Economic interactions and the distribution of wealth

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Abstract

This paper analyzes the equilibrium distribution of wealth in an economy where firms' productivities are subject to idiosyncratic shocks, returns on factors are determined in competitive markets, dynasties have linear consumption functions and government imposes taxes on capital and labour incomes and equally redistributes the collected resources to dynasties. The equilibrium distribution of wealth is explicitly calculated and its shape crucially depends on market incompleteness. In particular, a Paretian law in the top tail only arises if capital markets are incomplete. The Pareto exponent depends on the saving rate, on the net return on capital, on the growth rate of population and on portfolio diversification. On the contrary, the characteristics of the labour market mostly affects the bottom tail of the distribution of wealth. The analysis also suggests a positive relationship between growth and wealth inequality.

Keywords: wealth distribution, incomplete markets, earnings distribution, capital income taxation, productivity shocks, portfolio diversification
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1 Introduction

The statistical regularities in the distribution of wealth have attracted considerable interest since the pioneering works of Pareto (1897) (see Atkinson and Harrison (1978) and Davies and Shorrocks (1999) for a review). The efforts of economists have focused primarily on the understanding the micro-economic causes of inequality. A more recent trend, reviewed in Chatterjee et al. (2005), has instead focused on mechanistic models of wealth exchange with the aim of reproducing the observed empirical distribution. A general conclusion is that the Pareto distribution arises from the combination of a multiplicative accumulation process, and an additive term.

This paper attempts to establish a link between these two literatures, by showing that the same mathematical structure emerges in a model which takes into account explicitely the complexity of market interactions of a large economy. In brief, the model describes how idiosyncratic shocks in the production of firms propagating through the financial and the labor markets shape the distribution of wealth. Market networks, i.e. who works and who invests in each firm, play a crucial role in determining the outcome. As suggested in Aiyagari (1994), the shape of the equilibrium distribution crucially depends on market incompleteness, i.e. on the fact that individuals do not invest in all firms. With complete markets, the equilibrium distribution of wealth is determined solely by shocks transmitted through the labor market, and it takes a Gaussian shape, a result at odds with empirical evidence (see, e.g., Klass et al. (2006)). Only when frictions and transaction costs impede full diversification of dynasties' portfolios, the shape of the top tail of the distribution follows a Paretian law. The Pareto exponent computed explicitly allows to individuate the effects which different parameters have on wealth inequality. We find that an increase in the taxation of capital income or in the diversification of dynasties' portfolios increases the Pareto exponent, whereas changes in the saving rate or in the growth rate of the population impact inequality in different ways, depending on technological parameters, due to *indirect* effects on the return on capital.

The bottom tail of the equilibrium distribution of wealth is instead crucially affected by the characteristics of labour market. With a labour market completely decentralized, so that individual wages immediately respond to idiosyncratic shocks to firms, the support of the equilibrium distribution of wealth includes negative values; on the contrary if all workers receive the same wage, i.e. bargaining in the labour market is completely centralized, shocks are only transmitted through return on capital and the distribution of wealth is bounded away from zero.

Finally, we show that, if the growth rate of the economy is endogenous, there is a negative relationship between the latter and the Pareto exponent, i.e. wealth inequality.

2 The Model

We model a competitive economy in which F firms demand capital and labour. We assume all the wealth is owned by N households (assumed to be infinitely lived), who offer capital and labour and decide which amount of their disposable income is saved. Wages and returns on capital adjust to clear the labour and capital markets respectively.

We derive continuum time stochastic equations for the evolution of the distribution of wealth, specifying the dynamics over a time interval $[t, t+dt)$ and then letting $dt \to 0$. We refer the interested reader to Fiaschi and Marsili (2009) for details, and report directly the dynamical equations. The wealth p_i of household i obeys the following stochastic differential equation:

$$\frac{dp_i}{dt} = s\left[(1-\tau_k)\rho p_i + (1-\tau_l)\omega l_i + \tau_k \rho \bar{p} + \tau_l \omega \bar{l}\right] - \chi - \nu p_i + \eta_i, \tag{1}$$

where η_i is a white noise term with $E[\eta_i(t)] = 0$ and covariance:

$$E[\eta_i(t)\,\eta_{i'}(t')] = \delta(t-t')\,H_{i,i'}[\vec{p}], \tag{2}$$

The first three terms in the r.h.d. of Eq. (1) detail a simple behavioral model of how the consumption of household i depends on her income and wealth. The term in square brackets represents the disposable income of household i, which arises *i)* from the return on investment, at an interest rate ρ, taxed by government at a flat rate τ_k, and *ii)* from income from labor, which is taxed at a rate τ_l. Here ω is the wage rate and l_i is the labor endowment of household i. The last two terms in the square brackets denote the equal redistribution of collected taxes on capital and labor markets, respectively, where $\bar{p}$ and $\bar{l}$ are the average wealth and labor endowment. A fraction s of the income is saved, i.e. s is the saving rate on income. The term χ represents minimal consumption, i.e. the rate at which household would consume in the absence of wealth and income, whereas ν is the rate of consumption of wealth. This simple consumption model finds solid empirical support, as discussed in Fiaschi and Marsili (2009).

The return of capital markets ρ and the wage rate ω are fixed by the equilibrium conditions of the economy. In brief, each firm j buys capital k_j and labor l_j from households in capital and labor markets, i.e.:

$$k_j = \sum_{i=1}^{N} \theta_{i,j} p_i, \quad l_j = \sum_{i=1}^{N} \phi_{i,j}, \quad j = 1, \dots, F,$$

where $\theta_{i,j}$ ($\phi_{i,j}$) is the fraction of i's wealth (labor) invested in firm j. These are used as inputs in the production of firm j, and produce an amount $dy_j = q(k_j, l_j) dA_j$ of output in the time interval dt. Here $q(k, l)$ is the production function of firms, whereas $dA_j(t)$ is an idiosyncratic shock, which is modeled as a random variable with mean $E[dA_j] = adt$ and variance $a^2 \Delta dt$.

Under the standard assumption that $q(k, l) = lg(k/l)$ is an homogeneous function of degree one, when capital and labor markets clear, we find that *i)* each firm has the same capital to labor ration $k_j/l_j = \lambda$, *ii)* the return on capital is given by $\rho = ag'(\lambda)$ and *iii)* the wage rate is $\omega = a[g(\lambda) - \lambda g'(\lambda)]$. Since labor and capital are provided by households, and because of *i)*, the constant $\lambda = \bar{p}$ also equals household wealth per unit labor. Setting $l_i = 1$ for all i, the constant λ then equals the average wealth $\bar{p}$ of households.

The covariance of the stochastic noise in Eq. (1) is given by:

$$\begin{aligned} H_{i,i'}[\vec{p}] = \Delta s^2 \Big\{ & (1-\tau_k)^2 \rho^2 p_i p_{i'} \Theta_{i,i'} + (1-\tau_l)^2 \omega^2 l_i l_{i'} \Phi_{i,i'} + \\ & + (1-\tau_k)(1-\tau_l) \rho\omega \left[p_i l_{i'} \Omega_{i,i'} + l_i p_{i'} \Omega_{i',i} \right] + \\ & + \frac{\tau_k \rho + \tau_l \omega/\lambda}{N} \left[(1-\tau_k)\rho (p_i \vartheta_i + p_{i'} \vartheta_{i'}) + (1-\tau_l)\omega (l_i \varphi_i + l_{i'} \varphi_{i'}) \right] + \\ & + \frac{[\tau_k \rho + \tau_l \omega/\lambda]^2}{N^2} \sum_{j=1}^{F} k_j^2 \Big\}, \end{aligned}$$

where

$$\vartheta_i = \sum_{i'=1}^{N} \Theta_{i,i'} p_{i'}, \quad \varphi_i = \sum_{i'=1}^{N} \Omega_{i,i'} p_{i'}. \tag{3}$$

and

$$\Theta_{i,i'} = \sum_{j=1}^{F} \theta_{i,j} \theta_{i',j}, \quad \Omega_{i,i'} = \sum_{j=1}^{F} \theta_{i,j} \phi_{i',j} \text{ and } \Phi_{i,i'} = \sum_{j=1}^{F} \phi_{i,j} \phi_{i',j}. \tag{4}$$

The parameters in Eq. (3) characterize the degree of intertwinement of economic interactions, i.e. how random shocks *propagate* throughout the economy. For example $\Theta_{i,i'}$ is a scalar which represents the overlap of investments of dynasty i with those of dynasty i'.

3 Infinite Economy

We analyze the properties of the stochastic evolution of wealth discussed in the previous paragraph in the case of an infinite economy, that is of an economy where N and $F \to \infty$. In particular, we assume that $F = fN$, where f is a positive constant. This assumption is not a relevant limitation of the analysis because in a real economy N and F may be of the order of some millions. We take the further simplifying assumption that households do not differ among themselves in their endowment of labour l_i, in the diversification of their portfolios $\Theta_{i,i}$, in the allocation of their wealth among the firms where they are working $\Omega_{i,i}$ and in the number of firms where they are working $\Phi_{i,i}$, i.e. we assume that: $l_i = \bar{l} = 1$, $\Theta_{i,i} = \bar{\Theta}$, $\Omega_{i,i} = \bar{\Omega}$ and $\Phi_{i,i} = \bar{\Phi} \quad \forall i$. For example, $\bar{\Theta} = 1$ implies no diversification of the dynasties' portfolios (i.e. all wealth is invested in the same firm), whereas $\Theta = 1/F$ (i.e. $\Theta \to 0$ for $F \to \infty$) corresponds to maximal diversification of portfolios; similarly, $\Phi = 1$ means that each dynasty is working in just one firm.

In the limit $N, F \to \infty$, the per capita wealth $\bar{p}$ follows a deterministic dynamics given by

$$\frac{d\bar{p}}{dt} = s\left(\rho\bar{p} + \omega\right) - \chi - v\bar{p}. \quad (5)$$

Besides a technical condition[1], this result requires that the average wealth satisfies the Law of Large Numbers, i.e. that the wealth distribution $f(p)$ has a finite first moment.

Two different regimes are possible: *i)* the stationary economy where wealth is constant in equilibrium; and *ii)* the endogenous growth economy, where wealth is growing at constant rate in equilibrium.

3.1 Stationary Economy

If the growth rate of per capita wealth becomes negative for large value of $\bar{p}$, i.e. if

$$\lim_{\bar{p}\to\infty} g'\left(\bar{p}\right) < \frac{\nu}{sa}, \quad (6)$$

then the economy approaches a stationary state.[2] In this case, the distribution of wealth depends on the parameters $\bar{\Theta}$, $\bar{\Phi}$ and $\bar{\Omega}$:

- In an infinite economy when household can fully diversify both their income from capital investment and labour (i.e. $\theta_{i,j} = \phi_{i,j} = 1/F$), they can eliminate all

[1] The technical condition $\sum_{i=1}^{N} \theta_{i,j} \leq \bar{\theta} \; \forall j, N$ is needed to show this result.

[2] For the proof see Fiaschi and Marsili (2009).

sources of risk, i.e. $\bar{\Theta}, \bar{\Omega} = \bar{\Phi} = 0$. Therefore their income is deterministic and, in equilibrium, they all end up with the same wealth, i.e. $p_i = \bar{p}$. Therefore, if $\bar{\Theta}, \bar{\Omega} = \bar{\Phi} = 0$ (complete markets) then:

$$f(p_i) = \delta(p_i - \bar{p}). \tag{7}$$

- When households can fully diversify their portfolios ($\theta_{i,j} = 1/F$), but they work in a limited number of firms, the wealth distribution is determined by the uninsurable idiosyncratic shocks arising from labour income. In this case, in the infinite economy, $\bar{\Theta}, \bar{\Omega} = 0$ and $\bar{\Phi} > 0$ and, the equilibrium distribution of wealth attains a Gaussian shape,

$$f(p_i) = \mathcal{N} e^{-\frac{(z_0 - z_1 p_i)^2}{z_1 a_0}}, \tag{8}$$

with mean $z_0/z_1 = \bar{p}$ and variance $a_0/(2z_1)$ (these parameters are defined below in Eq. (9)).

- In the more realistic incomplete market case, i.e. $\bar{\Theta}, \bar{\Omega}, \bar{\Phi} > 0$, i.e. when full diversification is not possible, both in the capital and in the labor market (incomplete markets), then:

$$f(p_i) = \left[\frac{\mathcal{N}}{(a_0 + a_1 p_i + a_2 p_i^2)^{1+z_1/a_2}}\right] e^{4\left[\frac{z_0 + z_1 a_1/(2a_2)}{\sqrt{4a_0 a_2 - a_1^2}}\right] \arctan\left(\frac{a_1 + 2a_2 p_i}{\sqrt{4a_0 a_2 - a_1^2}}\right)}; \tag{9}$$

where

$$\begin{aligned}
z_0 &= s\left[\omega^* + \tau_k \rho^* \bar{p}\right] - \chi; \\
z_1 &= \nu - s(1 - \tau_k)\rho^*; \\
a_0 &= \Delta s^2 (1 - \tau_l)^2 \omega^{*2} \bar{\Phi}; \\
a_1 &= 2\Delta s^2 (1 - \tau_k)(1 - \tau_l)\rho^* \omega^* \bar{\Omega} \text{ and} \\
a_2 &= \Delta s^2 (1 - \tau_k)^2 \rho^{*2} \bar{\Theta},
\end{aligned}$$

where $\mathcal{N}$ is a constant defined by the condition $\int_{-\infty}^{\infty} f(p_i)\, dp_i = 1$. For large p_i $f(p_i) \sim p_i^{-\alpha-1}$ follows a Pareto distribution whose exponent is given by:

$$\alpha = 1 + 2z_1/a_2 = 1 + 2\frac{\nu - s(1 - \tau_k)\rho^*}{\Delta s^2 (1 - \tau_k)^2 \rho^{*2} \bar{\Theta}}. \tag{10}$$

We observe that z_1, $a_2 > 0$ (see Eq. 6) and hence $\alpha > 1$: this ensures that the first moment of the wealth distribution is indeed finite.

- The case $\bar{\Theta} > 0$ and $\bar{\Phi} = \bar{\Omega} = 0$ corresponds to the rather unrealistic situation where households distribute their labor on all firms. It turns out, however, that the resulting distribution of wealth is exactly the same as that of an economy in which Trade Unions have a very strong market power, such that the bargaining on labour market is completely centralized. Hence wages are fixed (*staggered wages*) in the short run and productivity shocks are absorbed by the returns on capital. Mathematically this corresponds exactly to the case $\bar{\Phi} = \bar{\Omega} = 0$, for which the distribution of wealth reads

$$f\left(p_i\right) = \frac{\mathcal{N}}{a_2 p_i^{2(1+z_1/a_2)}} e^{-\left(\frac{2z_0}{a_2 p_i}\right)}, \tag{11}$$

where $\mathcal{N}$ is a normalization constant, z_1 and a_2 are the same as above.

The results above indicate that while the bottom of the wealth distribution is determined by the labor market, the top tail only depends on the working of capital markets. If wages respond to productivity shocks and households are not able to fully diversify their employment (as is typically the case), then the distribution extends to negative values of the wealth. If, instead, staggered wages are imposed by a centralized bargaining in the labor market, then inequality in the bottom tail is highly reduced.

With respect to the upper tail, we observe that the assumption $\Theta_{i,i} = \bar{\Theta} \quad \forall i$ eliminates cross-household heterogeneity in Eq. (9). However, it is worth noting that if dynasties were heterogeneous in their portfolio diversification, i.e. $\Theta_{i,i} \neq \Theta_{i',i'}$, then the top tail distribution would be populated by the dynasties with the highest $\Theta_{i,i}$, that is by those dynasties with the less diversified portfolios. This finding agrees with the empirical evidence on the low diversification of the portfolios of wealthy households discussed in Guiso et al. (2001), Cap. 10.

The (inverse of the) exponent α provides a measure of inequality. Our results show that inequality increases with the volatility Δ of productivity shocks and with the concentration $\bar{\Theta}$ of household portfolios, and it decreases with capital taxation τ_k.

Changes in s and v have, on the contrary, an ambiguous effect on the size of the top tail of distribution of wealth. More precisely, an increase in the gross return on capital ρ^* amplifies inequality (i.e. $\partial\alpha/\partial\rho^* < 0$). When s increases a *direct* effect tends to decrease α, while an *induced* effect tends to increase α, because it causes an increase in the equilibrium per capita wealth $\bar{p}^*$, and hence a decrease in the return on capital ρ^*. When ν increases the contrary happens. Without specifying the technology $g(\lambda)$ it is not possible to determine which effect prevails (see Fiaschi and Marsili (2009) for some examples).

3.2 Endogenous Growth Economy

If the dynamics of per capita wealth obeys Eq. (5) and

$$\lim_{\bar{p}\to\infty} g'(\bar{p}) > \frac{v}{sa}, \tag{12}$$

then, in the long run, the returns on factors are given by:

$$\rho^* = \lim_{\bar{p}\to\infty} ag'(\bar{p}) \text{ and} \tag{13}$$

$$\omega^* = 0. \tag{14}$$

and per capita wealth grows at the rate[3]

$$\psi^{EG} = \lim_{\bar{p}\to\infty} sag'(\bar{p}) - \nu = s\rho^* - \nu. \tag{15}$$

Notice that ψ^{EG} is independent of the flat tax rate on capital[4] τ_k and of the diversification of dynasty i's portfolio $\bar{\Theta}$; however, ψ^{EG} increases with saving rate s and with return on capital ρ^* and it decreases with ν; changes in technology which increase the return on capital, therefore, also cause an increase in ψ^{EG}.

The distribution of wealth is best described in terms of the relative per capita wealth of households $u_i = p_i/\bar{p}$. In the long run household i's relative wealth obeys the following stochastic differential equation:

$$\lim_{t\to\infty} \frac{du_i}{dt} = s\rho^*\tau_k(1-u_i) + \tilde{\eta}_i, \tag{16}$$

where $\tilde{\eta}_i = \eta_i/\bar{p}$ is a white noise term with $E[\tilde{\eta}_i(t)] = 0$ and covariance:

$$E[\tilde{\eta}_i(t)\,\tilde{\eta}_{i'}(t')] = \delta(t-t')\,H_{i,i'}[\vec{u}], \tag{17}$$

where:

$$\lim_{t\to\infty}\lim_{N\to\infty} H_{i,i'}[\vec{u}] = \left[\Delta s^2(1-\tau_k)^2\rho^{*2}\Theta_{i,i'}\right]u_i u_{i'}.$$

In the limit $\bar{p}\to\infty$ the equilibrium wage rate converges to 0 and therefore wages do not play any role in the dynamics of relative per capita wealth of dynasty i, as stated

[3]If $g(0) > \chi/(sa)$, this result holds independently of the initial level of per capita wealth, otherwise endogenous growth sets in only if the initial per capita wealth is sufficient high (see Fiaschi and Marsili (2009)).

[4]This is due to the assumption of constant saving rate s. Generally, s increases with the net return on capital $(1-\tau_k)\rho^*$, hence s decreases with τ_k. This suggests that the growth rate ψ^{EG} decreases with capital taxation τ_k.

above. In the long run, the equilibrium distribution of the relative per capita wealth u_i, in the non-trivial (and realistic) case of incomplete markets $\bar{\Theta} > 0$, is given by

$$f^{EG}(u_i) = \frac{\mathcal{N}^{EG}}{u_i^{\alpha^{EG}+1}} e^{-(\alpha^{EG}-1)/u_i}, \tag{18}$$

where $\mathcal{N}^{EG}$ is a normalization constant, and

$$\alpha^{EG} = 1 + 2\frac{\tau_k}{\Delta s(1-\tau_k)^2 \rho^* \bar{\Theta}} \tag{19}$$

is the Pareto exponent.

We remark that while capital taxation τ_k has no direct effect on growth, it has a direct effect on inequality.[5] Hence capital taxes do not (directly) affect growth, but have a crucial redistributive function: wealth is redistributed away from wealthy to poor dynasties by an amount proportional to aggregate wealth, so preventing the possible ever-spreading wealth levels, and stabilizing the equilibrium distribution of relative wealth.

Finally, the Pareto exponent is continuous across the transition from a stationary to an endogenously growing economy, i.e.

$$\lim_{s\rho^* - \nu \to 0^-} \alpha = \lim_{s\rho^* - \nu \to 0^+} \alpha^{EG},$$

though it has a singular behaviour in the first derivative (with respect to ν or s). We remark that the Pareto exponent α^{EG} decreases with saving rate s, return on capital ρ^*, the diversification of portfolio $\bar{\Theta}$ and it increases with τ_k; α^{EG} is, on the contrary, independent of ν.

Interestingly, since ψ^{EG} increases with s and ρ^*, we find an inverse relationship between growth and wealth inequality. Indeed the Pareto exponent α^{EG} and the growth rate ψ^{EG} show an inverse relationship under changes in saving rate s and/or return on capital ρ^*. For example, an economy increasing its saving rate s (or its return on capital ρ^*) should move to an equilibrium where both its growth rate and its wealth inequality (in the top tail of the distribution of wealth) are larger than before. The behavior of the Pareto exponent and of the growth rate is illustrated in Fig. 1 for a particular choice of the production function.

[5] The results above, in the limit $\tau_k \to 0$, do not reproduce the behavior of the economy with $\tau_k = 0$: Indeed, Eq. (16), with $\tau_k = 0$ and $H_{i,i'} = 0$ for $i \neq i'$, describes independent log-normal processes $u_i(t)$.

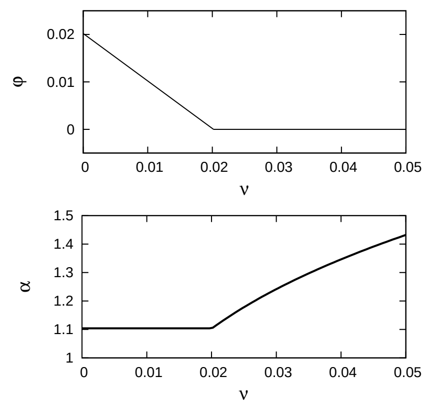

Figure 1: Behavior of the Pareto exponent as a function of the parameter ν for an economy where $g(\lambda) = [\epsilon\lambda^\gamma + 1 - \epsilon]^{1/\gamma}$ (constant elasticity of substitution technology) with $\epsilon = 0.2$ and $\gamma = 0.7$. The other parameters take values: $a = 1.0, s = 0.2, \tau_k = 0.2$ and $\Delta\Theta = 300$.

4 Conclusions and future research

This paper discusses how the equilibrium distribution of wealth can be derived from the equilibrium of an economy with a large number of firms and households, who interact through the capital and the labour markets. Under incomplete markets, the top tail of the equilibrium distribution of wealth is well-represented by a Pareto distribution, whose exponent depends on the saving rate, on the net return on capital, on the growth rate of the population, on the tax on capital income and on the degree of diversification of portfolios. On the other hand, the bottom tail of the distribution mostly depends on the working of the labour market: a labour market with a centralized bargaining where workers do not bear any risk determines a lower wealth inequality.

Our framework neglects important factors which have been shown to have a relevant impact on the distribution of wealth (see Davies and Shorrocks (1999)). Moreover, our analysis is relative to the equilibrium distribution of wealth and it neglects out-of-equilibrium behaviour and issues related to the speed of convergence. The relationship between the distribution of wealth and the distribution of income, as well as its relation with the distribution of firm sizes is a further interesting extension of our analysis.

An additional interesting aspect is that of finite size effects in aggregate fluctuations. This issue has been recently addressed by Gabaix (2008) in an economy in which aggregate wealth exhibits a stochastic behaviour. In the light of our findings, the latter behaviour can arises because of correlations in productivity shocks, which were neglected here, because dynasties concentrate their investments in few firms/assets or because the number of firms/assets is much smaller than the number of dynasties. This extension would draw a theoretical link between the dynamics of the distribution of wealth, the distribution of firm size and business cycle.

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