Public Education Expenditures, Growth and Income Inequality

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Growth and Inequality: Long-Term Effects of Short-Term Policies

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Introduction

- Public education represents a large share of GDP in most countries (5.6% in the US in 2012)
- Two potential effects of public education
  1. Increase growth
  2. Decrease inequality
- Mixed empirical results
- Recent research emphasizing the role of quality vs. quantity of education (e.g Manuelli and Seshadri (2014) , Hanushek and Woessmann (2012, 2015))

What We Do

- Revisit the relationship between public education, growth and inequality in a model with endogenous education quality (**supply side**) and occupational choice
- We show that:
  1. The effectiveness of public education policy at raising growth depends on the HC distribution
  2. The relationship between public education and inequality is potentially non-monotone (U-shaped)
- We provide empirical evidence for those predictions
- Quantitative exercise: trade-off between growth and inequality through public education policies for some countries

Model Structure

- Two-period Overlapping Generations Model of Endogenous Growth
- Young agents go to (public) school when young and accumulate human capital
- Mass one of old agents work and consume
- Heterogeneity in human capital (distribution $F(h)$) and occupational choice
  1. Worker
  2. Teacher
  3. Manager
- Human capital accumulation depends on investment in public education and the endogenous quality of teachers

Static Problem: Firms

- A firm matched with a manager with human capital h produces $y(h) = h\ n^{\alpha}$, where n are units of labor.
- Production is taxed at a rate τ to finance public education
- Workers are paid a wage w per unit of labor
- Managers receive the profit of their firms: $\pi(h) = (1-\alpha)\left(\frac{\alpha}{w}\right)^{\frac{\alpha}{1-\alpha}}[(1-\tau)h]^{\frac{1}{1-\alpha}}$

Public Education Expenditures, Teachers' Wage and Education Quality

- Government collects taxes equal to $\tau \int_M y(h)\ dF(h)$, where M is the set of managers
- Taxes are used to finance the wage of teachers and budget is balanced
- Wage of teachers: $w^T = \frac{\tau \int_M y(h)\ dF(h)}{\int_T dF(h)}$, where T is the set of teachers
- Education quality: $S = \int_T h\ dF(h)$

Static Problem: Old Agents

- Old-age utility is given by: $u = c - \mathbb{1}_T \gamma(h)$

  $\mathbb{1}_T = 1$ for teachers

  $\gamma'(h) < 0$, $\gamma''(h) > 0$

  $\lim_{h \to 0} \gamma(h) = \infty$ and $\lim_{h \to \infty} \gamma(h) = 0$.

- $Max \left[w, w^T - \gamma(h), \pi(h) \right]$

Occupational Choice: Cutoff Rule

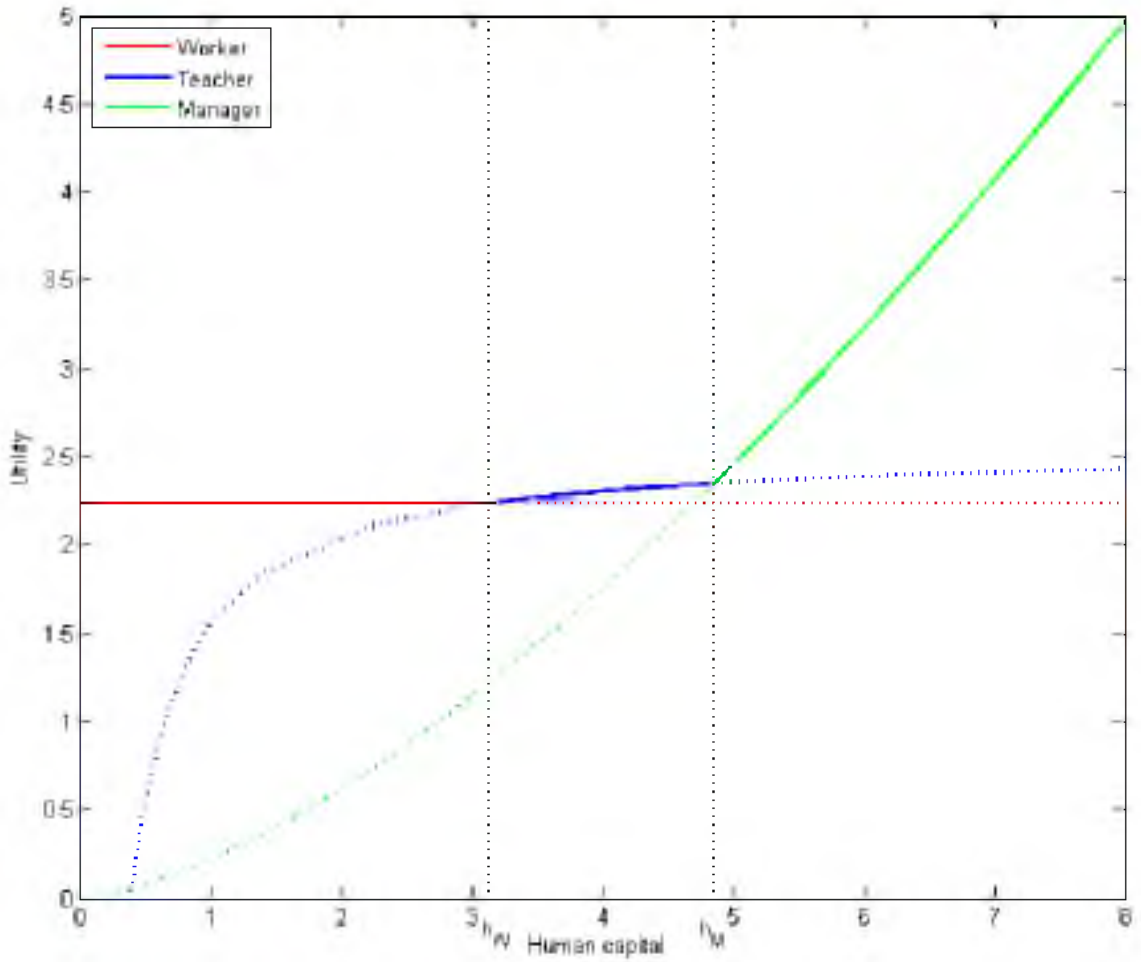

Figure: Occupational choice

$\gamma(x) = \frac{1}{x}$, $\alpha = \frac{1}{3}$, $\tau = 0.1$, $A = 1$ and F is a log-normal distribution with mean and variance equal to one

Comparative statics: τ

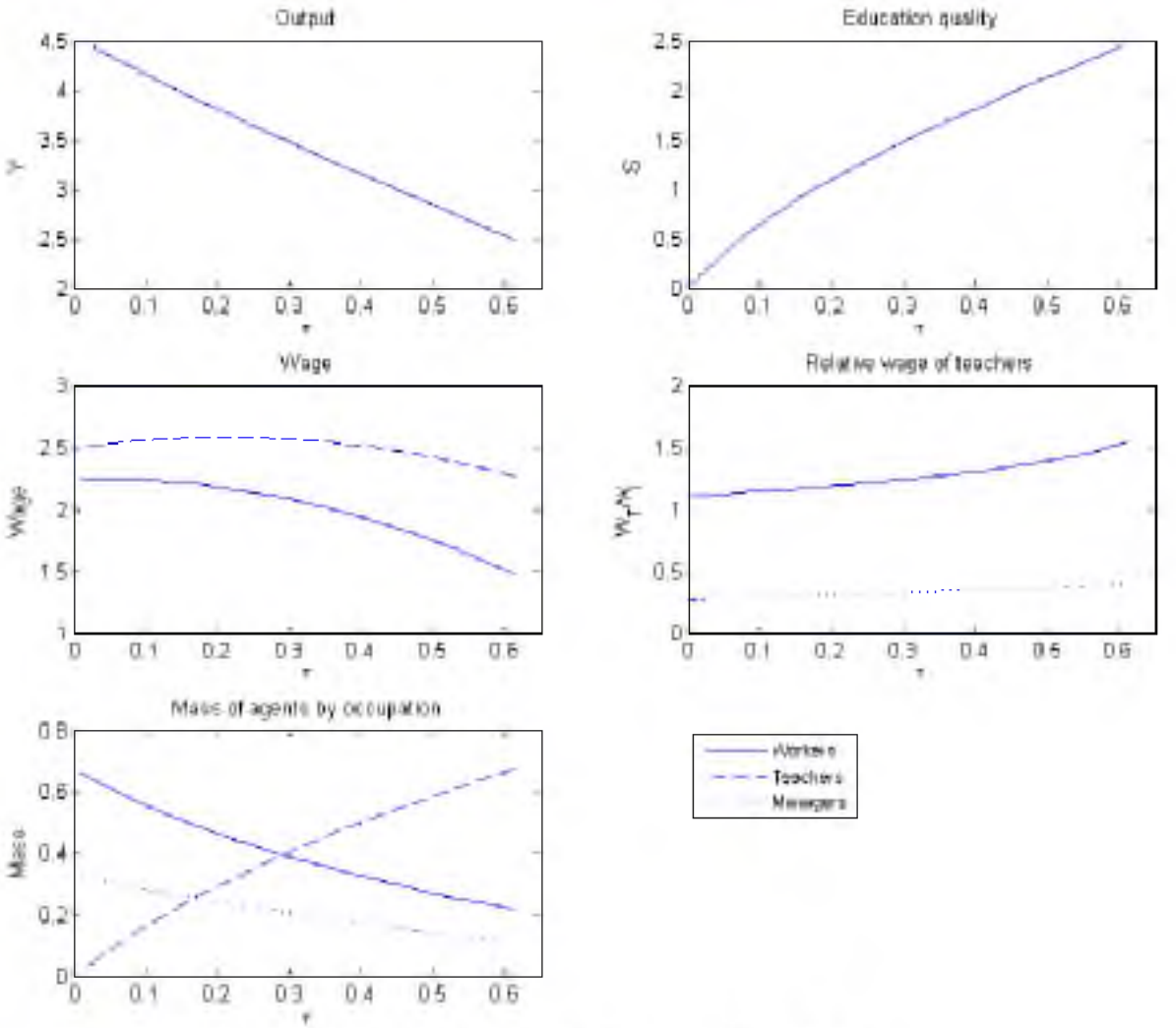

Figure: Comparative statics for τ.

$\gamma(x) = \frac{1}{x}$, $\alpha = \frac{1}{3}$ and $A = 1$. F is a log-normal distribution with mean and variance equal to one.

Dynamic Model

- Embed the static model in an OLG framework with two periods
  1. Young agents: go to school and accumulate HC
  2. Old agents: occupational choice as in static model
- Each old agent has one child
- Human capital of old agent in family i at time $t+1$:

$$h_{i,t+1} = a_{i,t} h_{i,t}^{\beta_1} s_t^{\beta_2}$$

where $a_{i,t} \sim G(a)$

Human Capital Distribution

- Assumptions:

$$\gamma_t(h) = \varphi \frac{\bar{h}_t^2}{h}$$

$$log(h_0) \sim \mathcal{N}(\mu_0, \sigma_0^2)$$

$$log(a_t) \sim \mathcal{N}(\mu_a, \sigma_a^2)$$

$$\beta_1 = 1 - \beta_2$$

- Human Capital distribution at time $t+1$:

$$log(h_{t+1}) \sim \mathcal{N}\left(\mu_a + \beta_1 \mu_t + \beta_2 log(S_t), \sigma_a^2 + \beta_1^2 \sigma_t^2\right)$$

Balanced Growth Path

Balanced Growth Path Definition: *A balanced growth path is a dynamic equilibrium in which:*

1. $h_{W,t}$, $h_{M,t}$, S_t, $Y_t = \int_{h_{M,t}}^{\infty} y_t(h)\, dF_t(h)$, w_t *and* w_t^T *all grow at the same rate* g.
2. $\sigma^2 = \frac{\sigma_a^2}{1-\beta_1^2}$
3. *The mass of workers, teachers and managers are constant.*

$$g \approx \mu_a + (1-\beta_1)\left[log(S_t) - \mu_t\right]$$

Public Education and Growth I

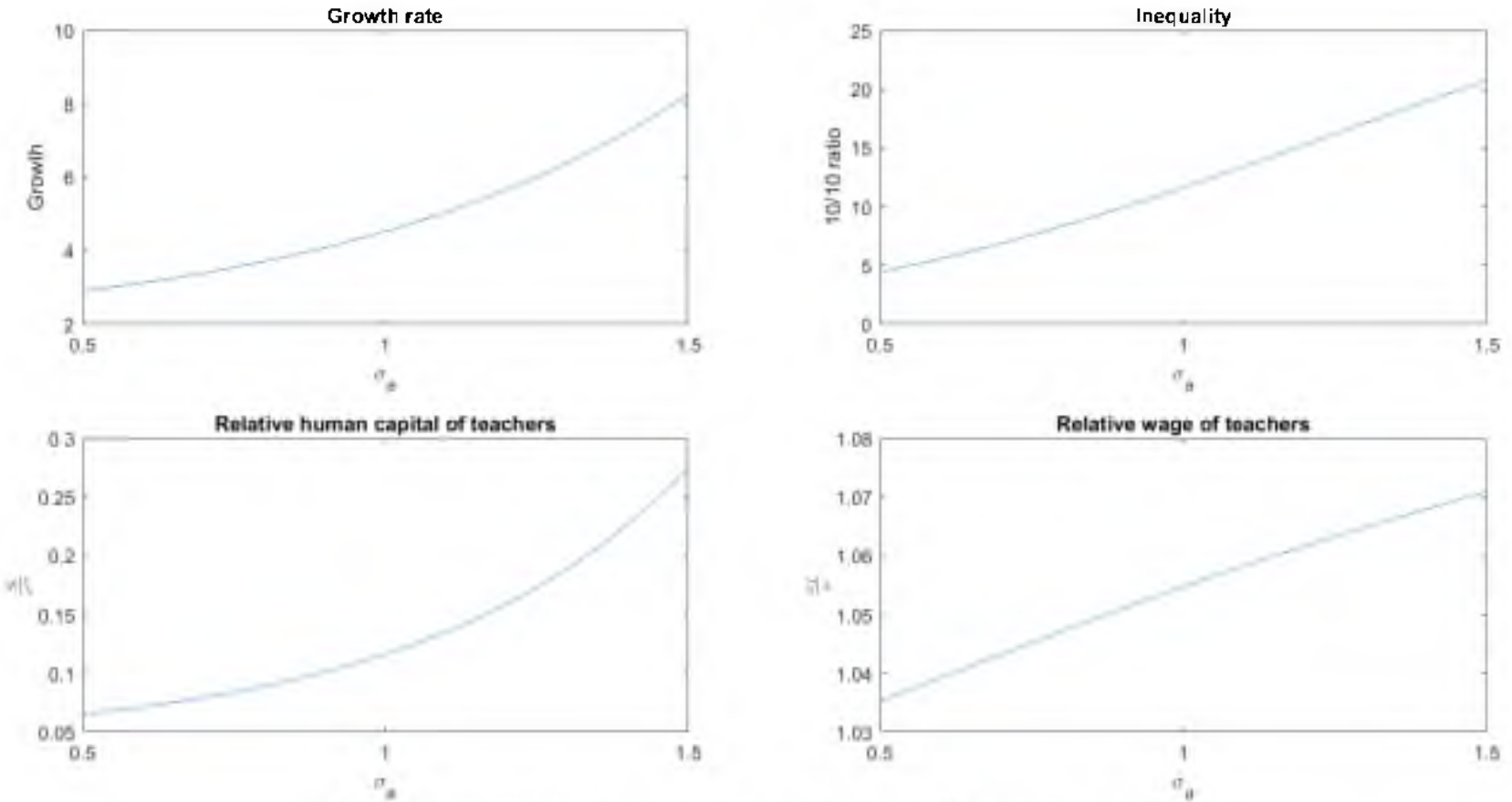

Figure: Comparative statics at the steady state: σ_a.

$\alpha = 0.2$, $\beta_1 = 0.4$, $\varphi = 0.01$, $\mu_a = 3$ and $\tau = 0.05$.

Public Education and Growth II

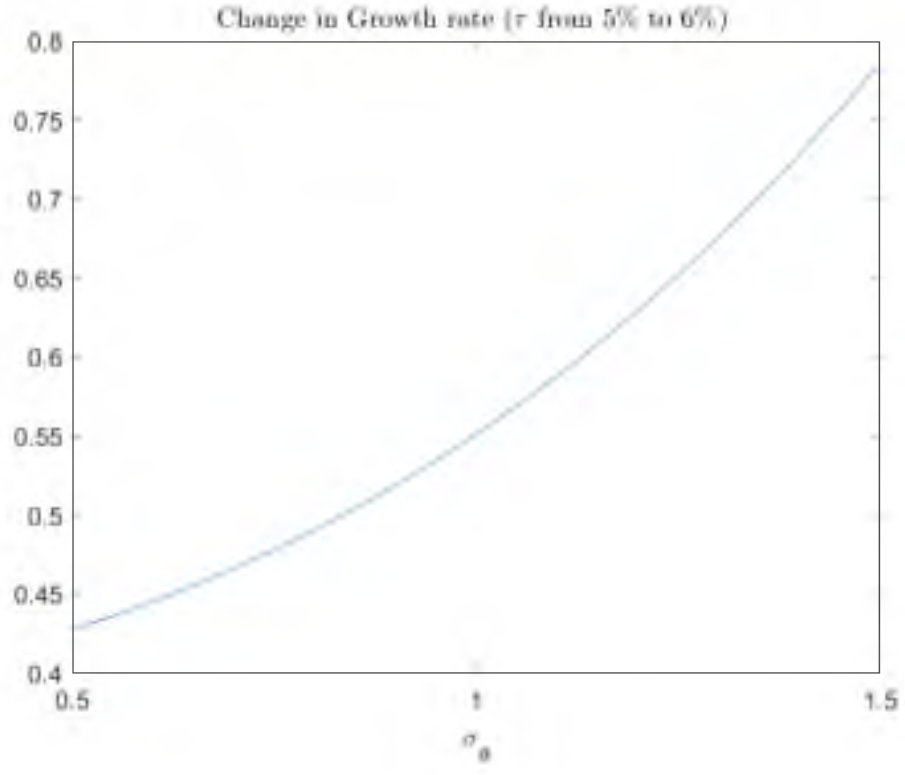

Figure: Comparative statics at the steady state: Growth effect of $\Delta\tau = 1\%$ as a function of σ_a.

$\alpha = 0.2$, $\beta_1 = 0.4$, $\varphi = 0.01$, $\mu_a = 3$ and $\tau = 0.05$

- Public education more effective at raising growth if fatter right tail of HC distribution

Public Education and Inequality I

$$10/10 ratio_t = \frac{(1-\alpha(1-\tau))\left(\frac{\alpha(1-\tau)}{w_t}\right)^{\frac{\alpha}{1-\alpha}} \int_{F_t^{-1}(0.9)}^{\infty} h^{\frac{1}{1-\alpha}}\, dF_t(h)}{0.1 w_t}$$

$$= \frac{(1-\alpha(1-\tau))(\alpha(1-\tau))^{\frac{\alpha}{1-\alpha}}}{0.1} \frac{1}{(\alpha(1-\tau))^{\frac{1}{1-\alpha}}} F_t(h_{W,t}) \frac{\int_{F_t^{-1}(0.9)}^{\infty} h^{\frac{1}{1-\alpha}}\, dF_t(h)}{\int_{h_{M,t}}^{\infty} h^{\frac{1}{1-\alpha}}\, dF_t(h)}$$

$$\frac{d(10/10\ ratio)}{d\tau} = \underbrace{Direct\ profit\ effect}_{\leq 0} + \underbrace{Direct\ labor\ demand\ effect}_{\geq 0}$$

$$+ \underbrace{Labor\ supply\ effect}_{\leq 0} + \underbrace{Manager\ distribution\ effect}_{\geq 0}$$

Public Education and Inequality II

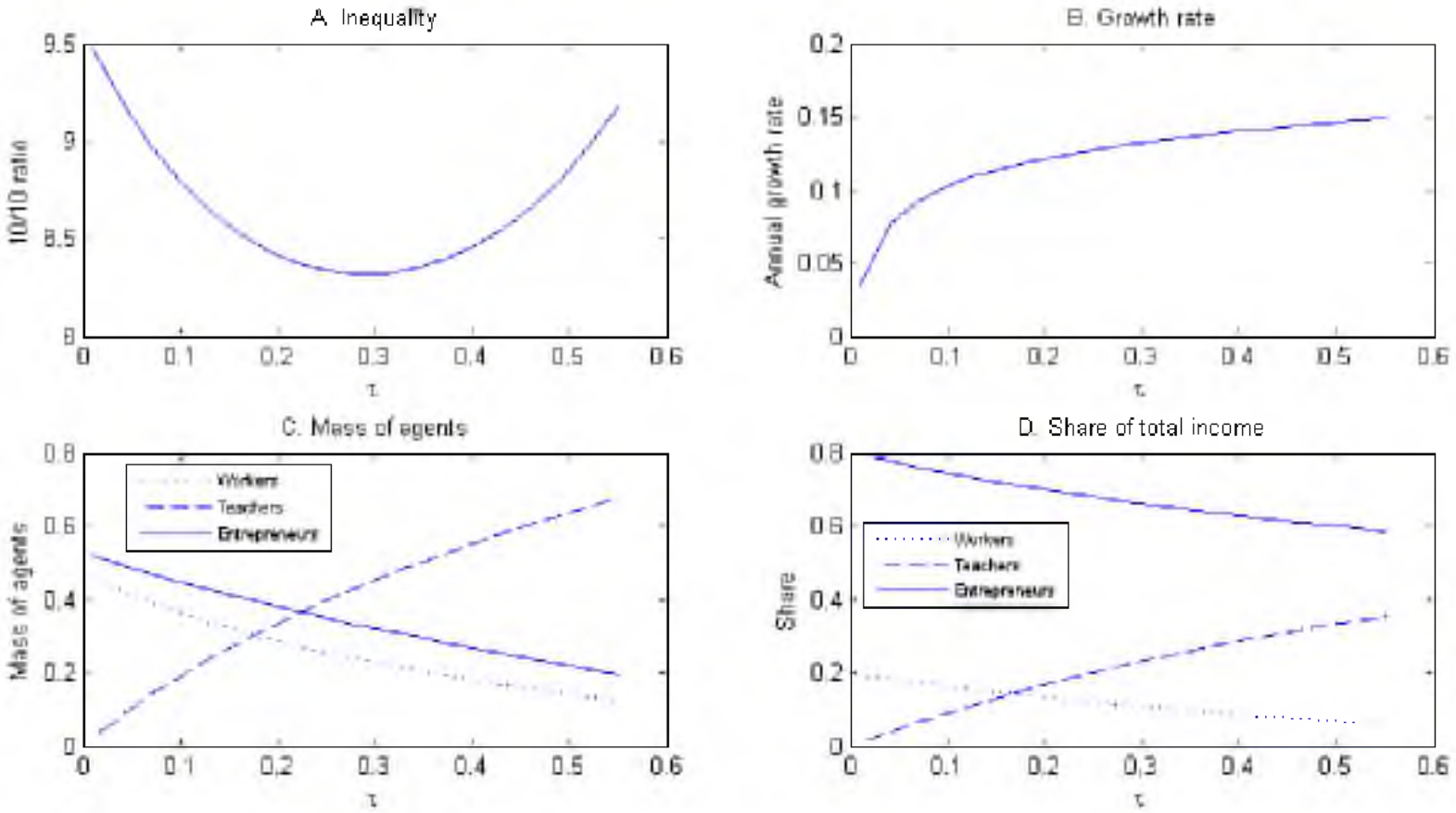

Figure: Comparative statics at the steady state: τ.

$\alpha = 0.2$, $\beta_1 = 0.4$, $\varphi = 0.01$, $\mu_a = 3$ and $\sigma_a = 0.85$

Testing Predictions of the Model

- Testing Growth and Inequality predictions of the model
- Data
  - US states for 1960, 1970, 1980, 1990, 2000 and 2010
  - Data on Per Capita Income, State and Local public education expenditures, teacher wages and measures of inequality

Public Education and Growth

	log(income)	log(income)
Pub. Educ.$_{-1}$	0.0147	-0.0357
	(0.0145)	(0.0267)
College$_{-1} * $ *Pub. Educ.*$_{-1}$		0.377**
		(0.182)
Time FE	Y	Y
Controls	Y	Y
Observations	144	144

Table: Growth Regressions: Arellano and Bover/ Blundel and Bond Estimates

Notes. US (contiguous) states from 1960 to 2010. Controls include the lag of (log) income, population, school enrollment, share of high school graduates, share of college graduates, inequality (income share of top 10%), state and local government spending (excluding education), population growth and growth of the share of high school graduates. GMM standard errors in parenthesis. Significance level: * 10%; ** 5% ; *** 1%

Public Education and Inequality

	Gini	Top 10%	Theil Index	Gini	Top 10%	Theil Index
Pub. Educ.$_{-1}$	0.0054	0.0040	0.0185	-0.0515***	-0.0468**	-0.219*
	(0.0032)	(0.0030)	(0.0126)	(0.0177)	(0.0221)	(0.113)
Pub. Educ.$^2_{-1}$				0.00478***	0.00428**	0.0200**
				(0.00142)	(0.00174)	(0.00921)
Time FE	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	143	143	143	143	143	143
R^2	0.75	0.61	0.67	0.75	0.60	0.66

Table: Inequality Regressions: First-Difference Estimates

Notes: US (contiguous) states from 1960 to 2010 Controls include the lag of income (in log), its squared value, population, school enrollment, share of high school graduates and income growth Standard errors in parenthesis (clustered at the state level) Significance level * 10%; ** 5% ; *** 1%

Quantitative Exercise I

- Use our model to estimate the potential trade-off between Growth and Inequality through public education
- Focus on 8 OECD country using data between 1991 and 2010.
- Target moments related to growth, income inequality, social mobility, share and wage of teachers.

Quantitative Exercise II

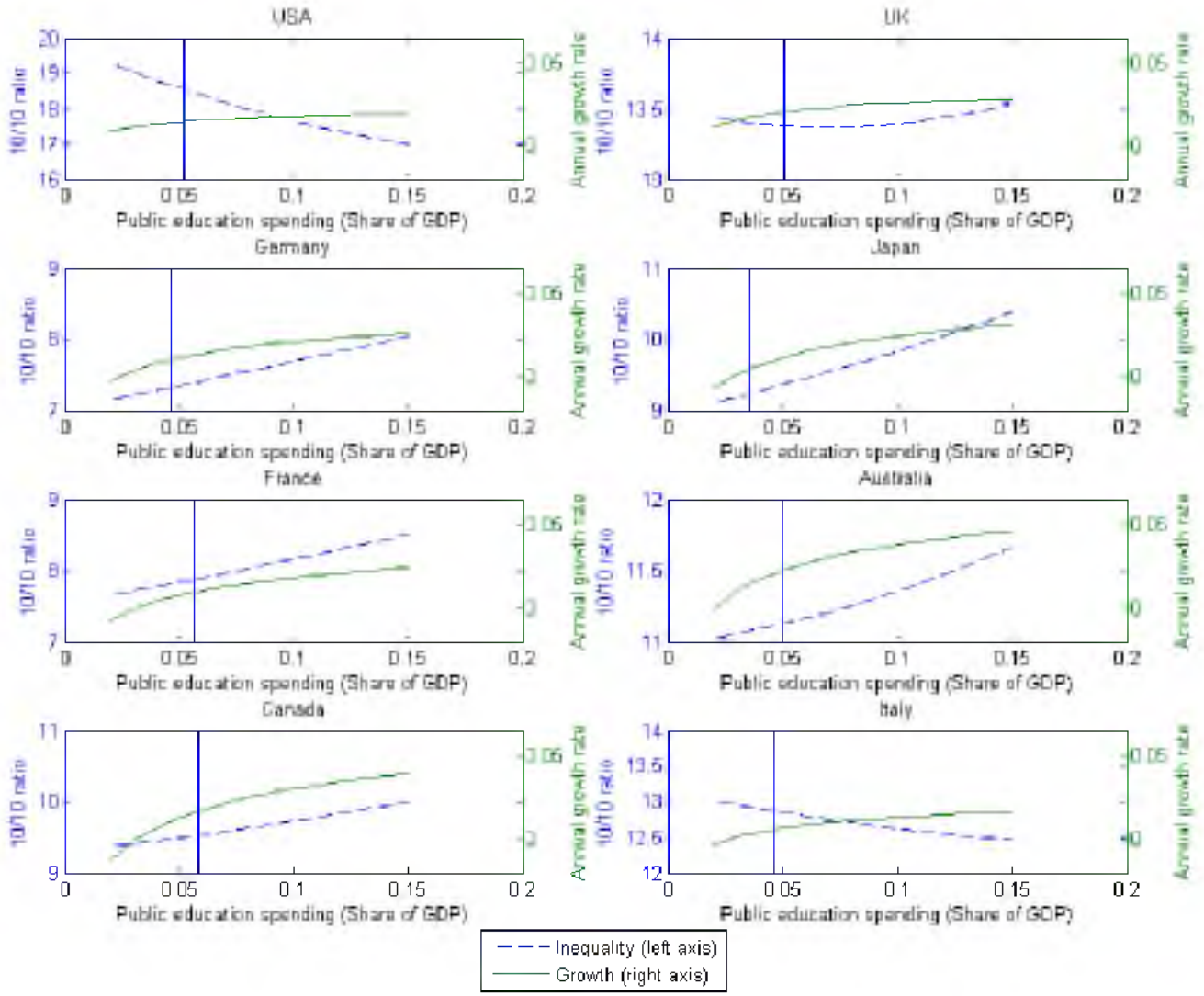

Figure: Quantitative Exercise: 8 OECD Countries (1991-2010)

Quantitative Exercise III

	Growth			Inequality(10/10 ratio)			Semi-elasticity
	Data	Prediction	Δ g	Data	Prediction	$\frac{\Delta ineq.}{ineq.}$	$\frac{\Delta ineq.}{\Delta g \ ineq.}$
Australia	2.27%	2.69%	0.42%	11.13	11.17	0.35%	0.83
Canada	1.69%	2.09%	0.40%	9.53	9.57	0.48%	1.19
France	0.97%	1.22%	0.25%	7.88	7.94	0.79%	3.11
Germany	1.06%	1.34%	0.28%	7.33	7.40	0.91%	3.24
Italy	0.60%	0.80%	0.20%	12.87	12.82	−0.41%	-2.08
Japan	0.50%	0.99%	0.49%	9.24	9.33	0.92%	1.89
UK	2.07%	2.21%	0.15%	13.38	13.37	−0.05%	-0.32
US	1.47%	1.58%	0.10%	18.54	18.34	−1.10%	-10.48

Table: Predicted change in annual growth and inequality after a one-percentage-point increase in public education spending

Conclusion

- We propose a model of Endogenous Growth with occupational choice and endogenous quality of public education.
- Growth
  1. Growth depends on the relative human capital of teachers
  2. Elasticity of growth to public education depends on HC distribution
- Inequality
  1. New mechanisms linking public education and inequality
  2. Potentially U-shaped relationship between inequality and pubilc education
- Provide empirical evidence for growth and inequality predictions of the model
- Calibrate the model to OECD countries and show that some countries face a trade-off between growth and inequality through public education

Dynamic Equilibrium

Dynamic Equilibrium Definition: *Given an initial distribution of human capital* $F_0 : \mathbb{R}^+ \to [0,1]$, *a distribution for the shock a* (G) *and a tax rate* (τ), *a dynamic equilibrium is a sequence of wages* $(w_t, w_t^T, \pi_t(h))$, *cutoffs* $(h_{W,t}, h_{M,t})$, *demand for workers* $(n_t(h))$, *education quality* (S_t) *and final good production* $(y_t(h))$ *so that, at every period:*

1. *Given wages, firms maximize profit.*
2. *Given wages, agents maximize utility by following a cutoff strategy in which agents with human capital in* $[0, h_{W,t})$ *become workers, agents with human capital in* $[h_{W,t}, h_{M,t})$ *are teachers and agents with human capital above* $h_{M,t}$ *work as managers.*
3. *Labor market clears:* $\int_{h_{M,t}}^{\infty} n_t(h)\ dF_t(h) = \int_0^{h_{W,t}}\ dF_t(h)$
4. *Government budget is balanced:* $\int_{h_{W,t}}^{h_{M,t}} w_t^T\ dF_t(h) = \int_{h_{M,t}}^{\infty} \tau y_t(h)\ dF_t(h)$
5. *Education quality is given by:* $S_t = \int_{h_{W,t}}^{h_{M,t}} h\ dF_t(h)$
6. *Human capital in the economy evolves as:* $h_{i,t+1} = a_i h_{i,t}^{\beta_1} S_t^{\beta_2}$

Country Regressions

Dep var	*Top* 10%	*Top* 20%	10/10 *ratio*	20/20 *ratio*	*gini*	*gini SWIID*
pub educ	-4 713**	-4 988**	-991 3	-446 2**	-5 377**	-4 828***
	(2 112)	(2 107)	(641 2)	(216 6)	(2 582)	(1 712)
pub educ ^{2}	58 14**	60 49**	12410 2*	5358 6**	66 72**	50 52**
	(24 27)	(23 87)	(6561 3)	(2340 7)	(28 81)	(19 38)
GDP ($1000)	-0 00520**	-0 00506**	-1 309*	-0 466**	-0 00509*	0 00101
	(0 00221)	(0 00232)	(0 683)	(0 231)	(0 00280)	(0 00256)
GDP^2	0 0000156	0 0000118	0 00574	0 00161	-0 00000727	-0 0000690
	(0 0000352)	(0 0000362)	(0 00947)	(0 00341)	(0 0000437)	(0 0000454)
growth	-0 394	-0 306	-73 73	-26 35	-0 414	-0 0778
	(0 299)	(0 315)	(107 7)	(36 01)	(0 393)	(0 301)
school	0 000478	0 000858	1 096	0 191	0 00158	-0 00150
	(0 00346)	(0 00349)	(0 990)	(0 329)	(0 00430)	(0 00328)
pub exp	-0 197	-0 215	-55 91	-8 500	-0 336	0 167
	(0 194)	(0 208)	(54 16)	(20 77)	(0 255)	(0 185)
open	-0 0146	-0 0103	-2 631	-1 096	-0 0106	-0 0195
	(0 0211)	(0 0222)	(7 823)	(2 350)	(0 0274)	(0 0191)
civil right	-0 0202***	-0 0214***	-5 117***	-1 917***	-0 0260***	-0 0218***
	(0 00561)	(0 00593)	(1 674)	(0 572)	(0 00721)	(0 00601)
priv cred	0 0604**	0 0584**	19 62**	6 505**	0 0655**	0 0412
	(0 0240)	(0 0264)	(8 660)	(2 674)	(0 0326)	(0 0269)
pop growth	2 586***	2 740***	579 6**	204 3***	3 397***	1 958**
	(0 713)	(0 708)	(228 1)	(68 97)	(0 854)	(0 763)

Teacher Wage and Inequality

	Gini	Top 10%	Theil Index
$log(Teach.\ wage_{-1})$	-3.366***	-1.717	-9.101*
	(0.885)	(1.031)	(5.111)
$log(Teach.\ wage_{-1})^2$	0.157***	0.0815*	0.427*
	(0.0406)	(0.0473)	(0.235)
Time FE	Y	Y	Y
Controls	Y	Y	
Observations	143	143	143
R^2	0.75	0.60	0.66

Table: Inequality Regressions: First-Difference Estimates

Notes: US (contiguous) states from 1960 to 2010. Controls include the lag of income (in log), its squared value, population, school enrollment, share of high school graduates and income growth. Standard errors in parenthesis (clustered at the state level). Significance level: * 10%; ** 5% ; *** 1%

Canada		France		Germany	
Data	Model	Data	Model	Data	Model
0.40	0.40	0.21	0.21	0.23	0.23
9.5	9.5	7.9	7.9	7.3	7.3
0.06	0.09	0.06	0.08	0.05	0.07
1.08	1.09	1.08	1.08	1.04	1.04
0.19	0.19	0.41	0.41	0.32	0.32

Japan		UK		US	
Data	Model	Data	Model	Data	Model
0.11	0.11	0.51	0.51	0.34	0.34
9.2	9.2	13.4	13.4	18.5	18.5
0.04	0.05	0.08	0.10	0.09	0.13
1.25	1.25	1.11	1.11	1.02	1.03
0.34	0.34	0.50	0.50	0.47	0.47

Calibration results

	Australia	
	Data	Model
GDP growth	0 57	0 57
10/10 ratio	11 1	11 1
Share of teachers	0 07	0 08
Teacher wage relative to other workers	1 14	1 14
Income elasticity	0 26	0 26

	Italy	
	Data	Model
GDP growth	0 13	0 13
10/10 ratio	12 9	12 9
Share of teachers	0 06	0 09
Teacher wage relative to other workers	1 01	1 02
Income elasticity	0 50	0 50

Table: Targeted moments: model vs data

Germany	Italy	Japan	UK	US
0.597	0.386	0.489	0.396	0.301
0.604	0.737	0.542	0.767	0.828
0.165	0.018	0.414	0.130	0.015
0.531	0.365	0.865	0.542	0.331
1.018	1.030	1.019	1.059	1.093

Parameter Values

	Australia	Canada	France
α	0.434	0.489	0.528
β_1	0.417	0.338	0.624
ψ	0.178	0.140	0.119
μ_a	1.085	0.982	0.725
σ_a	1.255	1.215	0.820

Table: Parameter values