6
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7
Appendix

7.1.
Equilibrium Definition

In order to define the equilibrium, we need a framework that accounts for the heterogeneity in the economy. At every point in time, the agents are heterogeneous with regard to their age t that evolves deterministically, a fixed level of human capital θ, and the individual state $x = (a,s,z)$ that evolves stochastically. Assume that a takes values in the compact $[0,\bar{a}]$. Let $X \equiv [0,\bar{a}] \times \{z_1,\ldots,z_n\} \times \{g,y\}$ be the state space and $B(X)$ be the Borel σ-algebra on X. Moreover, let (X, $B(X)$, $\psi_{t,\theta}$) be a probability space, where $\psi_{t,\theta}$ is a probability measure that returns the fraction of agents with age t and human capital θ for each subset of X in $B(X)$.

Since we assume agents are born with zero assets, it follows that the distribution of t = 1 agents at any level of human capital θ is given by the exogenous initial distribution of the productivity shock z. At subsequent ages, the distribution of agents in the state space is defined recursively by

$$\psi_{t+1,\theta}(\chi) = \int_X p_{t,\theta}(x,\chi)d\psi_{t,\theta}(x), \text{ for all } \chi \in B(X),$$

where the transition function $p_{t,\theta}(x,\chi)$ expresses the probability that an agent with age t, human capital θ and individual state x fall into the set $\chi \in \mathrm{B}(X)$ in the next period.

We are ready to define the equilibrium concept. A stationary competitive equilibrium consists of policy functions for the agents $c_t(x;\theta)$, $a'_t(x;\theta)$ and $s'_t(x;\theta)$; value functions $V_t(x;\theta)$ and $\tilde{V}_t(a)$; accidental bequests beq; policies for the firm K_y and H_y; prices w_y and r; government policies C_g, G and $\underline{z}(\theta)$, for all θ; and stationary distributions $\psi_{t,\theta}$ for all t and θ such that

1. Given prices and government policies, the policy functions $c_t(x;\theta)$, $a'_t(x;\theta)$ and $s'_t(x;\theta)$ solve the agent's problem defined in the text, with $V_t(x;\theta)$ and $\tilde{V}_t(a)$ being the associated value functions.
2. Given prices r and w_y, policies for the firm K_y and H_y maximize profits, i.e. $G^{\xi}K_y^{\alpha}H_y^{1-\alpha} - (r+\delta_y)K_y - w_y H_y$.
3. Accidental bequests $beq = \sum_t \mu_t (1-\pi_{t+1}) \sum_\theta \mu_\theta \int_X a'_t(x;\theta) d\psi_{t,\theta}(x)$ are distributed lump-sum to all agents.
4. Market clears:

   Capital market : $\sum_t \mu_t \sum_\theta \mu_\theta \int_X a d\psi_{t,\theta}(x) = K_y + D.$

   Private labor market : $\sum_{t<Tr} \mu_t \sum_\theta \mu_\theta \int_X I_{\{s'_t(x;\theta)=y\}} q_y(t,\theta,z) d\psi_{t,\theta}(x) = H_y.$
5. The government chooses Cg to balance its budget:

   $$\tau_a r(K_y + D) + \tau_c C_y + (\tau_h + \tau_{ss})(w_y H_y + w_g H_g) + \tau_{beq} beq$$
   $$= C_g + I_g + \Upsilon + rD + w_g H_g + \sum_{t\geq Tr} \mu_t b,$$

   where the other government policies – defined in the text – are treated as parameters in the computation of the benchmark economy.
6. The production of public goods is given by $G = A_g K_g^{\eta} H_g^{1-\eta}$, where $K_g = I_g/\delta_g$ and $H_g = \sum_{t<Tr} \mu_t \sum_\theta \mu_\theta \int_X I_{\{s'_t(x;\theta)=g\}} q_g(t,\theta,z) d\psi_{t,\theta}(x)$.
7. For each θ, the government sets a minimum level of required productivity $\underline{z}(\theta)$ in order to hire $\lambda(\theta)$ workers, which is specified exogenously.
8. Stationary distributions are defined recursively by

   $$\psi_{t+1,\theta}(\chi) = \int_X p_{t,\theta}(x,\chi) d\psi_{t,\theta}(x), \text{ for all } \chi \in \mathrm{B}(X).$$

   with $\psi_{1,\theta}$ being the invariant distribution of the productivity shock. Moreover, the transition probability function $p_{t,\theta}(x,\chi)$ is consistent with the policy functions for the agents and the stochastic process for the productivity shock.

7.2. Welfare Decomposition

The methodology used to decompose the welfare gains is based on Flodén (2001). In particular, we adapt it to an environment with overlapping generations in which social welfare weights only newborn agents under the veil of ignorance. For further discussion on this methodology we refer the aforementioned article.

First, note that the expected lifetime utility of a newborn agent, i.e. with age $t = 1$, with human capital θ at state (a,s,z) is given by

$$V_1(a,s,z;\theta) = E\left[\sum_{t=1}^{T} \beta^{t-1}\left(\prod_{i=1}^{t} \pi_i\right) \frac{c_t^{1-\gamma}}{1-\gamma} \middle| (a,s,z)\right]$$

The ex-ante utilitarian social welfare is given by the expected lifetime utility of a newborn agent under the veil of ignorance, which reads

$$W = \sum_{\theta} \mu_\theta \int V_1(a,s,z;\theta) d\psi_{t,\theta}(a,s,z)$$

Define economy A as the benchmark economy and economy B as the new stationary equilibrium after the policy change. We define total welfare gains ω by how much lifetime consumption has to increase uniformly across newborn agents in the benchmark economy in order to equalize welfare measures across stationary equilibriums.

Definition 1. The total welfare gains ω of a given policy change is defined implicitly by

$$\sum_{\theta} \mu_\theta \int E\left[\sum_{t=1}^{T} \beta^{t-1}\left(\prod_{i=1}^{t} \pi_i\right) \frac{[(1+\omega)c_t^A]^{1-\gamma}}{1-\gamma} \middle| (a,s,z)\right] d\psi_{1,\theta}(a,s,z) = W^B .$$

Notice we use superscripts A and B to denote objects in their respectively economies. The left hand side measures the social welfare under a hypothetical percentage change of ω in lifetime consumption, while the right hand side measures social welfare under the new policy. Finally, it can be shown that $\omega = \left(W^B / W^A\right)^{1/(1-\gamma)} - 1$.

The total welfare effect can be decomposed into three categories: (i) the level effect associated with changes in aggregate consumption; (ii) the inequality effect associated with changes in the distribution of consumption; and (iii) the uncertainty effect associated with changes in the degree of uncertainty in the economy.

Consider the level effect. Define average consumption by

$$C = \sum_t \mu_t \sum_\theta \mu_\theta \int c_t(a,s,z;\theta) d\psi_{t,\theta}(a,s,z) .$$

The level effect ω^{lev} is the percentage change in average consumption due to the new policy.

Definition 2. The level effect ω^{lev} is given by

$$\omega^{lev} = \frac{C^B}{C^A} - 1.$$

Consider the inequality and uncertainty effects. Let the certainty equivalent consumption bundle $\{\bar{c}(a,s,z;\theta)\}_{t=1}^{T}$ of a newborn agent at state (a,s,z) with human capital θ be defined implicitly by

$$V_1(a,s,z;\theta) = \sum_{t=1}^{T} \beta^{t-1}\left(\prod_{i=1}^{t}\pi_i\right)\frac{\bar{c}(a,s,z;\theta)^{1-\gamma}}{1-\gamma}.$$

Hence, the average certainty equivalent consumption of a newborn agent is given by

$$\bar{C} = \sum_{\theta}\mu_\theta \int \bar{c}(a,s,z;\theta)\,d\psi_{1,\theta}(a,s,z).$$

Notice that in a stationary equilibrium $\bar{C}$ is also the average certainty equivalent consumption of all agents.

Let ρ^{unc} and ρ^{ine} be the cost associated with uncertainty and inequality, respectively. In particular, ρ^{unc} is implicitly defined by

$$\sum_{t=1}^{T} \beta^{t-1}\left(\prod_{i=1}^{t}\pi_i\right)\frac{[(1-\rho^{unc})C]^{1-\gamma}}{1-\gamma} = \sum_{t=1}^{T} \beta^{t-1}\left(\prod_{i=1}^{t}\pi_i\right)\frac{\bar{C}^{1-\gamma}}{1-\gamma}.$$

In a stationary equilibrium, ρ^{unc} captures the cost of eliminating uncertainty in an equalitarian society, in which all agents consume the same amount of goods. It can be shown that $\rho^{unc} = \bar{C}/C - 1$.

Definition 3. The uncertainty effect ω^{unc} is given by

$$\omega^{unc} = \frac{1-\rho^{unc,B}}{1-\rho^{unc,A}} - 1 = \frac{\bar{C}^B}{\bar{C}^A}\frac{C^A}{C^B} - 1.$$

Similarly, ρ^{ine} is implicitly defined by

$$\sum_{t=1}^{T} \beta^{t-1}\left(\prod_{i=1}^{t}\pi_i\right)\frac{[(1-\rho^{ine})\bar{C}]^{1-\gamma}}{1-\gamma} = W$$

In a stationary equilibrium, ρ^{ine} captures the cost of eliminating inequality by giving the same average certainty equivalent consumption to all agents. It can be shown that $\rho^{ine} = W^{1/(1-\gamma)}/\bar{C} \times constant - 1$

Definition 4. The inequality effect ω^{ine} is given by

$$\omega^{ine} = \frac{1-\rho^{ine,B}}{1-\rho^{ine,A}} - 1 = \frac{\overline{C}^A}{\overline{C}^B}\left(\frac{W^B}{W^A}\right)^{\frac{1}{1-\gamma}} - 1$$

Finally, we can apply the previous definitions to prove the following proposition adapted from Flodén [2001].

Proposition 1. Total welfare effect ω is decomposable into a level effect ω^{lev}, a inequality effect ω^{ine} and a uncertainty effect ω^{unc} according to the following equation:

$$(1+\omega) = (1+\omega^{lev})(1+\omega^{unc})(1+\omega^{ine})$$

7.3.
Wage Setting Rules

In order to calibrate the model and estimate the wage setting rules, we use data on workers from the PNAD. Following Braga et al. (2009), we restrict the sample to those workers who worked between 20 and 70 hours and received positive earnings in the week of reference. As specified in the model, we only consider workers who are between 21 and 80 years old.

The variables of interest are experience *t* an individual has, which is proxied by the difference of the current age and the age at the first job, and dummies for the three levels of schooling (basic or no education, secondary education, and college education). The aim is to estimate

$$\ln(wage) = const + \gamma_1^y t + \gamma_2^y t^2 + \gamma_3^y t(\theta) + z = const + \gamma_1^y t + \gamma_2^y t^2 + \gamma_3^y t(\theta) + \rho z_{-1} + \varepsilon_{-1}$$

where *wage* is the hourly wage paid in the private sector according to the wage-setting rule defined in the main text. Notice that $\gamma_3^y(\theta_i)$ is the coefficient associated with the dummy variable for the *i*-th level of schooling.

We estimate the equation above by ordinary least square. To do so, we also control for individual characteristics, such as tenure in the job, and dummies whether the individual is male, white, head of the household, has a farm job, and lives in an urban area.[1] Thus, we claim that the variance of the residual, $z = \rho z_{-1} + \varepsilon_{-1}$, captures the residual wage inequality. Notice that

[1] For a small number of workers, at least one of these variables is misspecified. We exclude them from the sample. We end up with 19,873 public workers and 116,699 private workers. All descriptive statistics and estimations are weighted to make them representative of Brazil.

$\text{var}(z) = \sigma^2 / (1-\rho^2)$, where ρ and σ are the parameters associated with the AR(1) process for z. Therefore, after specifying a value for ρ and estimating var(z), one can calculate σ.

Finally, by relying on this same methodology, we estimate the public wage-setting rule and calculate $\hat{\sigma}$. Results are reported in Sections 4.1.2 and 4.1.3.