Should Robots be Taxed?
Replication README

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1 Overview

This replication package contains the *Matlab* code used to calibrate and solve the model described in the quantitative sections in Guerreiro, Rebelo and Teles (2021) "Should Robots be Taxed?" The replication package is split into four different folders: *Data*, *Simple Static Model*, *Calibration*, and *Optimal Policy*. Data includes all the data used in the calibration of the model. The folder *Simple Static Model* contains the code to solve the model in section 3. The folder *Calibration* contains the relevant codes to calibrate and solve the status-quo equilibrium described in sections 5.1 and 5.2. Finally, the folder *Optimal Policy* contains the codes that solve the optimal policy exercises in section 5.3.

The figures of the dynamic model are automatically copied to the folder *Figures* when running that code.

2 Data availability

The folder *data* contains the empirical evidence used in our analysis. The paper uses data obtained from the Federal Reserve Bank of St. Louis economic data for federal debt and gross domestic product. The citations can be found below as well as the links to access the data.

1. U.S. Department of the Treasury. Fiscal Service, Federal Debt: Total Public Debt [GFDEBTN], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GFDEBTN, December 19, 2019.

2. U.S. Bureau of Economic Analysis, Gross Domestic Product [GDPA], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/GDPA, December 19, 2019.

The paper also uses data on private and public consumption to GDP ratios from the World Development Indicators, The World Bank obtained from https://datacatalog.worldbank.org/dataset/world-development-indicators.

The paper also uses data obtained from NBER Taxsim which can be found in Feenberg, Daniel, and Elizabeth Coutts, "An Introduction to the Taxsim Model" Journal of Policy Analysis and Management Vol 12, Number 1, Winter 1993, and the data are obtained from http://users.nber.org/~taxsim/allyup/ [Feenberg and Coutts, 1993].

The paper also uses data obtained from Guvenen, Fatih, Karahan, Fatih, Ozkan, Serdar, and Song, Jae, "What Do Data on Millions of U.S. Workers Reveal about Life-Cycle Earnings Risk?", National Bureau of Economic Research (2015), retrieved from https://fguvenendotcom.files .wordpress.com/2014/04/moments_for_website_final.xlsx [Guvenen et al., 2015].

Finally, the paper uses data obtained from IPUMS: Flood, Sarah, King, Miriam, Rodgers, Renae, Ruggles, Steven, and Warren, J. Robert, "Integrated Public Use Microdata Series, Current Population Survey: Version 6.0", Minneapolis, MN: IPUMS (2018). IPUMS-CPS does not currently provide the ability to store or reference custom extracts, but allows for redistribution for the purpose of replication. The archive contains the time series which are used in the analysis in the folder *"Data/Occupations Data"*.

All data are publicly available.

2.1 Further details on the data

Government Data The original data is in excel format: *WorldBankData_US.xlsx* contains the World Bank data, *FredData.xlsx* contains the data obtained from FRED, and *MgAvgTaxes.xlsx* contains the NBER Taxsim data. The *Matlab* codes *SpendingAndDebtRatios.m* and *ProgressivityTimeSeries.m* import this data into the *Matlab* format and compute the necessary statistics which are described below.

We use FRED data to compute the debt-to-GDP ratio. We then divide the debt-to-GDP and the public consumption-to-GDP ratios by the private consumption-to-GDP ratio in order to obtain the debt to private consumption and public consumption to private consumption ratios.

Following Ferriere and Navarro [2014], we compute progressivity based on *NBER TAXSIM data.* This NBER dataset provides marginal and average income taxes at the state, federal, and combined levels. We use the combined aggregation level in the Fixed Sample population in order to compute progressivity in the U.S. economy. To recover progressivity, note that given our assumptions on the income tax system marginal and average income taxes can be computed as follows

$$T'(y) = 1 - (1-\gamma)\,\lambda y^{-\gamma}$$

$$\overline{T}(y) \equiv \frac{T(y)}{y} = 1 - \lambda y^{-\gamma},$$

respectively, where y denotes income, γ is the progressivity parameter, and λ denotes the average level of taxes. Combining this expressions, note that

$$\frac{T'(y) - \overline{T}(y)}{1 - T'(y)} = \gamma. \tag{1}$$

Lifecycle Data No changes are made with respect to the baseline data. This data can be found in the excel file *Earnings_Lifecycle.*

Occupations Data The occupations data includes the occ2_timeseries excel file which is obtained from computations using monthly CPS Data obtained from IPUMS [Flood et al., 2018]. We restrict out analysis to individuals in the labor force aged 17 to 64. We classify workers as belonging to routine or non-routine occupations following the approach in Cortes et al. [2014] and Cortes et al. [2017]. Based on this classification, we compute the share of routine and non-routine workers in the labor force for each month. If hourly wage data is not available, we compute the workers hourly wage by dividing weekly earnings by usual hours worked per week. We then compute average hourly wages for each occupation group and month.

The excel file *"occ2_timeseries.xlsx"* reports these statistics for each occupation group at the monthly level from January, 1982 to October, 2019. The *Matlab* code *OccupationsData.m* imports this data to and computes the non-routine wage premium and plots the time series of occupation shares and the wage premium.

3 Computation requirements and time

All codes use *Matlab software.* The code was run on *Matlab Release 2020b.* The optimization algorithms used are included in the Optimization Toolbox. Furthermore, we also use the HP filter algorithm from the Econometrics toolbox.

The full set of code should take 1-2 days to run. The code was last run on a 2-core Intel-based laptop with 8 GB RAM.

4 Description of code

4.1 Simple Static Model

This folder includes the programs to solve and draw the figures for the status-quo equilibrium in the static model. Running the file *Master.m* should run everything including obtaining the parameters of this model in the file *Parameters.m* and constructs the figure 1 with *DrawPlots.m*.

4.2 Calibration

This folder includes the calibration and solution of the status-quo equilibrium in our OLG economy. See the paper for details on the calibration method. The codes should be run in the following order:

1. *Code1_Calibrate_SS1987.m* - calibrates and solves the initial steady state equilibrium before automation. This program solves the system of equations in *EqbmEq_SS1987.m.* This program calls *Parameters.m* which includes all the externally calibrated parameter values. (Short running time)

2. *Code2_SolveSQ_FinalSS.m* - this program solves the final steady state. The equations are in *EqbmEq_FinalSS.m* (Short running time)

3. *Code3_CalibrateTransition.m* - This program calibrates and solves the transition from initial to final steady state. This uses the file *SolveTransition.m* to evaluate the quality of fit of the calibrated parameters, while the equilibrium equations for this transition can be found in *EqbmEq_Transition.m*. (Long running time - few hours)

4. *Code4_TransitionPost2017* - this program solves the equilibrium after the 2017 Tax Reform. (Long running time - few hours)

5. *Code5_Figures.m* - this program constructs figures 2, 3, and 4 in the paper. (Short running time)

4.3 Optimal Policy

This folder contains the relevant programs to solve the Mirrleesian policy exercise. The codes should be run in the following order:

1. *CodeA1_SteadyState.m* - solves the steady state of the baseline optimal policy exercise. The first order conditions for this problem are in *Equations_SS.m* (Running time: 30 seconds)

2. *CodeA2_Transition.m* - solves the transition for the baseline optimal policy exercise. To improve speed of computation we first solve a related problem without intensive margin constraints which is done by calling *CodeB1_Transition_OnlyExtensiveMargin.m* and uses the first order condition sin *Equations_Transition_OnlyExtensiveMargin.m*. It then uses this as the initial guess to solve the first order conditions in *Equations_Transition.m*. (Long running time)

3. *CodeA3_Transition_NoExtensiveMargin.m* - solves the optimal policy exercise for the economy without skill acquisition. This solves the first order conditions in *Equations_Transition_ NoExtensiveMargin.m*. (Long running time)

4. *CodeA4_WelfareGainsTauX.m* - solves the optimal policy exercise constrained to have zero robot taxes and then computes the welfare gains of the baseline policy. (Long running time)

5. *CodeA5_Figures.m* - constructs figures 5, 6, and 7. (Short running time)

6. *CodeB2_TransitionFrom1987.m* - solves the optimal policy exercise starting in 1987 and *CodeB3_ Figures.m* plots its associated figures. (< 1 hour).

4.4 Summary table

The following table list the code used to produce each figure. We list figures and codes in the order in which they should be run.

Table 1: Summary table

Exhibit		***Code***
Static Model		
Figure 1		Simple Static Model/Master.m
Calibration and status-quo equilibrium		
Figure 2	1.	Calibration/Code1_Calibrate_SS1897.m
	2.	Calibration/Code2_SolveSQ_FinalSS.m
	3.	Calibration/Code3_CalibrateTransition.m
Table 1		Calibration/Code3_CalibrateTransition.m
Figures 3 and 4	1.	Calibration/Code4_TransitionPost2017.m
	2.	Calibration/Code5_Figures.m
Optimal policy		
Figures 5 and 6	1.	Optimal Policy/CodeA1_SteadyState.m
	2.	Optimal Policy/CodeA2_Transition.m
Table 2	1.	Optimal Policy/CodeA1_SteadyState.m
	2.	Optimal Policy/CodeA2_Transition.m
Figure 7		Optimal Policy/CodeA4_WelfareGainsTauX.m
Figure 8	1.	Optimal Policy/CodeA3_Transition_NoExtensiveMargin.m
	2.	Optimal Policy/CodeA5_Figures.m
Table 3		Optimal Policy/CodeB3_Robustness.m

References

Guido Matias Cortes, Nir Jaimovich, Christopher J Nekarda, and Henry E Siu. The micro and macro of disappearing routine jobs: A flows approach. Working Paper 20307, National Bureau of Economic Research, July 2014.

Guido Matias Cortes, Nir Jaimovich, and Henry E Siu. Disappearing routine jobs: Who, how, and why? *Journal of Monetary Economics*, 91:69–87, 2017.

Daniel Feenberg and Elisabeth Coutts. An introduction to the taxsim model. *Journal of Policy Analysis and Management*, 12(1):189–194, 1993.

Axelle Ferriere and Gaston Navarro. The heterogeneous effects of government spending: It's all about taxes. 2014.

Sarah Flood, Miriam King, Renae Rodgers, Steven Ruggles, and J. Robert Warren. Integrated public use microdata series, current population survey: Version 6.0. 2018.

Fatih Guvenen, Fatih Karahan, Serdar Ozkan, and Jae Song. What do data on millions of u.s. workers reveal about life-cycle earnings risk? Working Paper 20913, National Bureau of Economic Research, 2015.