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Abstract

We develop a quantitative heterogeneous-agents general equilibrium model that reproduces the income inequalities of 32 countries in the Organization for Economic Co-operation and Development. Using this model, we compute the optimal income tax progressivity and redistribution for each country under the equal-weight utilitarian social welfare function. We simulate the voting outcome for the utilitarian optimal tax reform for each country. Finally, we uncover the Pareto weights in the social welfare functions of each country that justify the current redistribution policy.

Keywords: Income Inequality, Optimal Tax, Pareto Weights, Political Economy, Redistribution

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1. Introduction

The unequal distribution of economic resources and opportunities has been a primary concern for social scientists and policy makers. Income and wealth inequality is widespread across the world, and many countries adopt redistribution policies to alleviate this issue.[1] Figure 1 plots the Gini coefficients of incomes (for both before and after taxes/transfers) for 32 countries in the Organization for Economic Co-operation and Development (OECD) based on the OECD database.[2] The Gini coefficient of income before tax and transfers ranges from 0.34 (South Korea) to 0.58 (Ireland). The "improvement rate" in income inequality (measured by the percentage decrease in the income Gini coefficients between before and after taxes/transfer) ranges from 5% in Chile to 49% in Ireland.[3]

Understanding and comparing redistribution policies across countries in a unified framework is not an easy task. Economists' ability to quantitatively evaluate the political outcome of redistribution policies is limited because it requires modeling a complex political process and aggregating individual preferences. However, recent developments in quantitative general equilibrium heterogeneous-agents models enable us to take first steps in addressing these issues. We can compute the optimal income tax policy under various welfare criteria and simulate voting outcomes of alternative policies. We can even uncover the welfare weights (so-called Pareto weights) that would justify each country's current redistribution policy. To our knowledge, this is the first study that compares how societies (or governments) aggregate individual preferences over the redistribution policies, and does so across a large set of countries. We relate our estimated Pareto weights to

[1] Alesina and Glaeser (2004) provide a detailed survey of a broad range of sources, their interactions, and the socio-economic consequences of income and wealth inequality.

[2] Out of the 34 OECD countries, we exclude Mexico and Hungary from our analysis.

[3] The specific measures and degree of income redistribution caused by individual policies differ considerably across countries. Progressive income taxation and a variety of income transfer programs are typical redistribution policies intended to reduce the inequality of disposable income. There are also indirect transfer programs, which redistribute wealth through providing goods and services that individuals would have otherwise purchased at their own expense. Examples include free education, health care and child care. Different countries have a variety of policy tools. For example, according to the OECD (2015), the top statutory personal income-tax rate ranges from 15% (Czech Republic) to 57% (Sweden) and the property tax share of total tax revenue varies from a mere 1.1% (Estonia) to 13% (U.S.).

each country's Democracy Index, electoral turnout rates, and the social perception about income redistribution in the World Values Survey, all of which are often used in political science and sociology.

More specifically, we ask three questions: (i) What is the optimal progressivity of income tax for each country under the equal-weight utilitarian social welfare function? (ii) What would be the outcome of voting on the fiscal reform to adopt the utilitarian optimal progressivity of income tax? (iii) What are the Pareto weights in the social welfare function that justify the current tax policy (which is suboptimal according to the equal-weight criteria) in each country?

We examine these questions through the lens of the model seen in Aiyagari (1994), where households face uncertainty about future earnings. As a result of the precautionary savings and labor supply motive to insure against this future uncertainty, the cross-sectional wealth distribution emerges as an equilibrium.

We calibrate the model economy for each of the 32 OECD countries. The stochastic process of individual productivity shocks (which is the source of the cross-sectional income inequality) is chosen to match the *before*-tax income Gini coefficient in the data.[4] Summarizing the progressivity of taxes (especially for cross-country comparison) is not a simple task because of the complexity of the income tax schedule and various deductions. One practical way is to assume a specific parametric form of tax function with a few parameters. We assume that the individual income tax schedule follows the log-linear tax function, which is widely used in various literatures (e.g., Benabou (2002), Heathcote et al. (2016)). We choose the progressivity of income tax to match the after-tax Gini coefficient in the data. As a result, for each country, the model exactly matches the before- and after-tax income Gini coefficients. The progressivity of tax in our model turns out to be remarkably close to that in the data, indicating that our model captures important characteristics of income inequality and redistribution in these countries quite well.

According to our benchmark model, the optimal tax progressivity under the equal-

[4]Other parameters, such as tax progressivity or disutility from working, also affect the before-tax income Gini in our model. Therefore, strictly speaking, all parameters are chosen together to match all data moments. However, we explain each parameter and the closest moment together for an intuitive interpretation.

weight utilitarian social welfare function varies from 0.21 (South Korea) to 0.41 (Ireland), and the corresponding optimal redistribution, measured by the improvement rate of the income Gini, ranges between 20% (South Korea) and 37% (Ireland). For 10 of the 32 OECD countries we consider, the optimal progressivity is higher than the current one.[5] In the other 22 countries, mostly European countries, the opposite is true: the current progressivity is higher than optimal.

We then simulate the voting outcome for the reform policy needed to adopt the utilitarian optimal progressivity—i.e., the policy that changes the current tax progressivity to the optimal level that maximizes the equal-weight utilitarian social welfare function.[6] Optimal tax reform is favored by the majority of the population in almost all OECD countries we consider.[7] For example, in Chile, which has the weakest progressivity of income tax (0.06 according to our model-implied measure), 86% of the population supports the policy to increase progressivity to the social optimum of 0.345. Then, the improvement rate of the Gini in Chile increases from the current 5% to 32%.

If the optimal tax reform is supported by the majority of citizens in these countries, why haven't they adopted it yet? The "optimality" depends on the specification of the social welfare function. It is not obvious whether each government's goal is to maximize the equal-weight utilitarian welfare function despite its popular use in quantitative macroeconomic analysis. There are many other alternative criteria. One may argue that it is desirable for a society to maximize the welfare of the poorest members instead of the average (i.e., Rawlsian). The society's choice for redistribution is also affected by various factors such as the externality of public expenditure (Heathcote et al., 2016) or profession (Lockwood, Nathanson and Weyl, 2016), the preference heterogeneity (Lockwood and Weinzierl, 2015), the reference point (Charité, Fisman and Kuziemko, 2015),

[5]These countries are Australia, Canada, Chile, Israel, Japan, Korea, New Zealand, Switzerland, Turkey, and the U.S.

[6]For this, we compute the changes in the value functions of individual households not only in the new steady state with the optimal tax progressivity but also in route to the new steady state. If the majority of people benefit from the change in the progressivity, this policy reform can be supported as a political equilibrium.

[7]The only exceptions are Spain and Portugal, whose current porgressivity is very close to the optimal level.

benefit-based taxation (Weinzierl, 2016), or the "equal sacrifice" rule (Weinzierl, 2014). Moreover, the process under which policies are actually determined is much more complicated than the simple majority rule. For example, the political equilibrium under a multi-party system can be different from that under the median voter theorem. These questions are immensely important, but beyond the scope of this paper.

In this paper we instead ask a rather simple positive question within the utilitarian framework. For each country, we ask: what are the weights in the social welfare function that justify the current tax progressivity as optimal? We interpret these relative weights in the social welfare function as broadly representing each society's preferences for redistribution and political arrangement—i.e., a reduced-form representation of various factors. Thus, we interpret the persistence of the current suboptimal tax rate (despite overwhelming support for optimal tax reform) as evidence of deviation from the equal-weight utilitarian social welfare function. According to our calculations, in Sweden, the average Pareto weight on the richest 20% of the population is only 0.53, whereas that on the poorest 20% is 1.74. By contrast, in Chile, the Pareto weight on the richest 20% is 2.65, whereas that on the poorest 20% is a mere 0.15. We provide three potential interpretations of estimated Pareto weights across countries by relating our estimates to (i) the Democracy Index from the Economist Intelligence Unit, (ii) electoral voting turnout rates by income from Mahler (2008), and (iii) the society's preference for income redistribution from the World Values Survey.

Our results are closely related to those in the existing literature. Romer (1975) and Roberts (1977) present models of a median-voter-led income redistribution. Our model enables us to compute individual welfare under a specific policy and simulate a voting result. Acemoglu et al. (2013) find that among 184 countries, democracy has a significant and robust effect on tax revenues as a fraction of GDP. Since their measure of democracy is dichotomous, their results are better interpreted as the effect of democratization. Our findings suggest that the degree to which democracy is embraced in each OECD country affects the adoption of redistribution policies. Heathcote and Tsujiyama (2016) compare alternative tax systems in the U.S. based on the social weights that justify current tax rates. We examine the redistribution policies of 32 OECD countries and uncover the implied Pareto weights of the social welfare function of each country. A large literature, including Saez and Stantcheva (2016), and Lockwood and Weinzierl (2016), extends Mirrlees's (1971) framework to uncover social weights. While most of the Mirrleesian approaches are static, our model allows precautionary savings at the cost of assuming a simple parametric form for taxes.[8] We compare the estimated marginal social welfare weights from our model to those from Lockwood and Weinzierl (2016). Holter et al. (2015) measure the progressivity of labor income tax for 20 OECD countries and compute the additional tax revenues generated by increasing labor income taxes. Our measure of progressivity includes other income and public transfers as well as labor income, and we focus on the discrepancy between the current and the optimal progressivity.

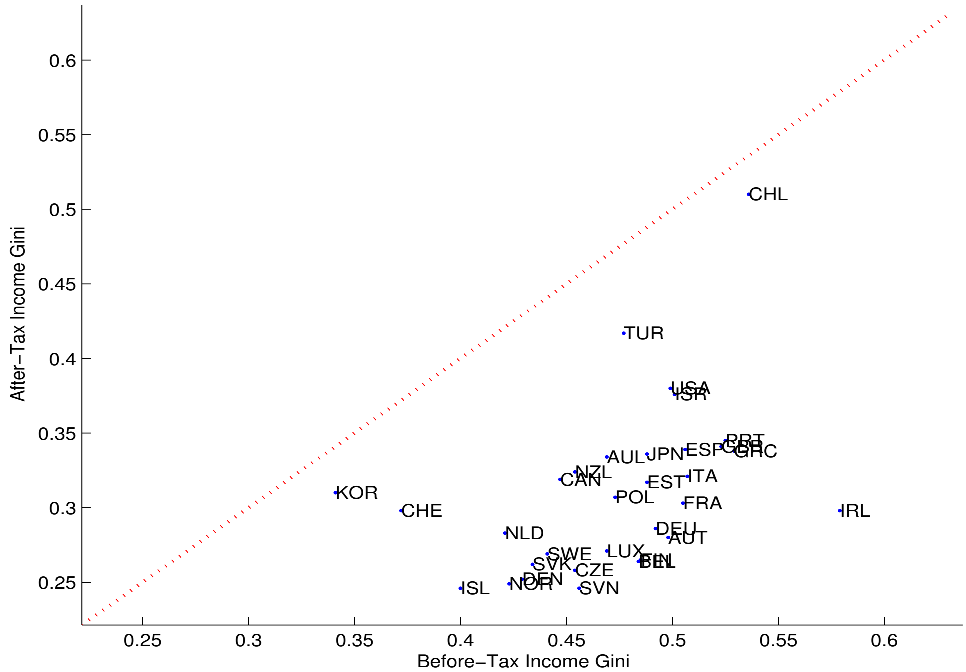
The remainder of the paper is organized as follows. Section 2 documents key statistics about equality and welfare across 32 OECD countries and investigates their relationships. Section 3 lays out the benchmark model economy, which is calibrated to match the before- and after-tax income Ginis for each country. In Section 4, we calibrate our model economy and show that our model generates a reasonable income distribution. In Section 5, we compute the optimal progressivity of income tax under the equal-weight utilitarian social welfare function and examine whether the optimal tax reform is supported by the majority of the population. We then uncover the Pareto weights that justify the current progressivity, relate our estimated Pareto weights to each country's Democracy Index, electoral voting turnout rates by income, and the perception of income redistribution in the World Values Survey, and compare our results to the Mirrleesian approach. Section 6 concludes.

2. Income Inequalities in the OECD Countries

In this section, we document stylized facts about the income inequality and redistri-

[8]Conesa and Krueger (2006) computed the optimal progressivity of the income tax in a dynamic equilibrium model with household heterogeneity. They argued that the optimal U.S. income tax is a flat tax rate (17.2%) and a fixed deduction using a utilitarian social welfare criterion. Under such conditions, a majority of the population can experience welfare gains. While we do use the U.S. as our benchmark case, we extend the analysis to include a wider set of economies (e.g., 32 OECD countries) at the cost of more detailed heterogeneity and tax functions.

Figure 1: Before-Tax and After-Tax Income Inequality



bution policies of the OECD countries. These facts are summarized in Tables 1 and 2. The first and second columns of Table 1 report the available before- and after-tax income Ginis for the OECD countries, which are taken from the OECD database.[9] The before-tax income Gini ranges from 0.34 (South Korea) to 0.58 (Ireland), with an average of 0.47 and a standard deviation of 0.05. The after-tax income Gini varies from 0.25 (Iceland) to 0.51 (Chile), with an average of 0.31 and a standard deviation of 0.06.

Figure 1 plots the before- and after-tax income Ginis for the 32 OECD countries. All 32 countries are located below the 45-degree line, indicating that, in all countries, incomes are redistributed from the rich to the poor. The two income Ginis are, however, modestly correlated with the correlation coefficient of 0.44, indicating varying degrees of redistribution policies across countries.

Based on before- and after-tax income Gini coefficients, we calculate the improvement rate in income inequality—i.e., the percentage decrease in the Gini coefficient after tax and

[9]The OECD database provides the income Gini coefficients, which are standardized across sources and measures. http://stats.oecd.org.

Table 1: Key Statistics for the 32 OECD Countries in 2010

	Before-Tax Gini	After-Tax Gini	Improvement (%)	Tax/Y (%)	Democracy Index	Wealth Gini	G/Y (%)
Australia	0.469	0.334	28.8	25.6	9.22	0.636	17.9
Austria	0.498	0.280	43.8	42.2	8.49	0.693	20.4
Belgium	0.484	0.264	45.5	43.5	8.05	0.655	23.6
Canada	0.447	0.319	28.6	30.6	9.08	0.728	22.0
Chile	0.536	0.510	4.9	19.5	7.67	0.774	12.3
Czech Republic	0.454	0.258	43.2	33.9	8.19	0.743	20.5
Denmark	0.429	0.252	41.3	47.4	9.52	0.701	27.6
Estonia	0.488	0.317	35.0	34.0	7.68	0.660	20.1
Finland	0.485	0.265	45.4	42.5	9.19	0.662	23.9
France	0.505	0.303	40.0	42.9	7.77	0.755	23.8
Germany	0.492	0.286	41.9	36.2	8.38	0.777	19.1
Greece	0.529	0.338	36.1	31.6	7.92	0.714	21.6
Iceland	0.400	0.246	38.5	35.2	9.65	0.663	24.7
Ireland	0.579	0.298	48.5	27.4	8.79	0.727	18.9
Israel	0.501	0.376	25.0	32.4	7.48	0.783	22.5
Italy	0.507	0.321	36.7	43.0	7.83	0.646	20.4
Japan	0.488	0.336	31.1	27.6	8.08	0.596	19.7
Korea	0.341	0.310	9.1	25.1	8.11	0.726	14.5
Luxembourg	0.469	0.271	42.2	37.3	8.88	0.623	16.5
Netherlands	0.421	0.283	32.8	38.9	8.99	0.812	26.5
New Zealand	0.454	0.324	28.6	31.1	9.26	0.725	19.8
Norway	0.423	0.249	41.1	42.6	9.80	0.779	21.4
Poland	0.473	0.307	35.1	31.7	7.05	0.753	19.3
Portugal	0.525	0.345	34.3	31.2	8.02	0.725	20.7
Slovak Republic	0.434	0.262	39.6	28.3	7.35	0.621	19.2
Slovenia	0.456	0.246	46.1	38.1	7.69	0.639	20.3
Spain	0.506	0.339	33.0	32.5	8.16	0.662	20.5
Sweden	0.441	0.269	39.0	45.4	9.50	0.806	25.2
Switzerland	0.372	0.298	19.9	28.1	9.09	0.806	10.7
Turkey	0.477	0.417	12.6	26.2	5.73	0.842	14.3
United Kingdom	0.523	0.341	34.8	34.9	8.16	0.675	21.6
United States	0.499	0.380	23.8	23.8	8.18	0.852	16.9
Average	0.472	0.311	33.9	34.1	8.34	0.717	20.2
Std. Dev.	0.049	0.056	10.7	7.1	0.87	0.069	3.8

Note: See Appendix A for a detailed description of the data.
Source: OECD (2015, 2016), Economist Intelligence Unit (2011), and Credit Suisse (2012)

Table 2: Correlations for the 32 OECD Countries

	Before Gini	After Gini	Improvement (%)	Tax/Y (%)	Democracy Index	Wealth Gini	G/Y (%)
Before-Tax Income Gini	1.00	0.44	0.21	-0.09	-0.34	-0.09	0.04
After-Tax Income Gini	0.44	1.00	-0.78	-0.67	-0.50	0.33	-0.52
Gini Improvement (%)	0.21	-0.78	1.00	0.70	0.32	-0.42	0.63
Tax/Y (%)	-0.09	-0.67	0.70	1.00	0.36	-0.16	0.74
Democracy Index	-0.34	-0.50	0.32	0.36	1.00	-0.08	0.36
Wealth Gini	-0.09	0.33	-0.42	-0.16	-0.08	1.00	-0.17
G/Y (%)	0.04	-0.52	0.63	0.74	0.36	-0.17	1.00

Source: Authors' calculation with data from OECD (2015, 2016), Economist Intelligence Unit (2011), and Credit Suisse (2012)

transfers—for each country, which serves as a measure of the strength of the redistribution policies. The improvement rate, shown in the third column of Table 1, varies widely, from 5% (Chile) to 49% (Ireland), with an average of 33.9% and a standard deviation of 10.7%. The improvement rates are only weakly correlated with the before-tax income Gini (the correlation coefficient of 0.21), suggesting that a country with high income inequality does not necessarily adopt a stronger redistribution policy.

Progressive income tax is commonly used in OECD countries. However, comparing the progressivity across countries is not a simple task because of the complexity of tax schedules and deductions that are specific to each country. The marginal income tax rate for the highest income group is often used as a proxy for tax progressivity. However, the top statutory tax rate is not at all systematically correlated with the improvement rate of income Gini coefficients across 32 OECD countries (correlation coefficient of 0.12).

One practical way to compare the progressivity is to assume a specific parametric form of tax function. We adopt a log-linear tax function widely used in the literature (e.g. Benabou (2002), Heathcote et al. (2016)) as follows.

$$\begin{aligned}
\text{Tax:} \quad & T(y_i) &&= y_i - \lambda y_i^{1-\tau} \\
\text{Disposable income:} \quad & D(y_i) &&= \lambda y_i^{1-\tau} \\
& \log D(y_i) &&= \log \lambda + (1-\tau) \log y_i
\end{aligned}$$

where λ is the average level of taxation and τ is a progressivity of income taxes and transfers. Using the Luxembourg Income Study (LIS) database, we estimate the tax progressivity of 25 OECD countries.[10] The LIS collects and harmonizes household data across countries. Market income is defined as factor income plus private transfers. Disposable income is defined as market income plus public transfers minus income taxes and contributions. We estimate tax progressivity ($\hat{\tau}$) by regressing the log of disposable income on the log of market income. All incomes are equivalized by household size.

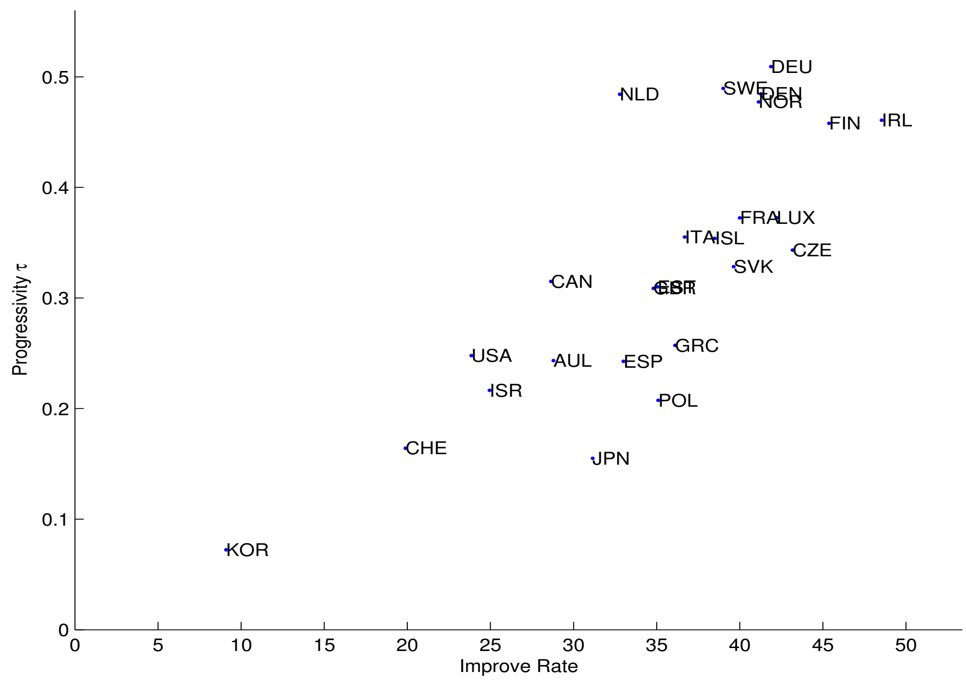
The estimated values of $\hat{\tau}$ for each country are provided in Table 3. Nordic countries (Denmark 0.485, Norway 0.477, Sweden 0.489) and Germany (0.509) operate more progressive tax systems, while Asian countries (Korea 0.07, Japan 0.155) and the U.S. (0.248) have less progressive systems. The progressivity of income tax in the U.S. is estimated to be 0.248. Heathcote et al. (2016) estimate the tax progressivity to be 0.151 (PSID) and 0.155 (CBO tables) without Social Security and Medicare transfers, and 0.232 (CBO tables) with Social Security and Medicare. Our estimates are close to the latter, since public transfers such as pension, unemployment benefits, and universal benefits are all included in our measure of disposable income. Holter et al. (2015) also estimate the progressivity of labor income tax using labor income and the progressivity tax wedge from the OECD data.[11] Their estimates, ranging from 0.101 (Japan) to 0.258 (Denmark), are smaller than our estimates, but the relative progressivity across countries is similar to ours: income taxes are more progressive in Nordic countries and less progressive in the U.S. (0.137) and Japan (0.101). Since they estimate the progressivity of only labor income tax, and do not include capital income tax or public transfers, their estimates are smaller than ours.

Our estimates for tax progressivity $\hat{\tau}$ are closely related to the improvement rates of income Ginis across countries (Figure 2), whose correlation coefficient is 0.79. The

[10]Data for 19 countries (Australia, Canada, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, Netherlands, Poland, Slovak Republic, Spain, the U.K. and the U.S.) are based on 2010 data. Data for the Czech Republic (2007), Japan (2008), Korea (2006), Norway (2004), Sweden (2005), and Switzerland (2004) are based on earlier years. Households with income lower than the 20th percentile in each country are excluded from the estimation.

[11]Holter et al. (2015) also assume the log-linear form of tax function on labor income, and estimate the parameter $\hat{\tau}$ using the progressivity tax wedge from the OECD data.

Figure 2: Tax Progressivity and Gini Improvement Rates



estimates are also highly correlated with the tax-to-GDP ratios (correlation coefficient of 0.73). This may imply that a simple form of tax function in our model summarizes the strength of income redistribution across countries quite well.

We have also collected the wealth Gini coefficients for OECD countries from the 2012 edition of the Global Wealth Databook issued by Credit Suisse. Wealth is distributed more unevenly than incomes are: the average wealth Gini coefficient among OECD countries is 0.72. Unfortunately, unlike the data on incomes, wealth data are known to be both less reliable and not standardized across countries. Thus, our analysis will mainly focus on income Gini coefficients.[12]

[12] The wealth Gini coefficient based on data from Credit Suisse shows a weak correlation (-0.09) with the before-tax income Gini from the OECD database, while it is positively correlated (0.33) with the after-tax income Gini. Interestingly, unlike income Ginis, the wealth Gini is not highly correlated with any of the redistribution policy measures we consider above, such as the tax-to-GDP ratio, the top statutory income tax rate, the property tax revenue share, or the Democracy Index. The correlation coefficients (with the wealth Gini) for those measures are -0.16, 0.05, 0.03, and -0.08, respectively. These patterns may arise due to the difficulty in collecting precise wealth data across countries. The wealth measures in the Credit Suisse data

Table 3: Estimates of Tax Progressivity

	$\hat{\tau}$	S.E.	Obs.	R^2
Australia	0.243	(0.004)	9,647	0.892
Austria	...	...	...	...
Belgium	...	...	...	...
Canada	0.315	(0.004)	16,124	0.781
Chile	...	...	...	...
Czech Republic	0.343	(0.006)	6,317	0.774
Denmark	0.485	(0.003)	55,367	0.691
Estonia	0.310	(0.008)	3,098	0.765
Finland	0.458	(0.008)	6,920	0.693
France	0.373	(0.007)	10,476	0.652
Germany	0.509	(0.007)	8,432	0.570
Greece	0.257	(0.009)	2,837	0.723
Iceland	0.354	(0.011)	2,350	0.773
Ireland	0.461	(0.009)	2,096	0.723
Israel	0.216	(0.005)	3,909	0.873
Italy	0.355	(0.013)	4,907	0.564
Japan	0.155	(0.009)	2,245	0.776
Korea	0.072	(0.003)	10,541	0.900
Luxembourg	0.373	(0.009)	3,665	0.673
Netherlands	0.484	(0.009)	7,708	0.592
New Zealand	...	...	...	...
Norway	0.477	(0.009)	10,046	0.643
Poland	0.207	(0.003)	22,065	0.791
Portugal	...	...	...	...
Slovak Republic	0.328	(0.010)	3,239	0.651
Slovenia	...	...	...	...
Spain	0.243	(0.006)	7,049	0.722
Sweden	0.489	(0.010)	10,828	0.625
Switzerland	0.164	(0.012)	2,390	0.762
Turkey	...	...	...	...
United Kingdom	0.309	(0.005)	13,951	0.722
United States	0.248	(0.001)	51,102	0.878

Note: We estimate $1 - \hat{\tau}$ from the LIS database (2016), and the reported standard errors are for $1 - \hat{\tau}$.

3. Model

The model economy will serve as a laboratory for various quantitative analyses. The benchmark economy extends Aiyagari's (1994) model to endogenous labor supply.

Households: There is a continuum (measure one) of worker-households that have identical preferences and face an idiosyncratic productivity shock x, which evolves over time according to a Markov process with a transition probability distribution function $\pi_x(x'|x) = \Pr(x_{t+1} \leq x'|x_t = x)$. When a household with labor productivity x_t chooses to work for h_t hours, its labor income is $w_t x_t h_t$, where w_t is the wage rate for the efficiency unit of labor. Households hold assets, a_t, that yield the real rate, r_t. Both labor and capital income are subject to progressive income taxes (log-linear tax function), which is determined by two parameters, λ (average level of taxation) and τ (tax progressivity). A household maximizes its lifetime utility:

$$\max_{\{c_t, h_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \frac{{c_t}^{1-\sigma} - 1}{1-\sigma} - B\frac{{h_t}^{1+1/\gamma}}{1+1/\gamma}$$

subject to

$$c_t + a_{t+1} = \lambda(w_t x_t h_t + r_t a_t)^{1-\tau} + a_t,$$

$$a_{t+1} \geq \underline{a},$$

where c_t is consumption. Parameters σ and γ represent the relative risk aversion and labor-supply elasticity, respectively. Capital markets are incomplete in the sense that physical capital is the only available asset for households to insure against idiosyncratic shocks to their productivity, and households face a borrowing constraint: $a_t \geq \underline{a}$ for all t. Households differ *ex post* with respect to their productivity x_t and asset holdings a_t, whose cross-sectional joint distribution is characterized by the probability measure $\mu_t(a_t, x_t)$.

Firms: The representative firm produces output through a constant-returns-to-scale Cobb-Douglas technology using capital, K_t, and effective units of labor, $L_t = \int h_t x_t d\mu$.

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are not as standardized across countries as those for income data in the OECD database.

Capital depreciates at the rate δ each period:

$$Y_t = F(L_t, K_t) = {L_t}^{\alpha} {K_t}^{1-\alpha}.$$

Government: The government operates a progressive tax system and incurs some expenditures, G_t, which do not directly enter into the household's utility function (or additively separable from the utility from private consumption). We assume that the government expenditures-to-output ratio is fixed. We also assume that the government runs a balanced budget:

$$G_t = \int \Big\{ \big(w_t x_t h(a_t, x_t) + r_t a_t \big) - \lambda \big(w_t x_t h(a_t, x_t) + r_t a_t \big)^{1-\tau} \Big\} d\mu(a_t, x_t).$$

Recursive Representation: It is useful to consider a recursive equilibrium. Let $V(a, x)$ denote the value function of a household with asset holdings a and productivity x. Then, V can be expressed as follows:

$$V(a, x) = \max_{c,h} \left\{ \frac{c^{1-\sigma} - 1}{1-\sigma} - B \frac{h^{1+1/\gamma}}{1+1/\gamma} + \beta \mathbb{E}\big[V(a', x') | x \big] \right\}$$

subject to

$$c + a' = \lambda (wxh + ra)^{1-\tau} + a,$$

$$a' \geq \underline{a}.$$

The intertemporal first-order condition for optimal consumption is:

$$c(a, x)^{-\sigma} = \beta \big\{ 1 + \lambda(1-\tau)(wxh + ra)^{-\tau} r \big\} \mathbb{E}\big[c(a', x')^{-\sigma} \big].$$

The intra-temporal first-order condition for optimal hours worked is:

$$Bh(a, x)^{1/\gamma} c(a, x)^{\sigma} = \lambda(1-\tau)(wxh + ra)^{-\tau} wx.$$

Equilibrium: A stationary equilibrium consists of a value function, $V(a, x)$; a set of decision rules for consumption, asset holdings, and labor supply, respectively, $c(a, x)$, $a'(a, x)$, and $h(a, x)$; aggregate input, K and L; and the invariant distribution of households, μ(a,x), such that:

1. Individual households optimize: Given w and r, the individual decision rules $c(a,x)$, $a'(a,x)$, $h(a,x)$, and $V(a,x)$ solve the Bellman equation.

2. The representative firm maximizes profits:

$$w = \alpha(K/L)^{1-\alpha}$$
$$r + \delta = (1-\alpha)(K/L)^{-\alpha}.$$

3. The goods market clears:

$$\int \{a'(a,x) + c(a,x)\} d\mu = F(L,K) + (1-\delta)K.$$

4. The factor markets clear:

$$L = \int xh(a,x)d\mu$$
$$K = \int a d\mu.$$

5. The government balances the budget:

$$G = \int \{wxh(a,x) + ra - \lambda(wxh(a,x) + ra)^{1-\tau}\} d\mu.$$

6. Individual and aggregate behaviors are consistent: For all $A^0 \subset \mathcal{A}$ and $X^0 \subset \mathcal{X}$,

$$\mu(A^0, X^0) = \int_{A^0, X^0} \left\{ \int_{\mathcal{A},\mathcal{X}} \mathbf{1}_{a'=a'(a,x)} d\pi_x(x'|x) d\mu \right\} da'dx'.$$

4. Quantitative Analysis

4.1. Calibration

Our calibration strategy is as follows. First, we benchmark our model to reproduce the salient features of the U.S. economy. Second, we assume that preferences (time preferences, risk aversion, and labor supply elasticity) and production technology are identical across countries. Third, four country-specific parameters (the disutility from working, the magnitude of individual productivity shocks, and two parameters in the tax function) are chosen to match data moments (the average hours of work, the government expenditure to GDP ratio, and the before- and after-tax income Gini coefficients) for each country.

Common Parameters: The time unit is one year. The labor-income share, α, is 0.64, and the annual depreciation rate of capital, δ, is 10%. Workers are not allowed to borrow, so $\underline{a} = 0$. Many households are actually in debt, but, as seen in Section 5.7, our results are rarely affected by introducing debt.[13] The relative risk aversion (σ) and the labor supply elasticity (γ) and time discount factor (β) may be important determinants of the optimal tax policy. For example, if households are more risk-averse or labor supply is less elastic, the optimal tax should increase. However, in one country the estimation of those parameters remains disputed, and obtaining country-specific estimates under a uniform framework is quite difficult. For these reasons, we assume that those parameters are common across countries.

As is common in the macroeconomic literature, the relative risk aversion, σ, is set to 1 (log utility in consumption) to be consistent with the balanced growth path. Chetty (2006) argues that a mean estimate of the risk aversion, implied by labor supply estimates, is close to 1. Gandelman and Hernández-Murillo (2015) estimate the coefficient of risk aversion for 75 countries and insist that the coefficient varies closely around 1. According to them, in the OECD countries only Korea rejects the null hypothesis of the coefficient 1. Since the level of productivity does not affect labor supply decisions under the balanced growth path, cross-country differences in productivity are abstracted from in our models.

The labor supply elasticity, γ, is set to 1. This value is larger than the typical micro estimate. However, considering that typical micro estimates do not reflect the extensive margin of labor (i.e., the labor-market participation decision), a somewhat larger value is desirable, according to Chang and Kim (2006). Prescott and Wallenius (2012) also argue that the elasticity of labor supply of the aggregate household is much higher than the elasticity of the identical households being aggregated. The time discount factor, β, is set

[13]In Section 5.7, we set the borrowing constraint in the U.S. to 50% of average annual household earnings.

so that the real interest rate is 4%, which is the average real rate of returns to capital in the U.S. for the post-World War II period.

Country-Specific Parameters: Despite the common elasticity of labor supply, we introduce differences in working hours across countries. The disutility from working, B, is chosen so that average hours worked in the steady state become the average work hours for each country, which is the average share of discretionary time devoted to working.[14] Individual productivity x is assumed to follow an AR(1) process: $\ln x' = \rho_x \ln x + \varepsilon_x$, where $\varepsilon_x \sim N(0, \sigma_x^2)$. A sizable literature has estimated this process using wages from panel data, including Floden and Linde (2001), Chang and Kim (2006), and Heathcote et al. (2008). While there are differences in the estimates of the magnitude of the shocks, the consensus is that these shocks are large and persistent. Our benchmark model adopts a persistence value of $\rho_x = 0.92$, also used in Floden and Linde (2001) and Pijoan-Mas (2006). We assume that this value is common across countries, consistent with many empirical studies that find highly persistent wage processes in various countries. The magnitude of the shocks, σ_x, is set to match the before-tax income Gini coefficient in each country. The chosen value of σ_x for the U.S. is 0.34, somewhat larger than the estimate (0.21) by Floden and Linde (2001) based on the Panel Study of Income Dynamics. We interpret x as a broad measure of households' ability to generate labor income (broader than the pure stochastic components of individual wages). Thus, the model requires a larger value of σ_x to match the overall cross-sectional distribution of household incomes. The required value of σ_x ranges from 0.20 (South Korea) to 0.45 (Ireland).

As described in the previous section, we assume that the individual income tax schedule follows the log-linear tax function. In the log-linear tax function, two parameters, λ (average level of taxation) and τ (tax progressivity), characterize disposal income (market income, y_i, minus taxes plus public transfer), $D(y_i)$, as a function of the household's market income y_i: $D(y_i) = \lambda y_i^{1-\tau}$. The average level of taxation, λ, is chosen to meet the government's balanced budget. The government expenditures-to-output ratio (G/Y)

[14]We normalize the average annual working hours in 2010 (OECD, 2015) by the total discretionary hours of 5,500.

of each country is set to the average government consumption-to-GDP ratio in the data. The current progressivity of income tax, τ_0, in our model is calibrated to match the Gini coefficients after taxes and transfers. Note that since the income distribution is endogenous, we need to iterate the values of σ_x and τ_0 until the model exactly match the before- and after-tax income Gini coefficients in the data. In the end, the model-implied τ_0 for the U.S. is 0.261, which is close to, but slightly higher than the estimate of 0.232 by Heathcote et al. (2016) and our own estimate of 0.248 based on the LIS data in Section 2. Across 32 countries, the model-implied τ ranges between 0.056 (Chile) and 0.512 (Ireland). Table 4 summarizes the parameter values of the benchmark model economy. Table C.1 in the Appendix lists the values of B, σ_x, and τ_0 for all 32 countries.

Table 4: Parameters of the Benchmark Economy

Common for All Countries		
β	0.9574	Time discount factor
σ	1.00	Relative risk aversion
γ	1.00	Labor supply elasticity
ρ	0.92	Persistence of idiosyncratic productivity
α	0.64	Labor share in production function
δ	0.10	Depreciation rate of captial
Country-Specific Parameters		
B	3.30 - 7.82	Disutility from working
σ_x	0.20 - 0.45	Std. deviation of idiosyncratic shocks
τ_0	0.06 - 0.51	Progressivity of income tax

Note: See Table C.1 in the Appendix for the values of B, σ_x, and τ for each country .

4.2. Steady State

Table 5 compares the tax progressivity for 3 countries: the U.S., Sweden, and Chile. (We report these statistics for all 32 OECD countries in Appendix Table C.1.) We chose Sweden as an example of countries that adopt an aggressive redistribution policy: the Gini coefficient decreases by 39% as a result of taxes and transfers. We chose Chile

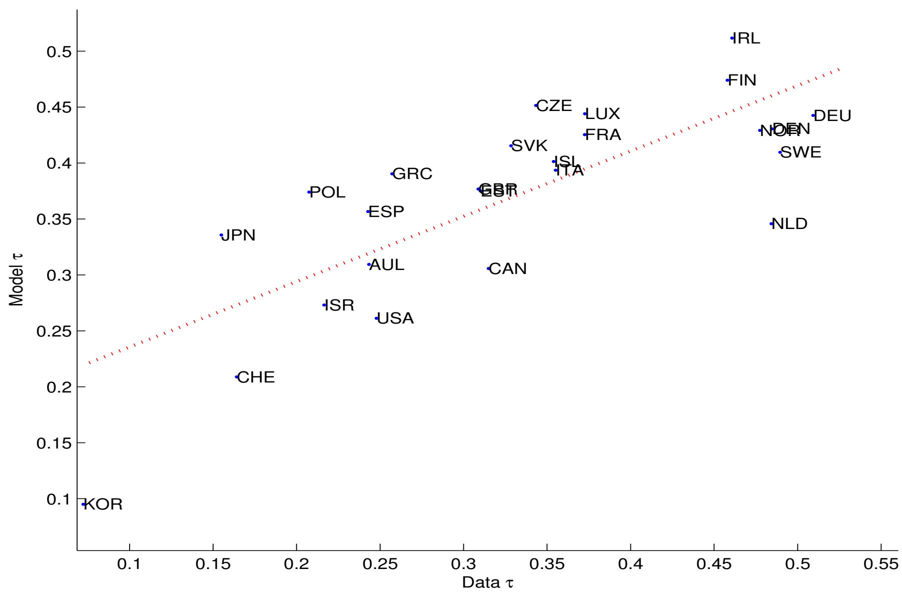
Table 5: Results for 3 Countries

	U.S.	Sweden	Chile
Magnitude of shocks (σ_x)	0.336	0.312	0.341
Model-implied progressivity (τ_0)	0.261	0.410	0.056
Model-implied marginal tax rate of median	0.291	0.490	0.175
Progressivity from data	0.248	0.489	...
Gini improvement rate	0.238	0.390	0.043
Optimal progressivity (τ^*)	0.341	0.314	0.345
Gini improvement rate under τ^*	0.317	0.293	0.320
Marginal tax rate of the median under τ^*	0.338	0.428	0.286
Approval rate for τ^*	0.626	0.644	0.857
Progressivity by the majority voting (τ^M)	0.341	0.320	0.336
Gini improvement rate under τ^M	0.317	0.299	0.311
Marginal tax rate of the median under τ^M	0.338	0.431	0.279
Weighting function parameter (η)	0.582	-1.109	1.411
Pareto Weight			
1st Quintile	0.600	1.743	0.146
2nd Quintile	0.827	1.114	0.384
3rd Quintile	0.979	0.892	0.679
4th Ouintile	1.144	0.723	1.146
5th Quintile	1.451	0.528	2.646

as an opposite case, the country that exhibits the lowest improvement rate in the Gini coefficient–a 4% decrease after taxes and transfers. The implied progressivity is closely related to the estimated progressivity from the LIS and the Gini improvement rate. For Sweden, the model-implied tax progressivity is 0.410, while the estimates from the LIS are 0.489, and Gini improvement rates are 0.390. For Chile, the implied tax progressivity is 0.056, while the Gini improvement rate is 0.043.

Figure 3 compares the tax progressivity in the LIS and those implied by our model. Two values are fairly closely related (correlation coefficient of 0.77). The tax progressivity implied by our model is almost perfectly correlated with the Gini improvement rates in the data (Figure 4), since the tax progressivity is chosen to match the after-tax income

Figure 3: Implied Tax Progressivity and Tax Progressivity in the Data



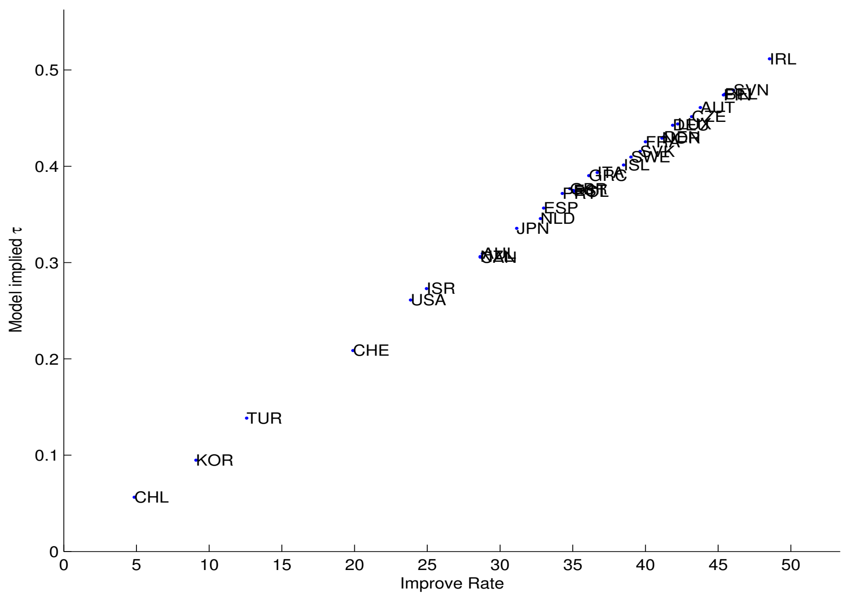
Source: LIS (2016) and authors' calculation.

Gini, given the before-tax income Gini.[15]

According to our calibration strategy, the model exactly matches the before- and after-tax Gini coefficients in the data. To check whether the income distributions in our model capture those from the data well, we also compare disposable income decile ratios (P90/P10, P90/P50, P50/P10) between the model and the data (Table 6). The "P90/P10" ratio is defined by the ratio of the 90th percentile to the 10th percentile. For the U.S. both the P90/P10 (5.7) and the P50/P10 (2.3) ratios in our models are slightly smaller than those (6.1 and 2.7) from the data. However, the overall decile ratios in our model are quite similar to those from the data and the correlation coefficients of those

[15]In the calibration of the benchmark (the U.S. economy), we set the preference parameters β. Since we choose the magnitude of the individual productivity shock (σ_x) and the income tax progressivity (τ_0) to exactly replicate the before- and after-tax income inequality, these parameters affect the equilibrium real interest rate (r) and hours worked (h). A larger σ_x implies a larger uncertainty for individual households. This strengthens precautionary savings motives, which in turn lowers the real interest rate and increases average hours worked (Pijoan-Mas, 2006). A strong redistribution policy in the form of a high tax progressivity (τ) reduces the incentive to work and provides insurance (thus raising the real interest rate). Table C.1 in the Appendix reports the equilibrium real interest rate and hours worked for all 32 countries.

Figure 4: Implied Tax Progressivity and Gini Improvement Rates



Source: OECD (2016) and authors' calculation.

ratios between our models and the data are 0.95 (P90/P10), 0.96 (P50/P10) and 0.85 (P50/P10) across countries.

5. Optimal Tax Reform and Pareto Weights

In the previous section, we developed a quantitative model that exactly matches the before- and after-tax income Gini coefficients in the data and illustrated that it approximates the redistribution policy of 32 OECD countries fairly well. We now address the following questions with this model economy: (i) What is the optimal progressivity of income tax for each country under the equal-weight utilitarian social welfare function? (ii) Would a majority of the population vote for the policy reform that proposes to adopt the utilitarian optimal progressivity? (iii) What are the Pareto weights in the social welfare function that justify the current progressivity, which is suboptimal under the equal weights?

Table 6: Disposable Income Ratios across Percentiles

	Model			Data		
	P90/P10	P90/P50	P50/P10	P90/P10	P90/P50	P50/P10
Australia	4.5	2.2	2.1	4.5	2.0	2.2
Austria	3.5	1.9	1.8	3.5	1.8	1.9
Belgium	3.2	1.8	1.8	3.3	1.7	2.0
Canada	4.2	2.1	2.0	4.1	2.0	2.1
Chile	11.5	3.6	3.2	...	...	...
Czech Republic	3.2	1.8	1.8	3.1	1.7	1.8
Denmark	3.1	1.8	1.8	2.9	1.6	1.8
Estonia	4.2	2.1	2.0	4.4	2.1	2.1
Finland	3.2	1.8	1.8	3.2	1.7	1.9
France	3.9	2.0	2.0	3.6	1.9	1.9
Germany	3.6	1.9	1.9	3.6	1.9	1.9
Greece	4.6	2.2	2.1	4.6	2.0	2.3
Iceland	3.0	1.7	1.8	2.8	1.6	1.7
Ireland	3.7	2.0	1.8	3.8	2.0	1.9
Israel	5.5	2.4	2.3	6.4	2.2	2.9
Italy	4.3	2.1	2.0	4.3	2.0	2.2
Japan	4.6	2.2	2.1	...	...	...
Korea	4.1	2.1	2.0	4.8	1.9	2.5
Luxembourg	3.4	1.8	1.8	3.4	1.9	1.8
Netherlands	3.6	1.9	1.9	3.3	1.8	1.8
New Zealand	4.3	2.1	2.0	...	...	...
Norway	3.1	1.7	1.8	2.9	1.6	1.8
Poland	4.0	2.0	2.0	4.0	1.9	2.1
Portugal	4.8	2.2	2.1	4.6	2.2	2.1
Slovak Republic	3.3	1.8	1.8	3.2	1.8	1.8
Slovenia	3.0	1.7	1.7	3.2	1.7	1.9
Spain	4.6	2.2	2.1	4.8	2.1	2.3
Sweden	3.4	1.8	1.8	3.3	1.7	2.0
Switzerland	3.8	2.0	1.9	...	...	...
Turkey	7.0	2.7	2.6	6.5	2.5	2.6
United Kingdom	4.7	2.2	2.1	4.1	2.1	2.0
United States	5.7	2.4	2.3	6.1	2.3	2.7

Note: The P90/P50 ratio in the data is calculated by “P90/P10” divided by “P50/P10” from the OECD (2016).

5.1. Optimal Tax and Social Welfare

One of the most important goals in public finance is to characterize the optimal tax policy. This task often requires appropriately aggregating individual preferences, which is challenging and controversial. A common practice is to use a social welfare function that averages the utility of the population with equal weights. For example, in the context of our model, when the society adopts a new tax progressivity τ (once-and-for-all change from τ_0), the social welfare is:[16]

$$\mathcal{W}(\tau, \tau_0) = \int V(a_0, x_0; \tau, \tau_0)\, d\mu(a_0, x_0; \tau_0),$$

where $V(a_0, x_0; \tau, \tau_0)$ is the discounted sum of the lifetime utility of a household with asset holdings a_0 and productivity x_0 and $\mu(a_0, x_0; \tau_0)$ is the steady state distribution of households under τ_0. In other words,

$$V(a_0, x_0; \tau, \tau_0) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ \frac{c(a_t, x_t; \tau, \tau_0)^{1-\sigma} - 1}{1-\sigma} - B \frac{h(a_t, x_t; \tau, \tau_0)^{1+1/\gamma}}{1 + 1/\gamma} \right\}.$$

First, we look for the tax progressivity τ^* that maximizes the above equal-weight utilitarian social welfare function for each of the 32 OECD countries. We assume that each country is at the steady state under its current tax progressivity τ_0 as reported in Table C.1. We then look for the new tax progressivity, τ^*, that maximizes $\mathcal{W}(\tau, \tau_0)$, *including* the welfare of households during the transition periods to the new steady state. A detailed computational algorithm is provided in Appendix B.2.[17]

Table 5 reports the optimal progressivity of income tax for 3 countries: the U.S., Sweden, and Chile. In the U.S., the optimal tax progressivity is 0.34, much higher than the current progressivity of 0.26. Under the new tax reform, the Gini improvement rate

[16] This utilitarian social welfare function has been commonly used in the literature, for example, in Aiyagari and McGrattan (1998).

[17] We include the welfare of households during the transition from the current steady state to a new steady state. When a new tax progressivity is in place at the current steady state, households start re-optimizing their consumption and hours worked. As a result, the corresponding paths of the value functions, $V_t(a_t, x_t; \tau, \tau_0)$, and the distribution, $\mu_t(a_t, x_t; \tau, \tau_0)$, will be different from those in the old steady state. Hence, the computation of the optimal progressivity needs to take into account changes in value functions and the distribution during transition periods until the economy reaches a new steady state.

(31.7%) is much higher than the current rate (23.8%). Under the optimal τ^*, the marginal tax rate of the median household would increase from 29.1% to 33.8%. For Chile, the optimal progressivity (0.34) and Gini improvement rate (32%) are almost 6 times larger than the current progressivity of 0.06 and Gini improvement of 4.9%. The marginal tax rate of the median household would increase from 17.5% to 28.6% under the optimal τ^*. For Sweden, however, the current redistribution policy is somewhat excessive from the perspective of the equal-weight utilitarian social welfare, as the optimal progressivity (0.31) and corresponding Gini improvement rate (29.3%) is much *lower* than the current ones (0.41 and 39%, respectively).

Table 7 reports the optimal progressivity of income tax rates for all countries. The optimal progressivity is higher than the current progressivity in 10 countries, whereas the opposite is true in 22 countries. All European countries except Switzerland are included in the latter group.

5.2. Approval Rate on Optimal Tax Reform

According to our model, the current tax progressivity is different from the optimal progressivity for almost all OECD countries.[18] However, any fiscal reform to adopt the optimal progressivity will hardly be Pareto improving—there will be winners and losers as a result of the reform. Thus, there is no guarantee that the optimal progressivity will be chosen as a political outcome. While the examination of a complicated political process to select a policy in each country is beyond the scope of this paper, we can still ask a simple question: would the majority of the population be better off from a fiscal reform that adopts the utilitarian optimal progressivity? To answer this question, we simulate a binary voting between the current (τ_0) and the optimal (τ^*) tax progressivity. We assume that this is a once-and-for-all change (permanent and irreversible change) in tax progressivity. A household would vote for the optimal tax reform if $V(a, x; \tau^*, \tau_0) > V(a, x; \tau_0, \tau_0)$. In computing welfare under the optimal fiscal reform, we include welfare during the transition

[18] In Canada (0.31), Portugal (0.37) and Spain (0.36), the current tax progressivity is almost identical to the utilitarian optimal progressivity.

Table 7: Tax Reform and Marginal Tax Rate

	Data	Current		Utilitarian Optimal			Majority Chosen	
	$\hat{\tau}$	τ_0	$T'(y_m)$	τ^*	$T'(y_m^*)$	Approve	τ^M	$T'(y_m^M)$
Australia	0.243	0.309	34.3	0.324	35.2	53.7	0.329	35.5
Austria	...	0.461	44.0	0.356	35.8	66.8	0.361	36.2
Belgium	...	0.475	48.9	0.349	39.6	70.5	0.355	40.0
Canada	0.315	0.306	39.7	0.309	39.9	52.2	0.316	40.3
Chile	...	0.056	17.5	0.345	28.6	85.7	0.336	27.9
Czech Republic	0.343	0.452	46.7	0.325	37.3	70.4	0.332	37.7
Denmark	0.485	0.430	52.9	0.308	45.3	69.4	0.320	45.9
Estonia	0.310	0.375	38.9	0.342	36.8	55.3	0.345	36.9
Finland	0.458	0.474	50.1	0.349	41.3	70.0	0.364	42.1
France	0.373	0.425	44.4	0.358	39.7	59.8	0.365	40.1
Germany	0.509	0.443	42.0	0.351	34.9	64.4	0.363	35.7
Greece	0.257	0.390	38.1	0.372	36.9	52.4	0.380	37.4
Iceland	0.354	0.401	50.1	0.283	42.6	68.8	0.291	43.0
Ireland	0.461	0.512	37.5	0.409	27.8	66.4	0.422	28.7
Israel	0.216	0.273	35.9	0.344	39.7	60.6	0.343	39.6
Italy	0.355	0.394	38.8	0.357	36.3	56.2	0.364	36.8
Japan	0.155	0.336	36.4	0.339	36.6	52.0	0.346	37.0
Korea	0.072	0.095	24.1	0.208	30.7	67.1	0.205	30.6
Luxembourg	0.373	0.444	41.5	0.334	32.8	67.8	0.344	33.5
Netherlands	0.484	0.346	47.5	0.295	44.5	57.8	0.296	44.6
New Zealand	...	0.306	37.0	0.314	37.5	52.6	0.316	37.6
Norway	0.477	0.429	48.0	0.301	39.0	70.4	0.309	39.4
Poland	0.207	0.374	39.0	0.331	36.2	57.3	0.334	36.4
Portugal	...	0.372	36.5	0.367	36.2	49.1	0.372	36.5
Slovak Republic	0.328	0.415	44.3	0.307	36.5	66.9	0.315	37.0
Slovenia	...	0.479	48.4	0.328	36.8	73.7	0.339	37.5
Spain	0.243	0.357	37.0	0.353	36.8	48.9	0.357	37.0
Sweden	0.489	0.410	49.0	0.314	42.8	64.4	0.320	43.1
Switzerland	0.164	0.209	25.3	0.240	27.4	55.8	0.239	27.3
Turkey	...	0.139	22.8	0.316	31.9	74.5	0.309	31.4
United Kingdom	0.309	0.377	33.9	0.366	33.1	50.7	0.367	33.2
United States	0.248	0.261	29.1	0.341	33.8	62.6	0.341	33.8

Note: Data $\hat{\tau}$ are the tax progressivity estimated from the LIS Database. "Current" denotes τ and $T'(y_m)$, the marginal tax rate (%) for the median income worker, implied by the current steady state of our model. "Approve" is the approval rate (%) for the optimal tax progressivity τ^*. "Majority Chosen" (τ^M) refers to the progressivity chosen by the successive majority voting.

to the new steady state.

Table 5 reports this binary voting outcome for the U.S, Sweden, and Chile, according to our model simulation. The optimal tax reform is supported by the majority of the population in all three countries. In the U.S., the policy proposal to increase the tax progressivity to the optimal level ($\tau^* = 0.34$) is supported by 63% of the population. In Chile, 86% of the population is better off under the optimal progressivity ($\tau^* = 0.35$). In Sweden, the approval rate to weaken the progressivity to the optimum ($\tau^* = 0.31$) is 64%. The approval rates for the optimal tax reform for all 32 OECD countries are reported in Table 7. Essentially, for all countries whose current tax progressivity deviates from the optimal progressivity, the fiscal reform to adopt the optimal tax progressivity is supported by the majority of the population.

5.3. Close-to-Optimal Tax Chosen by the Majority

As an alternative to the utilitarian optimal tax, one may argue that the political equilibrium should be the tax rate that maximizes the welfare of the median instead of the average—the so-called median voter theorem. However, the median voter theorem may not be easily applicable in our model where households differ in multiple dimensions (such as asset holdings and stochastic productivity) and the state of households changes over time. We address this issue by finding the close-to-optimal progressivity that would be approved by the majority under successive binary voting between the current and the proposed τ's. More specifically, starting with a newly proposed tax progressivity $\tau = \tau_0 + 0.01$ which is 0.01 point higher (or lower) than the current progressivity of τ_0, we simulate the binary voting between the current (e.g., $\tau_0 = 0.26$) and proposed progressivity (e.g., $\tau = 0.27$). If the proposed progressivity is approved by the majority, we immediately propose another progressivity ($\tau = \tau_0 + 0.02$) that is 0.02 point higher (or lower) than the current one and simulate the binary voting between the previous winner (e.g., $\tau = 0.27$) and the new contender (e.g., $\tau = 0.28$) and so forth. The final winner of the binary voting can be interpreted as a politically feasible reform that is closest to the optimal tax progressivity. The results based on this successive voting simulation for

32 countries are summarized in the last column in Table 7. The progressivity chosen by the successive voting is actually very close to the optimal progressivity in most countries. For example, in the U.S. the progressivity chosen by the majority voting ($\tau = 0.34$) is the same as the optimal progressivity.

5.4. Pareto Weights in Practice

We have shown that the current tax progressivity is far from optimal in almost all 32 OECD countries. We have also shown that the majority of the population would be better off if the optimal progressivity is adopted. Then, why haven't these countries adopted the optimal progressivity? The optimality depends on the specification of the social welfare function. For example, it is not obvious whether the equal-weight utilitarian welfare function (often used in the literature) is the actual objective of these societies (or governments). It is well known that equity is valued in many societies. Moreover, the decision-making process in selecting policies is much more complex than a simple majority rule. For instance, the rich often have more resources to influence the outcome of policy debates (e.g., lobbies). Heathcote et al. (2016) and Weinzierl (2016) emphasize the role of government expenditure in determining the optimal tax policy. Weinzierl (2014) presents the survey report that many respondents prefer the principle of "equal sacrifice" over conventional utilitarian objectives. Charité et al. (2015) argue that the reference point affects individual preferences for redistribution. These questions are immensely important but beyond the scope of this paper.

In this subsection, we ask a rather simple question within the utilitarian framework: for each country, what are the weights in the social welfare function that would justify the current tax progressivity? We interpret these weights—the so-called Pareto weights—as a reduced-form representation of a society's preferences and political decision-making process. For example, if a society is plutocratic, the government assigns relatively larger weights to rich households, whereas an egalitarian society is likely to assign larger weights to poor households.

To answer this question we assume that the Pareto weight $\theta(c(a_0, x_0))$ exhibits the following parametric form in consumption where η reflects the slope of Pareto weights in the cross-sectional distribution of consumption:

$$\mathcal{W}(\tau;\tau_0) = \int \theta(c(a_0,x_0);\tau_0)V(a_0,x_0;\tau,\tau_0)d\mu(a_0,x_0;\tau_0),$$

$$\text{where} \ \ \theta(c(a_0,x_0);\tau_0) = \frac{c(a_0,x_0)^\eta}{\displaystyle\int c(a_0,x_0)^\eta d\mu(a_0,x_0;\tau_0)}.$$

The case with $\eta = 0$ corresponds to the equal-weight utilitarian social welfare function: a flat slope for Pareto weights. The case with $\eta > 0$ can be interpreted as a plutocracy or the political system in which the rich have more influence in the determination of policies: a positive slope for Pareto weights. The case with $\eta < 0$ can be interpreted as sympathy for the poor, or a strong preference for an egalitarian society: a negative slope. As η goes to negative infinity, social preference approaches the Rawlsian. The value of η that justifies the current tax progressivity (τ_0) as the social optimum is the solution to the following problem:

$$\tau_0 = \operatorname*{argmax}_{\tau} \mathcal{W}(\tau;\tau_0) = \operatorname*{argmax}_{\tau} \int \theta(c(a_0,x_0);\tau_0)V(a_0,x_0;\tau,\tau_0)d\mu(a_0,x_0;\tau_0).$$

With the value of η that solves the above problem, we can uncover the Pareto weights on households based on the distribution of households $\mu(a,x;\tau_0)$.

We would like to mention a caveat regarding our choice of Pareto weights θ. The Pareto weights are often assumed to depend on a household's inherent characteristics (or permanent type) such as ability and preferences. In a static environment, a household's productivity is a natural choice (e.g., Heathcote and Tsujiyama (2016) and Saez and Stantcheva (2016)). Unfortunately, our model does not have any ex ante heterogeneity. In a dynamic environment such as our model where households can save and their productivities change over time, the state of the household depends on two variables: asset holdings (a) and productivity (x). (For technical reasons, we would like to have Pareto weights as one dimensional. When Pareto weights depend on multiple variables, we cannot guarantee the unique representation of Pareto weights for a given distribution of assets and productivity.) According to the permanent income hypothesis, consumption is a better proxy for the well-being of the household than the current level of productivity is. One drawback of using consumption is that it is an endogenous variable, which makes it difficult to use the weights, as they are, for an welfare analysis of an alternative (counter-factual) policy.[19] Despite the endogeneity issue, we believe that our attempt is still a valid exercise to infer information from a *steady-state* distribution and we can interpret the uncovered weights as reflecting the underlying social preferences (or political equilibrium) of the status quo.[20]

According to our model, $\eta = 0.58$ is required to justify the current tax progressivity τ_0 (given the steady state distribution $\mu(a, x; \tau_0)$) as socially optimal for the U.S. The Pareto weight increases with the level of consumption, as the social welfare function assigns larger weights to the rich. Table 5 reports the Pareto weights (implied by this value of η) for 5 consumption-quintile groups. The average Pareto weights are 0.60, 0.83, 0.98, 1.14, and 1.45, respectively, from the 1st (poorest 20%) to the 5th (richest 20%) quintiles. In Sweden, $\eta = -1.11$ justifies the current tax progressivity. The social welfare function assigns larger weights on the poor. The average Pareto weight on the poorest 20% of households is 1.74, whereas that on the richest 20% is only 0.53. By contrast, in Chile $\eta = 1.41$ justifies the currently very low tax progressivity and steady-state distribution. The average Pareto weight on the poorest 20% of households is a mere 0.15, but that on the richest 20% is 2.65.

We report the values of η and the Pareto weights that justify the current tax progressivity for each of 32 OECD countries in Table 8. Out of 32, 22 countries exhibit a negative slope of Pareto weights across consumption ($\eta < 0$): i.e., larger weights on the poor. In particular, northern and central European countries show strongly negatively sloped Pareto weights: Slovenia (-2.1), Finland (-1.7) and Belgium (-1.7) are the lowest η. On the opposite side, South Korea (1.07), Turkey (1.11), and Chile (1.41) exhibit strong

[19]See Chang (2016) for various counter-factual welfare analyses of changes in productivity trend when Pareto weights are assumed to depend on exogenous productivity only.

[20]From a practical point of view, it is not uncommon to tie the shape of Pareto weights to endogenous variables such as the observed income distribution (e.g., Lockwood and Weinzierl (2016) and many other empirical works), which may be contaminated by endogenous labor-supply responses (to productivity as well as non-labor income). While there is ample empirical evidence of a sizable income effect, many theoretical models assume no income effect in labor supply to obtain a simple formula for Pareto weights.

positively sloped Pareto weights: i.e., larger weights on the rich.[21]

5.5. Potential Sources for Pareto Weights

We found that the shape of Pareto weights in the social welfare function varies vastly across 32 OECD countries. A Pareto weight is a reduced-form representation of complex aspects of the society (such as preferences for equity, electoral system, and distribution of political power, etc.). Understanding how each of these components affects the Pareto weights is beyond the scope of this paper. Here, we propose three measures that are potentially important for the shape of Pareto weights: democracy of the political system, electoral voting turnout rates by income, and the society's perception of equity.

One may expect that a democratic society is less subject to plutocracy and tends to advocate an equal distribution of resources and opportunities. Thus, such a society is more likely to adopt a stronger redistribution policy. To examine this premise, we obtain the Democracy Index from the Economist Intelligent Unit (EIU). The EIU evaluates the development of democracy in a society based on 60 questions in 5 categories: (i) electoral process and pluralism, (ii) functioning of government, (iii) political participation, (iv) political culture, and (v) civil liberties. A country is scored from 0 to 10 in each of the 5 categories. A country's democracy index is its average score across these 5 categories, though not all questions are directly related to redistribution policy, including taxes and transfers.[22] According to the EIU, among the OECD countries, Norway (9.8) is the most democratic, Turkey (5.73) is the least, and the U.S. (8.18) is around the median. The

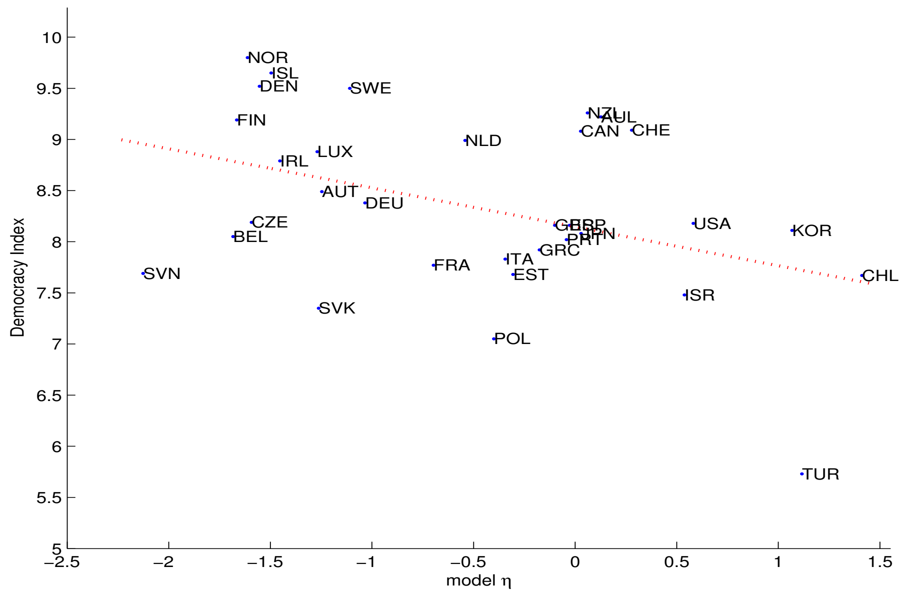
[21]The finding of a negative value of η, that is, larger weights on the poor, in most of the European countries is not surprising. Alesina and Glaeser (2004) explain this as differences in political structure. Almost all European countries have proportional representation systems, whereas the U.S. does not. Also, socialism does not succeed in the U.S., unlike in Europe.

[22]Two alternative—and perhaps more commonly used—measures of democracy are those from the Freedom House and Polity IV. However, these measures are not suitable for our analysis, since they do not show much variation across the 32 OECD countries. For instance, according to the Freedom House Democracy Index, 31 OECD countries are classified as "Free" and only Turkey is ranked "Partially Free." According to the Polity IV Index, most of the OECD countries score 10, with the exceptions of Estonia (9), France (9), Belgium (8), the Czech Republic (8), South Korea (8), and Turkey (8).

Table 8: Pareto Weights across OECD Countries

	Parameter	Consumption Quintile				
	η	1st	2nd	3rd	4th	5th
Australia	0.127	0.91	0.97	1.00	1.03	1.08
Austria	-1.247	1.89	1.13	0.86	0.67	0.46
Belgium	-1.683	2.16	1.12	0.80	0.57	0.35
Canada	0.028	0.98	0.99	1.00	1.01	1.02
Chile	1.411	0.15	0.38	0.68	1.15	2.65
Czech Republic	-1.593	2.07	1.11	0.82	0.61	0.39
Denmark	-1.553	2.01	1.11	0.83	0.63	0.42
Estonia	-0.306	1.22	1.06	0.98	0.92	0.83
Finland	-1.665	2.15	1.12	0.80	0.58	0.36
France	-0.697	1.50	1.10	0.94	0.81	0.64
Germany	-1.034	1.74	1.12	0.89	0.72	0.52
Greece	-0.175	1.13	1.04	0.99	0.95	0.89
Iceland	-1.496	1.94	1.11	0.85	0.66	0.45
Ireland	-1.453	2.10	1.14	0.81	0.58	0.36
Israel	0.538	0.63	0.84	0.98	1.13	1.41
Italy	-0.344	1.25	1.06	0.98	0.90	0.80
Japan	0.029	0.98	0.99	1.00	1.01	1.02
Korea	1.068	0.47	0.75	0.95	1.18	1.65
Luxembourg	-1.270	1.88	1.12	0.86	0.67	0.47
Netherlands	-0.541	1.35	1.08	0.96	0.87	0.74
New Zealand	0.061	0.96	0.99	1.00	1.02	1.04
Norway	-1.612	2.04	1.11	0.82	0.62	0.41
Poland	-0.400	1.28	1.07	0.97	0.89	0.78
Portugal	-0.042	1.03	1.01	1.00	0.99	0.97
Slovak Republic	-1.262	1.84	1.11	0.87	0.69	0.49
Slovenia	-2.126	2.40	1.09	0.73	0.50	0.28
Spain	-0.027	1.02	1.01	1.00	0.99	0.98
Sweden	-1.109	1.74	1.11	0.89	0.72	0.53
Switzerland	0.279	0.84	0.94	1.00	1.06	1.15
Turkey	1.116	0.32	0.61	0.87	1.21	2.00
United Kingdom	-0.100	1.07	1.02	1.00	0.97	0.94
United States	0.582	0.60	0.83	0.98	1.14	1.45

Figure 5: Democracy Index and Slope of Pareto Weights



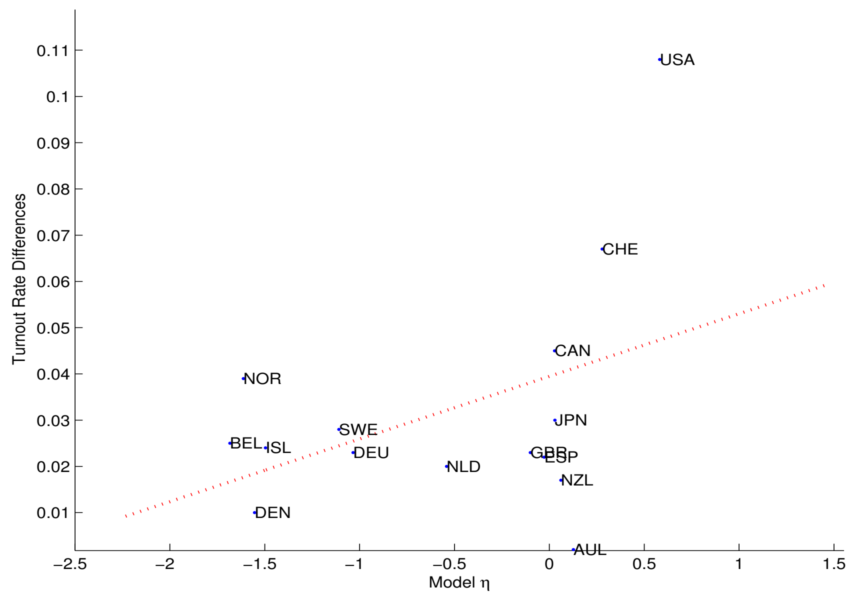
Note: Democracy Index (y-axis) is from the Economist Intelligence Unit (EIU).

Democracy Index is modestly positively correlated (0.36) with the tax-to-GDP ratio. It is modestly correlated (0.32) with the improvement rate of the income Gini. Figure 5 compares the slope of the Pareto weight η implied by our model to the Democracy Index ($y-$axis) across the 32 OECD countries. They are modestly negatively correlated (-0.41): a democratic society tends to put more weights on the poor. If we exclude formerly Communist societies, where equity is highly valued, the two variables are more strongly negatively correlated (-0.59).

Another interpretation of Pareto weights in the social welfare function is turnout rates in voting. It is well known that low-income earners tend to participate less in voting than high-income earners in the U.S. We use the estimates in Mahler (2008) of the electoral turnout rates across 15 countries from the Comparative Study of Electoral Systems.[23] Figure 6 plots the difference in the average turnout rates of the top 40% in the income distribution and that of the bottom 40% (y-axis) against our estimate of η across 15

[23]They include Australia, Belgium, Canada, Denmark, Germany, Iceland, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the U.K., and the U.S.

Figure 6: Voter Turnout Rates by Income and Slope of Pareto Weights

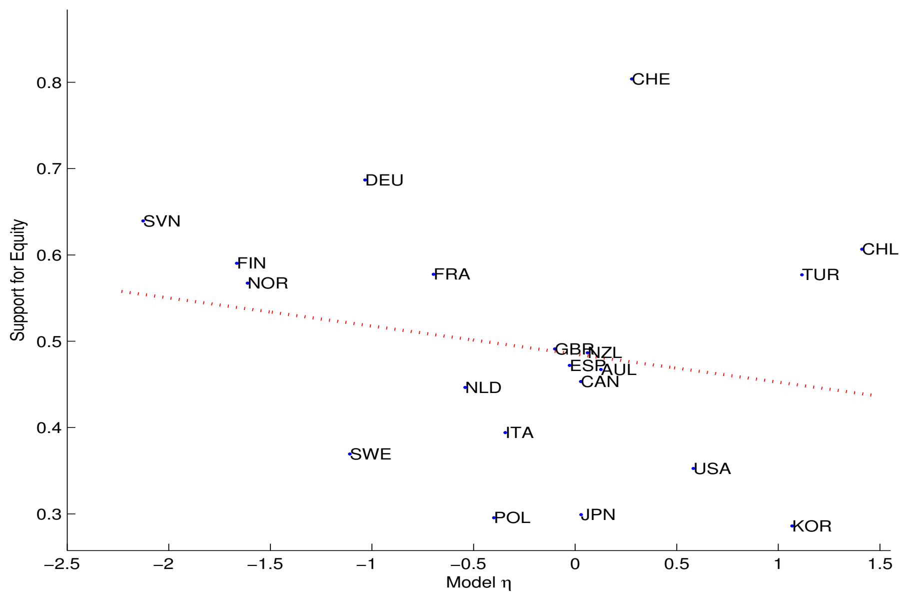


Note: The voter turnout rate differences between the top 40% and the bottom 40% of the income distribution (y-axis) are from Mahler (2008).

countries. The two variables are modestly positively correlated (0.42). In a country where the rich exhibit a higher voting turnout rate, they receive larger Pareto weights than the poor.

The society's preference for equity is probably different across countries, too. The World Values Survey examines the perception of various social issues in almost 100 countries. One question asks about the trade-off between equity and efficiency in income redistribution. The participants choose their views on a scale of 0-10 between "Incomes should be made more equal (0)" and "We need larger income difference as incentives for individual effort" (10). We calculate the fraction of the population with a scale between 0 and 5 (who are favorable to more income redistribution). Figure 7 compares the slope of Pareto weights η implied by our model for this measure (the fraction of people who favor redistribution). The two measures are mildly negatively correlated (-0.22). One caveat is necessary in interpreting the survey result. It is not clear whether respondents' answers in the WVS represent social preferences for equity. Respondents may have expressed their opinions (perhaps their frustration with) about the *current* redistribution policy. This

Figure 7: Fraction of Population That Favors Redistribution and Slope of Pareto Weights



endogenous nature of the survey answers may explain the low correlation between the two measures.

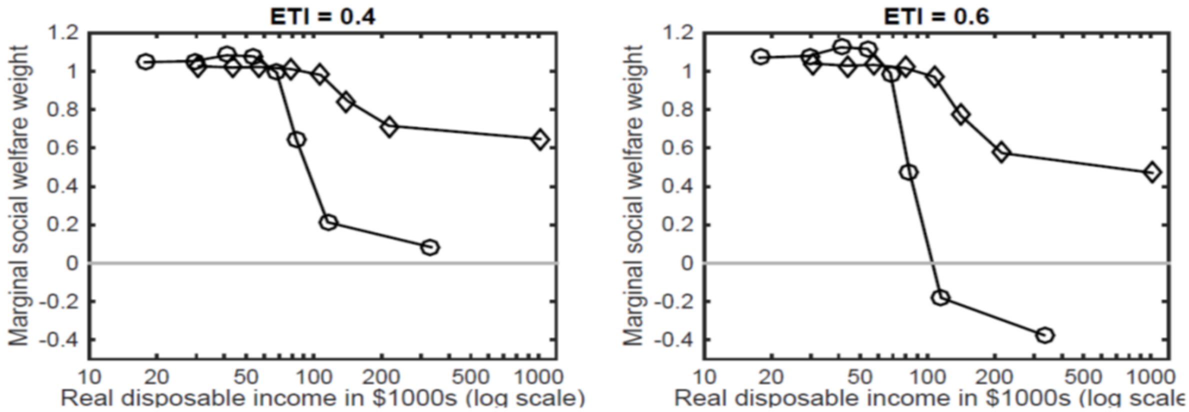
5.6. Comparison to the Mirrleesian (1971) Approach

A highly popular approach to estimating the Pareto weights is to use the Mirrlees (1971) model. While most Mirrleesian models are static, which prevents a direct comparison to our model (which allows for savings), it might still be of interest to compare the marginal weights in the social welfare function in two different approaches. Lockwood and Weinzierl (2016) estimate the marginal social weights (marginal utility multiplied by Pareto weight) of the U.S. based on the CBO's income data and marginal tax schedule from the NBER's TAXSIM. According to the optimal tax rate formula derived in Saez (2001), they derive the marginal social weights as:

$$g(y) = -\left(\frac{1}{f(y)}\right)\frac{d}{dy}\left[1 - F(y) - \frac{T'(y)}{1-T'(y)}(\epsilon y f(y))\right] \tag{1}$$

where $g(y)$, y, $F(y)$, $f(y)$, $T(y)$, and ϵ are marginal social welfare weights: observable earnings, the cumulative distribution of earnings, the marginal density of earnings dis-

Figure 8: Marginal Social Welfare Weights of U.S. from Lockwood and Weinzierl (2016)



Note: The average marginal weights across the 0-20th, 20-40th, 40-60th, 60-80th, 80-90th, 90-95th, and 95-99th percentiles of income distribution based on the CBO (Figure 4 in Lockwood and Weinzierl (2016)). The left (right) panel assumes the elasticity of taxable income (ETI) of 0.4 and (0.6).

tribution, the income tax code, and the elasticity of taxable income (ETI), respectively. Figure 8, which is borrowed from Lockwood and Weinzierl (2016), exhibits the estimated marginal social welfare weights across the 0-20th, 20-40th, 40-60th, 60-80th, 80-90th, 90-95th, and 95-99th percentiles of income based on the CBO for two values of ETI: 0.4 (left panel) and 0.6 (right panel) for 1980 (denoted by lines with circles) and 2010 (lines with diamonds).[24] The marginal weights are more or less flat from the 20th to the 80th percentiles and then fall sharply afterward.

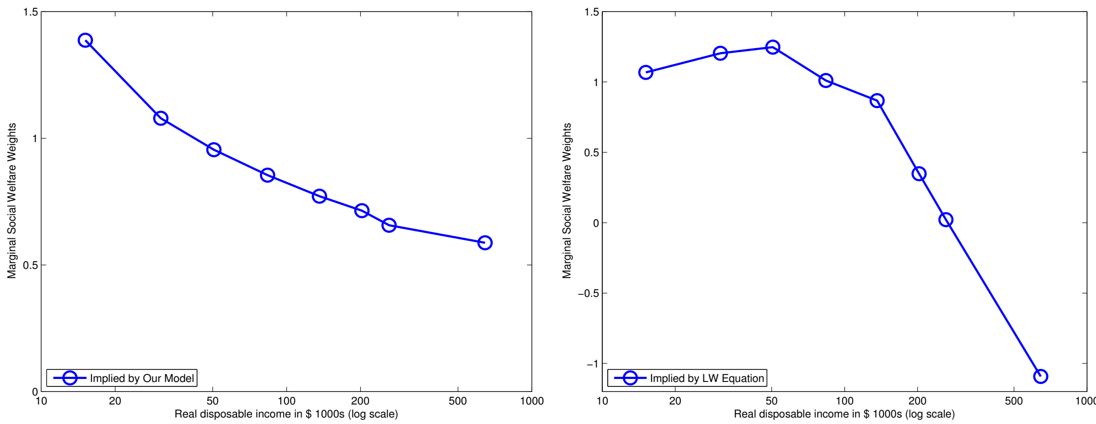
In our model, the marginal social welfare weights are (after normalization):

$$g(a,x) = u'(c(a,x)) \cdot \theta(c(a,x)) = \frac{c(a,x)^{\eta-\sigma}}{\int c(a,x)^{\eta-\sigma} d\mu}.$$

The left panel in Figure 9 shows the marginal social welfare weights of the U.S. economy uncovered by our model, respectively, across income groups. For a comparison to Lockwood and Weinzierl (2016), we rescale the incomes in our models so that the average income in our model matches that in the data ($79,300). While the Pareto weights

[24]They consider four values of ETI (which is close to the Hicksian labor supply elasticity in our model): 0.1, 0.3, 0.4 and 0.6. Since the Hicksian-income elasticity approximates to $(1/\sigma \cdot \gamma)/(1/\sigma + \gamma)$ (Keane and Rogerson (2012)), which is 0.5 in our model, we compare their results under the elasticity of 0.4 and 0.6 to ours.

Figure 9: Marginal Social Welfare Weights of U.S. According to Our Model



Note: The average marginal weights across the 0-20th, 20-40th, 40-60th, 60-80th, 80-90th, 90-95th, and 95-99th percentiles of income distribution in our models. The left panel exhibits the "true" marginal social welfare weights in our model. The right panel shows the marginal weights when the formula in Lockwood and Weinzierl (2016)–Equation (1)–was applied to our model-generated data. Incomes in our models are rescaled so that the average income in the model matches that in the data ($79,300).

increase with consumption in our models (η=0.58), the marginal social weights decrease with consumption, as the effect of marginal utility outweighs that of the Pareto weights.

The right panel in Figure 9 shows the marginal social welfare weights when the above formula in Lockwood and Weinzierl (2016)–Equation (1)–is applied to our model-generated income data and taxes.[25] The elasticity taxable income (ETI) is assumed to be 0.5. The marginal weights from our model-generated data, according to their formula, exhibit patterns similar to their estimates from the CBO data. From the bottom to middle income groups, the marginal weights increase slightly. As income approaches the 80th percentile, the welfare weight decreases sharply (even to negative values, as their estimates do for the 1980 data). Compared to their estimates, the weights on the rich are somewhat smaller in our model-generated data. There are several differences between our model and theirs. First, they assume a more fat-tailed distribution of income (Pareto log-normal) than ours (closer to log-normal as the productivity shocks are drawn from

[25] Lockwood and Weinzierl (2016) assume a Pareto distribution for income, whereas the model-generated equilibrium income distribution is closer to the log-normal distribution, which we smooth by a log-normal kernel density function when applied to the above formula (1).

the log-normal distribution). Second, their marginal tax rates, obtained from the NBER's TAXSIM, increases rapidly from the bottom to middle income groups and then becomes almost flat afterward. In our model, the marginal tax rates increase monotonically. Third, income is equal to consumption in a static environment: the marginal utility of consumption falls rapidly as income increases. However, under the Aiyagari economy as in our model economy, a household with high productivity saves a large portion of its income for precautionary motives: the marginal utility of consumption falls at a slower rate. Finally, Lockwood and Weinzierl (2016) use a quasilinear utility where there is no income effect on labor supply.

Table 9 summarizes the marginal social weights of all 32 OECD countries. In almost all countries, the marginal social weights decrease with consumption. However, in three countries (Chile, South Korea, and Turkey), which adopt much weaker redistribution policies, the marginal social weights of the poor are smaller than those of the rich.

5.7. Borrowing

The demand for social insurance may vary to the extent that financial markets are developed to provide private insurance against future income uncertainty. While our benchmark model does not allow households to borrow at all ($\underline{a} = 0$), most households do have access to financial markets or family to borrow from. While the development of financial markets varies across countries, it is difficult to measure the country-specific borrowing limits. To see whether our results are sensitive to the borrowing limit, we relax the borrowing limit in our benchmark calibration (i.e., U.S.). The exogenous borrowing constraint is now set to half of the average annual earnings in the model ($\underline{a} =$ -0.2) following Chang and Kim (2007), which is based on the maximum amount of credit card(s) limit (non-collateral debt) for the average household in the survey data. While households are liable to tax on interest income, most interest payments are not deductible. Thus, we modify the disposable income of households as:

$$
\begin{aligned}
D(y) = \quad & \lambda(wxh + ra)^{1-\tau}, \quad if\ a \geq 0 \\
& \lambda(wxh)^{1-\tau} + ra, \quad if\ a < 0.
\end{aligned}
$$

Table 9: Marginal Social Weights across OECD countries

	Parameter	Consumption Quintile				
	η	1st	2nd	3rd	4th	5th
Australia	0.127	1.76	1.10	0.88	0.72	0.54
Austria	-1.247	2.77	1.01	0.62	0.39	0.20
Belgium	-1.683	2.98	0.97	0.56	0.33	0.16
Canada	0.028	1.81	1.10	0.87	0.71	0.52
Chile	1.411	0.61	0.83	0.98	1.14	1.44
Czech Republic	-1.593	2.90	0.97	0.59	0.36	0.18
Denmark	-1.553	2.81	0.99	0.61	0.39	0.20
Estonia	-0.306	2.13	1.09	0.80	0.60	0.39
Finland	-1.665	2.97	0.97	0.56	0.34	0.16
France	-0.697	2.42	1.07	0.72	0.50	0.29
Germany	-1.034	2.64	1.03	0.66	0.43	0.24
Greece	-0.175	2.08	1.10	0.81	0.61	0.40
Iceland	-1.496	2.73	1.00	0.63	0.41	0.22
Ireland	-1.453	2.98	1.00	0.56	0.32	0.14
Israel	0.538	1.43	1.08	0.95	0.84	0.70
Italy	-0.344	2.18	1.09	0.78	0.58	0.37
Japan	0.029	1.86	1.10	0.86	0.68	0.49
Korea	1.068	0.96	0.99	1.00	1.02	1.04
Luxembourg	-1.270	2.75	1.01	0.63	0.40	0.21
Netherlands	-0.541	2.18	1.08	0.78	0.58	0.38
New Zealand	0.061	1.79	1.10	0.88	0.71	0.52
Norway	-1.612	2.85	0.98	0.60	0.38	0.19
Poland	-0.400	2.18	1.08	0.78	0.58	0.37
Portugal	-0.042	1.97	1.10	0.84	0.65	0.45
Slovak Republic	-1.262	2.68	1.01	0.65	0.43	0.23
Slovenia	-2.126	3.17	0.91	0.50	0.29	0.13
Spain	-0.027	1.93	1.10	0.85	0.66	0.46
Sweden	-1.109	2.59	1.03	0.67	0.45	0.25
Switzerland	0.279	1.52	1.09	0.93	0.81	0.65
Turkey	1.116	0.90	0.97	1.00	1.04	1.09
United Kingdom	-0.100	2.02	1.10	0.83	0.63	0.43
United States	0.582	1.39	1.08	0.95	0.85	0.72

Table 10 compares results with and without borrowing for the U.S.[26] According to our model, 20% of households are now in debt when borrowing is allowed. The wealth Gini increases to 0.648 from 0.605 in the benchmark model without borrowing.[27] Due to non-deductible interest payments, households in debt face higher tax rate than those without debt, even though their incomes (after interest payments) are the same. Hence, the tax progressivity (0.263) generating the same after-tax income Gini is slightly higher in the model with borrowing.

Since the demand for social insurance diminishes when borrowing is allowed, the optimal progressivity ($\tau^* = 0.332$) under the equal-weight utilitarian social welfare function is slightly smaller than that (0.341) in the benchmark model without borrowing. The slope of Pareto weights (η) also decreases from 0.582 to 0.496, raising the Pareto weights on the poor (relative to the rich). Overall, the impact on the uncovered Pareto weights is small—a change of less than 10%. For example, the weights on the bottom quintile increase from 0.600 to 0.654.

[26] As in the benchmark case, the time discount factor (β), disutility from labor (B), the standard deviation of innovation (σ_x), tax progressivity (τ), and average level of taxation (λ) are all re-calibrated to match interest rates, working hours, Gini coefficients, and the government expenditure-to-output ratio in the data.

[27] The magnitude of the productivity shock (σ_x) required to match the before-tax income Gini is somewhat smaller. Since household debt lowers aggregate savings, a higher time discount factor (β) is required to maintain the steady-state rate of returns to capital.

Table 10: Results with and without Borrowing

	Benchmark	With Borrowing
Time discount factor (β)	0.957	0.959
Disutility from labor (B)	5.477	5.488
S.D. of productivity shock (σ_x)	0.336	0.333
Model-implied progressivity (τ_0)	0.261	0.263
Model-implied marginal tax rate for median	0.291	0.292
Gini improvement rate	0.238	0.238
Wealth Gini	0.605	0.648
Optimal progressivity (τ^*)	0.341	0.332
Gini improvement rate under τ^*	0.317	0.306
Marginal tax rate for median under τ^*	0.338	0.333
Weighting function parameter (η)	0.582	0.496
Pareto weights		
1st Quintile	0.600	0.654
2nd Quintile	0.827	0.857
3rd Quintile	0.979	0.990
4th Quintile	1.144	1.126
5th Quintile	1.451	1.372

6. Conclusion

Economic inequality is at the heart of policy debates. We develop a general equilibrium model that can be used for a quantitative analysis of the political economy of income inequality and redistribution policy. With the model calibrated to reproduce the cross-sectional income inequality and progressivity of the income tax code of each of the 32 OECD countries, we ask the following: (i) What is the optimal income tax progressivity under the equal-weight utilitarian social welfare function? (ii) Will the optimal tax reform be supported by the majority of the population? (iii) What is the Pareto weight in the social welfare function that justifies the current progressivity?

According to our model, the optimal progressivity of income tax under the equal-weight utilitarian social welfare function varies vastly across countries, between 0.21 (South Korea) and 0.41 (Ireland). For 10 countries, the current level of progressivity is lower than optimal. For the other 22 countries, the current progressivity is higher than optimal. According to the voting simulation, a policy reform to adopt the optimal tax progressivity is supported by the majority of the population in almost all countries. For example, in Chile the policy to increase the tax progressivity (0.06) to the socially optimal level (0.35) is supported by 86% of the population.

We argue that the persistence of the current suboptimal progressivity (despite the population's overwhelming support for optimal tax reform) is evidence of unequal Pareto weights in the social welfare function. For the U.S., the average Pareto weight on the richest 20% of population is 1.45, more than twice as large as that (0.6) of the poorest 20%. In Chile, the average Pareto weight on the richest 20% is 2.65, whereas that on the poorest 20% is a mere 0.15. We provide some evidence, although indirect, that the Pareto weights uncovered by our model may be accounted for by a country's Democracy Index, voting turnout rates by income, and preferences for equity.

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Appendix A: Data Appendix

A.1. Income and Wealth Distribution

The income Gini coefficients and income decile ratio used in this paper are obtained from the Organization for Economic Cooperation and Development (OECD) database (http://stats.oecd.org, extracted on 2015-12-17 (Gini) and 2016-04-04 (decile ratio)) The base year is 2010 except for the coefficients of Chile, Hungary, Ireland, Japan, New Zealand, Switzerland, and the UK, where the base year is 2009. The OECD database provides two Gini coefficients (before- and after-taxes and transfers) based on household income per equivalent-household member. The social security contributions and transfers are also included. The Income decile ratios are based on disposable income. P90/P10 and P50/P10 decile ratio are from the OECD, and P90/P50 ratio are calculated by dividing the former by the latter. The wealth Gini coefficients for OECD countries are obtained from the 2012 version of the Global Wealth Databook by Credit Suisse. Wealth is defined as the marketable value of financial assets plus non-financial assets less debt.

A.2. Taxes, Expenditures, and Working Hours

Data on tax revenues, tax rates, and tax wedges are from the OECD tax database (http://stats.oecd.org, extracted on 2015-01-30). The base year is 2010. The tax wedge is the difference between labor costs to the employer and the corresponding net take-home pay of the employee, which is calculated by expressing the sum of personal income tax and employee plus employer social security contributions together with any payroll tax, minus benefits as a percentage of labor costs (definition by the OECD). The OECD provides the tax wedges for several types of households categorized by the number of members in the household, number of earners, and income level. The composition of general government expenditure is also from the OECD database ("National Accounts at a Glance", http://stats.oecd.org, extracted on 2015-01-30). The gap between tax revenues and expenditures reflects the government budget deficit and non-tax revenue. Working hours are calculated using the information on average annual working hours from the OECD database (http://stats.oecd.org, extracted on 2015-04-16). We divide the OECD's numbers by 5500 hours, the total amount of annual discretionary time. Goverment consumption, GDP (extracted on 2015-10-05) and Per capita GDP (extracted on 2014-06-22) are also obtained from the OECD database (http://stats.oecd.org)

A.3. Democracy Index

The Democracy Index is obtained from the Economist Intelligent Unit (EIU). The EIU evaluates the development of democracy in a society based on 60 questions in 5 categories: (i) electoral process and pluralism, (ii) functioning of government, (iii) political participation, (iv) political culture, and (v) civil liberties. A country is scored from 0 to 10 in each of the 5 categories. The Democracy Index is the average of these 5 scores.

A.4. World Values Survey

The World Values Survey (www.worldvaluessurvey.org) is a global network of social scientists studying changing values and their impact on social and political life. The WVS consists of nationally representative surveys conducted in almost 100 countries, which contain almost 90 percent of the worlds population, using a common questionnaire. We use the WVS 2005-2009 data. Twenty countries out of 32 OECD countries are included: Australia, Canada, Chile, Finland, France, Germany, Italy, Japan, Korea, the Netherlands, New Zealand, Norway, Poland, Slovenia, Spain,Sweden, Switzerland, Turkey, the U.K. and the U.S. One of the questions is related to the equity-efficiency trade-off. The participants choose their views between "Incomes should be made more equal (0)" and "We need larger income difference as incentives for individual effort" (10). We calculated the fraction of the population with a scale between 0-5, who are favorable to income redistribution, as an indicator of support for the equity.

A.5. Luxembourg Income Study

The Luxembourg Income Study (LIS, http://www.lisdatacenter.org) collects and harmonizes micro datasets around the world (46 countries as of 2016). The LIS datasets contain variables on market income, public transfers and taxes, household- and person-level characteristics, labor market outcomes, and, in some datasets, expenditures. Twenty-five countries out of 32 OECD countries report detailed information on market and disposable income in the LIS database; we define market income as factor income (factor) plus private transfer (hitp), and disposable income as market income plus public transfer (hits) minus taxes and contributions (hxit). The base year in 19 countries (Australia, Canada, Denmark, Estonia, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Luxembourg, the Netherland, Poland, Slovak Republic, Spain, the U.K. and the U.S.) is 2010. The Czech Republic (2007), Japan (2008), Korea (2006), Norway (2004), Sweden (2005), and Switzerland (2004) are based on earlier years. All incomes are equivalized by household size. The microdata runs were completed on January, 2016. In estimating tax progressivity, we drop 20% of low-income households, since those data are very noisy.

Appendix B: Computational Procedures

B.1. Steady-State Equilibrium

The distribution of households, $\mu(a, x)$, is time-invariant in the steady state, as are factor prices. We modify the algorithm suggested by José-Víctor Ríos-Rull (1999) in finding a time-invariant distribution μ. Computing the steady-state equilibrium amounts to finding the value functions, the associated decision rules, and the time-invariant measure of households. We search for (i) the discount factor β that clears the capital market at the given annual rate of return of 4%; (ii) the disutility parameter B to match the average hours worked, 0.323; (iii) the standard deviation of idiosyncratic productivity, σ_x and the tax progressivity (τ) that match the before- and after- tax Gini coefficient (0.499, 0.380); and (iv) the average level of taxation (λ) to match Government consumption-to-output ratio (16.9%). The details are as follows:

1. Choose the grid points for asset holdings (a) and idiosyncratic productivity (x). The number of grids is denoted by N_a and N_x, respectively. We use $N_a = 309$ and $N_x = 21$. The asset holding a_t is in the range of [0, 39.9]. The grid points of assets are not equally spaced. We assign more points on the lower asset range to better approximate the savings decisions of households near the borrowing constraint.

2. Pick initial values of β, B, σ_x, τ and λ. For idiosyncratic productivity, we construct a grid vector of length N_x, whose elements (each denoted by $\ln x_j$) are equally spaced on the interval $[-3\sigma_x/\sqrt{1-\rho_x^2}]$. Then, we approximate the transition matrix of the idiosyncratic productivity using the algorithm from Tauchen (1986).

3. Given β, B, σ_x, τ, and λ, we solve the individual value functions V at each grid point for individual states. In this step, we also obtain the optimal decision rules for asset holdings $a'(a_i, x_j)$ and labor supply $h(a_i, x_j)$. This step involves the following procedure:

   (a) Initialize value functions $V_0(a_i, x_j)$ for all $i = 1, 2, \cdots, N_a$, and $j = 1, 2, \cdots, N_x$.

(b) Update value functions by evaluating the discretized versions:

$$V_1(a_i, x_j) = \max\Big\{u\big(\big(\lambda(wh(a_i, x_j)x_j + ra_i)\big)^{1-\tau} + a_i - a', h(a_i, x_j)\big) \\ + \beta \sum_{j'=1}^{N_x} V_0(a', x'_j))\pi_x(x_{j'}|x_j)\Big\},$$

where $\pi_x(x_{j'}|x_j)$ is the transition probability of x, which is approximated using Tauchen's algorithm.

(c) If V_1 and V_0 are close enough for all grid points, then we have found the value functions. Otherwise, set $V_0 = V_1$, and go back to step 3(b).

4. Using $a'(a_i, x_j)$ and $\pi_x(x_{j'}, x_j)$ obtained from step 3, we obtain the time-invariant measures $\mu^*(a_i, x_j)$ as follows

   (a) Initialize the measure $\mu_0(a_i, x_j)$.

   (b) Update the measure by evaluating the discretized version of a law of motion:

$$\mu_1(a_{i'}, x_{j'}) = \sum_{i=1}^{N_a}\sum_{j=1}^{N_x} \mathbf{1}_{a_{i'}=a'(a_i,x_j)}\mu_0(a_i, x_j)\pi_x(x_{j'}|x_j).$$

   (c) If μ_1 and μ_0 are close enough in all grid points, then we have found the time-invariant measure. Otherwise, replace μ_0 with μ_1 and go back to step 4(b).

5. We calculate the real interest rate, Gini coefficients, individual's working hours, net tax revenues, and other aggregate variables of interest using μ^* and decision rules. Net tax revenues are:

$$TR = \int_{a,x} \{wxh + ra - \lambda(wxh + ra)^{1-\tau}\}d\mu(a, x).$$

   If the calculated real interest rate, average hours worked, and before- and after- tax Gini coefficient and government consumption are close to the assumed ones, we have found the steady state. Otherwise, we choose a new β, B, σ_x, τ and λ and go back to step 2.

The computational procedure for other countries is similar except that we fix β from the U.S. case.

B.2. Optimal Tax Reform

Individual utilities include those in the transition periods from the initial to the new steady state. We compute the value functions and decision rules backwards and the measure of households forward. Computing the transition equilibrium amounts to finding the value functions, the associated decision rules, and measure of households in each period. The details are as follows:

1. Compute the initial steady state under the current tax progressivity (τ_0). Use the algorithm for the steady-state equilibrium.

2. Choose a new tax progressivity (τ) and compute all transition paths as follows:

   (a) Compute the final steady state under a new tax progressivity. Use the algorithm for steady-state equilibrium.

   (b) Assume that the transition is completed after $T-1$ periods, and that the economy is in the initial steady state at time 1 and in the final steady state at T. Choose a T big enough so that the transition path is unaltered by increasing T.

   (c) Guess the capital-labor ratios $\{K_t/E_t\}_{t=2}^{T-1}$ and compute the associated $\{r_t, w_t\}_{t=2}^{T-1}$.

   (d) Guess the path of the average level of taxation $\{\lambda_t\}_{t=2}^{T-1}$. Note that the average level of taxations are all different in each period, since decision rules and measures are different. Going backward, compute the value functions and policy functions for all transition periods by using $V_T(\cdot)$ from the final steady state. Using the initial steady-state distribution μ_1 and the decision rules, find the measures of all periods $\{\mu_t\}_{t=2}^{T-1}$.

   (e) Based on the decision rules and measures, compute the aggregate variables and net tax revenues. If the net tax revenue is close to the assumed government consumption (a constant ratio of output), we obtain the average level of taxation. Otherwise, choose a new path of the average level of taxation and go back to 2(d).

(f) Compute the paths of aggregated capital and effective labor and compare them with the assumed paths. If they are close enough in each period, we find the transition paths. Otherwise, update $\{K_t/E_t\}_{t=2}^{T-1}$ and go back to 2(c).

3. Choose the tax progressivity that yields the highest social welfare. This is the optimal tax progressivity under the utilitarian criteria. We also compute the voting outcome for this tax reform policy. Voting takes place at the beginning of period 2, after the idiosyncratic productivity shock has been realized. The voting decision of an individual with state (a, x) is determined as follows: if $V(a, x; \tau, \tau_0) > V(a, x; \tau_0, \tau_0)$, then this individual votes in favor of the new tax progressivity.

B.3. Pareto Weights

We search for the value of η so that the current tax progressivity provides the highest social welfare. Details are as follows:

1. Define a set of tax progressivity around the current one.

2. Given a tax progressivity, compute $c(a, x)$, $V(a, x)$, $\mu(a, x)$, and other related variables using the algorithm for the steady-state equilibrium.

3. Assume η and compute the social welfare under each tax progressivity:

$$\mathcal{W}(\tau, \tau_0) = \int \theta(c(a_0, x_0); \tau_0) V(a_0, x_0; \tau, \tau_0) d\mu(a_0, x_0; \tau_0),$$

where

$$V(a_0, x_0; \tau, \tau_0) = \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t; \tau, \tau_0) \quad \text{and } \theta(c(a_0, x_0); \tau_0) = \frac{c(a_0, x_o)^\eta}{\displaystyle\int c(a_0, x_o)^\eta d\mu(a_0, x_0)}$$

4. Compare the social welfares and choose the highest social welfare and the corresponding tax progressivity (τ^*). If the tax progressivity (τ^*) is close enough to τ_0, then we obtain η and Pareto weights for individuals. Otherwise, we choose a new η and go back to step 3.

Appendix C: Additional Tables

Table C.1: Steady State for OECD

	Disutility from Labor (B)	SD of Innovation (σ_x)	Implied Tax Porgreesivity (τ)	Interest Rates (r)	Hours Worked (H)
Australia	5.660	0.318	0.309	0.049	0.307
Austria	4.145	0.368	0.461	0.062	0.304
Belgium	4.626	0.360	0.475	0.069	0.282
Canada	5.560	0.301	0.306	0.055	0.309
Chile	5.228	0.341	0.056	0.019	0.376
Czech Republic	3.690	0.328	0.452	0.068	0.329
Denmark	5.231	0.306	0.430	0.078	0.281
Estonia	4.000	0.344	0.375	0.054	0.342
Finland	3.939	0.361	0.474	0.071	0.305
France	5.675	0.368	0.425	0.061	0.269
Germany	6.187	0.358	0.443	0.059	0.256
Greece	3.300	0.382	0.390	0.051	0.367
Iceland	4.751	0.277	0.401	0.075	0.307
Ireland	4.046	0.454	0.512	0.053	0.280
Israel	4.533	0.341	0.273	0.046	0.349
Italy	4.300	0.363	0.394	0.054	0.322
Japan	5.068	0.338	0.336	0.050	0.315
Korea	4.683	0.201	0.095	0.044	0.398
Luxembourg	4.642	0.338	0.444	0.060	0.297
Netherlands	7.816	0.286	0.346	0.068	0.251
New Zealand	5.226	0.306	0.306	0.052	0.320
Norway	6.404	0.299	0.429	0.071	0.257
Poland	3.789	0.331	0.374	0.055	0.353
Portugal	4.625	0.375	0.372	0.049	0.316
Slovak Republic	4.062	0.305	0.415	0.065	0.329
Slovenia	4.032	0.335	0.479	0.070	0.305
Spain	5.184	0.356	0.357	0.050	0.304
Sweden	4.914	0.312	0.410	0.071	0.297
Switzerland	7.296	0.232	0.209	0.045	0.297
Turkey	5.875	0.304	0.139	0.032	0.341
United Kingdom	5.140	0.373	0.377	0.047	0.300
United States	5.477	0.336	0.261	0.040	0.323

Table C.2: Gini Coefficients under the Optimal Tax Reform

	Current			Optimal Tax (τ^*)			Majority Chosen (τ^M)		
	Before Tax	After Tax	%Δ	Before Tax-	After Tax	%Δ	Before Tax	After Tax	%Δ
Australia	0.469	0.334	28.8	0.467	0.326	30.2	0.466	0.322	30.8
Austria	0.498	0.280	43.8	0.519	0.349	32.7	0.518	0.346	33.3
Belgium	0.484	0.264	45.5	0.510	0.346	32.2	0.509	0.342	32.8
Canada	0.447	0.319	28.6	0.447	0.317	29.0	0.445	0.313	29.6
Chile	0.536	0.510	4.9	0.493	0.335	32.0	0.494	0.340	31.1
Czech Republic	0.454	0.258	43.2	0.478	0.334	30.2	0.477	0.330	30.9
Denmark	0.429	0.252	41.3	0.451	0.321	28.8	0.449	0.314	30.1
Estonia	0.488	0.317	35.0	0.494	0.337	31.7	0.493	0.335	32.0
Finland	0.485	0.265	45.4	0.511	0.346	32.2	0.508	0.337	33.7
France	0.505	0.303	40.0	0.518	0.347	33.1	0.517	0.342	33.8
Germany	0.492	0.286	41.9	0.510	0.345	32.4	0.508	0.337	33.6
Greece	0.529	0.338	36.1	0.533	0.350	34.2	0.531	0.345	35.1
Iceland	0.400	0.246	38.5	0.419	0.308	26.6	0.418	0.303	27.5
Ireland	0.579	0.298	48.5	0.604	0.381	36.9	0.601	0.371	38.3
Israel	0.501	0.376	25.0	0.489	0.332	32.0	0.489	0.333	31.9
Italy	0.507	0.321	36.7	0.514	0.345	32.9	0.513	0.340	33.6
Japan	0.488	0.336	31.1	0.487	0.334	31.5	0.486	0.330	32.1
Korea	0.341	0.310	9.1	0.329	0.263	20.0	0.329	0.264	19.7
Luxembourg	0.469	0.271	42.2	0.490	0.338	30.9	0.488	0.332	32.0
Netherlands	0.421	0.283	32.8	0.429	0.310	27.7	0.429	0.310	27.8
New Zealand	0.454	0.324	28.6	0.453	0.320	29.4	0.452	0.318	29.6
Norway	0.423	0.249	41.1	0.445	0.320	28.2	0.444	0.315	29.0
Poland	0.473	0.307	35.1	0.480	0.332	30.8	0.480	0.331	31.1
Portugal	0.525	0.345	34.3	0.526	0.348	33.8	0.525	0.345	34.3
Slovak Republic	0.434	0.262	39.6	0.453	0.323	28.7	0.451	0.318	29.5
Slovenia	0.456	0.246	46.1	0.485	0.338	30.4	0.484	0.331	31.5
Spain	0.506	0.339	33.0	0.507	0.341	32.7	0.506	0.339	33.0
Sweden	0.441	0.269	39.0	0.458	0.324	29.3	0.457	0.320	29.9
Switzerland	0.372	0.298	19.9	0.368	0.284	22.9	0.368	0.284	22.8
Turkey	0.477	0.417	12.6	0.452	0.318	29.6	0.453	0.322	28.9
United Kingdom	0.523	0.341	34.8	0.525	0.348	33.7	0.525	0.348	33.8
United States	0.499	0.380	23.8	0.486	0.332	31.7	0.486	0.332	31.7

Note: All numbers are income Gini under the steady state. “Current” denotes the current steady state from the model. “%Δ” denotes the percentage between before- and after-tax Ginis, the improvement rate.