Machines, Buildings, and Optimal Dynamic Taxes

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November 1, 2013
CERGE-EI

Motivation

Differential Taxation of Capital Assets (DTC):

- U.S. statutory tax rate on *all* corporate income is 35%.
- However, *effective* marginal tax rates on income from capital assets vary with asset type (Auerbach 1983; Gravelle 2011).
- Example (Gravelle 2011):
  - capital equipments: 26%,
  - capital structures: 32%.
- How? Via capital type specific tax depreciation rules that differ from actual economic depreciation. ▸ Differential Asset Taxation

Motivation

Reform proposals:

- Since 70's, many proposals (both academic and policy) to abolish tax differentials.
- President Obama State of the Union Address (2011): abolish the tax rules that create differential taxation of capital assets in order to "*level the playing field*" across companies.
- Similarly the Framework for Business Tax Reform (2012) calls for a reform that "*... would eliminate dozens of different tax expenditures and fundamentally reform the business tax base to reduce distortions that hurt productivity and growth.*"

Contribution

This paper:

- Uncovers an economic mechanism that provides a theoretical justification for optimality of DTC.
- Analyzes the importance of this mechanism in terms of tax differentials and welfare quantitatively.

Key Model Ingredients

- People skilled or unskilled, skill level changes over time.
- Gvt. wants to spend, provide insurance and redistribution.
- Gvt. has access to a large set of taxes (NDPF).
- Two types of capital: equipments (i.e., machines and software) and structures (i.e., non-residential buildings).
- **Equipment-skill complementarity**: (KORV, 2000)
  - Degree of complementarity between equipment and skilled labor is higher than that between equipment and unskilled.
  - Structure capital neutral.

Preview of Results

- Main theoretical results:
  - Differential taxation of capital is optimal.
  - Relevant case: Tax on equipment capital higher than on structure capital (in each period).

    At odds with actual U.S. code: on average, equipment capital taxed 5 p.p. less than structure capital.
- Main quantitative results:
  - Optimal tax on equipment capital more than 25 p.p. higher than on structure capital (in all periods including long-run).
  - Welfare gains of optimal DTC up to 0.4%.

Mechanism and Interpretation

DTC as an indirect redistribution tool:

- Gvt wants to redistribute from skilled to unskilled.
- $\uparrow$ eq. capital taxes $\Rightarrow \downarrow$ eq. capital level $\Rightarrow \downarrow$ skill premium $\Rightarrow$ (indirect) redistribution from skilled to unskilled.
- As long as labor income taxes distortionary, optimal to use this channel as well.

General point:

- We know: If non-distortionary redistribution (insurance) not possible, optimal to use distortionary channels.
- This paper uncovers and analyzes one such channel.

Related Literature

- Diamond and Mirrlees (1971).
    - Optimal tax systems maintain productive efficiency.
- Optimality of DTC: Auerbach (1979).
    - OLG without heterogeneity, with restrictions on labor taxes.
- (Static) optimal tax model with endogeneous wages: Stiglitz (1982), Naito (1999).
- New Dynamic Public Finance: Golosov et al (2003).
    - Does not analyze DTC.

Rest of the Talk

- Environment.
- Theoretical results.
- Quantitative analysis.
- Conclusions.

Environment

Environment

∞ horizon growth model with:

- Government and a measure 1 of agents.
- 2 types of capital: equipments and structures.
- 2 types of labor (skilled and unskilled).

Agent Heterogeneity

- In each period skilled or unskilled, $j \in H = \{s, u\}$.
- Skills drawn from a general stochastic process π.
- $\pi_t(h^t)$ probability of partial history $h^t \in H^t$.

Production Function

$$F(K_s, K_e, L_s, L_u)$$

- K_s structure capital. K_e equipment capital.
- L_s aggr. skilled labor. L_u aggr. unskilled labor.
- **Assumption.** Skilled (unskilled) have to work in skilled (unskilled) occupation.
- Define: $\widetilde{F} = F + (1 - \delta_s)K_s + (1 - \delta_e)K_e$.

Assumption. The ratio of MPL's (wage ratio, skill premium):

1. $\frac{w_s}{w_u}$ is independent of K_s.
2. $\frac{w_s}{w_u}$ is strictly increasing in K_e.
3. $\frac{w_s}{w_u}$ is strictly decreasing in L_s.
4. $\frac{w_s}{w_u}$ is strictly increasing in L_u.

Utility, Allocation and Feasibility

- **Utility.** $\sum_{t=1}^{\infty} \sum_{h^t \in H^t} \pi_t(h^t)\beta^{t-1}\left[u(c_t(h^t)) - v(l_t(h^t))\right]$

- **Allocation.** An allocation is $x = (c_t(h^t), l_t(h^t), K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t})_{t=1}^{\infty}$.

- **Feasibility.** An allocation is feasible if

$$\sum_{h^t \in H^t} \pi_t(h^t)c_t(h^t) + K_{s,t+1} + K_{e,t+1} + G_t \leq \widetilde{F}(K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t}).$$

Government's Problem

- Gvt.'s objective: Maximize agents' welfare + finance G_t.
- NDPF approach: Choose a tax schedule, which can be arbitrarily non-linear in people's history of income.
- Restriction: Tax schedule cannot depend on skill, occupation or labor supply directly.

Social Planner's Problem

- Following NDPF, we transform the tax problem to an auxiliary social planner's problem (SPP).
- In SPP the planner chooses allocation directly s.t. *incentive compatibility constraints*.
- After we solve (characterize) the SPP, we recover the properties of optimal taxes from the optimal allocation.

Social Planner's Problem

- People's skill types are privately known to themselves.
- People are assigned consumption c and asked to generate income $y = w \cdot l$ based on their report (history).
- Allocation should be s.t. agents report their true types, i.e. allocation satisfies incentive compatibility constraints.
- Incentive compatibility constraints are the analog of the restriction on taxes.

▸ Incentive Constraints

Social Planner's Problem

$$\max_{c,l,K_s,K_e} \sum_{t=1}^{\infty} \sum_{h^t \in H^t} \pi_t(h^t)\beta^{t-1}\left[u(c_t(h^t)) - v(l_t(h^t))\right]$$

s.t. incentive compatibility and feasibility constraints.

Theoretical Results

Optimality of DTC via a Simple Example

- Suppose $T = 2$.
- Types are permanent: those who start (un)skilled remain so.
- Gvt. wants to redistribute from the rich to the poor.
- $G_1 = G_2 = 0$.
- $K_{1,s}$ and $K_{1,e}$ are given.

Planning Problem:

$$\max_{c,l,K_s,K_e} \sum_{h=u,s} \pi_h [u(c_1(h)) - v(l_1(h)) + \beta u(c_2(h)) - \beta v(l_2(h))]$$

s.t.

$$\sum_{h=u,s} \pi_h c_1(h) + K_{2,s} + K_{2,e} \leq \widetilde{F}(K_{1,s}, K_{1,e}, L_{1,s}, L_{1,u}) \qquad (\lambda_1)$$

$$\sum_{h=u,s} \pi_h c_2(h) \leq \widetilde{F}(K_{2,s}, K_{2,e}, L_{2,s}, L_{2,u}) \qquad (\lambda_2)$$

$$u(c_1(s)) - v(l_1(s)) + \beta u(c_2(s)) - \beta v(l_2(s)) \qquad (\mu)$$
$$\geq u(c_1(u)) - v\left(\frac{l_1(u)w_1(u)}{w_1(s)}\right) + \beta u(c_2(u)) - \beta v\left(\frac{l_2(u)w_2(u)}{w_2(s)}\right)$$

Optimality of DTC via a Simple Example

FOC's:

$$
\begin{aligned}
(K_{s,2}) \quad &: \quad -\lambda_1 + \lambda_2 \widetilde{F}^*_{s,2} = 0, \\
(K_{e,2}) \quad &: \quad -\lambda_1 + \lambda_2 \widetilde{F}^*_{e,2} + X^*_2 = 0.
\end{aligned}
$$

Here

$$
X^*_2 = \mu \beta v' \left(\frac{l^*_2(u) w^*_2(u)}{w^*_2(s)} \right) l^*_2(u) \frac{\partial \left(\frac{w^*_2(u)}{w^*_2(s)} \right)}{\partial K_{e,2}} < 0,
$$

since equipment-skill complementarity implies

$$
\frac{\partial \left(\frac{w^*_2(u)}{w^*_2(s)} \right)}{\partial K_{e,2}} < 0.
$$

So

$$
\widetilde{F}^*_{s,2} = \widetilde{F}^*_{e,2} + \frac{X^*_2}{\lambda^*_2} < \widetilde{F}^*_{e,2}.
$$

Optimality of DTC via a Simple Example

- Why $\widetilde{F}^*_{s,2} < \widetilde{F}^*_{e,2}$?
- Increasing equipment capital has an extra cost: increasing the skill premium tightens the IC.
- Therefore: K_e level $\downarrow$ relative to $\widetilde{F}^*_{s,2} = \widetilde{F}^*_{e,2}$.
- As a result: $\widetilde{F}^*_{s,2} < \widetilde{F}^*_{e,2}$.
- Intuition: $K_e \downarrow \Rightarrow$ skill premium $\downarrow$ thus providing indirect redistribution from skilled to unskilled.
- In general: $\widetilde{F}^*_{s,2} \neq \widetilde{F}^*_{e,2}$ (direction depends which IC's bind).

General Results

Proposition: At the optimal allocation, in any t :

$$\widetilde{F}^*_{s,t+1} = \widetilde{F}^*_{e,t+1} + \frac{X^*_{t+1}}{\lambda^*_{t+1}},$$

$$X^*_{t+1} = \sum_{\left\{h^{t+1} \in H^{t+1}\right\}} \mu^*_{t+1}(h^{t+1}) v' \left(\frac{l^*_{t+1}(h^t, h^o_{t+1}) w_{t+1}(h^o_{t+1})}{w_{t+1}(h_{t+1})} \right) l^*_{t+1}(h^t, h^o_{t+1}) \frac{\partial \frac{w_{t+1}(h^o_{t+1})}{w_{t+1}(h_{t+1})}}{\partial K^*_{e,t+1}}.$$

- X_{t+1} more complicated because there are many more IC's.
- Same logic: K_e changes the wage ratio affecting the IC's.

Inverse Euler Equations

Implication: IEE satisfied for K_s, but not for K_e.

Proposition:

1. Following any history h^t, the optimality condition for K_s is:

$$\frac{1}{u'(c_t^*(h^t))} = \frac{1}{\beta \tilde{F}_{s,t+1}^*} E_t \left\{ \frac{1}{u'(c_{t+1}^*(h^{t+1}))} | h^t \right\}.$$

   As in Rogerson (1985), GKT (2003).

2. Following any history h^t, the optimality condition for K_e is:

$$\frac{1}{u'(c_t^*(h^t))} = \frac{1}{\beta \left(\tilde{F}_{e,t+1}^* + X_{t+1}^* / \lambda_{t+1}^* \right)} E_t \left\{ \frac{1}{u'(c_{t+1}^*(h^{t+1}))} | h^t \right\}.$$

What are the implications for optimal distortions?

Definition: The intertemporal/capital wedge $\tau_{K,i}(h^t)$ is:

$$u'(c_t^*(h^t)) = \left(1 - \tau_{K,i}(h^t)\right) \cdot \beta \widetilde{F}_{i,t+1}^* E_t \left\{ u'(c_{t+1}^*(h^{t+1})) | h^t \right\}$$

Proposition: Wedges on structure and equipment capital satisfy:

$$\tau_{K,s}(h^t) \quad > \quad 0 \qquad \text{[Rogerson (1985), GKT (2003)]}$$

$$\left[1 - \tau_{K,e}(h^t)\right] \quad = \quad \left[1 + \frac{X_{t+1}^* / \lambda_{t+1}^*}{\widetilde{F}_{e,t+1}^*}\right] \left[1 - \tau_{K,s}(h^t)\right]$$

Follows from non-arbitrage condition.

Non-arbitrage Condition

Summary

1. Optimality of DTC: Generically, structure capital wedge is different from the equipment capital wedge:

$$\tau_{K,s}(h^t) \neq \tau_{K,e}(h^t).$$

2. Relevant case: With redistribution from skilled to unskilled (downward IC's binding):

$$\tau_{K,s}(h^t) < \tau_{K,e}(h^t).$$

   Note: in the U.S. tax code the opposite.

3. Extra wedge on equipment capital is history independent; so can be applied at the corporate level (through differences in depreciation allowances as in the U.S. tax code).

Intratemporal Wedges

Definition: The intratemporal/labor wedge $\tau_Y(h^t)$ is:

$$v'(l_t^*(h^t)) = \left(1 - \tau_Y(h^t)\right) \cdot w_t^*(h_t) u'(c_t^*(h^t))$$

Proposition: The labor wedge on the skilled is negative in the relevant case (i.e., skilled labor is subsidized on the margin):

$$\tau_{Y,s}(h^t) \quad < \quad 0.$$

- Unlike in a model without complementarity, in which "*no distortion at the top*" holds, i.e. $\tau_{Y,s}(h^t) = 0$.
- Intuition: $L_{s,t} \uparrow \Rightarrow$ skill premium$\downarrow$, indirect redistribution.
- Generalizes the Stiglitz (1982) result to a dynamic environment with capital.

Skill Biased Technological Change

- Modify the feasibility constraint:

$$\sum_{h^t \in H^t} \pi_t(h^t) c_t(h^t) + K_{s,t+1} + q_t K_{e,t+1} \leq$$
$$F(K_{s,t}, K_{e,t}, L_{s,t}, L_{u,t}) + (1 - \delta_s) K_{s,t} + (1 - \delta_e) q_t K_{e,t}.$$

- Assume that q_t, the relative price of K_e, changes over time.
- Can recover the results from above.

Implementation

- We characterized the solution to SPP.
- How to achieve it in incomplete markets with taxes?
- At the consumer level (a la Kocherlakota, 2005):
  - History dependent and non-linear labor income taxes to set labor wedges and income transfers correctly.
  - History dependent, linear savings tax, to create savings wedge.
- At the corporate level:
  - Differential (effective) taxes on equipment and structure capital income.
  - Tax differential created through differences in depreciation allowances as in the U.S. tax code.

Summary and Next

- Summary:
  - Optimal to tax structure and equipment capital differentially (due to equipment capital-skill complementarity).
  - Relevant case: Tax equipment capital more than structure capital (unlike in the U.S. tax code).
- Next:
  - Does DTC matter quantitatively?

Quantitative Results

Quantitative Analysis

Overview:

- Consider a model with permanent skill types. ▸ Permanent Types
- Calibrate model parameters in a competitive equilibrium (CE) with the current U.S. tax system.
- Solve for optimal taxes using the calibrated parameters.
- Assess the importance of differential capital taxation.

Table : Government Policy Parameters

Parameter	Symbol	Value	Source
Tax on labor income	τ_l	0.27	HSV (2010)
Tax on structure capital income	τ_s	0.422	Gravelle (2011)
Tax on equipment capital income	τ_e	0.371	Gravelle (2011)
Government expenditure	G/Y	0.16	NIPA 1980 - 2012

Calibrating the Model Economy

Parameterization:

- Production function: use KORV (2000).

  $$Y = K_s^{\alpha}\left(\nu\left[\omega K_e^{\rho} + (1-\omega)L_s^{\rho}\right]^{\frac{\eta}{\rho}} + (1-\nu)L_u^{\eta}\right)^{\frac{1-\alpha}{\eta}}$$

  Use parameters from KORV (2000), calibrate ω and ν.

- Utility: $u(c,l) = \frac{c^{1-\sigma}}{1-\sigma} - \phi\frac{l^{1+\gamma}}{1+\gamma}$.

  In benchmark use $\sigma = 2, \gamma = 1$, calibrate β and ϕ.

Benchmark Parameters

Calibrating the Model Economy

Table : Calibrated Parameters

Parameter	Value	Target	Data value
Discount factor (β)	0.985	Capital to output ratio	2.9
Disutility of labor (ϕ)	67.8	Labor supply	1/3
Income share of K_e (ω)	0.477	Labor share	2/3
1 - income share of L_u (ν)	0.657	Skill premium	1.8

Optimal Dynamic Taxes

- With the calibrated parameters, we solve the dynamic social planner's problem (SPP).
- Gvt. needs to finance the same level of expenditure.
- Gvt. starts with initial capital levels of CE, economy converges to a new steady state.
- Endogenous factor prices critical: need general equilibrium.

Steady State Comparison

Optimal Capital Income Taxes

Table : Optimal (Linear) Capital Income Taxes in Steady State

	τ_e^{ss}	τ_s^{ss}
CE	37%	42%
Optimal	40%	0%

- Optimal tax on structure capital is zero (in every period) - uniform commodity taxation result.
- Optimal tax on equipment capital is strictly positive (in every period) to decrease skill premium - indirect redistribution.
- Chamley-Judd result does not apply: $\tau_e \nrightarrow 0$.

Optimal Labor Wedges

Table : Optimal Labor Wedges in Steady State

	$\tau_{y,s}^{ss}$	$\tau_{y,u}^{ss}$
Optimal	-11%	27%

- Skilled agents subsidized on the margin.
- Unskilled agents taxed on the margin.
- Encourages skilled labor, discourages unskilled labor and decreases the skill premium - indirect redistribution.

Optimal Indirect Redistribution

Table : Indirect Redistribution in Steady State

	K_e/K_s	l_s/l_u	Skill premium
CE	1.02	0.82	1.80
Optimal	0.93	1.11	1.47

- Equipment capital tax depresses K_e relative to K_s.
- Marginal subsidy (tax) on skilled (unskilled) increases L_s relative to L_u.
- Both decrease skill premium, creating indirect redistribution.

Direct Redistribution

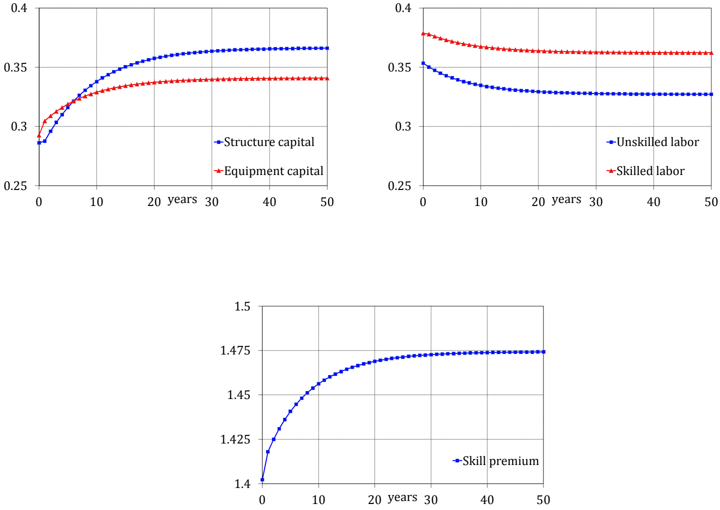
Table : Optimal *Average* Labor Taxes in Steady State

skilled	unskilled
18%	6%

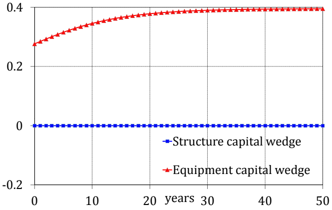
- Direct redistribution achieved via deductions/taxes that depend on income brackets.

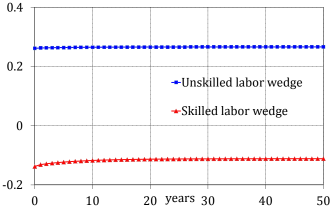
Transition

Allocations at the Constrained Efficient Allocation



Wedges at the Constrained Efficient Allocation





Welfare Gains

Welfare Gains of Differential Taxation of Capital

- Analyze welfare differences between 3 tax systems:
  - Optimal DTC.
  - Optimal NDTC: Both capitals taxed at the same rate.
  - Current DTC : $\tau_s = 42\%$ and $\tau_e = 37\%$.
- Labor taxes chosen optimally in all 3 tax systems.
- Benchmark welfare gains:
  - Partial: Optimal DTC - Optimal NDTC $= 0.05\%$.
  - Full: Optimal DCT - Current DTC $= 0.19\%$.

Table : Welfare Gains from DTC

σ	$\gamma = 1$		γ	$\sigma = 2$	
	Full	Partial		Full	Partial
1	0.24%	0.23%	0.5	0.20%	0.10%
2	0.19%	0.14%	1	0.19%	0.14%
4	0.21%	0.07%	2	0.22%	0.21%

- Welfare gains of full reform 0.17% – 0.29% for other parameter combinations (in the matrix).
- Up to 0.4% for higher complementarity.
- Welfare gains larger for a non-utilitarian planner.

Welfare Gains of Differential Taxation of Capital

- Recall: Welfare gains of DTC are computed when labor taxes optimally chosen and no shocks.
- Welfare gains of differential capital taxation different with:
  - current labor tax code,
  - labor productivity shocks.
- Topic of ongoing research.

Conclusions

- We uncover a mechanism which calls for taxing equipment capital more heavily than structure capital.
- Reason is intuitive: Decreases skill premium, providing indirect redistribution (insurance).
- Substantial tax differentials between structure and equipment capital along the transition and in the long run.
- Welfare gains from DTC are considerable, even with no shocks and labor income taxes optimally chosen.

Differential Asset Taxation

- τ : statutory corporate income tax rate.
  k_i : amount of capital type i.
  F_i : gross return to capital type i.
  d_i : economic depreciation rate of i.
  $\bar{d}_i$: tax depreciation of i.

- Effective rate is the actual fraction of income of an asset that is paid as tax:
$$\bar{\tau}_i = \frac{(F_i - \bar{d}_i)k_i\tau}{(F_i - d_i)k_i}.$$

- If $\bar{d}_i = d_i$ for all i, then $\bar{\tau}_i = \tau$. (Samuelson, 1964)

- If $\bar{d}_i > (<) d_i$, then $\bar{\tau}_i < (>) \tau$.

▸ Return

Non-arbitrage Condition

- Recall the capital return wedge:

$$\widetilde{F}^*_{s,t+1} = \widetilde{F}^*_{e,t+1} + \frac{X^*_{t+1}}{\lambda^*_{t+1}}.$$

- Therefore the following 2 are equivalent:

$$\left[1 - \tau_{K,e}(h^t)\right] = \left[1 + \frac{X^*_{t+1}/\lambda^*_{t+1}}{\widetilde{F}^*_{e,t+1}}\right]\left[1 - \tau_{K,s}(h^t)\right],$$

$$\widetilde{F}^*_{e,t+1}\left[1 - \tau_{K,e}(h^t)\right] = \widetilde{F}^*_{s,t+1}\left[1 - \tau_{K,s}(h^t)\right].$$

Return

Incentive Constraints

- Define:
  - Report at t: $\sigma_t : H^t \to \{u, s\}$.
  - A reporting strategy is $\sigma = (\sigma_t)_{t=1}^{\infty}$.
  - Truth telling σ^*: $\forall h^t$, $\sigma_t^*(h^t) = h_t$.
- Define the expected discounted value of using reporting strategy σ given an allocation x:

$$W(\sigma|x) = \sum_{t=1}^{\infty} \sum_{h^t \in H^t} \pi_t(h^t)\beta^{t-1} \left[u(c_t(\sigma(h^t))) - v\left(\frac{l_t(\sigma(h^t))w_t(\sigma_t(h^t))}{w_t(h_t)} \right) \right].$$

- An allocation is incentive-compatible if $\forall \sigma$

$$W(\sigma^*|x) \geq W(\sigma|x).$$

▸ Return

Simplifying the Incentive Constraints

- One Stage Deviation Property: An allocation is incentive compatible if and only if it is *temporary* incentive compatible.
- Meaning: The planner needs to worry about deviation strategies that have lying in one node only.

$$
\begin{gathered}
u(c_t(h^{t-1}, h_t)) - v(l_t(h^{t-1}, h_t)) \\
+ \textstyle\sum_{m=t+1}^{\infty} \sum_{\{h^m \in H^m | h^m \succ h^t\}} \pi_m(h^m) \beta^{m-t} \left[u(c_m(h^m)) - v(l_m(h^m))\right] \\
\geq \\
u(c_t(h^{t-1}, h_t^o)) - v\left(\frac{l_t(h^{t-1}, h_t^o) w_t(h^{t-1}, h_t^o)}{w_t(h^{t-1}, h_t)}\right) \\
+ \textstyle\sum_{m=t+1}^{\infty} \sum_{\{h^m \in H^m | h^m \succ h^t\}} \pi_m(h^m) \beta^{m-t} \left[u(c_m(\tilde{h}^m)) - v(l_m(\tilde{h}^m))\right]
\end{gathered}
$$

Return

Permanent Types

We abstract from skill shocks.

3 reasons:

1. Initial heterogeneity accounts for most of the variation in lifetime earnings:
   - Huggett, Ventura, Yaron (AER, 2011) over 60%.
   - Storesletten et al. (JME, 2004) almost 50%.
   - Keane and Wolpin (JPE, 1997) as high as 90%.
2. If there is an (imperfect) insurance channel for labor income shocks, then they are less important in designing tax system.
3. We identify skilled as college graduates. This characteristics is not changing over time.

Return

Calibrating the Model Economy

Table : Benchmark Parameters Taken from Literature and Data

Parameter	Symbol	Value	Source
CEIS coefficient	σ	2	
Inverse Frisch elasticity	γ	1	
K_s depreciation rate	δ_s	0.056	GHK (1997)
K_e depreciation rate	δ_e	0.124	GHK (1997)
Output share of K_s	α	0.117	KORV (2000)
Elasticity of subs. between K_e and L_u	η	0.401	KORV (2000)
Elasticity of subs. between K_e and L_s	ρ	-0.495	KORV (2000)
Tax on labor income	τ_l	0.27	HSV (2010)
Tax on structure capital income	τ_s	0.422	Gravelle (2011)
Tax on equipment capital income	τ_e	0.371	Gravelle (2011)
Government expenditure	G/Y	0.16	NIPA 1980 - 2012
Relative supply of skilled workers	p_s/p_u	77.8%	U.S. Census 2010
Relative wealth of skilled workers		2.680	U.S. Census 2010

Return