Growth and Income Inequality in an Endogenous Growth Model with Public Capital under Progressive Taxation

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Exploring the Public Capital-Inequality Link

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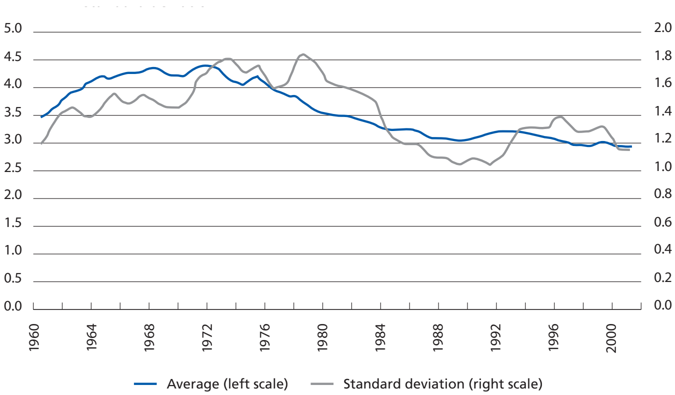

Figure: Government investment average in OECD countries and its standard deviation, 1960-2001. Source: Ward and De Haan (2005)

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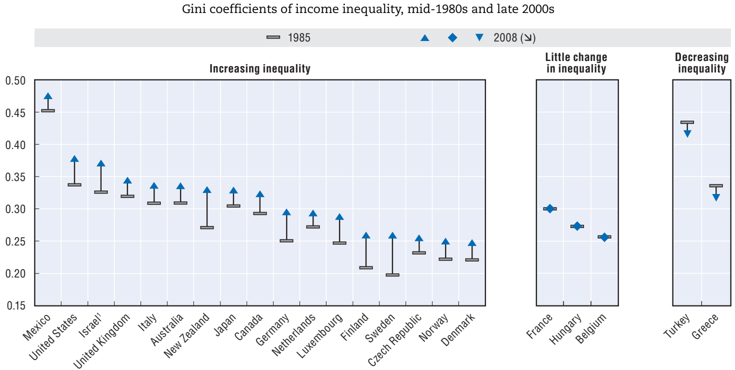

Figure: Changes in Gini coefficients in OECD countries, 1985 and 2008. Source: OECD (2011)

Extending the Representative Agent Framework

- Growth-inequality relationship receives increasing attention, e.g. "*We are the 99 percent!*", Piketty, IMF (2011, 2014).

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- Ramsey/stationary models: Sorger (2002), Garcia-Penalosa and Turnovsky (2008b), Carroll and Young (2009)

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- Progressive tax systems are approximated by one proportional tax rate in representative agent models
- Complementary and more popular literature in the incomplete asset market framework: Altig et al (1997), Ventura (1999), Benabou (2000, 2002)...

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  - Koyuncu and Turnovsky (2016): Elastic labor. Shows how the labor supply responses of different classes may differ under progressive taxes.

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- Glomm and Ravikumar (1997); Kneller et al. (1999): Distinction between productive and non–productive spending
- **Chatterjee and Turnovsky (2012):** Only heterogeneous agent model with public capital. Shows higher public investment worsens inequality. Considers flat taxation.

What this paper adds to the literature

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- Different levels of progressivity on capital and labor income to make a deeper analysis and to make comparisons with flat tax cases.

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- Higher public investments $\Rightarrow$ Higher inequality and growth rates.
- Higher tax progressivity $\Rightarrow$ Lower inequality and growth rates.
- Combination of the two to discuss fiscal policy options to reduce inequality without harming growth.
- Different levels of progressivity on capital and labor income to make a deeper analysis and to make comparisons with flat tax cases.
- Simultaneous determination of aggregate and distributional variables enables a more realistic analysis

Firms and Technology

- Chatterjee and Turnovsky (2012): Identical firms produce output according to

$$Y_j = A[\alpha(X_P L_j)^{-\rho} + (1-\alpha)K_j^{-\rho}]^{-\frac{1}{\rho}}$$

$$X_P = K^{\varepsilon} K_G^{1-\varepsilon},\ 0 \leq \varepsilon \leq 1$$

- $s \equiv 1/(1+\rho)$ represents the elasticity of substitution in production between capital and effective units of labor.
- Equations per aggregate private capital:

$$y \equiv y(z,\ell) = A[(1-\alpha) + \alpha\{(1-\ell)z^{1-\varepsilon}\}^{-\rho}]^{-\frac{1}{\rho}}\ ;\ \ell = 1 - L$$

$$r \equiv r(z,\ell) = (1-\alpha)A^{-\rho} y(z,\ell)^{1+\rho}$$

$$w = \omega(z,\ell)K;\ \omega(z,\ell) \equiv \alpha A^{-\rho} y(z,\ell)^{1+\rho} z^{-\rho(1-\varepsilon)}(1-\ell)^{-(1+\rho)}$$

- The ratio of public to private capital: $z = K_G/K$

Preferences

- A unit mass of a continuum of infinitely-lived consumers, indexed by i, heterogenous in their rates of time preference, β_i.

$$U_i = \int_0^\infty \frac{1}{\gamma}[C_i^{-\nu} + \theta(X_U \ell_i)^{-\nu}]^{-\frac{\gamma}{\nu}} e^{-\beta_i t}\,\mathrm{d}t$$

$$X_U = K^\varphi K_G^{1-\varphi},\ 0 \leq \varphi \leq 1$$

- $q \equiv 1/(1+\nu)$: the intra-temporal elesticity of substitution between consumption and leisure.
- $e \equiv 1/(1-\gamma)$: the inter-temporal elesticity of substitution.

Tax Schedule

- Following Guo and Lansing (1998); progressive tax rates on capital income $\tau_{k,i}$ where ϕ_k measures progressivity

$$\tau_{k,i} = \zeta_k \left(\frac{rK_i}{rK} \right)^{\phi_k} = \zeta_k \left(\frac{K_i}{K} \right)^{\phi_k}$$

- Progressive tax rates on labor income: $\tau_{w,i}$ where ϕ_w measures progressivity

$$\tau_{w,i} = \zeta_w \left(\frac{w(1-\ell_i)}{w(1-\ell)} \right)^{\phi_w} = \zeta_w \left(\frac{1-\ell_i}{1-\ell} \right)^{\phi_w}$$

- Flat tax rate on consumption: τ_c
- Endogenously determined lump-sum tax rates (or subsidies) to equalize the target government investment rate: τ

Households' Utility Maximization

- The budget constraint of the agent i:

$$\dot{K}_i = (1 - \tau_{k,i})rK_i + (1 - \tau_{w,i})w(1 - \ell_i) - (1 + \tau_c)C_i - T$$

- Individual i's consumption per aggregate capital:

$$c_i \equiv \frac{C_i}{K} = \ell_i \Omega_i(\ell_i, \ell, z)$$

$$\Omega_i(\ell_i, \ell, z) \equiv \left[\frac{\omega z^{\nu(1-\varphi)}}{\theta(1+\tau_c)}\right]^{\frac{1}{1+\nu}} \left(1 - \tau^m_{w,i}\right)^{\frac{1}{1+\nu}}$$

- TVC $\Rightarrow$ The upper limit for the private capital accumulation:

$$\frac{\dot{K}_i}{K_i} < r(1 - \tau^m_{k,i})$$

Government

- The flow equation for financing public investments, G:

$$\dot{K}_G = gY = G$$

$$G = r \int [\tau_{k,i} K_i] \mathrm{d}i + w \int [\tau_{w,i}(1 - \ell_i)] \mathrm{d}i + \tau_c C + \tau Y$$

$$gy = \frac{\dot{K}_G}{K} = r\bar{\tau}_k + \omega\bar{\tau}_w(1 - \ell) + \tau_c \bar{\Omega}\ell + \tau y$$

Equations for the evolution of the economy

- Growth rate of the aggregate wealth:

$$\frac{\dot{K}}{K} = (1-g)y(z,l) - \bar{\Omega}(z,\ell,\ell_1,\dots,\ell_N)\ell$$

- Evolution of relative wealth:

$$\dot{k}_i = k_i\left(\frac{\dot{K}_i}{K_i} - \frac{\dot{K}}{K}\right) = \Big[(1-\tau_{w,i})\omega(1-\ell_i) - (1+\tau_c)\ell_i\Omega_i - \tau y\Big]$$
$$-\Big[(\tau_{k,i} - \bar{\tau}_k)r + (1-\bar{\tau}_w)\omega(1-\ell) - (1+\tau_c)\bar{\Omega}\ell - \tau y\Big]k_i \; ; \; k_i \equiv \frac{K_i}{K}$$

- The flow equation for public investment:

$$\frac{\dot{z}}{z} = \frac{\dot{K}_G}{K_G} - \frac{\dot{K}}{K} = \frac{gy(z,\ell)}{z} - [(1-g)y(z,\ell) - \bar{\Omega}\ell]$$

Equations for the evolution of the economy

- The evolution of time devoted to leisure:

$$\frac{\dot{\ell}_i}{\ell_i} = \frac{\beta_i - r(1-\tau^m_{k,i}) - (\gamma-1)\frac{\dot{K}}{K} - \Gamma_{N,i}(\ell_i,\ell,z)\frac{\dot{\ell}}{\ell} - \Gamma_{O,i}(\ell_i,\ell,z)\frac{\dot{z}}{z}}{\Gamma_{M,i}(\ell_i,\ell,z)}$$

$$\frac{\dot{\ell}}{\ell} = \frac{\int \frac{\ell_i E_i}{\Gamma_{M,i}} \mathrm{d}i}{\ell + \int \frac{\ell_i \Gamma_{N,i}}{\Gamma_{M,i}} \mathrm{d}i}$$

where

$$E_i = \beta_i - r(1-\tau^m_{k,i}) - (\gamma-1)\frac{\dot{K}}{K} - \Gamma_{O,i}\frac{\dot{z}}{z}$$

Steady state equations

- The balanced growth path of the economy: $\dot{\ell}_i = \dot{\ell} = \dot{z} = \dot{k}_i = 0$
- The growth rate of aggregate and individual-specific wealth:

$$\tilde{\psi}_i = \tilde{\psi} = \frac{\beta_i - r(\tilde{z}, \tilde{\ell})(1 - \tau^m_{k,i})}{\gamma - 1} = \frac{gy(\tilde{z}, \tilde{\ell})}{\tilde{z}}$$

- Steady state relative wealth of the individual i:

$$\tilde{k}_i = \left[\frac{(\gamma - 1)gy(\tilde{z}, \tilde{\ell})/\tilde{z} + r(\tilde{z}, \tilde{\ell}) - \beta_i}{r(\tilde{z}, \tilde{\ell})(1 + \phi_k)\zeta_k}\right]^{\frac{1}{\phi_k}}$$

Steady state equations

- The relationship between individual's wealth and labor supply decision:

$$\left[\frac{gy(z,\ell)}{z} - r(1-\tau_{k,i})\right](k_i - 1) + r(\tau_{k,i} - \bar{\tau}_k)$$
$$= \omega\left[(\ell - \ell_i) + (1-\ell)\bar{\tau}_w - (1-\ell_i)\tau_{w,i}\right] + (1+\tau_c)(\bar{\Omega}\ell - \Omega_i\ell_i)$$

- $k_i > 1 \Leftrightarrow \ell_i > \ell$

Numerical analysis: General properties

- Numerical analyses for the 5-agent case.
- Comparison of the results with the base model in Chatterjee - Turnovsky (2012).
- Introducing government investment shocks using different tax policies.
- Repeating the shock scenarios for different levels of tax progressivity.
- Transition path analyses to investigate the saddle-path stability of the economy and the SR/LR responses of the economy to the shocks.

Benchmark calibration

Table: Parameter values for the benchmark economy

Parameter	Description	Value(s)
$e = 1/(1-\gamma)$	Inter-temporal elasticity of substitution	0.4
θ	The relative weight of leisure in utility	1.75
$q = 1/(1+\nu)$	Intra-temporal elasticity of substitution between consumption and leisure in the utility function	1
A	Technology shift parameter	0.6
α	Share of efficiency units of labor	0.6
$s = 1/(1+\rho)$	Elasticity of substitution in production between capital and effective units of labor	1
ε, φ	Geometric weight of the aggregate private capital in the aggregate composite externalities	0.6
β_i	Rates of time preference	0.036, 0.038, 0.040, 0.042, 0.044

Benchmark calibration

Table: Benchmark calibrations

	g	Level of tax schedule	Tax progressivity
This paper	0.05	$\zeta_k = 0.05$; $\zeta_w = 0.05$	$\phi_k = 0.75$; $\phi_w = -0.75$
CT2012	0.05	$\tau = 0.05$	n/a

Table: Steady state values for the benchmark economies

Policy	$\tilde{z}$	$\tilde{\ell}$	$\tilde{y}$	$\tilde{\psi}(\%)$
This paper	0.611	0.719	0.249	2.04
CT2012	0.531	0.714	0.243	2.29

Long run responses to various fiscal policy shocks - Growth effects

Table: Steady state growth rates (%) after each shock

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	$g = 0.05$	$g = 0.08$	$g = 0.08$	$g = 0.08$	$g = 0.08$	$g = 0.08$
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	2.06	2.33	2.44	2.50	2.13	2.46
(0.75,-0.75)	2.04	2.29	2.41	2.48	2.04	2.45
(1.125,-1.125)	2.00	2.23	2.38	2.43	1.92	2.44
(0.5,0.5)	2.00	2.20	2.36	2.42	2.06	2.29
(0.75,0.75)	1.93	2.10	2.29	2.35	1.94	2.20
(1.125,1.125)	1.85	1.96	2.20	2.25	1.77	2.07

Long run responses to various fiscal policy shocks - Size of the public capital to private capital ratios

Table: Steady state size of the public-private capital ratio, z

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
	g = 0.05	g = 0.08	g = 0.08	g = 0.08	g = 0.08	g = 0.08
	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	0.596	0.956	0.890	0.883	1.075	0.888
(0.75,-0.75)	0.611	0.987	0.910	0.901	1.141	0.905
(1.125,-1.125)	0.629	1.036	0.937	0.928	1.251	0.926
(0.5,0.5)	0.605	0.978	0.902	0.894	1.091	0.912
(0.75,0.75)	0.625	1.024	0.929	0.920	1.166	0.945
(1.125,1.125)	0.653	1.094	0.966	0.957	1.295	0.992

Long run responses to various fiscal policy shocks - Income distribution

Table: Steady state income distributions after each shock (in terms of coefficients of variation)

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
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(0.5,-0.5)	15.70	8.99	14.69	14.64	5.20	14.91
(0.75,-0.75)	9.23	5.05	8.58	8.52	2.81	8.70
(1.125,-1.125)	5.02	2.67	4.65	4.64	1.42	4.78
(0.5,0.5)	16.79	10.00	15.65	15.58	5.54	17.13
(0.75,0.75)	10.19	5.89	9.42	9.36	3.10	10.64
(1.125,1.125)	5.81	3.37	5.37	5.31	1.65	6.37

Long run responses to various fiscal policy shocks - Welfare distribution

Table: Steady state welfare distributions after each shock (in terms of coefficients of variation)

	benchmark case	combined income tax financed	consumption tax financed	lump-sum tax financed	capital income tax financed	labor income tax financed
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	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0.0363$	$\tau_c = 0$	$\tau_c = 0$	$\tau_c = 0$
	$\zeta_k = 0.05$	$\zeta_k = 0.08$	$\zeta_k = 0.05$	$\zeta_k = 0.05$	$\zeta_k = 0.125$	$\zeta_k = 0.05$
(ϕ_k, ϕ_w)	$\zeta_w = 0.05$	$\zeta_w = 0.08$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.05$	$\zeta_w = 0.1$
(0.5,-0.5)	26.85	14.94	24.21	24.72	8.66	24.97
(0.75,-0.75)	15.58	8.32	13.93	14.27	4.70	14.32
(1.125,-1.125)	8.37	4.32	7.47	7.63	2.37	7.61
(0.5,0.5)	27.32	15.50	24.67	25.24	8.86	26.01
(0.75,0.75)	16.08	8.81	14.42	14.70	4.87	15.35
(1.125,1.125)	8.81	4.72	7.88	8.03	2.50	8.49

Linearization

- To check for saddle-path stability
- To document the evolution of the economy from a before-shock steady state to a post-shock one.
- Once the $z(t)$ and $\ell_i(t)$'s are obtained, $\ell(t)$, $\psi(t)$ and $k_i(t)$'s can be obtained. Following $(N+1)x(N+1)$ system is sufficient to obtain the transition path dynamics:

$$\begin{bmatrix} \dot{z} \\ \dot{\ell}_1 \\ \vdots \\ \dot{\ell}_N \end{bmatrix} = \begin{bmatrix} \frac{\partial \dot{z}}{\partial z} & \frac{\partial \dot{z}}{\partial \ell_1} & \cdots & \frac{\partial \dot{z}}{\partial \ell_N} \\ \frac{\partial \dot{\ell}_1}{\partial z} & \frac{\partial \dot{\ell}_1}{\partial \ell_1} & \cdots & \frac{\partial \dot{\ell}_1}{\partial \ell_N} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial \dot{\ell}_N}{\partial z} & \frac{\partial \dot{\ell}_N}{\partial \ell_1} & \cdots & \frac{\partial \dot{\ell}_N}{\partial \ell_N} \end{bmatrix} \begin{bmatrix} z(t) - \tilde{z} \\ \ell_1(t) - \tilde{\ell}_1 \\ \vdots \\ \ell_N(t) - \tilde{\ell}_N \end{bmatrix}$$

Transition path characterization

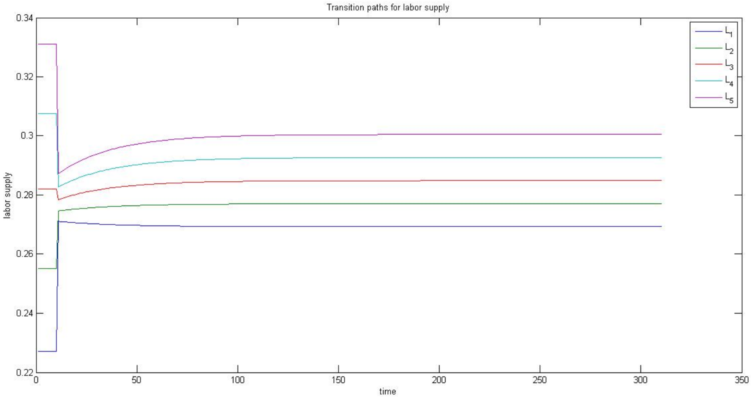
- In order to have a stable transition path, one need to have a number of negative eigenvalues equal to the number of variables persistent to shocks.
- The 6x6 linearized system for $i = 5$:

$$z(t) = \tilde{z} + [z(0) - \tilde{z}]e^{\mu t}$$
$$\ell_i(t) = \tilde{\ell}_i + \nu_i[z(t) - \tilde{z}] \qquad \forall i$$

- where μ is the stable root and the ν_i's are the components of the normalized eigenvector corresponding ℓ_i's.
- Having a combination of high levels of labor income tax progressivity, ϕ_w, and labor income tax schedule, ζ_w, may destabilize the linearized system.

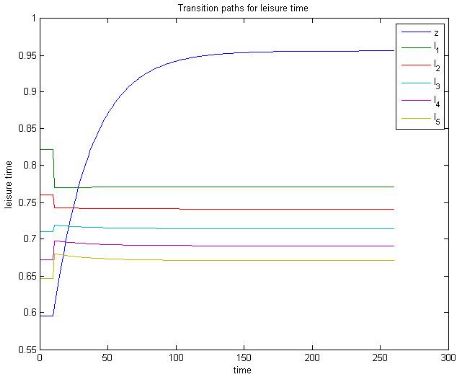
An example of the transition of labor supply

- g increases from 0.05 to 0.08 through a ζ_k shock.



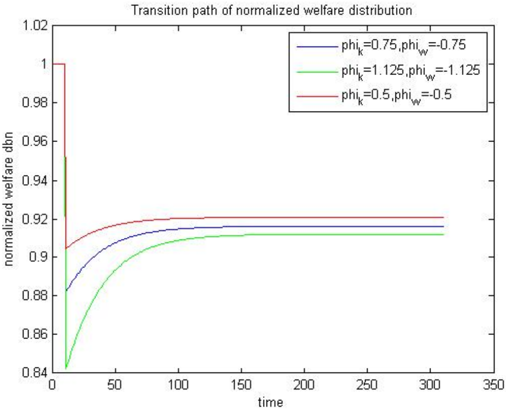
An example of the transition of government size and leisure

- g increases from 0.05 to 0.08 through a combined ζ_k, ζ_w shock.



Responses of welfare distribution under different progressivity levels

- g increases from 0.05 to 0.08 through increased lump-sum taxation.



Conclusion

- Chaterjee and Turnovsky (2012) using flat taxes, increases in public services are accompanied by worsened income distribution. By using progressive taxes to finance government services, this effect can be overcome. Still need to study the parameter space this result holds.
- Capital income tax has the strongest effects on both growth and income inequality.
- It is possible to decrease income and wealth inequality without harming GDP growth by setting a balanced progressivity level. This is accompanied by a high increase in the size of government capital.
- Possible extensions:
    - Heterogenizing the wage rates, i.e. by adding skill heterogeneity or human capital.
    - Dividing government expenditure into its components and heterogenizing in terms of regions or business groups.
    - Adding a political economy framework with disproportionately influential wealthy groups.

Growth and Income Inequality in an Endogenous Growth Model with Public Capital under Progressive Taxation

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