$$

where $\widetilde{H}$ denotes the law of motion for $\Gamma$ induced by the deviation, while all future distributions evolve according to $H$: Note that the future value function $v$ is given by the solution to the household problem in (10) and (14) of the definition of a Recursive Competitive Equilibrium. A solution to this problem generates

$$
\begin{aligned}
c &= \widetilde{\phi}_c(a, s; \Gamma, \tau^k, \tau^{k\prime}), && (33)\\
a' &= \widetilde{\phi_{a'}}(a, s; \Gamma, \tau^k, \tau^{k\prime}), && (34)\\
l &= \widetilde{\phi}_l(a, s; \Gamma, \tau^k, \tau^{k\prime}). && (35)
\end{aligned}
$$

Each household votes for $\tau^{k\prime} = \arg\max \widetilde{v}(a, s; \Gamma, \tau^k, \tau^{k\prime})$. As we can see in these value functions, households need to compute a sequence of distributions of assets in the future. Thus, the primary reason why a solution to the politico-economic equilibrium is difficult to find is that the capital tax choice $\tau^{k\prime}$ and associated decision rules induce a new sequence of distributions $(\Gamma', \Gamma'', ...)$. The evolution of the joint distribution $\Gamma$ is given by the equilibrium function $H(\Gamma, \tau^k)$, such that

$$
\begin{aligned}
\Gamma' &= \widetilde{H}(\Gamma, \tau^k, \tau^{k\prime})\\
\Gamma'' &= H\left(\widetilde{H}(\Gamma, \tau^k, \tau^{k\prime})\right)\\
\Gamma''' &= H\left[H\left(\widetilde{H}(\Gamma, \tau^k, \tau^{k\prime})\right)\right]\\
& \quad ....
\end{aligned}
$$

Higher future capital tax rate choices, for example, imply the paths of aggregate asset level, $A$, that are monotonically decreasing. This is because higher future capital tax rates generate decreases in individual savings that are reflected in the paths to the new invariant distribution associated with the high future capital tax rate. The effects of the tax change disappear slowly. In the small open economy setting, the GDP and government consumption, $G$, are constant. Therefore, as $A$ monotonically decreases, $\tau^l$ monotonically increases. More specifically, holding the initial condition constant, choosing a high future capital tax rate implies a low labor tax rate in the near future (not necessarily forever). Since households value today's consumption more than tomorrow's consumption, especially for the young, working households, this decrease in $\tau^l$ in the near future may make them better off.

Next, I define the solution concept:

*Definition (PRCE) : a Politico-Economic Recursive Competitive Equilibrium is:*

*(i) a set of functions* $\{v, \phi, H, \Psi, \tau^l\}$ *that satisfy the definition of RCE,*

*(ii) a set of functions* $\{\widetilde{v}, \widetilde{\phi_c}, \widetilde{\phi_l}, \widetilde{\phi_{k'}}\}$ *that solve (25) and (29), at prices that*

*clear markets and satisfy the government budget constraint, and $\widetilde{H}$ satisfying*

$$\Gamma'(a',y) = \left[\omega_i \int I_{\{\phi_{a'}(a,y;\Gamma,\tau^k)=a'\}} d\Gamma(a,y) + \Upsilon_{new} I_{\{a'=0\}}\right], \tag{36}$$

$$\Gamma'(a',o) = \left[(1-\omega_i) \int I_{\{\phi_{a'}(a,y;\Gamma,\tau^k)=a'\}} d\Gamma(k,y) + \gamma_i \int I_{\{\phi_{a'}(a,o;\Gamma,\tau^k)=a'\}} d\Gamma(a,o)\right]. \tag{37}$$

*with continuation values satisfying (i).*

*(iii) in individual state $(a,s)_i$, household $i$'s most preferred tax policy $\tau_i^{k\prime}$ satisfies*

$$\tau_i^{k\prime} = \psi((a,s)_i, \Gamma, \tau^k) = \arg\max_{\tau^{k\prime}} \widetilde{v}(a,y;\Gamma,\tau^k,\tau^{k\prime}). \tag{38}$$

*(iv) the policy outcome function $\tau^k_{median} = \Psi(\Gamma,\tau^k) = \psi((a,s)_{median},\Gamma,\tau^k)$ satisfies*

$$\begin{aligned} \int I_{((a,s):\tau_i^k \geq \tau^k_{median}\}} d\Gamma(a,s) &\geq \frac{1}{2} \\ \int I_{((a,s):\tau_i^k \geq \tau^k_{median}\}} d\Gamma(a,s) &\geq \frac{1}{2}. \end{aligned} \tag{39}$$

The condition (iv) defines the median voter.

I only focus on a stationary equilibrium in this study.

*Definition : (SSPRCE). A Steady State PRCE is a PRCE which satisfies $\Gamma^* = H(\Gamma^*, \tau^{k*})$ and $\tau^{k*} = \Psi(\Gamma^*, \tau^{k*})$.*

Thus, the stationary equilibrium is an equilibrium such that the initial tax rates are equal to the voting outcome for the permanent future tax rates.

## 1.4 Numerical Analysis

I calibrate a small open economy model, using standard parameter values from the neoclassical growth/RBC literatures. The major exercise is to compute a capital and labor tax rate for each sample country (21 total simulated data points) and compare them with the data. After calibration, to assess the quantitative significance of the relationship between the old dependency ratios and the tax ratios, I feed the country-specific retirement and death probability into the model to deliver a steady state capital and labor tax rates in each country for each period.

### 1.4.1 Calibration

I need to calibrate the following 10 deep parameters: the world real interest rate, $r^*$; the discount factor, the coefficient of relative risk aversion, disutility from labor, and intertemporal elasticity of labor supply, $\{\beta, \sigma, \psi, \varepsilon\}$, respectively, in preferences; the capital share and the capital depreciation rate, $\{\alpha, \delta\}$, in production; exogenous government consumption and social security replacement rate, $\{g, b\}$; and country specific demographics parameters, $\{\omega_i, \gamma_i\}$. Technically, size of government expenditure and social security replacement rate are endogenous variables. The regression analysis has shown that $g$ and $b$ are not significantly correlated with tax ratios, and therefore, I set $g$ and $b$ to be exogenous and equal to the sample averages. In addition, this study focuses on how differences in the demographics may affect the tax ratio, and allowing only one dimensional heterogeneity in demographics makes it easy to see how much of the difference in the tax ratios can be explained by the differences in demographics. Further more, as in Klein, Quadrini, and Rios-Rull (2005), the size of government expenditure is negatively correlated with the tax ratio, and this effect is present in my model as well. It is difficult to write a model in which the size of government expenditure has no impact on the tax ratio, and this is left for the future research. In summary, only the demographics parameters are country specific, and all the other parameters are common across sample countries.

The model period is 4 years. The world real interest rate, $r^*$, is $1.04^4 - 1$ as in a standard small open economy model for developed countries like Mendoza (1991). This is based on the return to the US risk-free treasury bill. Although my model has a life cycle structure, since there is an annuity market, $\beta$ needs to be the inverse of the world gross real interest rate, $\beta = 0.96^4$. I assume that $\sigma = 1$, so, the utility function becomes a log-utility function. The disutility of labor, $\psi$, is the only model specific parameter. The average hours worked is an informative moment to pin down this parameter in my model. I set the average hours worked as 30% of total endowed time available as in Heathcote (2005), when the model is computed for the US economy. $\varepsilon$ is the intertemporal elasticity of labor supply. I set $\varepsilon = 0.3$ since there is little evidence of large labor supply responses to the changes in marginal tax rates that occurred during the 1980s in the US (Slemrod and Bakija, 2000). Heathcote (2005) also sets $\varepsilon = 0.3$ in his study of fiscal policy with heterogeneous agents and incomplete markets.[4] The capital share, $\alpha$, is set to be 0.33 as in a standard Growth/RBC model (Gollin, 2002). The capital depreciation rate, $\delta$, is set to be $1 - (1 - 0.06)^4$ (Stokey and Rebelo, 1995). $g$ is a share of government consumption excluding wages as a share of GDP. 8% is the sample average. $b$ is the social security replacement rate. I estimate $b$ for each country based on government expenditure for the old as a share of GDP from SourceOECD, $\kappa$, which consists of mainly cash benefit for the old. It can be written, mathematically, as

$$wbL\varphi = \kappa Y. \tag{40}$$

[4] This relatively conservative estimate for the elasticity makes sure that my result is not generated by an unreasonably high elasticity. A very elastic intertemporal labor supply typically helps an OLG model to have a high capital tax rate.

Since $w = (1-\alpha)K^{\alpha}L^{-\alpha}$ and $Y = K^{\alpha}L^{1-\alpha}$, this equation can be written as

$$b = \frac{\kappa}{\varphi(1-\alpha)}. \tag{41}$$

For the US in 1980s, $b$ is estimated to be approximately 40%, which is consistent with other studies. The sample average is 47%. Table 2 displays the common parameters.

*Table* 1.2 (Common parameters)

| | | |
|---|---|---|
| $t$ | 4 years | Model period |
| $r^*$ | $1.04^4 - 1$ | Mendoza (1991) |
| $\beta$ | $0.96^4$ | |
| $\sigma$ | 1 | Log-preference |
| $\varepsilon$ | 0.3 | Heathcote (2005) |
| $\psi$ | 1.8 | Hours worked in the US calibration = 0.3 |
| $\alpha$ | 0.33 | Gollin (2002) |
| $\delta$ | $1-(1-0.06)^4$ | Stokey and Rebelo (1995) |
| $b$ | 0.47 | Sample average social security replacement rate |
| $g$ | 0.08 | Sample average government consumption |

I assume that the average length of lifespan is 14 model periods. Young households enter into the economy when they are 20 years old and live for 56 years on average. Thus, on average their average lifespan is 76 years, which is roughly consistent with the data. Then, I can write the probability of becoming old as

$$(1-\omega)=\frac{1}{14-1/(1-\gamma)}. \tag{42}$$

Thus, $\gamma$ is the only parameter to determine the demographics. Again, the ratio of the old to the young, or the old dependency ratio, is

$$\varphi=\frac{1}{14(1-\gamma)-1}. \tag{43}$$

Thus, $\gamma$ is matched such that $\varphi$ is equal to the old dependency ratio in the data. Table 3 summarizes the distribution of $\{\omega_i, \gamma_i\}$. It is worth emphasizing that except for $\psi$, all of the deep parameters are chosen directly from the data, and the choice is independent of my model.

*Table* 1.3 (Summary statistics for country specific parameters)

| Parameter | Mean | STD | Moments |
|---|---|---|---|
| $\omega$ | 0.0873 | 0.0026 | (Common) average lifespan = 14 model periods |
| $\gamma$ | 0.4027 | 0.0560 | Country specific old dependency ratio |

### 1.4.2 Computation Algorithm

It is instructive to describe how to find a stationary polito-economic equilibrium with commitment to understand some properties of the model.

There are three major steps in computing my one-time voting model. First, I compute a steady state for different initial capital tax rates ($\tau^k$). This step is very similar to Aiyagari (1994). Since $\tau_l$ can be pinned down by the government budget constraint, given $\tau_k$, I can determine a steady state competitive equilibrium. This is at $t = 0$. Then, each household in the economy votes for the capital tax rate in the next period, $\tau_k'$. I assume that $\tau_k'$ stays constant forever from the next period on, $t \geq 1$.

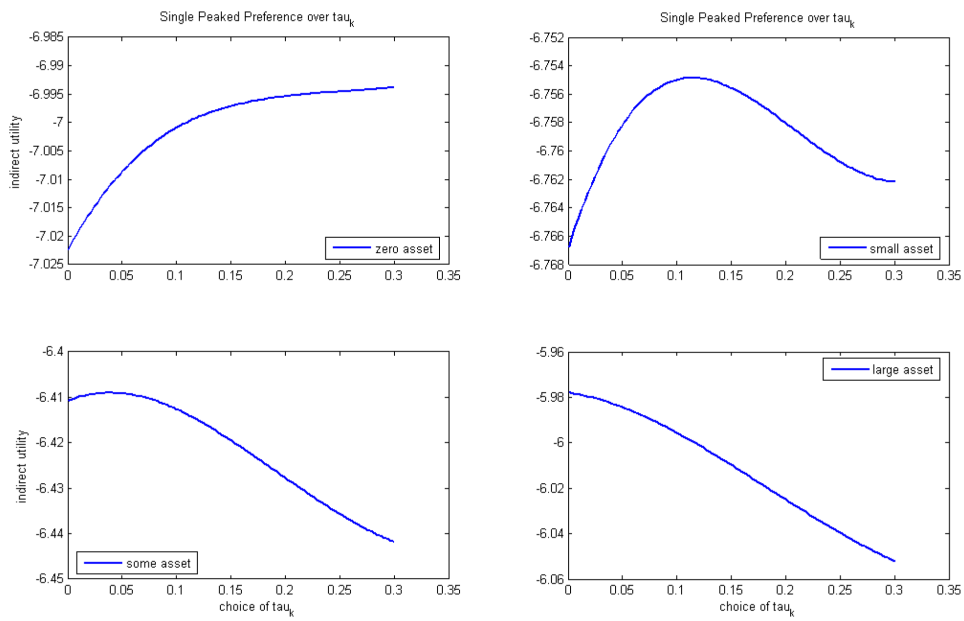
Second, I compute a transition from one steady state to another for each possible combination of $\tau^k$ and $\tau^{k\prime}$. Technically, the initial capital tax rate, $\tau_k$, and the future capital tax rate, $\tau_k'$, are continuous variables and there are infinitely many initial steady states and new steady states. In the computation I discretize the $\tau_k$ grid. So, there is only a finite number of steady states. By computing the transition dynamics, I can find an indirect utility of voting for $\tau_k'$ for all possible $\tau_k'$, given an initial $\tau_k$.

Lastly, for each initial steady state, I determine who the median voter is by looking at the distribution of the most preferred tax rate and what tax rate, $\tau_k'$, the median voter votes for.

### 1.4.3 Model Properties and Results

There is no analytical proof of a single-peaked preference over tax rates, existence of equilibrium, and uniqueness of equilibrium. Therefore, I show these properties numerically. Figure 2 shows some selected indirect utility functions for working households with different levels of initial asset holdings. For example, a young household without any assets gets the highest utility by voting for a high capital tax rate (the upper left graph). There are two important model properties in Figure 2. First, tax preference (the indirect utility function) is single-peaked. This single peakedness allows me to rank all agents in the economy according to their tax preference. Second, there is a one-to-one mapping from the initial asset holdings and most preferred tax rate for the young households. The more assets a working household holds, the lower capital tax rate she prefers. This is intuitive. Although the life-cycle structure in my model is very simple, the model still generates working households with different levels of assets; thus, it mimics the fact that older working households have more capital than younger working households in the data.

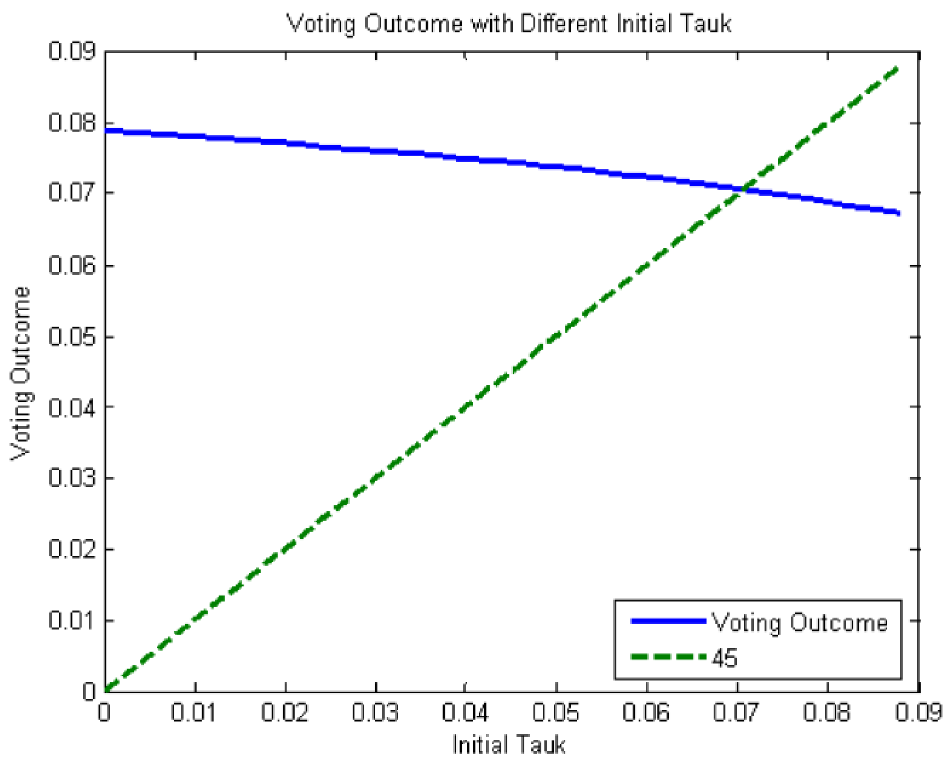
*Figure* 1.2 (Preferences over $\tau_k'$ of young households with different initial asset level




The x-axis indicates for $\tau_k'$

Figure 3 displays the mapping from the initial capital tax rate, $\tau_k$, to the voting outcome, $\tau_k'$. Although I cannot prove analytically, this function is monotonically decreasing. Therefore, there exists a stationary politico-economic equilibrium and the equilibrium is unique. The reason that this mapping is monotonically decreasing is because if an economy starts with a low initial capital tax rate, there are large amounts of assets; i.e. the (capital) tax base is bigger. Figure 3 also shows that a zero capital tax rate is not sustainable in a sense that it cannot be a stationary equilibrium outcome, although the steady state average social welfare may be highest when $\tau_k = 0$ for some parameterization.

$Figure$ 1.3 (Existence of Stationary Equilibrium and Uniqueness)




Time zero voting with commitment does have two advantages compared to sequential voting as in CDK. In time zero voting with commitment, politico-economic equilibrium exists and it is unique with reasonable parameter values. In sequential voting, we need to find laws of motion for asset distributions and tax rates as in Krusell and Smith (1998). A problem is that there might not be equilibrium law of motion for these variables. For example, $R^2$ for the law of motion for one of the aggregate variables in CDK is less than .95. This is much lower than $R^2$ in Krusell and Smith that is practically 1. There is no theory of how high this $R^2$ needs to be. Even if all the $R^2$ is practically 1, we still do not know if that is the only set of laws of motion. Thus, equilibrium may not be unique. In addition, in CDK, the results from sequential voting and time zero voting with commitment are very similar.

I find that as long as there are more young households than old households, the median voter is always a young household and the asset distribution for the young is sufficient information to determine the median voter since the old always vote for the zero capital tax rate and there is only one dimensional heterogeneity among young households. At least when using a reasonable set of parameters, there is a monotonic relationship between the amount of assets young households own and their tax preference. More precisely, the more capital they have, the lower capital tax rate they vote for. Thus, in my model, there is something similar to a "median capital" as in Krusell and Rios-Rull (1999). Krusell and Rios-Rull show that a household with the median capital is the median voter, although my model is closer to a commitment equilibrium in CDK, where both the asset holding and current labor productivity determines the median voter.

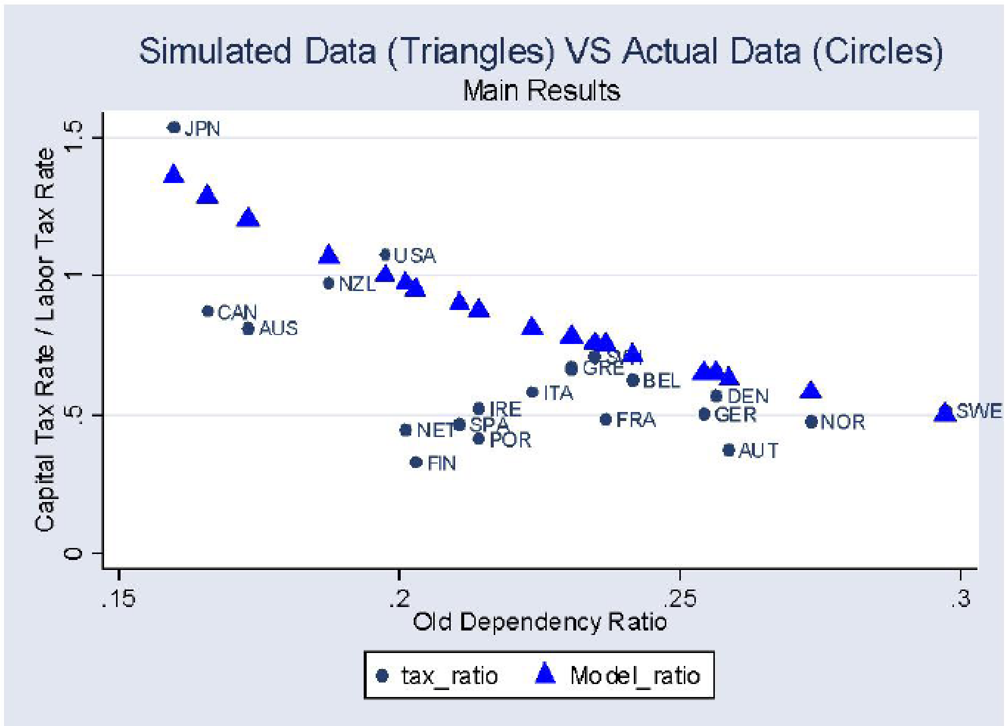
Given the single-peaked preferences, existence of the equilibrium, and its uniqueness, I discuss how well the model is able to replicate the tax ratios in the data. The capital tax rate from the model is a compound tax rate for four years. Therefore, I need to derive the annualized capital tax rate. In a small open economy model, the real interest rate is constant, and there is a simple closed form mapping from the compound rate to the annual rate:

$$\begin{aligned} \left[1 + r^*_{ann}(1 - \tau^k_{ann})\right]^4 &= 1 + r^*(1 - \tau^k) \quad (44) \\ \tau^k_{ann} &= 1 - \frac{\left[1 + r^*(1 - \tau^k)\right]^4 - 1}{r^*_{ann}} \quad (45) \end{aligned}$$

The labor tax rate is not a compound rate, and there is no need for transformation like this.

Figure 4 shows the model prediction against the data from Carey and Tchilinguirian (2000). The calibrated model generates a significant negative correlation between the old dependency ratio and the tax ratio, solely by the difference in the demographics. In addition, the model can match the level of tax ratio. In the calibration, a higher the old dependency ratio is positively correlated with a high probability of retirement, and a low the probability of death. Under a high old dependency ratio, young households face a higher risk of retirement and expect a longer retirement period on average. Therefore, the young accumulate more assets. In the simulation, the median voter of a country with a high old dependency ratio has more assets than the median voter of a country with a low old dependency ratio. Since the wage is constant across countries (they are all small open economies with the same world real interest rate), the median voter in a high old dependency ratio country depends relatively more on capital income than the median voter in a low old dependency ratio. Thus, the median voter in a high old dependency ratio country chooses a lower capital tax rate. The calibration exercises confirm that this difference in the asset level of the median voter across countries, generated by the difference in demographics, is quantitatively important and explains the significant portion of the differences in the tax ratio.

*Figure* 1.4 (Model Prediction: diamond VS. Data: circle)




x axis - old dependency ratio, y axis - $\tau_k/\tau_l$

The model can also generate the non-linear relationship between the old dependency ratio and tax ratio. This is consistent with the fact that once a country reaches a certain level of old dependency ratio, the tax ratio becomes insensitive to the changes in the old dependency ratio. This result may not be as intuitive as the previous results. In the model, the relationship between the old dependency ratio and death probability is non-linear. Equation (43) can be written as

$$.(1-\gamma)=\frac{1}{14}\left(\frac{1}{\varphi}+1\right) \tag{46}$$

where the left hand side of the equation is probability of dying and $\varphi$ is the old dependency ratio[5]. This nonlinear relationship helps the model to generate the nonlinearity in the main results. In summary, although the model has a simple shock structure, the model is able to generate the negative correlation between the old dependency ratios and the tax ratios and the average level of the tax ratios, as well as the non-linear relationship.

## 1.5 Conclusion

This study investigates why the OECD countries tax capital income and labor income differently, especially focusing on the ratio of the capital tax rate to the labor tax rate. First, I document a strong negative correlation between the old dependency ratio and the tax ratio in the data. The regression analysis shows that the old dependency ratio is the variable of primary importance in

[5] The retirement probability can be written as

$$(1-\omega)=\frac{1}{14}(1+\varphi) \tag{47}$$

where the left hand side of the equation is probability of retirement.

the determination of tax ratios. The intuition is that retired households who depend mainly on capital income prefer a low capital tax rate to a low labor tax rate, whereas working households do the opposite. Second, this study develops a micro-founded dynamic OLG political economy of taxation and calibrates the model to the data from 21 OECD countries. By extending Gertler (1999), the model is simple enough to compute, and at the same time rich enough to bring to the data. The calibrated model is able to generate a significant negative correlation between the tax ratio and old dependency ratio. In addition, this model reflects the fact that the tax ratio becomes less sensitive to the changes in the demographics when the old dependency ratio is high, as well as remarkably reflecting the level of tax ratio.

Despite these promising results, the model may also have a few limitations and weaknesses. First, this study just compares different steady state equilibria. The demographics change over time. The model presented here ignores the dynamic changes in demographics. Computing the sequence of tax rates with transitions in demographics requires an assumption that an economy converges to a certain steady state in the future. However, there is no good economic theory of forecasting the future demographics, and it is hard to predict such a steady state.

Second, two possibly important political variables, government expenditure and social security, are exogenous to the model presented here. It may be important to endogenize the size of government expenditure and social security. This extension may be difficult in a majority voting model since this class of model usually allows only one political parameter to vote for. Bassetto (2007) has recently made some progress in this dimension by developing a sequential Nash bargaining model between the young and the old. In his model, all capital tax rates, labor tax rates, government expenditure, and social security were endogenously determined. However, his model period was 30 years, and there is no household with both capital and labor income, which makes it hard to bring to the data. Extending his model in a less stylized setting may be important.

Lastly, the quantitative exercise presented here focuses only on the heterogeneity in demographics. There is also variation in size of government expenditure and size of social security. In the reduced form-estimations, these variables are not significantly correlated with the tax ratio. However, this does not mean that size of government expenditure or size of social security is unimportant in a structural macroeconomic model. For example, in Klein, Quadrini, and Rios-Rull (2005), size of government expenditure has a direct implication on the equilibrium tax rates. More specifically, a country with a large government expenditure has a low capital/labor tax ratio. My model is not an exception. It is difficult to develop a model that is insensitive to changes in the size of government expenditure and social security for the equilibrium tax rates. This is left for future research.

## Appendix 1.A Data Source

All the capital, labor, and consumption tax rates are taken from the tables in Carey and Tchilinguirian (2000). Old dependency ratio is constructed, using the age distribution data from UN. The size of population relative to the rest of the world is defined as the size of population over 20 years old relative to the total population over 20 years old among the all the sample countries. The population data is also from UN. Government consumption is from SourceOECD. And, social security replacement rate is constructed, using the government expenditure for the old from SourceOECD.

# Chapter 2

# A Political Consequence of Population Aging on Capital and Labor Tax Rates and Social Welfare in Japan

*"Japan's population is ageing fast and shrinking. That has implications for every institution, and may even decide the fate of governments" (Economist, 2007)*

## 2.1 Introduction

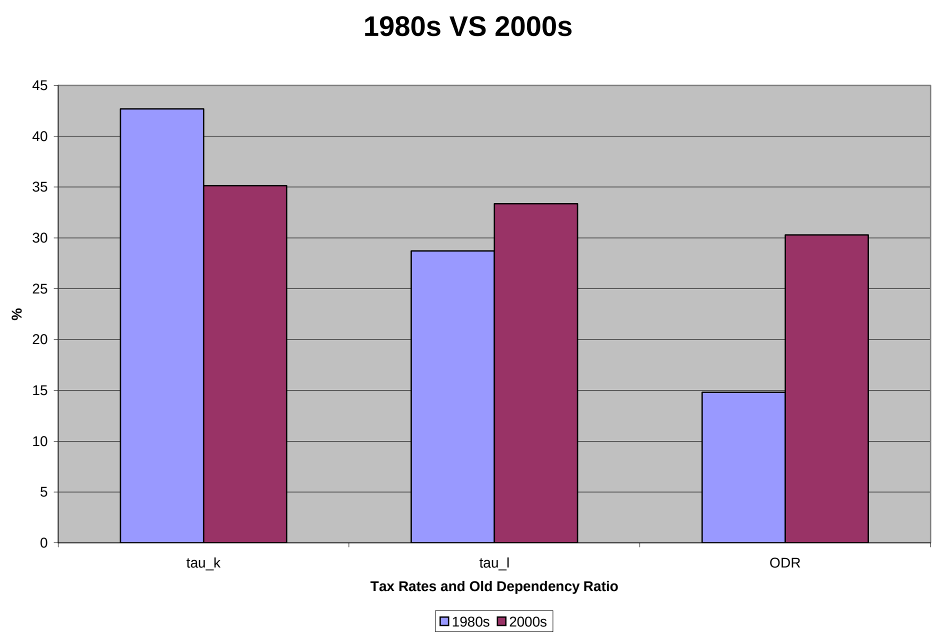
The demographics changes in Japan are fast and serious. From 1980 to 2000, the old dependency ratio[6] increased from 13% to 25%, and it is estimated to reach 50% by 2025. As in the quote from *Economist*, this may have a serious implication for the different institutions and the government, and consequently social welfare of the Japanese. Academic researchers have also been concerned about the implication of population aging in Japan. Whereas their studies mainly focus on the social security system, I study capital and labor tax rates. As Japan's population ages, the Japanese economy has experienced significant changes in tax policies. Using Mendoza, Razin, and Tesar's definition of the average effective capital and labor tax rates (1994), the capital tax rate has decreased from 42% to 35% and the labor tax rate increased from 29% to

[6] The data is from World Population Prospective (UN, 2006). The definition of old dependency ratio is the ratio of population older than 65 years old to population between 20 and 65 years old.

33% by looking at the 1980s average and the 2000s average (Figure 1)[7]. This relationship between the effective capital and labor tax rates and demographics in Japan is interesting and important for the following reason. Pay-As-You-Go social security system is a transfer mechanism from workers to retirees. Reasonably assuming that workers depend more on a labor income and retirees depend more on a capital income, lowering a capital tax rate and increasing a labor tax rate also transfers some wealth from workers to retirees. This mechanism may be as important as the social security mechanism, and needs to be studied.

[7] Mendoza has the data upto 1996 on his website. I estimated the tax rates between 1997 and 2005 by using their method. I used OECD national accounts and revenue statistics. Note that now the national accounts are based on SNA93. I define $\widetilde{\tau}_l = 1-(1-\tau_l)/(1+\tau_c)$ where $\widetilde{\tau}_l$ is the labor tax rate in the graph.

*Figure* 2.1 (Capita and Labor Tax Rates and Demographics in Japan)




In this chapter, I ask whether the observe population aging can explain some part of the decrease in the capital tax rate and the increase in the labor tax rate between 1980s and 2000s in Japan. To answer this question I use a parsimonious dynamic overlapping generations (OLG) political economy model. In the model, there are a working state and a retirement state. Working households face uninsurable, idiosyncratic retirement shocks and retired households face idiosyncratic death shocks, similar to Gertler (1999) and Cagetti and DeNardi (2004). With incomplete markets, working households gradually accumulate assets to self-insure against the retirement shocks. This precautionary savings mechanism reflects the fact that older working households hold more capital than younger working households since they save for their retirement. I, further, use a political equilibrium concept developed in Krusell and Rios-Rull (1999) and extended by Corbae, D'Erasmo, and Kususcu (2008). Specifically, political outcomes are endogenously determined by a median voter with commitment who chooses a future, constant capital tax rate (and a labor tax rate is set to satisfy the government budget constraint) that is required to be consistent with a time-zero voting equilibrium with commitment. In the model, the retired households and relatively old working households depend more on capital income than labor income, and prefer a low capital tax rate to a low labor tax rate, while relatively young working households depend more on labor income than capital income, and prefer a low labor tax rate to a low capital tax rate. As a result, the model shows that an economy with more retired households have a relatively lower capital tax rate and high labor tax rate.

The specific experiment I consider here is to calibrate the initial retirement and death shock process using the old dependency ratio data and the average life span in 1980s. Then, I re-calibrate the economy to match the increase in the old dependency ratio and ask what capital tax rate the median voter would choose. The model is able to explain the decrease in the capital tax rate and the increase in the labor tax rate solely by the increase in the old dependency ratio. Another remarkable finding is that the utilitarian government who maximize the social welfare would set the capital tax rate to be zero as in many standard optimal capital tax studies (Chamley, 1986). Therefore, this study shows that it is important to study a political economy model, instead of a Ramsey type model, which economists have been using to analyze macroeconomic policy for decades. Given the success in explaining the changes in capital and labor taxes, I use the model to predict how much the capital and labor taxes may change in the next 20 years as population ages even more. The model predicts that the capital tax rate would decrease to 26.53% and the labor tax rate would increase to 45.86%.

The model is also useful in estimating changes in the social welfare as the population ages, since people are concerned about what will happen to the Japanese economy as the population ages significantly. Assuming that the total factor productivity (TFP) grows at the annual rate of 1%, the social welfare would increase by 1% if the capital and labor tax rates change endogenously in the politico-economic equilibrium, while the social welfare would decrease by 1% if the capital and labor tax rates remain constant at their 2000s level. The reason for this result is that as the population ages, the capital tax rate decreases and converges to 0%, which is the capital tax rate that the utilitarian government would choose. Thus, the population aging may not be as concerning as it may seem.

This study is not the first study to link the demographics and capital and labor tax rates in a political economy context. Mateos-Planas (2006) studies the decrease in the capital tax rate in the US as the baby-boomers get older. The main differences from his work are that, first, I study the Japanese economy in which the changes in demographics seem to be more important; second, I compare the political economy results with the utilitarian results and find a significant difference; third, I also study the welfare implication; forth, I simplify his model significantly by extending Gertler (1999) to reduce the number of parameters to calibrate.

The chapter is organized as follows. I present the model in Section 2. In Section 3, I discuss the calibration and computation of the benchmark model, and presents the numerical results. Section 4 concludes.

## 2.2 Model

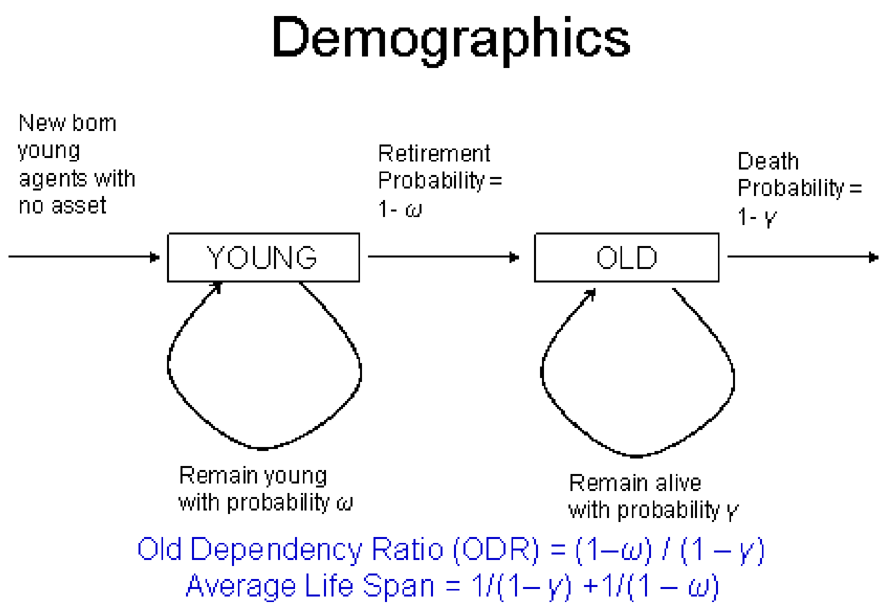
I develop a type of OLG model with a majority voting mechanism[8] that simplifies Mateos-Planas (2006) to be more tractable and to focus only on the effect of demographics. I model a production economy with idiosyncratic shocks of retirement and death, and an incomplete market. In my model, the productivity of young agents are set to be one and the productivity of old agents are set to be zero. Once young agents receive a retirement shock, they can never go back to the working state again. I model the Japanese economy as a closed economy. This assumption is standard as in Hayashi and Prescott (1999) and Chen, Imrohoroglu, and Imrohoroglu (2006).

### 2.2.1 Demographics

A model economy consists of a unit-measure continuum of households without access to private insurance markets. Households go through two stages, not necessarily two model periods, of life: young/working stage and old/retirement stage. A young, working household faces a constant probability of retiring during each period, $1-\omega$, and a retired household faces a constant probability of dying during each period $1-\gamma$. Those who died are replaced by young households without any assets. Namely, the average working

[8] I use "majority voting model" and "median voter model" interchangably in this study. See Corbae, D'Erasmo, and Kuruscu (2007) for why they are equivalent in this class model.

period is $1/(1-\omega)$ and the average retirement period is $1/(1-\gamma)$.




If appropriately parameterized, this framework generates realistic average lengths of the working period, the retirement period, and the total lifespan. Let $N_t$ be the number of young working households at $t$. Then, $(1-\omega)N_t$ of young agents are born at $t$. The ratio of the retired to the working, $\varphi$, is thus

$$\varphi \equiv \frac{1-\omega}{1-\gamma}.$$

This model may look non-standard. However, it actually nests both a standard infinitely lived agent model and a standard OLG model in which agents live for only two periods. When $\omega = 1$, the model becomes an infinitely lived agent model, since the young never retire or die, and there is no retired household. When $\omega = 0$ and $\gamma = 0$, the model becomes a standard infinite-horizon OLG model in which agents live only for two periods, since the young become old with probability one and the old die with probability one.

### 2.2.2 Household's Problem

Households maximize their expected utility. I use Epstein-Zin preference as in Guvenen (2006a,b). There are several reasons for using Epstein-Zin preference. In the data, the coefficient of relative risk aversion and intertemporal substitution parameter are different (Guvenen, 2006a,b). CRRA preference is a special case of Epstein-Zin preference where the coefficient of relative risk aversion and intertemporal substitution parameter are the same. Gertler (1999) also uses a version of Epstein-Zin preference. From a computational viewpoint, I can approximate the value functions for Epstein-Zin preference more accurately with fewer grid points using a spline interpolation than for CRRA preference. In CRRA preference, indirect utility goes to negative infinity as consumption goes to zero. On the other hand, in Epstein-Zin preference, indirect utility is equal to zero when consumption is zero. This implies that there is much more curvature around zero in CRRA preference than Epstein-Zin preference. The household maximization problem can be written by

$$U_t = \max_{\{c_t, k_{t+1}\}} \left[ c_t^{\rho} + \beta \left( E U_{t+1}^{1-\xi} \right)^{\rho/(1-\xi)} \right]^{1/\rho} \tag{48}$$

subject to

$$\begin{aligned} c_t + k_{t+1} &\leq w_t e_t (1 - \tau_t^l - \tau_t^b) + (1 - e_t) w_t b_t + (1 + r_t (1 - \tau_t^k)) k_t && (49) \\ c_t &\geq 0, k_{t+1} \geq \underline{k} && (50) \end{aligned}$$

$c$ and $k$ denote consumption and capital, respectively. $w$ is wage and $r$ is a risk-free rate of return on capital. $e$ is labor productivity. $e = 1$ when agents are young and working and $e = 0$ when agents are old and retired. $b$ is social security benefit. $\tau^l$ is labor income tax and $\tau^k$ is capital income tax. $\tau^b$ is social security tax, which is different from labor income tax, although $\tau^b$ is levied only on the labor income. Consumption tax is ignored for two reasons. First, in a majority voting model, I can have only one political parameter to vote for. Otherwise, single-peakedness of tax preference may be violated. Second, consumption tax is theoretically equivalent to labor income tax and in the data I combine the consumption tax rate and labor tax rate. $\beta \in (0, 1)$ is the discount factor. Once an agent dies, $c_t$ is zero forever. $\xi$ is coefficient of relative risk aversion. $\sigma = 1/(1 - \rho)^{-1}$ is the intertemporal elasticity of substitution. This preference nests a standard CRRA preference when $1-\xi=\rho$. An individual household can self-insure against idiosyncratic shocks by holding $k_t$ units of capital which pays a risk free rate of return $r_t$. No borrowing is permitted ($\underline{k}=0$) as benchmark, which limits the ability of low-wealth households (new young agents) to smooth consumption. Allowing households to borrow causes a problem since old households could die with strictly negative asset holding. I assume that new born agents start with no asset holding.

### 2.2.3 Firm's Problem

There also exists a continuum of identical firms in the economy. I assume that the market is perfectly competitive and the production function has a constant return to scale. Thus, the number of firms can be normalized to one in equilibrium. For simplicity, there is no corporate taxation. I need this assumption for single-peakedness of the tax preference. A firm uses labor and capital as inputs and maximizes the profit.

$$\max F(K_t, N_t) - W_t N_t - R_t K_t \tag{51}$$

where capital letters denote aggregates. Further, $N_t$ is constant in my economy and equal to measure of young households. I assume that production takes place with a constant return to scale function. Capital depreciates at the rate $\delta$. Perfect competition in factor markets implies

$$r_t = F_K(K_t, N_t) - \delta \tag{52}$$

$$w_t = F_N(K_t, N_t) \tag{53}$$

### 2.2.4 Government

The government collects tax revenue from the capital income and labor income, and finance exogenous useless government expenditure $G$. I also assume the balanced budged

$$G_t = \tau_t^k r_t K_t + \tau_t^l w_t N_t \tag{54}$$

For the model to have one political parameter to choose, I cannot allow the government to issue debts. Later in my voting case, households vote over the capital income tax $\tau^k$, and this constraint pins down the labor income tax, $\tau^l$. I also assume that the government provides an annuity market to the old. The government collects all the asset which old agents who just died have left and transfer it to the rest of the old households who have survived. The existence of an annuity market simplifies the model by eliminating any accidental bequest to the new born agents. The government also provides pay-as-you-go social security benefit to the old. The budget for social security is independent from the budget for $G_t$. In Japan, social security is financed by tax specifically for social security benefit. I assume that social security is entirely financed through tax on the labor income with rate $\tau^b$.

$$b_t w_t N_t \frac{1-\omega}{1-\gamma} = \tau^b w_t N_t \tag{55}$$

Note that $\frac{1-\omega}{1-\gamma}$ is the ratio of the young to the old. The left hand side is total benefit and the right hand side is total social security tax revenue. Since my model is an incomplete market model with idiosyncratic shocks, one may ask whether such risks are actually insurable or not. I assume that $b_t$ is exogenous to the government since there is no change in $b$ in the data that this study looks at.

### 2.2.5 Recursive Formation of the Problem

Let the distribution of capital for the young and old be denoted as $\Gamma_t^y(k_t)$ and $\Gamma_t^o(k_t)$, and the joint distribution of capital be denoted as $\Gamma(k_t, s) \equiv [\Gamma_t^y(k_t), \Gamma_t^o(k_t)]$, where $s \in \{y, o\}$ Let the law of motion be $\Gamma_{t+1} = H(\Gamma_t, \tau_t^k)$. Note that since I assume the balanced budget, once $\tau^k$ is determined, $\tau^l$ is also determined by the government budget constraint. Then the aggregate capital stock is given by

$$K_t = \int k_t d\Gamma_t(k_t, s) \tag{56}$$

and the total population is normalized to be one. $N_t$ is constant and the measure of the young.

The economy-wide resource constraint in each period is given by

$$C_t + K_{t+1} = F(K_t, N_t) + (1-\delta)K_t \tag{57}$$

I write my problem using dynamic programing. For a heuristic purpose only, I write it as if $\sigma = 1 - \xi$ and the Epstein-Zin preference is equivalent to a CRRA preference. Let $u(c) = c^{1-\xi}/(1-\xi)$. An old agent solves

$$v(k, o; \Gamma, \tau^k) = \max_{\{c,k'\}} u(c) + \beta\gamma v(k', o; \Gamma', \tau^{k\prime}) \tag{58}$$

subject to

$$c + k' = \frac{1 + r(K)(1-\tau^k)}{\gamma} k + bw(K) \tag{59}$$

$$\Gamma' = H(\Gamma, \tau^k) \tag{60}$$

$$\tau^{k\prime} = \Psi(\Gamma, \tau^k) \tag{61}$$

where the law of motion for the asset distribution and capital tax rate is $H$ and $\Psi$, respectively. Since the government provides an annuity market, old households who survive receive a higher return than just $r$. A young agent solves

$$v(k, y; \Gamma, \tau^k) = \max_{\{c,k\}} u(c) + \beta \left[\omega v(k', y; \Gamma', \tau^{k\prime}) + (1-\omega) v(k', o; \Gamma', \tau^{k\prime})\right] \tag{62}$$

subject to

$$c + k' = \big(1 + r(K)(1 - \tau^k)\big)\, k + w(K)(1 - \tau^l - \tau^b) \tag{63}$$

$$\Gamma' = H(\Gamma, \tau^k) \tag{64}$$

$$\tau^{k\prime} = \Psi(\Gamma, \tau^k) \tag{65}$$

The solution to the individual's problem generates decision rules which I denote

$$c = \phi_c(k, s; \Gamma, \tau^k) \tag{66}$$

$$k' = \phi_{k'}(k, s; \Gamma, \tau^k) \tag{67}$$

Before moving to the endogenous determination of tax rate by a via majority voting or by a utilitarian government, it is useful to state a competitive equilibrium with all the political parameters given.

*Definition (RCE). Given* $\Psi(\Gamma, \tau^k)$*, a Recursive Competitive Equilibrium is a set of functions* $\{v, \phi_c, \phi_{k'}, r, w, \tau^l\}$ *such that:*

*(i) given* $(\Gamma, \tau^k, H, \Psi)$*, the function* $v(.), \phi_c(.)$*, and* $\phi_{k'}(.)$ *solve the household's problem in (11) and (15).*

*(ii) Prices are competitively determined as in (5) and (6).*

*(iii) The resource constraint is satisfied*

$$K' = K^\alpha N^{1-\alpha} + (1 - \delta)K - \int \phi_c(k, s; \Gamma, \tau^k) d\Gamma(k, s) \tag{68}$$

*(iv) The government budget constraint (7) is satisfied.*

*(v) $H(\Gamma, \tau^k)$ is given by*

$$\Gamma'(k', y) = \left[\omega \int I_{\{\phi_{k'}(k,y;\Gamma,\tau^k)=k'\}} d\Gamma(k,y) + \Upsilon_{new} 1_{\{k'=0\}}\right] \tag{69}$$

$$\Gamma'(k', o) = \left[(1-\omega) \int I_{\{\phi_{k'}(k,y;\Gamma,\tau^k)=k'\}} d\Gamma(k,y) + \gamma \int I_{\{\phi_{k'}(k,o;\Gamma,\tau^k)=k'\}} d\Gamma(k,o)\right] \tag{70}$$

*where $\Upsilon_{new}$ is the measure of new young agents*[9].

*(vi) the social security market clears*

$$(1-\gamma)b = (1-\omega)\tau^b \tag{71}$$

I also define a stationary recursive competitive equilibrium

*Definition (SRCE). A Stationary Recursive Competitive Equilibrium is a special case of a RCE such that the aggregate variables and the distribution of asset are invariant.*

### 2.2.6 Politico Economic Recursive Competitive Equilibrium

In this section, I endogenize the tax choice to households. In particular,

[9] $\Upsilon_{new} = N(1-\omega)$

I allow households to vote for a future permanent tax rate, $\tau^{k\prime}$. It is as if the government can commit to the future tax rate. In a recursive form, $\tau^{k\prime\prime} = \Psi(\Gamma', \tau^{k\prime}) = \tau^{k\prime}$ for all $\Gamma'$ and $\tau^{k\prime}$. The future labor tax rate adjusts such that the government budget constraint is balanced every period. Since households are rational and forward-looking, they evaluate the equilibrium effects of a tax rate they vote for, calculate the expected discounted utility associated with each $\tau^{k\prime}$, and choose the permanent future tax rate that gives them the highest utility. Since households are heterogenous in two dimensions ($a$ and $\{y, o\}$), I do not know who the median voter is until I construct the distribution of "most preferred" tax rates. However, since the model has only one political parameter to vote for, each household's derived utility can be numerically shown to be single peaked. Then, the median of the most preferred tax rates is chosen.

To choose the most preferred tax rate for each household, the household must choose among alternatives. Suppose that the household starts with state vector as before $(a, s, \Gamma, \tau^k)$ and consider a permanent deviation for an arbitrary future permanent tax rate, $\tau^{k\prime}$. The old household's problem is given by

$$\widetilde{v}(k, o, \Gamma, \tau^k, \tau^{k\prime}) = \max_{\{c,k'\}} u(c) + \beta\gamma\widetilde{v}(k', o; \Gamma', \tau^{k\prime}) \tag{72}$$

subject to

$$
\begin{aligned}
c + k' &= \frac{1 + r(K)(1-\tau^k)}{\gamma} k + bw(K) && (73) \\
\Gamma' &= \widetilde{H}(\Gamma, \tau^k) && (74)
\end{aligned}
$$

A young agent solves

$$
\widetilde{v}(k, y; \Gamma, \tau^k, \tau^{k\prime}) = \max_{\{c,k'\}} u(c) + \beta \left[\omega \widetilde{v}(k', y; \Gamma', \tau^{k\prime}) + (1-\omega)\widetilde{v}(k', o; \Gamma', \tau^{k\prime})\right] \tag{75}
$$

subject to

$$
c + k' = \left(1 + r(K)(1-\tau^k)\right) k + w(K)(1 - \tau^l - \tau^b) \tag{76}
$$

A solution to this problem generates

$$
\begin{aligned}
c &= \widetilde{\phi}_c(k, s; \Gamma, \tau^k, \tau^{k\prime}) && (77) \\
k' &= \widetilde{\phi_{k'}}(k, s; \Gamma, \tau^k, \tau^{k\prime}) && (78)
\end{aligned}
$$

Each household votes for $\tau^{k\prime} = \arg\max \widetilde{v}(k, s; \Gamma, \tau^k, \tau^{k\prime})$. As we can see in these value functions, households need to compute a sequence of distributions of assets in the future. Thus, the primary reason why a solution to the politico-economic equilibrium is difficult to find is that the capital tax choice $\tau^{k\prime}$ and associated decision rules induce a new sequence of distributions $(\Gamma', \Gamma'', ...)$.

The evolution of the joint distribution $\Gamma$ is given by the equilibrium function $H(\Gamma, \tau^k)$, such that

$$
\begin{aligned}
\Gamma' &= \widetilde{H}(\Gamma, \tau^k, \tau^{k\prime}) \\
\Gamma'' &= H\left(\widetilde{H}(\Gamma, \tau^k, \tau^{k\prime})\right) \\
\Gamma''' &= H\left[H\left(\widetilde{H}(\Gamma, \tau^k, \tau^{k\prime})\right)\right] \\
& \quad \ldots.
\end{aligned}
$$

Higher future capital tax rate choices, for example, imply the paths of aggregate asset level, $K$, that are monotonically decreasing. This is because higher future capital tax rates generate decreases in individual savings that are reflected in the paths to the new invariant distribution associated with the high future capital tax rate. The effects of the tax change disappear slowly. As $K$ monotonically decreases, $\tau^l$ monotonically increases. More specifically, holding the initial condition constant, choosing a high future capital tax rate implies a low labor tax rate in the near future (not necessarily forever). Since households value today's consumption more than tomorrow's consumption, especially for the young, working households, this decrease in $\tau^l$ in the near future may make them better off.

From each household choice I generate the distribution of "most preferred" tax rates and provided each household's derived utility is single-peaked, the median of the most preferred tax rates is chosen. To choose the most preferred tax rate, the household must choose among alternatives. Suppose that the household starts with state vector as before $(k, s, \Gamma, \tau^k)$ and consider a one period deviation for next period's tax rate to $\tau^{k\prime}$ which is not necessarily given by $\tau^{k\prime} = \Psi(\Gamma, \tau^k)$. The household's problem is given byI am ready to define the solution concept

*Definition (PRCE) : a Politico-Economic Recursive Competitive Equilibrium is:*

*(i) a set of functions* $\{v, \phi, H, \Psi, r, w, \tau^l\}$ *that satisfy the definition of RCE.*

*(ii) a set of functions* $\{\widetilde{v}, \widetilde{\phi_c}, \widetilde{\phi_{k'}}\}$ *that solve (25) and (28), at prices which clear markets and the government budget constraint, and* $\widetilde{H}$ *satisfying*

$$\Gamma'(k', y) = \left[\omega \int I_{\{\phi_{k'}(k,y;\Gamma,\tau^k)=k'\}} d\Gamma(k, y) + \Upsilon_{new} I_{\{k'=0\}}\right] \tag{79}$$

$$\Gamma'(k', o) = \left[(1-\omega) \int I_{\{\phi_{k'}(k,y;\Gamma,\tau^k)=k'\}} d\Gamma(k, y) + \gamma \int I_{\{\phi_{k'}(k,o;\Gamma,\tau^k)=k'\}} d\Gamma(k, o)\right] \tag{80}$$

*with continuation values satisfying (i). And, the transfer is equal to accidental bequest.*

*(iii) in individual state* $(k, s)_i$*, household* $i'$*s most preferred tax policy* $\tau_i^{k\prime}$

*satisfies*

$$\tau_i^{k\prime} = \psi((k,s)_i, \Gamma, \tau^k) = \arg\max_{\tau^{k\prime}} \widetilde{v}(k, y; \Gamma, \tau^k, \tau^{k\prime}) \tag{81}$$

*(iv) the policy outcome function* $\tau_m^k = \Psi(\Gamma, \tau^k) = \psi((k,s)_m, \Gamma, \tau^k)$ *satisfies*

$$\int I_{((k,s):\tau_i^k \geq \tau_m\}} d\Gamma(k,s) \geq \frac{1}{2} \tag{82}$$

For now, I focus on a stationary equilibrium only.

*Definition : (SSPRCE). A Steady State PRCE is a PRCE which satisfies* $\Gamma^* = H(\Gamma^*, \tau^{k*})$ *and* $\tau^{k*} = \Psi(\Gamma^*, \tau^{k*})$.

I can also see from Equation (37) that the ratio of the young to the old explicitly affects the median voter. By keeping my model simple and tractable, I can derive some propositions that are useful to understand the mechanism of my model.

## 2.3 Numerical Analysis

### 2.3.1 Calibration

I analyze how this change in demographics may affect the average effective capital and labor tax rates in Japan after 1980 when the old dependency ratio has increased significantly. Another reason for focusing on the economy after 1980 is that in 1960s and 1970s the Japanese economy was still experiencing a rapid growth and it may not be suitable for a steady state type analysis. For example, the TFP growth rate was 3.3% on average before 1980 and it has dropped to 1.1% on average since 1980 (Hayashi and Prescott, 1999). The saving rate was significantly large and to explain such a high saving rate a standard growth model needs to incorporate the rapid TFP growth into the model (Chen, Imrohoroglu, and Imrohoroglu, 2006). Tax policies in such a growing economy is beyond a scope of this study. Social security was very different before 1970 and the 1970s is the transition period.

The model period is four years to speed up the computation. The preference and production parameters are taken from a standard growth/RBC literature. $\beta = 0.96^4$, $\alpha = 0.36$, $\rho = 3$, $\xi = -1.0$, and $\delta = 1 - (1 - 0.09)^4$. The intertemporal elasticity of substitution is typically between 0.1 and 1. I set it to be 0.5. Guvenen (2004) documents that stockholder's IES is 1 and non-stockholder's IES is 0.1 in the United States. Since I do not have stockholders or non-stockholders, I pick the IES between the two. In Japan, the social security benefit is approximately 36% of the wage. This implies that $\tau^b = 0.36\frac{1-\omega}{1-\gamma}$. I set $G$ to be 23% of the GDP, which is the average government consumption and investment as a share of GDP between 1980 and 2005. The only parameters left to calibrate are $\{\omega, \gamma\}$. I use the average life span (14 model periods) and old dependency ratio to calibrate these two parameters. Fixing the average length of lifespan to be 14 model periods (56 years), I can write the probability of becoming old as

$$(1-\omega) = \frac{1}{14 - 1/(1-\gamma)} \tag{83}$$

Thus, $\gamma$ is the only parameter to determine the demographics. Again, the ratio of the old to the young is

$$\varphi = \frac{1}{14(1-\gamma) - 1}$$

For the 1980s calibration, $\omega = 0.082$ and $\gamma = 0.5570$. For the 2000s, $\omega = 0.091$ and $\gamma = 0.3322$. Table 1 summarizes the calibration for the 1980s.

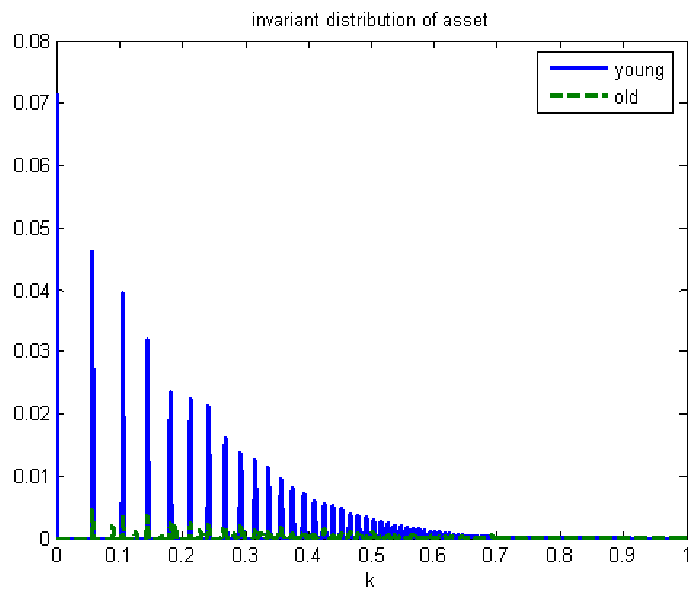
*Table* 2.1 (Calibration)

| Parameters | Values | Moments to match or data source |
|---|---|---|
| $t$ | 4 years | |
| $\beta$ | $0.96^4$ | |
| $\sigma$ | $-1.00$ | Guvenen (2006a,b) |
| $\xi$ | 3.00 | CRRA (Carroll, 1998) |
| $\alpha$ | 0.36 | capital share (Hayashi and Prescott) |
| $\delta$ | 0.31 | depreciation rate (Hayashi and Prescott) |
| $1-\omega$ | 0.08 | average lifespan = 14 model periods |
| $1-\gamma$ | 0.56 | old dependency ratio = 14% |
| $b$ | 0.36 | social security replacement rate |
| $g$ | 0.23 | government expenditure as a share of GDP |

### 2.3.2 One-time Voting Algorithm and Results

It is instructive to discuss the computation algorithm in order to describe the politico-economic equilibrium before showing the results. So, I will start with an explanation of the computation algorithm developed by Corbae, D'Erasmo, and Kurusucu (2008). There are three major steps in computing my one-time voting model. First, I compute a steady state for different initial capital tax rates ($\tau^k$). This step is very similar to Aiyagari (1994). Since $\tau_l$ can be pinned down by the government budget constraint, given $\tau_k$, I can determine a steady state competitive equilibrium. This is at $t = 0$. Then, each household in the economy votes for the capital tax rate in the next period, $\tau_k'$. For simplicity, I assume that $\tau_k'$ stays constant forever from the next period on, $t \geq 1$. Figure 2 shows an invariant distribution of asset holding. The model can mimic the fact that older working households (those who remain young for many periods) accumulate more capital than younger working households. Although the model has a very simple shock structure, it can still generate a significant amount of heterogeneity among households so that median voting is non-trivial. For example, if a model was a standard OLG model with only young and old households, the median voter would be trivially young as long as the old dependency ratio is less than 0.5, and such a model would not generate sufficient heterogeneity among households to study political equilibrium.

*Figure* 2.2 (Significant Heterogeneity among Households)

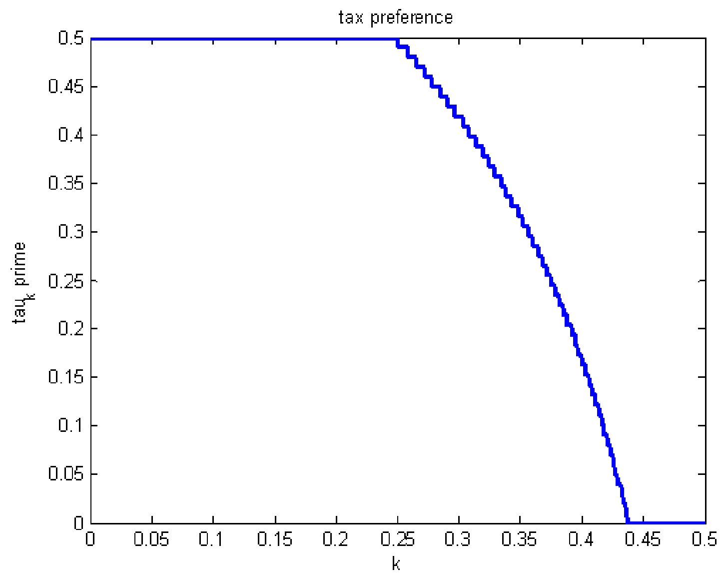



Second, I compute a transition from one steady state to another for each possible combination. Technically, the initial capital tax rate $\tau_k$ and the future capital tax rate $\tau_k'$ are continuous variables and there are infinitely many initial steady states and new steady states. In the computation I discretize the $\tau_k$ grid.[10] So, there is only a finite number of steady states. By computing the transition dynamics, I can find an indirect utility of voting for $\tau_k'$ for all

[10]I do not need the range of $\tau^{k\prime}$ to be between 0 and 1. Here, I set $\tau^{k\prime} \in [0, 0.5]$. This speeds up the computation and does not change any results since the median voter does not choose $\tau^{k\prime} > 0.5$ in the calibration here.

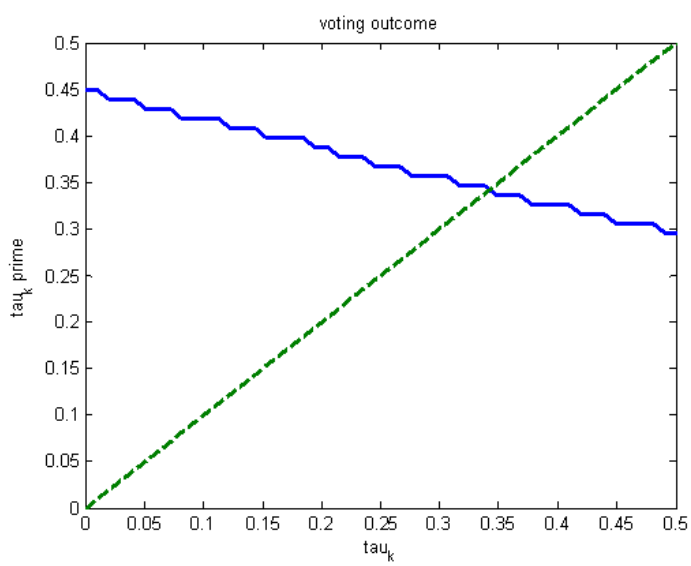
possible $\tau_k'$, given an initial $\tau_k$. Figure 3 shows the voting preference over capital tax for different asset holding for the working households, holding the initial capital tax rate constant. There is a one-to-one mapping from the initial asset holdings and most preferred tax rate for the young households. The more assets a working household holds, the lower capital tax rate she prefers. In my calibration, old households always vote for 0. Thus, the model is successful in reflecting the basic economic intuition such that working households who depend more on a labor income than a capital income prefer a low labor tax rate, whereas retired households who depend more on a capital income than a labor income prefer a low capital tax rate.

*Figure* 2.3 (The Most Preferred Capital Tax Rate)




Lastly, for each initial steady state, I determine who the median voter is by looking at the distribution of the most preferred tax rate and what tax rate, $\tau_k'$, the median voter votes for. Figure 4 displays the mapping from the initial capital tax rate, $\tau_k$, to the voting outcome, $\tau_k'$. Although there is no analytical proof, this function is monotonically decreasing. Therefore, there exists a unique stationary equilibrium. The reason that this mapping is monotonically decreasing is because if an economy starts with a low initial capital tax rate, there are large amounts of assets; i.e. the (capital) tax base is bigger. Figure 3 also shows that a zero capital tax rate is not sustainable in a sense that it cannot be a stationary equilibrium outcome. When the initial capital tax rate is equal to zero, the median voter would chooses as high as 45% for the future capital tax rate, and this cannot be a stationary equilibrium. However, the steady state average social welfare may be highest when $\tau_k = 0$ for some parameterization.

*Figure* 2.4 (Uniqueness of Equilibrium)




I compute a stationary politico-economic equilibrium for the 1980s, the 2000s, and the 2020s. Table 2 summarizes the results. My calibrated dynamic majority voting model shows that the change in demographics alone can explain the change in the effective tax rates. The model slightly under-predicts the capital tax rate. My model also predicts that the capital tax rate continues to decrease to 25% and the labor tax rate continues to increase to 46% by 2025.

*Table* 2.2 (Data VS Model Prediction)

| | | $\tau^k$ | $\tau^l$ | welfare | ODR |
|---|---|---|---|---|---|
| Data | 1980s | 42.69 | 28.72 | | 14% |
| | 2000s | 35.14 | 33.36 | | 30% |
| Model | 1980s | 43.88 | 26.95 | 1.09 | 14% |
| | 2000s | 33.67 | 36.12 | 1.00 | 30% |
| | 2020s | 26.53 | 45.86 | 1.01 | 47% |

Another important result is that if a social planner was to set the tax rates instead of the median voter, the social planner or utilitarian government which maximizes the sum of indirect utilities would have set the capital tax rate to be zero as in Chamley (1986). Given the distribution of capital, the mean voter owns more capital than the median voter, which leads to a lower capital tax rate in the utilitarian equilibrium, than in the politico-economic equilibrium. This result highlights the importance of modeling political mechanism.

The social welfare is simply defined as the average indirect utility and normalized to the welfare in the 2000s' model prediction after adjusting for the exogenous TFP growth rate of 1%. In this model, a high old dependency ratio implies a low labor input. Therefore, the social welfare is expected to be low as population ages. The model predicts that the decrease in the social welfare is large. The expected social welfare actually increase by 1.2% between the 2000s and 2020s because of the decrease in a capital tax rate. I also compute the expected social welfare if there is no change in the tax rates. In this case, the social welfare decreases by 1.5%. Thus, the effect of the endogenous decrease in the capital tax rate dominates the effect of reduction in labor input.

## 2.4 Conclusion

This study investigates the political consequence of population aging in Japan, focusing on capital and labor tax rates. My calibrated majority voting model can explain almost all of the changes in the capital and labor tax rates in Japan and the model emphasizes the importance of demographics changes in the determination of the capital and labor tax rates. The social planning capital tax rate is zero as in many standard models because in the calibrated model the median voter depends more on the labor income than the mean voter. Therefore, modeling a political economy is very important to explain and understand tax rates in the real world. The model also predicts an increase in the social welfare by the 2020s, because of the lower capital tax rate.

There are two major future possible research topics. First, it is important to test how the model prediction may change if one is able to compute a model with dynamic demographics changes with sequential voting. This may face significant computational difficulty. Second, endogenizing both social security benefit and capital and labor tax rates may be interesting since they could potentially play a similar role in redistributing some wealth from the young to the old. This may also be difficult to compute since, in this class of political economy model, we can usually have only one political parameter to vote for.

## Appendix 2.A Computational Algorithm for One-time Voting

It takes approximately three hours to run the Fortran95 program for this model.

Step 1: Calculating a steady state for exogenous tax rates ($\tau^k$)

1. Guess a value for the aggregate capital stock $K$. This implicitly determines $r$ and $w$. Then, using the government budget constraint, $\tau^l$ is also determined.

2. Solve for the household's problem to find the value function and decision rules.

3. Find the time invariant distribution associated with the decision rules.

4. Check that the aggregate capital stock is consistent with the household's decision rules.

Step 2: Solving for transition path for exogenous tax rates

1. Choose $t^*$, the number of periods to reach a steady state.

2. For each $\tau_0^k = \tau_j^k$ and each $\tau_{t^*}^k = \tau_n^k$, make an initial guess for the sequence $\{K_t\}_{t=0}^{t^*}$, where $K_{t^*}$ is the steady state level of capital associated with $\tau_n^k$.

3. Starting in period $t^* - 1$ with current capital $K_{t^*-1}^{j,n}$ and future capital

$K_{t^*}^{j,n}$, solve for $v_{t^*-1}(k, s; K_{t^*-1}, \tau^n)$ and $\phi_{k',t^*-1}(k, s; K_{t^*-1}, \tau^n)$ by solving the value functions, with $v_{t^*}(k, s; K_{ss}^n, \tau^n)$.

4. Continue solving backwards until $t = 0$.

5. Find the new path of the aggregate capital.

6. If the new sequence is close enough to the old sequence, done. Otherwise, update the sequence by taking convex combination of the old and new sequences.

Step 3: Finding the median voter.

1. For each $(\tau_j^k, \Gamma_{j,ss})$, obtain $\psi(k, s, \tau_j^k, \Gamma_{j,ss})$ for every $(k, s)$

2. Given $\psi(k, s, \tau_j^k, \Gamma_{j,ss})$ and $\Gamma_{j,ss}$, obtain a distribution of the most preferred tax rates.

3. Find the median $\tau_m^k$ of this distribution.

4. Find the stationary equilibrium such that $\tau_m^k = \tau_{initial}^k$.

# Chapter 3

# Quantitative Dynamic General Equilibrium Analysis of Illegal Immigration to the US

## 3.1 Introduction

Passel (2005) estimates the number of illegal immigrants in the United States to be more than 10 millions in 2005, and the recent trend shows that the number may be even larger as of 2008 than that, which is approximately 6% of the US native labor force. The illegal immigration from Mexico accounts for more than 50 percent of the total illegal immigration and researchers do not have extensive data on illegal immigration from other countries. Due to this data ability, I focus on illegal immigration from Mexico to the US. Academic researchers and policy makers are increasingly interested in the effects of the illegal immigration to the US economy. Immigration policy reforms are always one of the hot policy topics discussed in the presidential election campaigns. Typical arguments we hear on the news or see in academic journals are the following: the illegal immigrants take jobs away from the native workers and the unemployment rate increases, the increase in the labor force leads to a decrease in the wages and an increase in the interest rates. These arguments seem reasonable and intuitive. The question is how quantitatively important these effects are, and ultimately how much these effects may impact the welfare of different individuals in the US. Furthermore, it is important to study what illegal immigration policy reform the US government needs to implement. To answer these question, I develop a two country dynamic general equilibrium model, which can quantitatively explain the size of illegal immigration. To analyze an impact of illegal immigration, one may start with no illegal immigration equilibrium and then simulate a transition to an equilibrium with illegal immigration. This approach is common in a trade model to study the impact from a country opening up to international trades. However, I start with an equilibrium with illegal immigration simply because the benchmark US economy does have illegal immigrants. For calibration, I need some moments from the US and Mexican economy data. Since the actual data is already reflecting the effects of illegal immigration, my benchmark model needs to have illegal immigration. After calibrating a model, I simulate the most extreme policy reform that is to deport all the illegal immigrants and not to allow any more illegal immigrant to cross the border illegally. Other policy reforms are between this extreme policy and the status quo. Therefore, this exercise can shed lights on the upper bounds for effects from different policy reforms.

The first step of this study of developing a reasonable, normative model of illegal immigration seems difficult because the previous studies have found the number of illegal immigrants in the US to be too small, given the small observable costs of crossing the border illegally (mainly, payments to smugglers) and the huge wage gap between the United States and Mexico and other sending countries (see Hanson (2006) for the substantial survey which argues that this is a puzzle). Hanson (2006) argues that the reason for the small number of illegal immigrants relative to what a standard model predicts is unobserved costs of immigration: being away from home, not knowing the language. These unobservable costs are very difficult to be included in a standard dynamic macroeconomic model. Even if we can write a model with disutility from being away from home and not knowing English, it is hard to calibrate the parameters regarding these unobservable costs.

Fortunately and surprisingly, I find that the size of illegal immigration is not too small if potential illegal immigrants are reasonably risk-averse. The previous studies mainly in labor economics assume that potential illegal immigrants are risk neutral. This assumption may be necessary for a model to be tractable enough to have a closed form solution, which leads to an econometrically testable implication. I use a calibrated dynamic general equilibrium model to analyze the illegal immigration issue, and therefore, I can relax this assumption of risk-neutrality and explain the size of the illegal immigration. The key elements are risk aversion, wage uncertainty in the US, wage inequality and credit constraints in Mexico. In most previous studies, preferences are typically linear (Borjas, 1987). This linear preference assumption creates this puzzle for three reasons. First, when preferences are linear, only the mean wage in the US matters. The mean wage for the illegal immigrants in the US is as high as $7 per hour. In the standard deviation is quite large. Many illegal immigrants receive a very low wage. This large standard deviation and the concentration around the very low wages discourage risk averse households from crossing the border. Second, linear preferences ignore smooth consumption behaviors. In Mexico, wage inequality is large. The poorest households face the largest wage gap between in the US and Mexico. However, for the poorest to afford the fixed costs of crossing the border illegally, they have to save a significant amount of their income. Considering the consumption smoothing, the poorest find it too costly to sacrifice today's consumption and save enough to pay the fixed costs. Third, trivially, if preferences are linear, borrowing constraints do not play an important role. I show that a model with risk averse households can explain the size of illegal immigration.

To investigate the policy questions above, I embed this mechanism into a two country dynamic general equilibrium model in which the wage, interest rate, and unemployment rate are endogenously determined in equilibrium. I extend a model economy with production, search, and unemployment insurance developed by Young (2004). Young (2004) extends Aiyagari (1994) by introducing job search so that the unemployment rate is endogenous to the model, unlike Huggett (1993). Young (2004) also allows my model to mimic the unemployment benefit system very close to the actual US system.

The specific quantitative exercise is to compute a rather extreme policy reform; the US government deports every illegal immigrant and builds a fence on the border, unexpectedly. Other policies (Guest Worker Program, etc.) are somewhere between this extreme policy and status quo. Therefore, the no-illegal-immigrant policy provides an useful upper bound of the effects of different policy reforms. The simulation shows that the aggregate social welfare increases by 0.01% on average and the welfare increases by 0.1 % for the poorest households. The unemployment rate initially decreases by 0.4%. The unemployment rate in the new steady state is lower by 0.3% than in the initial steady state. The wages initially increase by 1% and slowly converge back to the initial level. The interest rate initially decreases by 4% and slowly coverage back to the initial level. In sum, this extreme policy has a relative large impact on the wages and interest rates initially, but a negligible impact on the social welfare except for the poorest households.

This chapter is organized as follows. Section 2 presents the model. Section 3 calibrates the model to the US data and shows how much the model can explain the puzzle and Section 4 presents the welfare results with the policy experiment. Section 5 concludes.

## 3.2 Model

The model economy consists of two countries: Mexico and the United States. I describe the Mexican economy and US economy separately, and discuss the aggregation and interaction.

### 3.2.1 Mexican Economy

I model the Mexican economy without an explicit domestic capital market, since the capital market in Mexico is not as developed as in the US. Since the Mexican economy is small compared to the US economy or the world economy, I also assume that, when there is a change in the Mexican labor force due to illegal immigration, the (foreign) capital flow in or out of Mexico until the interest rate in Mexico and the world interest rate coincide. This also implies that under Cobb-Douglus production function, the wage and interest rate in Mexico are constant and determined by the world real interest rate. This mechanism is not explicitly modeled here for the simplicity. THe focus is on effects in the US and endogenizing the mexican wage would give similar results in the US.

The only cross country interaction is illegal migration. There is no trade of goods. The Mexican model economy consists of a $M$-measure continuum of households without access to private insurance markets. Households die with probability $\theta$. Preferences for the Mexican households are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \log c_t. \tag{84}$$

where $c_t$ is consumption. Households discount their future utility by $\beta = \widetilde{\beta}(1-\theta)$ where $\widetilde{\beta}$ is the discount factor. Most previous studies assume that preferences are linear (Borjas, 1987). Linear preferences make uncertainty about wages in the US and credit constraints unimportant. Therefore, it is important to assume that households are risk-averse.

I classify Mexican households into three categories: households who have never crossed the border (potential immigrants), households who are currently in the US (illegal immigrants), and households who have been to the US and are currently in Mexico (returners). The difference between the potential immigrants and the returners is that the potential immigrants do not know their labor productivity in the US, whereas the returners do know their labor productivity in the US. In my model, the first time they go to the US, they draw a labor productivity from a certain distribution $f(\epsilon)$. They cannot re-draw the labor efficiency in the US labor market by going back and forth between the two countries. If Mexican households could re-draw their labor efficiency every time they travel to the US, they would go back and forth until they draw a very high labor efficiency. To keep every Mexican household from eventually moving to the US, it is important to assume that they can draw their productivity in the US only once in their life.

All Mexican households face idiosyncratic (Mexican) wage shocks, $\omega_t$. For the immigrants, these idiosyncratic shocks can be considered as a job offer from home. After realizing the wage shocks, they decide to be in Mexico or in the US. Every time they cross the border illegally, they have to incur costs of "coyote price", $\kappa$, for smugglers so that they can cross the border without being caught by the border patrol. Hanson (2006) report that recently most illegal immigrants use smugglers because the US government has changed the border patrol policy and the number of people who get killed, trying to cross the border, has been increasing. Thus, I do not allow Mexican households to cross the border without using the smugglers. I also assume that there is no credit market in Mexico. However, they can self-insure the wage risk or finance the coyote price by saving as a form of cash, $m_t$. The financial market in Mexico is not as developed as in the United States. Further, if a bank does not have an incentive to lend any resource to those who may attempt to cross the border and may never come back. Thus, this incomplete market assumption seems reasonable. The budget constraint for the potential immigrants and returners who remain in Mexico is given by

$$c_t + m_{t+1} \leq \omega_t + m_t \tag{85}$$

Those who are crossing the border in the current period is given by

$$c_t + m_{t+1} \leq m_t - \kappa \tag{86}$$

The budget constraint for the immigrants who stay in the US is given by

$$c_t + m_{t+1} \leq w_t \epsilon_t + m_t \tag{87}$$

where $w_t$ is the US wage level and $\epsilon_t$ is the labor productivity in the US. Finally, the budget constraint for the immigrants who return to Mexico is given by

$$c_t + m_{t+1} \leq m_t \tag{88}$$

Since $m$ is cash, $m \geq 0$. I also assume that they do not have an access to the US capital market. The unemployment rate or the duration of unemployment of illegal immigrants is unknown. Since this study focuses more on the welfare of the US households, instead of the Mexican households, I assume that the flow of illegal immigrants are solely driven by the job opportunity that they have in Mexico. For example, one might decide to come to the US illegally when he receives the lowest productivity shock in Mexico. A few periods later, he may receive a good productivity shock (a good job offer) in Mexico, and then he may decide to go back to Mexico. Thus, without unemployment shocks in the US, the model can generate migration flows.

### 3.2.2 US Economy

The US economy is almost identical to Young (2004). The US model economy consists of a unit-measure continuum of households without access to private insurance markets, as in a standard Bewley-Huggett-Aiyagary economy. One of the major contribution of Young (2004) is to introduce labor search and endogenize the unemployment rate that is also an important variable in my study of illegal immigration. The US economy does have a capital market and the equilibrium interest rates and wages are also endogenously determined, based on the aggregate amount of capital and labor in the United States. This element is also necessary for my study since academic researchers and policy makers are concerned about a possible decrease in wages because of a large illegal immigrant population. Further, the environment also allows me to model a realistic unemployment benefit system. A lack of the realistic unemployment benefit system may mislead my social welfare analysis since without unemployment benefit there would be households with a very small amount of capital whose indirect utility is significantly low.

Preferences for the US households are given by

$$E_0 \sum_{t=0}^{\infty} \beta^t \left[ \frac{c_t^{1-\sigma}}{1-\sigma} - a_t^{\chi} \right], \tag{89}$$

where $c_t$ is consumption and $a_t$ is job search/retention effort. $\chi$ measures the curvature of the disutility of effort function. The coefficient of relative risk aversion is $\sigma$.

Timing within a period is as follows. At the beginning of the period, employed households engage in job-retention effort and unemployed households engages in job-search effort, realizing the wages and interest rates for this period. A household retains or receives a job in the current period with probability

$$\Pr(\varepsilon_t = 1 | e_t = j) = 1 - \exp(-\gamma_j a_t) \tag{90}$$

where $e_t$ denotes the agent's relevant employment history and $\varepsilon_t$ denotes current job status that is, $\varepsilon_t = 1$ denotes an individual who is currently employed and $\varepsilon_t = 0$ is one who is currently unemployed, and an an agent in state $e_t = j$

has $j$ consecutive periods of unemployment, up to some maximum $J$. There are no job rejections.

After observing the outcome of their job retention/search outcome, households make a consumption/savings decision. They face a budget constraint such that

$$c_t + k_{t+1} = k_t + (1-\tau)(r_t k_t + \varepsilon_t w_t) + (1-\varepsilon_t) b_t w_t \tag{91}$$

where $k_t$ is current capital, $r_t$ and $w_t$ represent the interest rate and wage, $\tau$ is the income tax rate used to finance the unemployment insurance system, and $b_t$ is the unemployment benefit replacement rate. They also face a borrowing constraint: $k_{t+s} \geq \underline{k}$.

There also exist a continuum of identical firms in the US economy. The production function takes a standard Cobb-Douglas form

$$F(K_t, N_t) = K_t^{\alpha} N_t^{1-\alpha} \tag{92}$$

where $K_t$ is the aggregate level of capital and $N_t$ is the sum of individual labor productivity of native workers as well as illegal immigrants. This implies that the interest rates and wages satisfy the familiar marginal product conditions, in equilibrium,

$$r_t = \alpha K_t^{\alpha-1} N_t^{1-\alpha} - \delta \tag{93}$$

$$w_t = (1-\alpha) K_t^{\alpha} N_t^{-\alpha} \tag{94}$$

where $\delta$ is a capital depreciation rate.

The US government collects income taxes and distributes benefits which cannot be contingent on effort levels, as these efforts are unobservable to the government. It sets a benefit structure $(b_{et})_{e=0}^{\infty}$ and a flat tax rate $\tau$ to satisfy the budget constraint

$$\tau(r_t K_t + w_t (1-u_t)) = \sum_{e=0}^{\infty} b_{et} w_{et} u_{et} \tag{95}$$

where $u_t$ denotes the unemployment rate and $u_{et}$ is the amount of unemployed in state $e$ and thus receiving benefits $w_{et} b_{et}$. Unlike Young (2004), the unemployment benefit depends of the previous wage as oppose to the current wage rate in the economy, although this specification does not make any difference in a steady state analysis. This specification becomes important in the policy experiment.

### 3.2.3 Recursive Representation of the Model

The economy admits a recursive representation for the households' problems. Especially for Mexican households, it is easier to see their maximization problems in a recursive form since they make discrete choices. I also study only a steady state in this section.

The potential immigrants', immigrants', and returners' value functions can be written as

$$V_p(m,\omega) = \max \left\{ \begin{array}{c} \max_{\{m'\}} \log(m+\omega-m') + \beta E_{\omega'|\omega} V_p(m',\omega'), \\ \max_{\{m'\}} \log(m-m'-\kappa) + \beta E_{\epsilon;\omega'|\omega} V_i(m',\omega';\epsilon) \end{array} \right\} \tag{96}$$

$$V_i(m,\omega;\epsilon) = \max \left\{ \begin{array}{c} \max_{\{m'\}} \log(m-m') + \beta E_{\omega'|\omega} V_r(m',\omega';\epsilon), \\ \max_{\{m'\}} \log(m+w\epsilon-m') + \beta E_{\omega'|\omega} V_i(m',\omega';\epsilon) \end{array} \right\} \tag{97}$$

$$V_r(m,\omega;\epsilon) = \max \left\{ \begin{array}{c} \max_{\{m'\}} \log(m+\omega-m') + \beta E_{\omega'|\omega} V_r(m',\omega';\epsilon), \\ \max_{\{m'\}} \log(m-m'-\kappa) + \beta E_{\omega'|\omega} V_i(m',\omega';\epsilon) \end{array} \right\} \tag{98}$$

respectively. The reason for distinguishing the potential immigrants from the returners is not to allow households to travel back and forth just to get a good draw for $\epsilon$. The solutions to the discrete choice problems are denoted as $\Delta_p, \Delta_i$, and $\Delta_r$, where $\Delta = 1$ if an agent decides to be in Mexico. The optimal savings functions are denoted as $\Phi_p, \Phi_i$, and $\Phi_r$.

The Bellman equation for the US households is

$$v(k,e)=\max_{\{a\}}\left\{\begin{array}{c}\max_{\{k'\}}\left[1-\exp(-\gamma_e a)\right]\left[\frac{(k+(1-\tau)(rk+w)-k')^{1-\sigma}}{1-\sigma}+\beta v(k',0)\right]\\ +\max_{\{k'\}}\left[1-\exp(-\gamma_e a)\right]\left[\frac{(k+(1-\tau)rk+wb_e-k')^{1-\sigma}}{1-\sigma}+\beta v(k',\min\{e+1,J\})\right]\\ -a^{\chi}\end{array}\right\} \tag{99}$$

I denote $\phi$ as the optimal savings function and $\psi$ as the optimal effort function.

Letting $\Gamma(k,e)$ denote a distribution of capital for different employment histories, $G_p(m,\omega), G_i(m,\omega;\epsilon)$, and $G_r(m,\omega;\epsilon)$ denote the distributions for cash for the potential immigrants, the illegal immigrants, and the returners, respectively, I can formally define the following object:

**Definition 1 (Stationary Recursive Competitive Equilibrium).** A stationary recursive competitive equilibrium for this economy consists of a value functions $\{v, V=(V_p,V_i,V_r)\}$, savings functions $\{\phi,\Phi=(\Phi_p,\Phi_i,\Phi_r)\}$, an effort function, $\{\psi\}$, migration decision functions $\{\Delta=(\Delta_p,\Delta_i,\Delta_r)\}$, equilibrium prices $r(K,N)$ and $w(K,N)$, an unemployment insurance system $(\tau,(b_e)_{e=0}^{J})$, and an invariant distribution $\{\Gamma, G=(G_p,G_i,G_r)\}$ such that

1. $V$, $\Delta$, and $\Phi$ solve the Mexican households' problems given prices, policy variables, and $G$;

2. $v$, $\phi$, and $\psi$ solve the US households' problems given prices, policy

variables, and $\Gamma$;

3. the (US) capital market clears: $K = \int kd\Gamma(k, e)$;

4. the (US) labor market clears: $N = \int [1 - \exp(-\gamma_e a)]\, d\Gamma(k, e) + \int \epsilon dG_i(m, \omega; \epsilon)$;[11]

5. $K$ and $N$ solve the firm's problem given prices;

6. the government budget constraint holds;

7. $\Gamma$ and $G$ are invariant.

## 3.3 Numerical Analysis

### 3.3.1 Calibration

In the previous section, I left the earnings process and the distribution of labor productivity in the US for Mexican households rather ambiguous to keep the expressions simple. For calibration, I need to parameterize the earnings process and the labor efficiency distribution. I set the number of elements for the Mexican wages, $\omega$, to three, so $\Omega = \{\omega_1, \omega_2, \omega_3\}$ and set $\omega_2$ such that $\sum_i \pi_i^* \log(\omega_i) - \log(w)$ to be the actual US-Mexico log wage difference from

[11]Storesletten (1999) also uses a similar labor market clearing condition to aggregate the native and immigrant workers' productivity.

the data, where $\pi_i^*$ is the unconditional probability of $\omega_i$ for $i = 1, 2, 3$. I choose the transition matrix to reproduce the moments in the data with the least number of parameters due to the data availability. I set $\Pi$ to

$$\Pi = \begin{bmatrix} p & \frac{1-p}{2} & \frac{1-p}{2} \\ \frac{1-p}{2} & p & \frac{1-p}{2} \\ \frac{1-p}{2} & \frac{1-p}{2} & p \end{bmatrix} \tag{100}$$

Then, the total number of free parameters is three: the transition probability $p$ and two of the wages $\omega_1$ and $\omega_3$. This $\Pi$ trivially implies that $\pi_i^* = \frac{1}{3}$ for $i = 1, 2, 3$.

The moments available and useful are:

1. the coefficient of variation of wages

$$C.V. = \frac{Var(\omega)}{\overline{\omega}^2} = \frac{\sum_i \pi_i^*(\omega_i - \overline{\omega})^2}{\sum_i \pi_i^* \omega_i} \tag{101}$$

2. given that $\pi_1^* + \pi_2^* \geq \frac{1}{2} \geq \pi_1^*$, the median to mean wage

$$\frac{median(\omega)}{\overline{\omega}} = \frac{\omega_2}{\overline{\omega}} \tag{102}$$

$p$ is assumed to be between the persistent for the US earnings process and 1 since the less developed countries have relatively high persistent earnings process especially for the poor (no American dream). The simulation results do not seem to matter as long as $p$ is in this range.

I also assume that the labor efficiency in the US for the illegal immigrants is log-normally distributed since the log-normal distribution seems to fit the wage distribution from the data fairly well and is typically used in the previous studies. Formally, the log-normal distribution is characterized with two parameters $\mu$ and $\sigma_\epsilon$ such that

$$\log \epsilon \sim N(\mu, \sigma_\epsilon). \tag{103}$$

These two parameters are calibrated using the data set from the Mexican Migration Project 114.

The rest of parameters are calibrated to match certain observations in the US data. I set $\alpha = 0.36$,which is capital share of income in the post-war period. The model period is one quarter of a year. To study the unemployment rate and the duration of unemployment, frequency of the model period needs to be short. At the same time, the model cannot be computationally too demanding. A quarterly model seems to be the optimal choice in these regards. The death probability, $\theta$, is set to be $\frac{1}{4\times 60}$ so that households live for 60 years on average after entering the labor market. The depreciation rate $\delta$ is set to be 0.025 from NIPA. I set the discount factor, $\widetilde{\beta} = 0.99$, which roughly matches the capital/output ratio. The parameters, $\gamma_0, \gamma_{1,}$ and $\gamma_2$ in the search functions are calibrated to replicate the following features of the US distribution of unemployment, estimated from CPS data by Wang and Williamson (2001): total unemployment is 7.4%, 69.8% of the unemployed are in state $e = 0$, and 15.5% of the unemployed are in state $e = 1$ for the baseline unemployment insurance (UI) system, which is described below. Finally, the borrowing constraint is set to zero, $\sigma = 1$, and $\chi = 2$.

The baseline UI system matches the US system as closely as computationally feasible as in Young (2004). In the US, the duration of unemployment benefit is approximately 6 months (i.e. $J = 2$) and the replacement rate is around 50% of the last wage earned. The replacement rate for welfare payments after the government stops the unemployment benefit provision is 17%. This implies that $b_0 = b_1 = 0.5$ and $b_{j \geq 2} = 0.17$.

*Table* 3.1 (Calibration)

| Description | Parameter | Value | Matched Moments or Source |
|---|---|---|---|
| Discount factor | $\beta$ | 0.99 | Capital/Output ratio |
| Capital share | $\alpha$ | 0.36 | NIPA |
| Depreciation rate | $\delta$ | 0.025 | NIPA |
| CRRA | $\sigma$ | 1 | Young (2004) |
| Disutility of efforts | $\chi$ | 2 | Young (2004) |
| Search parameters | $\gamma_0$ | 10.59 | CPS |
| | $\gamma_1$ | 2.96 | CPS |
| | $\gamma_2$ | 1.27 | CPS |
| UI replacement | $b_0, b_1$ | 0.5 | Wang & Williamson (1996) |
| Welfare replacement | $b_2$ | 0.17 | Wang & Williamson (1996) |
| Death probability | $\theta$ | 1/240 | Average life span |
| Size of Mexico | $M$ | 0.27 | (Mexican Labor Force)/(US Labor Force) |

### 3.3.2 Explaining the Size of Illegal Immigration

There is one more deep parameter to calibrate in the model, which is the coyote price, $\kappa$. What labor economists have found puzzling is that the number of illegal immigrants from Mexico to the US is too small, given the huge wage gap and the observable costs of crossing the border illegally, when the preference is linear. I claim that the model with risk averse households can explain the size of illegal immigration without introducing any unobservable variables such as disutility from being away from home.

Cornelius (2005) documents that the average coyote prices between 1996 and 1998, and 2002 and 2004, were \$1180 and \$1680, respectively. I choose $\kappa$ such that difference between the predicted number of illegal immigrants in the calibrated model and the actual number of illegal immigrants from Mexico is minimized. The implied coyote prices in the model are \$1063, which is very close to Cornelius's estimation, and at the same time, the predicted number of illegal immigrants is very close to what we observe in the data.

Therefore, a simple idea of the wage inequality and the credit constraint in Mexico can explain the size of illegal immigration, without taking into account any other unobservable costs which Hanson (2006) claims to be important. In equilibrium, the poorest Mexican households do not cross the border since they cannot afford to hire the smugglers. The richest households also do not cross the border since the benefit of crossing the border is too small. Thus, most illegal immigrants are middle income households. This result is also consistent with some empirical findings from the previous labor literature; labor economists find that the middle income group is more likely to cross the border illegally than the low income group or the high income group.

## 3.4 Policy Experiment and Welfare Analysis

So far, I have shown that the model developed here is consistent with the moments from the US and Mexican data, including the coyote prices, the wage gaps, and the number of illegal immigrants. I use this reasonable normative model to address some positive economic questions regarding immigration policy reforms. More specifically, I compute a transition from the benchmark economy to an economy with no illegal immigrants by deporting every illegal immigrant and building a wall between the US and Mexico.

The computation of this class of transition can be done by solving the model backward from the new steady state to the old steady state as in Young (2004). However, when the unemployment benefit depends on the previous wage, instead of the current wage for those who are employed, a simple backward induction cannot be used since there is no way to identify one's previous wage or one's employment history.

Therefore, I simulate the model forward, instead of backward, using the method innovated by Krusell and Smith (1999), although there is no aggregate uncertainty in the model. I approximate the distribution of capital across different employment histories by the aggregate capital level. The (US) households' problem can be rewritten as

$$\widetilde{v}(k,e,\widetilde{w};K)=\max_{\{a\}}\left\{\begin{array}{c}\max_{\{k'\}}\left[1-\exp(-\gamma_e a)\right]\left[\frac{c^{1-\sigma}}{1-\sigma}+\beta\widetilde{v}(k',0,w;K')\right]+\\ \max_{\{k'\}}\left[1-\exp(-\gamma_e a)\right]\left[\frac{c^{1-\sigma}}{1-\sigma}+\beta\widetilde{v}(k',\min\{e+1,J\},\widetilde{w};K')\right]\\ -a^{\chi}\end{array}\right\} \tag{104}$$

subject to

$$c+k' \leq k+(1-\tau)(r(K,N)k+w(K,N)\varepsilon)+\widetilde{w}b_e(1-\varepsilon) \tag{105}$$

$$K' = \widetilde{\beta}_0^K+\widetilde{\beta}_1^K K+\widetilde{\beta}_2^K K^2+\widetilde{\beta}_3^K\sqrt{K} \tag{106}$$

$$N = \widetilde{\beta}_0^N+\widetilde{\beta}_1^N K+\widetilde{\beta}_2^N K^2+\widetilde{\beta}_3^N\sqrt{K} \tag{107}$$

$$\tau = \widetilde{\beta}_0^\tau+\widetilde{\beta}_1^\tau K+\widetilde{\beta}_2^\tau K^2+\widetilde{\beta}_3^\tau\sqrt{K} \tag{108}$$

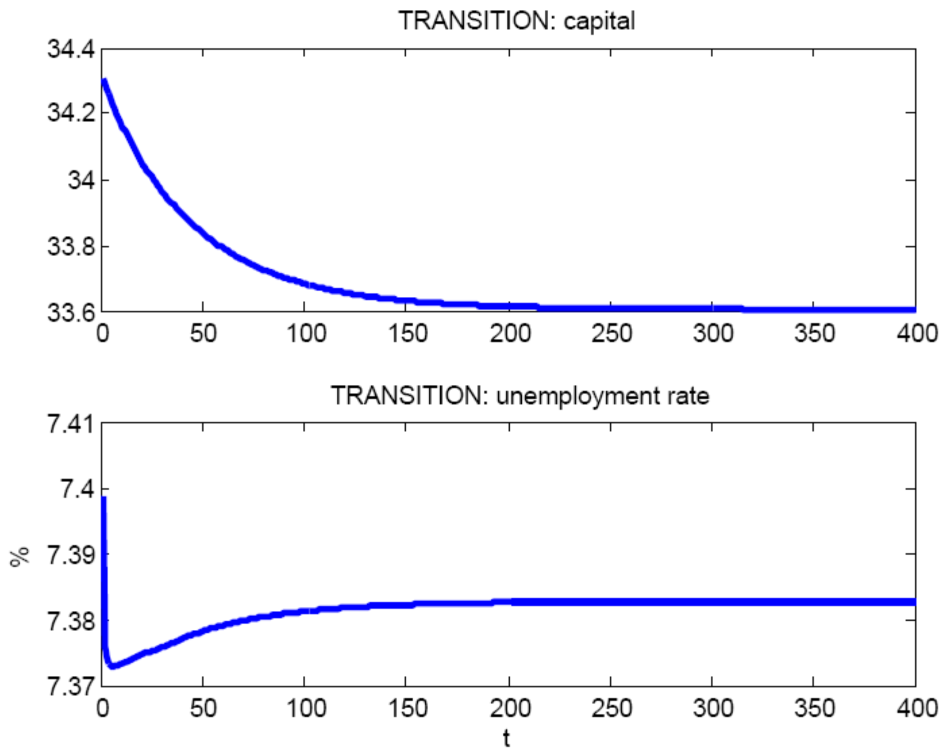
Table 2 summarizes the OLS results for the coefficients for these laws of motion for $K'$, $N$,and $\tau$. In this specification, every regression coefficient is statistically significant and $R^2$ is greater than 0.99. Any simpler specification generates a significantly low $R^2$.

*Table* 3.2 (The Laws of Motion)

| | $K'$ | $N$ | $\tau$ |
|---|---|---|---|
| $K$ | $1.29E^{-2}$ | $8.94E^{-6}$ | $-5.37E^{-6}$ |
| $K^2$ | $1.37E^{-2}$ | $2.37E^{-6}$ | $-2.79E^{-6}$ |
| $\sqrt{K}$ | $1.43E^{-2}$ | $2.44E^{-6}$ | $-2.91E^{-6}$ |
| $cons.$ | 17.66 | 0.92 | $3.31E^{-2}$ |
| $R^2$ | 0.9993 | 0.9903 | 0.9985 |

Figure 1 and 2 show how aggregate capital, the unemployment rate, the interest rate, and the wage change over the transition. The aggregate capital level gradually decreases since the US economy has lost the labor force without any capital. The unemployment rate initially decreases only by 0.4%, which is surprising since the initial increase in the wage is almost 1%. The initial drop of the interest rate is 4%. Thus, this extreme policy does have a significant impact of the interest rates and wages.

*Figure* 3.1 (Transitions of the Aggregate Capital and the Unemployment Rate)




If I computed the transition assuming that the unemployment benefit depends on the current economy-wide wage level, as opposed to the previous wage level, the unemployment rate initially increases since the unemployed also get benefit from the increase in the current wage because of the sudden decrease in $N$. However, in the simulation I performed here, the unemployed realize that the wage suddenly increased and put more efforts to search for a job. This scenario is much more realistic and intuitive. Therefore, it is important to simulate the model forward, using Krusell-Smith algorithm.

*Figure* 3.2 (Transition of the Interest Rates and Wages)

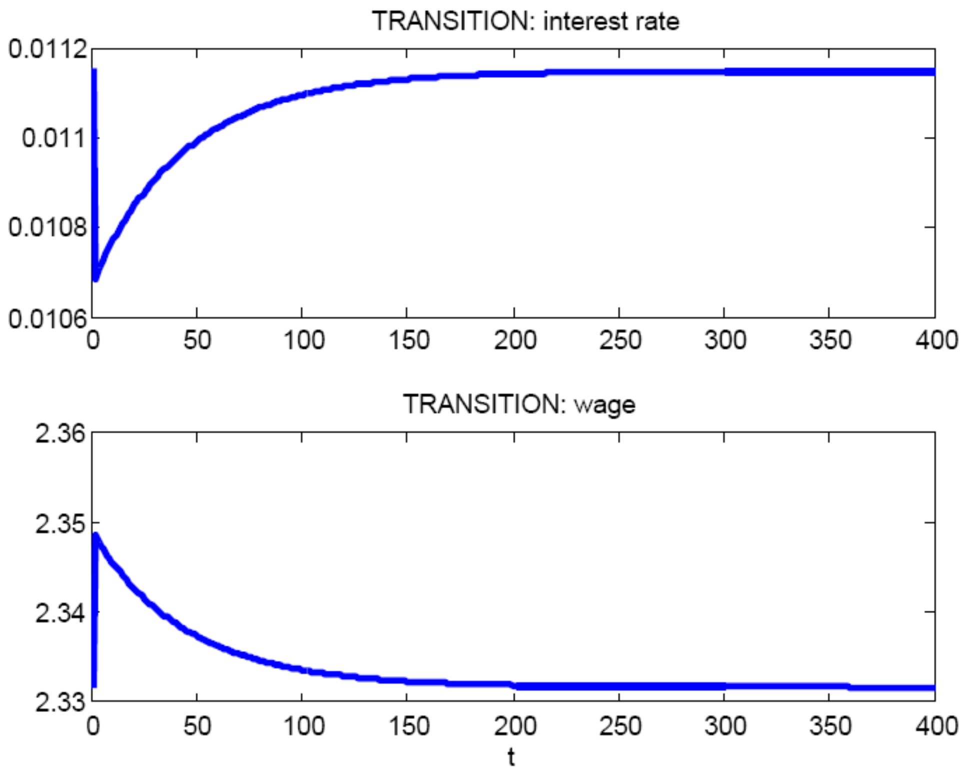
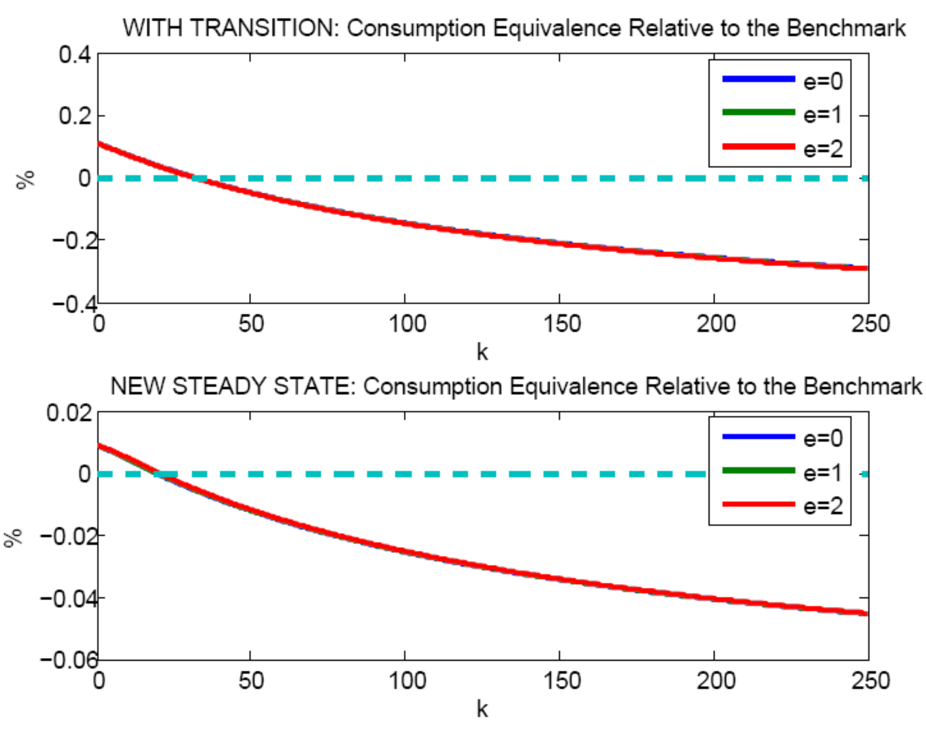



Figure 3 represents the welfare gain of agents as a function of their initial state $(k, e)$. The y-axis indicates $\xi(k, e)$ such that

$$W_1(k, e) = W_0(k, e) + \frac{1}{1-\beta}\log(1 + \xi(k, e)) \qquad (109)$$

where $W_0$ is the expected utility in the baseline case and $W_1$ is expected utility under the policy change. Thus, the least wealthy households gain by 0.1%, which is fairly large, and the most wealthy households loose by 0.3% when taking the transition into consideration. However, the welfare effects are much smaller when just comparing the two initial and end steady state because of the standard general equilibrium effects. This implies that if the number of illegal immigrants change gradually, the impact on the unemployment rate, the interest rate, and the wages is very small.

*Figure* 3.3 (Welfare Analysis)

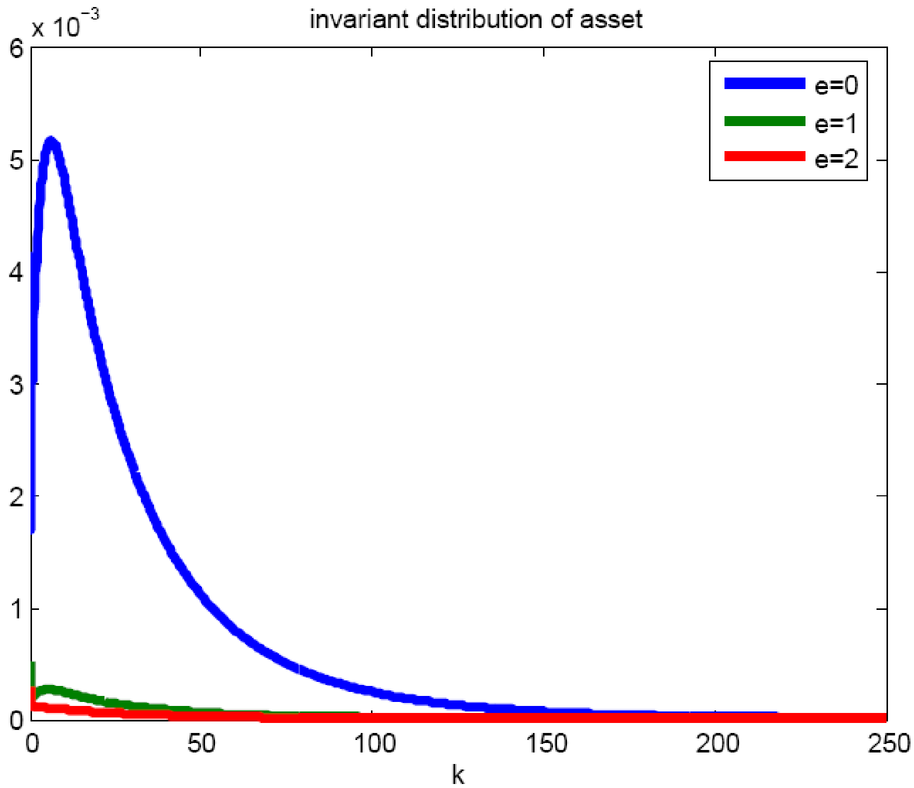



To fully understand Figure 3, it is important to show the distribution of wealth. Figure 4 plots the initial distribution of wealth that is the invariant distribution of wealth in the benchmark economy. It has the usual shape as in Young (2004); there is a concentration of agents with little or no wealth. Introduction of death probability helps the model to increase the Gini coefficient on wealth (0.8 in the model and 0.78 in the data). Since the households are concentrated toward zero capital, 64% of households get better off from this policy changes, so that majority voting would implement this extreme policy reform, assuming that the tangible costs (sending all the illegal immigrants back to Mexico and building a wall) are negligible. However, once I aggregate the welfare and find $\xi^*$ such that

$$\int W_1(k,e)d\Gamma(k,e) = \int W_0(k,e)d\Gamma(k,e) + \frac{1}{1-\beta}\log(1+\xi^*), \tag{110}$$

$\xi^*$ is 0.01%.

*Figure* 3.4 (Invariant Distribution of Asset in a Stationary Equilibrium)




## 3.5 Conclusion

This study is one of the first studies to explain the size of illegal immigration without introducing any unobservable variables such as disutility from being away from home, and investigate the welfare effects of the immigrant policy reforms by using a solid micro-founded dynamic general equilibrium model and serious calibration. What labor economists have found puzzling is that the number of illegal immigrants from Mexico to the US is too small given the huge wage gap between Mexico and the US and the small unobservable costs of crossing the border illegally (Hanson, 2006). A simple two country Bewley-Huggett-Aiyagari class of model can explain the size of illegal immigration with a reasonable fixed cost of crossing the border illegally since the Mexican households who could potentially get most benefit by crossing the border are actually facing the tight credit constraint and cannot finance payments to the smugglers.

In the model developed here, the unemployment rate, the wage, and the interest rate are all endogenously determined in equilibrium, which allows me to provide some answers to a hot policy debate regarding the immigration policy reform. The particular experiment I considered here is to suddenly deport all the illegal immigrants and build a fence. This extreme policy reform predicts that the interest rate will initially decrease by 4%, the wage will initially increase by 1%, and the unemployment rate will initially decrease by 0.4%. Most of the previous studies tried to estimate these effects, but they stopped there. What the policy makers are ultimately interested in is the welfare effects on different individuals. When considering the transition, the poorest households gain welfare by 0.1%, which is fairly large, and the richest households loose welfare by 0.3%, whereas without considering the transition, these effects are 10 times smaller and almost negligible. The transition simulation also shows that this rather extreme policy change would be popular (more than 60% of households get better off), although on average the social welfare increases only by 0.01%.

There are some weaknesses in this study. First, due to the lack of data availability for illegal immigrants from countries other than Mexico, I ignored these illegal immigrants that account for approximately 40% of the total illegal immigrants. If their characteristics are not too far from those of Mexican illegal immigrants, the effects on the prices, the unemployment rate, and the welfare may be significantly larger.

Second, I did not allow Mexican households to legally immigrants to the US. The number of legal immigrants from Mexico is smaller than the number of illegal immigrants and legal immigrants are typically wealthy since the visa application is very costly. Therefore, legal immigration policy reform is still an important topic, but only marginally related to the illegal immigration policy reform, although it may not look that way.

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