Growth, Learning and Redistributive Policies

Vincenzo Quadrini *

Department of Economics and Fuqua School of Business

Duke university

September 2, 1999

Abstract

This paper develops an endogenous growth model with redistributive taxation in which the growth rate of the economy affects the agents' preferences over redistributive policies, and therefore, the equilibrium level of taxation. The main mechanism through which the growth rate affects policy preferences is by changing the ability of the agents to learn their positions in the future distribution of incomes. The main result of the paper is that during periods of growth, the society opts for less taxation and less redistribution. The model also predicts that growing economies are characterized by higher inequality in the distribution of income and by greater mobility of agents within income classes over time.

Key words: Bayesian learning, economic growth, income distribution, median voter

JEL Classification: D30, D78, H30, O40

*Send correspondence to Vincenzo Quadrini, Department of Economics, Duke University, 305 Social Sciences Building, Durham, NC 27708-0097. Phone: (919) 660-1817; Fax: (919) 660-7963; E-mail: quadrini@econ.duke.edu

Introduction

How does the growth pattern of the economy affect the agents' preferences over redistributive policies? Does the society's attitude toward taxation change when the economy experiences different levels of growth? This paper investigates these questions by developing a model of endogenous redistributive policies in which the growth pattern of the economy affects the agents' preferences over redistributive policies and, consequently, the equilibrium level of redistribution. The key mechanism through which the growth rate of the economy affects the agents' preferences over redistributive policies, is by changing their ability to forecast their position in the future distribution of income. Since agents vote on future tax rates, what is relevant in characterizing their voting preferences is the expectation of their future incomes. When the economy is growing, the "expected" income of the decisive voter is closer to the "average" income and, as a result, he or she votes for lower taxation. In this way, the growth of the economy has a negative impact on the equilibrium level of redistribution.

Three assumptions, formalized in the model, are important in characterizing this result. The first assumption is related to the determinants of growth. The growth of the economy is driven by innovations carried out on the level of the individual. The innovation activity of the individual has an external connotation deriving from the dependence of its expected return from the widespread diffusion of innovations, that is, the fraction of agents implementing innovative technologies. The second assumption is that each agent is characterized by some ability to generate income and the distribution of abilities across the population is skewed. The third assumption is related to the informational structure. When agents are born, they do not know the value of their specific ability parameter; they only know how skills are distributed throughout the population. The observation of the production result allows agents to learn their specific abilities through a process of Bayesian learning which is similar to the learning process formalized in Jovanovic & Nyarko (1996). However, the bigger the noise associated with the production process, the lower the learning for each agent. Because the implementation of innovative technologies increases the noise, as agents innovate, they enhance the production possibilities of the economy as a whole, but they learn less about their individual ability. This implies that the distribution of beliefs over the individual skill is less skewed, and therefore, the decisive voter (that is, the voter with the median belief) prefers a less redistributive policy. However, when agents do not implement innovative technologies, and the economy does not experience growth, the noise in the production process is lower and the agents' learning about their ability is higher. Consequently, the distribution of beliefs is more skewed and the median voter votes for greater redistribution.

The externalities associated with innovation activities and the presence of a fixed cost to innovate, both allow for the existence of multiple self-fulfilling steady state equilibria. Under certain conditions, in fact, two steady state equilibria exist: a steady state with positive growth and a steady state with zero growth. As will be shown, the equilibrium tax rate in a steady state with growth is smaller than the equilibrium tax rate in a steady state without growth.

It should be noted that this result is not a consequence of income inequality as is the case in some other models developed in political economy (Bertola (1993), Perotti (1993), Persson & Tabellini (1994), Alesina & Rodrik (1994), Krusell, Quadrini, & Ríos-Rull (1997)). In the model developed in this paper, the ex-post distribution of income is more skewed when there are innovations and the economy is growing. Here, the result of a negative association between growth and taxation is a consequence of the effect of growth on the informational structure of the economy. Because the tax rate is voted one period in advance, what is important in determining the equilibrium tax rate is the distribution of agents' beliefs over the next period income. When the economy is growing and the learning ability of the agents is lower, the distribution of beliefs over the next period income is less concentrated than in the case of a stagnant economy, despite the fact that the ex-post distribution of income is less equal. Consequently, the voter with median preferences, that is the voter with the median belief, votes for less redistribution.

The negative effect of growth on redistributive policies is consistent with the results of Kristov, Lindert, & McClelland (1992). Using data on a subset of OECD countries for which data on government social transfers are available, they find that the growth rate of the economy has a negative impact on the level of government transfers.

The impact of growth on agents' preferences over redistributive policies is also analyzed by Wright (1996) which reaches a similar conclusion in terms of association between growth and transfers. However, the mechanism through which the growth rate of the economy affects the voting preferences of agents is different. In Wright's model, fiscal policies have an insurance benefit and this benefit depends on the future growth rate of the economy. The model economy developed in this paper, instead, abstracts from the insurance benefits of fiscal policies, and the negative association between growth and redistribution results from the effects of growth on the informational structure of the economy. Moreover, while in Wright's paper the growth rate of the economy is exogenous, in this study the growth rate is endogenous and multiple equilibrium growth rates are possible.

A further prediction of the paper is the positive association between growth and social mobility, that is, the movement of agents among income classes along time. This results from the fact that in growing economies, relative to stagnant economies, the importance of random realizations (luck) in determining individual incomes is greater than the importance of individual skills (ability). As in Piketty (1995), the mobility experiences of the agents affect their policy preferences by affecting their beliefs. However, the types of beliefs that are important in shaping the agents' preferences are different. In Piketty, agents are altruistic and they have different preferences because they have different beliefs about the process that generates individual incomes. In this paper, on the contrary, agents are not altruistic and they have different preferences because they form different beliefs about their own position in the future distribution of income.

The organization of the paper is as follows: Section 1 describes the model. Section 2 considers the problem faced by agents when choosing the allocation of working time and in the choice of the production technology. Section 3 analyzes the properties of the model when taxes are exogenous. Although the analysis of the economy with exogenous taxes is not the primary concern of this paper, a brief consideration is useful to highlight the main properties of the economic model. Section 4 considers the model with endogenous taxes. This section derives the voting preferences of the agents over the level of taxation, characterizes the politico-economic equilibria and shows the main result of the paper. Section 5 examines the relationship between growth, inequality and mobility and Section 6 analyzes how risk aversion affects the results of the paper. Finally, Section 7 reviews some empirical studies that are relevant for the conclusions of this paper and Section 8 concludes.

1 The model

1.1 Preferences and technology

The economy is populated by a continuum of agents that are alive for two periods. Each agent is characterized by a skill parameter θ that affects his or her productivity. An important assumption is that this parameter is not known when the agent is born. Agents' utility is given by the sum of consumption when young and consumption when old, that is, $W = c_1 + c_2$.

Agents are endowed in both periods of life with one unit of working time that is divided between the two sectors of the economy in which consumption goods are produced. One of the differences between the two sectors is that the income generated in the first sector is taxed, while the income generated in the second sector is not taxed. Accordingly, I will refer to the first sector as the "taxed sector", and the second sector as the "non-taxed sector". The taxed sector includes the main market activities, while the non-taxed sector encompasses activities that are not declared for tax purposes (tax-evaded incomes), activities in the underground economy, illegal activities, homework production, etc.

Production in both sectors of the economy can be implemented by employing one of the two available technologies: the standard technology and the innovative technology. More specifically, the agent's production in the taxed sector of the economy is given by:

$$y_T = A \cdot f(\theta + i\omega) \cdot l_T \tag{1}$$

and in the non-taxed sector is given by:

$$y_{NT} = A \cdot f(\theta + i\omega) \cdot \left(l_{NT} - \frac{l_{NT}^2}{2} \right) \tag{2}$$

where A is the economy-wide technological knowledge; θ is the agent's specific ability parameter; i is an indicator function taking the value of zero when the agent implements the standard technology and one when the agent implements the innovative technology; ω is an idiosyncratic shock associated with the innovative technology; f is a continuous function with properties specified below; l_T is the agent's fraction of working time allocated to taxed activities and l_{NT} the fraction of time allocated to non-taxed activities.

The production function in the non-taxed sector is strictly increasing and concave in the relevant interval $l_{NT} \in (0, 1)$, while the technology in the taxed sector is linear in l_T. Therefore, while the technology in the first sector of the economy displays constant return to scale with respect to labor, the technology in the second sector displays decreasing return to scale.

The specific ability parameter θ represents the genetic skill endowment of the agent when he or she is born. The distribution of this parameter among the population of each generation is defined by the following assumption.

Assumption 1.1 *The skill parameter θ is normally distributed among the population of each generation with mean $\bar{\theta}$ and variance σ_θ^2.*

The shock associated with innovative technologies have the following properties.

Assumption 1.2 *The technology shock ω is an independent and identical normal variate with mean zero and variance σ_ω^2. The independence of the shock is over time and across agents running innovative technologies.*

The ability parameter and the innovation shock determine the agent's productivity through the function f which satisfies the following properties.

Assumption 1.3 *The function f is positive, continuous, strictly increasing, strictly convex and the term:*

$$\frac{\int f(\theta+\omega)dF(\theta+\omega)}{\int f(\theta)dF(\theta)}$$

is nonincreasing in the variance of θ, where F is the distribution function of the variable in the argument.[1]

The monotonicity assumption of f guarantees that the agent's productivity is increasing in the ability parameter θ and in the shock ω. The convexity assumption guarantees that the expected productivity (before the realization of the innovation shock) of the innovative technology is higher than the expected productivity of the standard technology. Moreover, the innovative technology is also more productive ex-post for the whole economy. The convexity assumption also implies that the distribution of productivity in the first sector of the economy across agents implementing the same technology is skewed and, more specifically, that the median productivity is smaller than the average productivity.[2] This property can be motivated by the empirical findings of several studies of the distribution of earnings. See, for example, Diaz-Gimenez, Quadrini, & Ríos-Rull (1997). The purpose of the last assumption is to limit the degree of convexity of the function f. One particular case in which the above assumptions are satisfied is when f assumes the exponential form, that is, $f(z) = e^z$. When f is an exponential function, and all agents adopt the same technology—for example in one hypothetical steady state—assumptions 1.1 and 1.2 imply that the distribution of agents' productivity in the taxed sector of the economy is lognormal. Moreover, if all agents choose the same allocation of working

---

[1] *Throughout the paper I will use F to denote the distribution function of the variable in the argument. So, for example, given assumptions 1.1 and 1.2, $F(\theta)$ denotes a normal distribution with mean $\bar{\theta}$ and variance σ_θ^2, while $F(\theta+\omega)$ denotes a normal distribution with mean $\bar{\theta}$ and variance $\sigma_\theta^2 + \sigma_\omega^2$.*

[2] This property also extends to the second sector of production if all agents choose the same allocation of time between the two sectors.

time between sectors, also the distribution of income is lognormal. The log-normality assumption is consistent with the results of several empirical studies for which the distribution of income is well approximated by a lognormal distribution. See, for example, Aitchison & Brown (1969).

Given assumptions 1.2, and before the realization of the innovation shock, the expected labor productivity of the standard (innovative) technology in the taxed sector is higher than the expected labor productivity of the standard (innovative) technology in the non-taxed sector, independently of the allocation of labor between the two sectors. This implies that, if the agent has to decide the allocation of labor before observing the shock, the whole amount of working time will be allocated to taxed activities. The taxation of the income earned in the first sector, however, has the effect of reducing the private return from working in this sector and the agent may decide to spend part of the working time in the second sector. The role that the non-taxed sector plays in this model is similar to the role that in other models is played by leisure.[3]

In order to implement the innovative technology, the agent needs to acquire the innovation know-how by paying a cost. This cost is assumed to take the form Aq, where A is the economy-wide technology level and q is a constant. The choice of whether to acquire the innovation know-how is made in the early stage of life and an agent that acquires it is able to implement the innovative technology in both periods of life.[4] The higher expected productivity of the innovative technology implies that, if the agent decided to acquire the innovation know-how, he or she will always implement the innovative technology in both periods of life. Moreover, an agent that did not acquire the innovation know-how when young, cannot implement the innovative technology when he or she is old.

What is left to define is the law of motion for the economy-wide technological knowledge

[3]The model considers a second sector, rather than leisure, in order to overcome some technical difficulties related to the imposition that the fraction of working time is constant in the balanced growth path. A Cobb-Douglas utility in consumption and leisure allows for this property but it would complicate the whole analysis.

[4]We can interpret this cost as the cost to acquire training or education. In order to allow agents to pay for this cost we can assume that they are born with an initial non-taxed endowment.

A, which describes the evolution of this variable along time. Define π_t^0 to be the average labor productivity of the standard technology in the taxed sector of the economy at time t. This is given by:

$$\pi_t^0 = \int A_t f(\theta) dF(\theta) \tag{3}$$

Moreover, define π_t^Ψ to be the average labor productivity in the taxed sector of the young generation at time t. This is given by:

$$\pi_t^\Psi = (1 - \Psi_t) \int A_t f(\theta) dF(\theta) + \Psi_t \int A_t f(\theta + \omega) dF(\theta + \omega) \tag{4}$$

where Ψ_t is the fraction of agents in the young generation that at time t are running the innovative technology. Of course $\pi_t^\Psi = \pi_t^0$ when $\Psi_t = 0$. The evolution of the productivity of the standard technology is defined by the following assumption.

Assumption 1.4 *The next period average productivity of the standard technology in the taxed sector of the economy is equal to the current productivity of the young generation in that sector, that is,* $\pi_{t+1}^0 = \pi_t^\Psi$.

Equation (1.4) formalizes the idea that the increase in productivity depends on the diffusion of innovative activities in the more productive sector, that is, the taxed sector: larger is the fraction of innovating agents, larger is the increase in productivity. The productivity growth of the standard technology is not affected, however, by the fraction of innovating agents among the old generation.[5]

Using the definition of π^0 and π^Ψ given in (3) and (4), assumption 1.4 defines the following evolution of A:

$$A_{t+1} = A_t(1 + \alpha \Psi_t) \tag{5}$$

[5]This assumption can be justified by the fact that the old generation does not survive to the next period, and therefore, is unable to transmit the knowledge accumulated to the next young generation.

where $\alpha = \left[\frac{\int f(\theta+\omega)dF(\theta+\omega)}{\int f(\theta)dF(\theta)} - 1\right]$, is a positive constant. Therefore, the growth rate of the economy-wide technological knowledge is an increasing function of the fraction of innovative agents Ψ_t. It reaches the maximum value when all agents adopt the innovative technology while the economy does not experience growth when agents do not innovate.

1.2 The role of the government and the political mechanism

The role of the government is to collect taxes from incomes earned in the taxed sector of the economy at rate $\tau \in [0, 1]$, and to redistribute the revenue with lump sum transfers denoted by T. Therefore, $T = \tau Y$, where Y is the average per capita output produced in the taxed sector of the economy. Denote by l_T the input of labor in the taxed sector of the economy. As we will see, l_T is independent of the agent's type and age. Moreover, denote by Ψ^j the fraction of agents of age $j \in \{1, 2\}$ implementing the innovative technology. Then Y is given by:

$$Y = \frac{1}{2}\sum_{j=1}^{2}\left[(1-\Psi^j)\int Af(\theta)l_T dF(\theta) + \Psi^j \int Af(\theta+\omega)l_T dF(\theta+\omega)\right] \tag{6}$$

The proportional tax on income is determined according to a majority voting rule where the vote is on the next period tax rate. The election takes place at the end of each period, and only the young generation votes.[6]

1.3 Timing and informational structure

When an agent is born, he or she does not know the individual skill parameter θ, and the choice of whether to acquire the innovation know-how, and therefore, the technological choice i, is made before knowing this parameter. However, the agent knows the distribution of θ across the population which, in absence of other information, represents his belief or prior distribution

[6] Given the timing of the voting process, it is reasonable to assume that only young agents vote. Because elections take place at the end of the period, and therefore, after all production decisions have been made, only the agents belonging to the current young generation have an interest in deciding the next period tax rate.

over this parameter at the moment of making the technological choice i. After selecting the production technology, the agent chooses the allocation of labor between the two production sectors, starts the production processes and observes the production results. Based on these results he or she tries to infer the value of the skill parameter θ. If the agent adopted the standard technology, he or she will be able to fully determine θ by observing the output results. In the other case the agent is not able to fully determine this parameter, given the dependence of the production from the stochastic variable ω. In that case the agent's belief is updated using Bayes rule and the posterior distribution, that is the new belief, is normal with mean:

$$\mathrm{E}(\theta \mid y_T, y_{NT}) = \frac{\sigma_\omega^2}{\sigma_\theta^2 + \sigma_\omega^2}\bar{\theta} + \frac{\sigma_\theta^2}{\sigma_\theta^2 + \sigma_\omega^2}(\theta + \omega) \tag{7}$$

and variance:

$$\mathrm{Var}(\theta \mid y_T, y_{NT}) = \frac{\sigma_\theta^2 \sigma_\omega^2}{\sigma_\theta^2 + \sigma_\omega^2} \tag{8}$$

This can be shown as follows. The initial belief of the agent is $\theta \sim N(\bar{\theta} and \sigma_\theta^2)$, $\omega \sim N(0, \sigma_\omega^2)$, implying that the prior joint belief over the observed variable $(\theta + \omega)$ is $N(\bar{\theta}, \sigma_\theta^2 + \sigma_\omega^2)$. The posterior belief over θ is the distribution of θ conditional on the realization of $(\theta + \omega)$. Because the distribution of a variable that is normally distributed, conditional on a normally distributed variable, is also normal, then the ex-post belief over the parameter θ is normal. For the derivation of the conditional mean and variance see, for example, Greene (1990, pag. 78-79).

It is this limited learning of the specific parameter θ, along with the skewness in the distribution of the individual productivity, that in the prevalence of innovative activities, and therefore growth, the society opts for less taxation and redistribution. This point will be clear below in the analysis of the politico equilibrium.

2 The agent's problem

The per period utility of the agent is equal to consumption. Because goods cannot be stored and there is not a market to borrow from, consumption is equal to the incomes earned in the two sectors of the economy, net of taxes and transfers, minus the innovation cost. Therefore:

$$U_j = Af(\theta + i\omega)l_T(1-\tau) + Af(\theta + i\omega)\left(l_{NT} - \frac{l_{NT}^2}{2}\right) + T - Aq \cdot i \cdot (2-j) \tag{9}$$

where $j \in \{1, 2\}$ denotes the age of the agent. The first term is the income earned in the taxed sector net of taxes; the second term is the output produced in the non-taxed sector; T denotes government transfers and Aq is the cost to innovate. Notice that the innovation cost disappears for old agents ($j = 2$) and/or for agents that do not innovate ($i = 0$). Using the restrictions $l_T + l_{NT} = 1$ and after rearranging, the per-period utility becomes:

$$U_j = Af(\theta + i\omega)l(1-\tau) + \frac{1}{2}Af(\theta + i\omega)(1 - l^2) + T - Aq \cdot i \cdot (2-j) \tag{10}$$

where, henceforth, l without subscript is understood to be the fraction of time allocated in taxed activities. This specification of the utility function makes clear the trade-off faced by the agent in choosing the allocation of time between taxed and non-taxed activities: on the one hand, by increasing the allocation of working time in taxed activities, the agent increases the earned income, and therefore, consumption. On the other, there is a cost consisting in the reduction of output in the non-taxed sector which is accounted by the second term in (10).

Consider first the problem of an agent belonging to the old generation. Only those agents that in the previous period acquired the innovation know-how, have the option of implementing the innovative technology in the current period. Consequently, because innovative technologies bring higher expected returns in both sectors of the economy, the technological choice of an old agent consists in the implementation of the innovative technology if he or she innovated in the previous period. Therefore, the problem of an old agent only consists in the choice of l conditional on the previous technological choice i. The optimization problem is:

$$\max_l E\left\{ Af(\theta + i\omega)l(1-\tau) + \frac{1}{2}Af(\theta + i\omega)(1 - l^2) + T \,\middle|\, y_T, y_{NT} \right\} \tag{11}$$

where y_T and y_{NT} are the agent's productions observed in the previous period, and E is the expectation operator based on the agent's belief over the skill parameter θ, and therefore, conditional on the realization of y_T and y_{NT}. If in the previous period the agent decided to run the standard technology, that is, $i = 0$, then the belief is degenerate and it is given by the true skill parameter. If the agent run the innovative technology, the belief over the parameter θ is normal with mean and variance defined in (7) and (8).

Differentiating (11) with respect to l we obtain the optimal allocation of working time in the taxed sector, $l(\tau) = 1 - \tau$. Substituting this solution into the objective we get:

$$E(U_2|y_T, y_{NT}) = \frac{1}{2}AE\left[f(\theta + i\omega)\,\middle|\, y_T, y_{NT}\right][1 + (1-\tau)^2] + T \tag{12}$$

which defines the expected indirect utility of an old agent that in the previous period obtained y_T and y_{NT} units of output in the two production sectors.

Consider now the problem of a young agent. When young, the agent chooses first whether to acquire the innovation know-how, and therefore, which technology (standard or innovative) to implement in production, and second, the allocation of working time in the taxed and non-taxed sectors. The analysis of these choices proceeds by solving first for l, conditional on the technological choice i, and then by solving for the technological choice by comparing the expected lifetime utilities reached under the two alternatives. With respect to the allocation of working time, the agent problem is:

$$\max_l E\left\{Af(\theta + i\omega)l(1-\tau) + \frac{1}{2}Af(\theta + i\omega)(1 - l^2) + T - iAq + E(U_2|y_T, y_{NT})\right\} \tag{13}$$

where $E(U_2|y_T, y_{NT})$ is the next period expected utility derived in (12). Taking first order conditions gives the solution $l(\tau) = 1 - \tau$. Using this solution in the objective we obtain:

$$W(\tau, i) = \frac{1}{2}A[1 + (1-\tau)^2]E[f(\theta + i\omega)] + T - iAq + \frac{1}{2}A'[1 + (1-\tau')^2]E[f(\theta + i\omega')] + T' \tag{14}$$

where the prime denotes the next period variable.

The function $W(\tau, i)$ is the expected lifetime utility, conditional on the tax rate τ and on the choice of i, and it is what the agent evaluates to decide whether to acquire the innovation know-how.[7] The innovation choice is based on the sign of $W(\tau,1) - W(\tau,0)$, which is equal to:

$$W(\tau,1) - W(\tau,0) = \frac{1}{2}AE[f(\theta+\omega) - f(\theta)]\left\{[1 + (1-\tau)^2] + [1 + (1-\tau')^2]\frac{A'}{A}\right\} - Aq \qquad (15)$$

Because the factor $AE[f(\theta+\omega) - f(\theta)]$ is positive, the sign of $W(\tau,1) - W(\tau,0)$ is not affected if we divide it by the term $(1/2)AE[f(\theta+\omega) - f(\theta)]$. It would be convenient, then, to redefine a new function $\chi(\tau)$ obtained by dividing (15) by this term and replacing A'/A using equation (5). The function χ is given by:

$$\chi(\tau) = [1 + (1-\tau)^2] + [1 + (1-\tau')^2](1 + \alpha\Psi) - \phi \qquad (16)$$

where $\phi = \frac{2q}{E[f(\theta+\omega)-f(\theta)]}$, is a positive constant which depends on the parameter q. I will refer to ϕ as the cost parameter.

The innovation choice of the agent is based on the function $\chi(\tau)$. Notice that τ is the only variable, known to the agent, that affects the choice of i. The other relevant variables—specifically, the fraction of innovating agents in the current young generation Ψ, and the next period tax rate τ'—are unknown at the moment of making this choice. Therefore, agents need to form expectations. These expectations are based on the aggregate law of motion $\Psi = H(\tau)$ and the policy rule $\tau' = P(\Psi; H)$. In the policy rule P, the law of motion enters as an explicit argument because H is not necessarily unique, and different laws of motion can give rise to different equilibria, and therefore, different policy rules. The agent takes as given the functions H and P, and the optimal choice is given by:

[7] The function W also depends on other two states of the economy, that is the fraction of innovating agents in the old generation and the economy-wide technological knowledge A. However, these variables are not explicitly included in the argument of the function because they do not affect the agent's choice of i.

$$
i(\tau; H) = \begin{cases} 0 & \text{if} \quad \chi(\tau) < 0 \\ 1 \text{ with prob } \psi & \text{if} \quad \chi(\tau) = 0 \\ 1 & \text{if} \quad \chi(\tau) > 0 \end{cases} \tag{17}
$$

The optimal choice is to implement the innovative technology if the expected utility associated with this choice is greater than the expected utility associated with the implementation of the standard technology. If both choices give the same expected utility, then the agent is indifferent and he or she chooses a mixed strategy consisting in the implementation of the innovative technology with probability ψ, and the standard technology with probability $1-\psi$. In this case any probability $0 \leq \psi \leq 1$ is a solution to the agent's problem. In the choice function it is made explicit the dependence of this choice from the law of motion H. In equilibrium, individual behavior must be consistent with aggregate behavior, and therefore, $H(\tau) = \int i(\tau; H) dF(\theta)$.

In order to characterize the policy function P, we need to analyze the voting problem of the agents and derive the politico equilibrium. Before that, however, the following section analyzes the economy with exogenous taxes. When taxes are exogenous, solving for the technological choice does not require to forecast the next period tax rate. This considerably simplifies the agent's problem because this problem only depends on the expectations over the technological choice of the current young generation. The succeeding section, then, will analyze the economy with endogenous taxes. The introduction of endogenous taxes complicates the agent's problem because in order to make the technological choice, the agent needs to forecast the next period tax rate. But to forecast the next period tax rate, the technological choice of the next young generation needs to be forecasted.

3 The economy with exogenous taxes

Let's assume that the tax rate is constant and exogenously given. Under this condition, the choice function (16) becomes:

$$
\chi = \left[1 + (1-\tau)^2\right](2 + \alpha\Psi) - \phi \tag{18}
$$

With exogenous taxes, the technological choice of a young agent depends only on the innovation choices of the current young generation. If the agent expects that a large number of young agents adopt the innovative technology, then the economy-wide technological knowledge in the following period is higher, and the expected return from the innovative technology will also be higher. Depending on the parameter cost ϕ, and on the tax rate τ, different equilibria are possible.

Definition 3.1 (Equilibrium) *An equilibrium for this economy is defined as a sequence of laws of motion* $\{H_t(\tau)\}_{t=0}^{\infty}$ *and decision rules* $i(\tau; H)$ *and* $l(\tau)$*, such that agents optimize, given the sequence of laws of motion, and the individual decisions are consistent with aggregate behavior, that is,* $H(\tau) = \int i(\tau; H)dF(\theta)$.

Proposition 3.1 *Define* $\phi_1 = 2 \cdot [1 + (1-\tau)^2]$ *and* $\phi_2 = (2+\alpha) \cdot [1 + (1-\tau)^2]$. *Then* ϕ_1 *and* ϕ_2 *define different regions in the space of the cost parameter* ϕ*, with different types of equilibria:*

(a) If $\phi < \phi_1$ *or* $\phi > \phi_2$*, only one equilibrium exists: the equilibrium with growth in the first case, and the equilibrium without growth in the second.*

(b) If $\phi = \phi_1$ *or* $\phi = \phi_2$*, two equilibria exist: the growth equilibrium with* $\Psi = 1$*, and the stagnant equilibrium with* $\Psi = 0$.

(c) If $\phi_1 < \phi < \phi_2$*, three equilibria exist: the stagnant equilibrium with* $\Psi = 0$*, the medium growth equilibrium with* $0 < \Psi < 1$*, and the maximum growth equilibrium with* $\Psi = 1$.

Proof 3.1 *If* $\phi < \phi_1$*, then* χ *defined in (18) is positive for all* $0 \leq \Psi \leq 1$*, and therefore, there exists only the equilibrium in which all agents innovate. If* $\phi > \phi_2$*, then* $\chi < 0$ *for all* $0 \leq \Psi \leq 1$*, and therefore, there exists only the equilibrium in which no agent innovates. When* $\phi = \phi_1$, $\chi = 0$ *if* $\Psi = 0$*, and* $\chi > 0$ *for all other values of* Ψ*. Therefore two equilibria are possible: the equilibrium in which no agent innovates, and the equilibrium in which all agents innovate. When* $\phi = \phi_2$, $\chi = 0$ *if* $\Psi = 1$*, and* $\chi < 0$ *for all other values of* Ψ*. Therefore, also in this case there exists two equilibria. Finally, in the case* $\phi_1 < \phi < \phi_2$, $\chi < 0$ *if* $\Psi = 0$*, and* $\chi > 0$ *if* $\Psi = 1$*. Because the function* χ *is continuous and strictly increasing in* Ψ*, there is* $0 < \Psi^* < 1$ *for which* *the function is equal to zero. In this case agents play mixed strategies. If the aggregation of these strategies satisfies* $\int i(\tau, \Psi^*)dF(\theta) = \Psi^*$*, then this is also an equilibrium. Q.E.D.*

The case in which $\phi_1 < \phi < \phi_2$, that is point (c) of the above proposition, is of particular interest. With the values of ϕ so restricted, the equilibria of the economy are self-fulfilling, and different expectations give raise to different equilibria. If the agent expects that other agents do not innovate, that is if $\Psi = 0$, then it is optimal not to innovate and as a result expectations are fulfilled. On the other hand, if the agent expects that other agents innovate, that is $\Psi = 1$, then it is optimal for him to innovate and expectations are also fulfilled. There is also a third possibility. If all agents expect that a fraction $0 < \Psi < 1$ of agents innovate, and under this expectation they are indifferent to the type of technology to implement, then a mixed strategy consisting in the implementation of the innovative technology with probability $0 \leq i(\tau, \Psi^*) \leq 1$ is optimal. If the strategies played by all agents satisfy $\int i(\tau, \Psi^*)dF(\theta) = \Psi^*$, then expectations are fulfilled and this is also an equilibrium.

This multiplicity of equilibria comes from the externality nature of the innovations: when a large fraction of agents innovate, the future return from innovative activities is greater. Figure 1 shows the set of equilibrium growth rates, as characterized by proposition 3.1, for different values of the cost parameter ϕ.

[Place figure 1 here]

Proposition 3.1 assumes a given tax rate τ. Assuming that ϕ is such that a growing equilibrium is feasible, what happens when the tax rate increases? For moderate changes in the level of taxation, the growth rate of the economy is not affected. However, high taxes may cause the economy to stagnate. On the other hand, low taxes may allow the economy to grow persistently. In this respect, the properties of the model economy with exogenous taxes is consistent with the conclusions of the endogenous growth literature for which taxes have a negative impact on the long run growth of the economy. See for example Barro (1990), Jones & Manuelli (1990), King & Rebelo (1990) and Rebelo (1991). When taxes are endogenous, in addition to this negative effect of taxes on the growth rate of the economy, the equilibrium level of taxation depends on whether the economy is in a growing or non growing path.

4 The economy with endogenous taxes

This section extends the model economy analyzed in the previous section by assuming that the tax rate is endogenously determined through the political mechanism. In order to characterize the politico equilibrium, we have to derive first the agents' preferences over the tax rate. Therefore, the next subsection is devoted to the analysis of the tax preferences and the succeeding subsection will analyze the politico-economic equilibrium.

4.1 The agent's voting problem

The voting for next period tax rate takes place at the end of the period, after all relevant choices have been made. Only agents belonging to the young generation vote. The voter's problem (of young agents) reads:

$$\begin{aligned} V(i, y_T, y_{NT}) &= \max_{\tau' \in [0,1]} \left\{ \frac{1}{2} A' E \left[f(\theta + i\omega') \,\middle|\, y_T, y_{NT} \right] [1 + (1-\tau')^2] + \tau' Y' \right\} \qquad (19) \\ & \quad \text{subject to} \\ A' &= A(1 + \alpha\Psi) \\ Y' &= A'(1-\tau') \int f(\theta) dF(\theta) \left\{ 1 + \frac{1}{2}\alpha(\Psi + \Psi') \right\} \\ \Psi' &= H(\tau') \end{aligned}$$

where Y is the aggregate per-capita output produced in the taxed sector of the economy and the prime denotes the next period variable. The equation defining Y has been derived from (6) after substituting the optimal labor choice $l = 1 - \tau$. The function $V(i, y_T, y_{NT})$ is the value function of the voter (which is given by the expected utility in the old stage of life) given the individual states at the moment of voting, that is, the variables i, y_T and y_{NT}. The function $H(\tau)$ describes the evolution of Ψ as a function of the tax rate.

From (19) is evident that the preferred tax rate differs across agents according to the factor $E[f(\theta+i\omega')|y_T, y_{NT}]$. This factor is equal to $f(\theta)$ for agents that did not innovate, because they were able to perfectly infer the skill parameter by observing the production result. For agents that innovated, instead, the term $E[f(\theta + i\omega')|y_T, y_{NT}]$ is more complicated. However, it only depends on the realization of the variable $\theta+\omega$, which is indirectly observed by the agent. Given the assumptions on f, the term $E[f(\theta + i\omega')|y_T, y_{NT}]$ is strictly increasing in the realization of the variable $\theta + \omega$. Let's define the variable x as:

$$x = \begin{cases} f(\theta), & \text{if } i = 0 \\ E[f(\theta + \omega')|\theta + \omega], & \text{if } i = 1 \end{cases} \tag{20}$$

This variable characterizes the tax preferences of the agent and the optimal tax rate (the tax rate optimizing the agent's utility) will be denoted by $\tau(\Psi, x; H)$.

The characterization of the voting solution is complicated by the fact that the level of taxation may affect the innovation choice of the next young generation, which in turn affects the next period transfers. This is because the technological choice of the next young generation depends not only on the agents' expectations over the innovation behavior of that generation, but also on the next period tax rate: higher tax rates reduce the expected return from innovating and, in particular circumstances, it may induce the agent to adopt the standard technology. The effect of τ' on the next period fraction of innovating agents is captured by the function $H(\tau')$. The dependence of the preferred tax rate τ' from Ψ' does not allow us to characterize the voting solution with first order conditions. Moreover, the voting solution is not necessarily unique (non single-peaked preferences). However, despite these difficulties, it will be shown that the most preferred tax rate is monotone with respect to the variable x, and therefore, the decisive voter can uniquely be identified. This is formally stated in the following lemma.

Lemma 4.1 (Tax preferences) *The measure of agents with non single-peaked preferences is zero and the optimal (most preferred) tax rate $\tau(\Psi, x; H)$ is decreasing in x.*

Proof 4.1 *See the appendix.*

The lemma states that there is at most one type of agents for which the voting problem solution is not unique. Given that the economy is populated by a continuum of agents, the measure of agents with non single-peaked preferences is zero. Moreover the most preferred tax rate can be ordered monotonically—although not strictly—with respect to the variable x. Figure 2 shows this result by reporting the most preferred tax rate as a function of x. As can been seen, there is one and only one value of x for which agents are indifferent over two tax rates.

[Place figure 2 here]

Given that the voter's optimal tax rate is monotone in x, the median voter theorem applies, and the decisive voter is the voter with median preferences. Consequently, the policy function P is defined as:

$$P(\Psi; H) = \tau(\Psi, x_{Med}; H) \tag{21}$$

If the agent with non single-peaked preferences is the median voter, the equilibrium tax rate is not unique, but it is still true that the equilibrium tax rate is the one chosen by this voter.

Lemma 4.2 (Median Voter) *The fraction of innovating agents Ψ is a sufficient statistic for the identification of the median voter. Moreover, when $\Psi = 0$ the median voter is the agent with skill parameter θ equal to $\bar{\theta}$, and when $\Psi = 1$ the median voter is the agent with skill parameter θ and realizations of the shock ω satisfying $(\theta + \omega) = \bar{\theta}$.*

Proof 4.2 *The ordering of the agent's most preferred tax rate is based on the variable x defined in (20). When $\Psi = 0$, x is an increasing function of θ which is normally distributed. Because the median of a normal variable is equal to the mean, the median agent is the agent with mean θ, that is, $\bar{\theta}$. Similarly, when $\Psi = 1$, x is an increasing function of $\theta + \omega$ which is also normally distributed, and therefore, the median is the agent with realization $\theta + \omega$ equals to $\bar{\theta} + \bar{\omega} = \bar{\theta}$. When $0 < \Psi < 1$, the distribution of x is more complex. However, given that it results from the aggregation of two functions that are strictly increasing in normally distributed variables, once Ψ is known, the median agent can uniquely be identified.*

The fact that the fraction of innovating agents is a sufficient statistic for the identification of the median voter—and it is the only aggregate state variable that is relevant in characterizing the voting preferences—justifies the specification of the policy rule P as a function of Ψ.

4.2 The politico-economic equilibrium

After analyzing the voting problem of the agents, and after identifying the decisive voter, we can now turn to the analysis of the politico-economic equilibrium.

Definition 4.1 (Equilibrium) *A politico-economic equilibrium is defined as a sequence of laws of motion $\{H_t(\tau)\}_{t=0}^{\infty}$, a policy function $P(\Psi; H)$ and individual decision rules $i(\tau; H)$, $l(\tau)$ and $\tau(\Psi, x; H)$, such that agents optimize given the sequence of laws of motion and the policy function, and individual decisions are consistent with aggregate behavior, that is, $H(\tau) = \int i(\tau; H) dF(\theta)$ and $P(\Psi; H) = \tau(\Psi, x_{Med}; H)$.*

In this economy there is a multiplicity of equilibria, and the remaining part of this paper will concentrate on the analysis of steady state equilibria, that is equilibria in which the economy experiences a balanced growth path.

Definition 4.2 (Steady state equilibrium) *A steady state equilibrium is such that the fraction of agents implementing the innovate technology Ψ^*, the tax rate τ^* and the growth rate of outputs (in the taxed and non-taxed sectors) are constant over time. The constant fraction of innovating agents Ψ^* is the fix point of the mapping $\Psi^* = H(P(\Psi^*; H))$ for a constant sequence of laws of motion H.*

Proposition 4.1 formally states the existence of steady state equilibria.

Proposition 4.1 (Existence of steady states) *There are ϕ_1 and ϕ_2, with $0 < \phi_1 < \phi_2$, sectioning the space of the cost parameter ϕ, such that:*

(a) If $\phi > \phi_2$, then only one steady state equilibrium exists. This is the only equilibrium of the economy and it is characterized by $\Psi = 0$.

(b) If $\phi < \phi_1$, then only one steady state equilibrium exists. This is the only equilibrium of the economy and it is characterized by $\Psi = 1$.

(c) If $\phi_1 \leq \phi \leq \phi_2$ then two steady state equilibria exists: the steady state without growth in which $\Psi = 0$, and the steady state with growth in which $\Psi = 1$.

Proof 4.1 *See the appendix.*

The proof of the above proposition is based on the idea that, in a steady state equilibrium in which agents expect that this equilibrium will persist in the future, there is not incentive to deviate from the actions predicted by this equilibrium. The proof is complicated by the existence of cases in which the optimal solution of the median voter cannot be characterized with first order conditions. This is because there are circumstances in which by choosing a tax rate that solves the median first order conditions (under the assumption that the choice of the tax rate does not affect the technological choice of future generations), the economy would not be able to experience growth (because agents do not have an incentive to innovate, that is, $\chi < 0$). However, by choosing a smaller tax rate, the economy would be able to experience growth ($\chi \geq 0$), and this may be optimal for the median voter. Given the notational complexity of the proof, I relegated it in the appendix.

Corollary 4.1 *A steady state with mixed strategies, that is $0 < \Psi < 1$, does not exist.*

Proof 4.1 *By contradiction. Assume that $0 < \Psi < 1$ exists. For that to be an equilibrium agents have to be indifferent between innovating and not innovating. Then a small reduction in the tax rate has the effect of inducing all agents to innovate which in turn implies higher next period transfers. Given the marginal reduction in the tax rate this is strictly preferred by the median voter. Q.E.D.*

Therefore, an important difference between the economy with exogenous taxes and the economy with endogenous taxes is that, while in the former a steady state equilibrium with mixed strategy ($0 < \Psi < 1$) is feasible, in the latter such an equilibrium does not exist.

We are now ready to characterize the tax rate in steady state equilibria.

Proposition 4.2 *The equilibrium tax rate in a stagnant steady state is strictly greater than the the equilibrium tax rate in a growing steady state.*

Proof 4.2 *The proof is implicitly provided by the proof of proposition 4.1. In particular, the steady state tax rate in a non growing economy is given by:*

$$\tau^* = \frac{\displaystyle\int f(\theta)dF(\theta) - f(\bar{\theta})}{2\displaystyle\int f(\theta)dF(\theta) - f(\bar{\theta})}$$

while in the steady state with growth the equilibrium tax rate, denoted by τ^{**}, is not greater than:

$$\underline{\tau} = \frac{\displaystyle\int f(\theta+\omega)dF(\theta+\omega) - E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]}{2\displaystyle\int f(\theta+\omega)dF(\theta+\omega) - E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]}$$

Notice that $\underline{\tau}$ is decreasing in $E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]$. Because assumption 1.3 guarantees that

$$\frac{\displaystyle\int f(\theta+\omega)dF(\theta+\omega) - \int f(\bar{\theta}+\omega)dF(\omega)}{2\displaystyle\int f(\theta+\omega)dF(\theta+\omega) - \int f(\bar{\theta}+\omega)dF(\omega)} \leq \tau^*$$

and the convexity of f implies that $E[f(\theta+\omega')|\theta+\omega=\bar{\theta}] > \int f(\bar{\theta}+\omega)dF(\omega)$, then $\tau^* > \underline{\tau} \geq \tau^{**}$. Q.E.D.

Therefore, when the economy is growing, the equilibrium tax rate is smaller. The effect of learning on the equilibrium tax rate is summarized by the term $E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]$. The lower the learning ability of the agent is, the greater the value of this term. This in turn implies a lower value of the equilibrium tax rate. With some further restrictions on the functional form of f, we can have the situation in which the different equilibrium tax rates in growing and non growing economies is only the result of the reduced ability of the agents to infer their skill parameters. This is the case, for example, when the function f assumes the exponential form.

4.3 A particular specification of the function f

It is interesting to analyze the model when f is an exponential function, that is, $f(z) = e^z$. It can be verified that the exponential form satisfies assumption 1.3. Given assumption 1.1 and 1.2, when all agents adopt the same technology and choose the same allocation of working time between sectors—for example in the steady state—the distribution of income is lognormal in both sectors of the economy. The log-normality assumption is consistent with the results of several empirical studies. See, for example, Aitchison & Brown (1969).

In a stagnant steady state, that is an equilibrium in which no one innovates and $\Psi = 0$, the equilibrium tax rate τ^* is derived by solving the first order conditions of the median voter problem, and it is given by:

$$\tau^* = \frac{e^{\frac{\sigma_\theta^2}{2}} - 1}{2e^{\frac{\sigma_\theta^2}{2}} - 1} = \bar{\tau} \tag{22}$$

In a steady state equilibrium with growth, the equilibrium tax rate τ^{**} satisfies:

$$\tau^{**} \leq \frac{e^{\frac{\sigma_\theta^2}{2}\frac{\sigma_\theta^2}{\sigma_\theta^2+\sigma_\omega^2}} - 1}{2e^{\frac{\sigma_\theta^2}{2}\frac{\sigma_\theta^2}{\sigma_\theta^2+\sigma_\omega^2}} - 1} = \underline{\tau} \tag{23}$$

It can be easily verified that $\bar{\tau} > \underline{\tau}$, and therefore, growing economies are characterized by lower redistributive policies. But differently from the results obtained in the endogenous growth literature, the negative association between the rate of growth of the economy and the level of redistributive policies, is not only a consequence of the distortional effects of taxation. In the model developed in this paper, it is the growth of the economy that creates conditions for which the demand for redistributive policies is lower. These conditions are given by the limited agents' learning of their position in the distribution of skills when the economy is growing. Without this asymmetry in the agents' ability to learn their individual skills, the equilibrium tax rate would be the same in growing and non growing economies. In fact, if agents learn their individual skills after the first period production independently of their innovation choices, then the tax rate in a growing equilibrium is equal to the tax rate in a stagnant equilibrium and it is given by τ^*.

The tax rate in growing and non growing economies, as a function of the cost parameter ϕ, is plotted in figure 3. Coherently with the result of proposition 4.1, the tax rate curve for the stagnant steady state is defined for $\phi \geq \phi_1$, while the tax rate curve in the growing steady state is defined for $\phi \leq \phi_2$.

Place figure 3 here]

The shape of the tax rate curve in a growing steady state is of particular interest. For a range of values of the cost parameter between ϕ_1 and ϕ_2, the tax rate is decreasing in ϕ: for less efficient economies, that is for economies in which the implementation of the innovative technology is more expensive, the median voter chooses a lower tax rate. This is the range of values of ϕ for which the tax rate resulting from the solution of the first order conditions of the median voting problem is not optimal. In these cases it is optimal for the median voter to reduce the level of taxes so that the economy would be able to grow. But, higher is the innovation cost, lower must be the level of taxes for which it is optimal for all agents to innovate. In this context, that is in this range of the parameter cost, the distortional effect of taxes increases as the cost parameter ϕ increases. As a consequence, the incentive to tax decreases as ϕ increases and the median voter, by internalizing this higher distortional effect, chooses a lower level of taxation.

This result is not new in the politico-economy literature. For example Brennan & Buchanan (1977) show how policy inefficiencies may reduce the demand for these policies. In their model, policies do not have beneficial effects for the society, and consequently, greater inefficiency implies a smaller role played by the public sector and greater welfare for the society. Another example is Krusell, Quadrini, & Ríos-Rull (1996), which compare economies with income and consumption taxes. Because income taxes have greater distortional effects than consumption taxes, the economy that implements redistributive policies by taxing incomes chooses less redistribution than the economy in which redistribution is implemented by taxing consumptions. On the whole, the economy with income taxes is characterized by higher income, despite the higher distortion of this type of taxes per unit of resources redistributed.

5 Inequality and mobility

One of the predictions of this paper is that the distribution of income is more unequal when the economy is growing. One way to measure the degree of inequality is to use the ratio of average income to median income. When the economy is growing, this ratio is given by:

$$\frac{\text{Ave}(Y)}{\text{Med}(Y)} = \frac{\displaystyle\int f(\theta+\omega)dF(\theta+\omega)}{f(\bar{\theta})}$$

while in a stagnant steady state this ratio is given by:

$$\frac{\text{Ave}(Y)}{\text{Med}(Y)} = \frac{\displaystyle\int f(\theta)dF(\theta)}{f(\bar{\theta})}$$

Given the convexity of f, the above inequality index is greater when the economy is growing. Moreover, the degree of inequality increases with the variance of the innovation shock which also determines the growth rate of the economy. In the special case in which f is an exponential function, the inequality index in a growing steady state is given by:

$$\frac{\text{Ave}(Y)}{\text{Med}(Y)} = e^{\frac{\sigma_\theta^2}{2}+\frac{\sigma_\omega^2}{2}}$$

while in a stagnant steady state is given by:

$$\frac{\text{Ave}(Y)}{\text{Med}(Y)} = e^{\frac{\sigma_\theta^2}{2}}$$

Furthermore, greater is the steady state growth rate—which depends on σ_ω^2—and greater is the difference between these two ratios. Therefore, in the model economy developed in this paper, inequality is not necessarily harmful for growth but is a consequence of it.

There are two different ways to analyze the relationship between inequality and the level of fiscal policies: if we consider inequality in the distribution of skills, that is the parameter θ, then redistributive policies are positively correlated with inequality. This is consistent with the conclusion reached by several works in political economy. For example, Bertola (1993), Perotti

(1993), Persson & Tabellini (1994), Alesina & Rodrik (1994), Krusell et al. (1997). The second source of inequality, derives from random realizations associated with innovative technologies. This source of inequality is negatively associated with redistributive policies.

These two contrasting effects of inequality on redistributive policies have important empirical implications. In a cross-countries analysis, we may observe either a positive or a negative association between inequality and redistribution if we do not separate the inequality deriving from the distribution of skills and the inequality caused by the growth of the economy. In a time series analysis of the same country, instead, where it is more reasonable to assume a certain stability in the distribution of skills, the model clearly predicts a negative association between inequality and redistributive policies.

Another prediction of the model is that growing economies are characterized by greater mobility. While in a stagnant economy the income position of each agent does not change over time—that is the income of the agent when young is equal to the income when old—if the economy is growing, the income of the agent also depends on the realization of an idiosyncratic shock with the same stochastic properties across agents. One way to measure the degree of mobility is to compute the proportion of agents whose income is smaller than the average income in the first period of life, and greater than the average income in the second period of life. According to this mobility measure, higher is the importance of the idiosyncratic shock relative to the ex-ante inequality (genetic skills), higher is the degree of mobility.

In summary, the model developed in this paper predicts that growing economies are characterized by higher inequality and greater mobility. On the other hand, stagnant economies are characterized by a more equal distribution of income but lower mobility.

6 The model with risk-averse agents

All of the results obtained so far have been derived by assuming risk neutral agents. This section discusses how the results would change if the utility of the agents is concave in consumption. Let's assume that agents maximize $W = u(c_1) + u(c_2)$, where u is the per-period utility, c_1 is the agent's consumption when young and c_2 is the agent's consumption when old. The function u is assumed to be of the constant relative risk aversion class, that is, $u(c) = c^{1-\gamma}/(1-\gamma)$. The choice of this utility is motivated by its wide use in the growth literature.

Risk aversion has several implications. First, although the expected productivity of the innovative technology is higher, the greater income uncertainty associated with the implementation of the innovative technology might induce lower utility even in the absence of innovation costs. Second, it may be optimal to implement the innovative technology only in one sector. In this case, agents learn their levels of skills after the first period, by observing the output results, and learning does not play any role in the voter's behavior. Third, because taxes have an insurance benefit, an increase in the tax rate might increase—rather than decrease—the incentive to undertake risky innovations. In this instance, growth can be encouraged by raising the tax rate rather than reducing it. Finally, the insurance benefit of taxes is also taken into account by the voters: when the economy is growing, voters may prefer more redistribution as a means of insuring themselves against income uncertainty.

In order to assure that all of the results obtained in the previous sections still hold when agents are risk averse, it is necessary to restrict the degree of concavity of the utility function. In the remaining part of this section, I will show that with γ sufficiently small, all the results obtained in the previous sections hold in the case of risk-averse agents. In the interest of space, the presentation will be synthetic.

For simplicity, assume that the adoption of the innovative technology in one sector requires the adoption of the innovative technology also in the other sector. This excludes the possibility that the agent chooses to innovate in only one of the two sectors and fully learns his or her skill after the first period.[8] Given this assumption, the optimal allocation of labor is still given by

[8] Although I take this as an assumption, it is also possible to prove that for a sufficiently low γ, this would be the optimal choice of the agent.

$l = 1 - \tau$, and the agent's consumption is equal to:

$$c_j(i) = \frac{1}{2} A f(\theta + i\omega)[1 + (1-\tau)^2] + T - Aq \cdot i \cdot (2 - j) \qquad j \in \{1, 2\} \tag{24}$$

A sufficient condition for the innovative technology to give higher expected utility is that:

$$\int u\left(Af(\theta + \omega)\right) dF(\theta + \omega) > \int u\left(Af(\theta)\right) dF(\theta) \tag{25}$$

This condition guarantees that, when the innovation cost is zero, the expected utility from implementing the innovative technology is greater than the expected utility from implementing the standard technology, even if transfers are zero. Using the specification of u, this condition reduces to:

$$\int \left(f(\theta + \omega)\right)^{1-\gamma} dF(\theta + \omega) > \int \left(f(\theta)\right)^{1-\gamma} dF(\theta) \tag{26}$$

The sign of the inequality is reversed if $\gamma > 1$. From this expression it is easy to see that there is $\bar{\gamma} > 0$ for which the inequality is satisfied for $\gamma \in [0, \bar{\gamma})$.[9]

Another property of the model analyzed in the previous sections which is important for the derivation of some of the results, is that the incentive to implement the innovative technology is decreasing in the tax rate. With risk aversion this property holds if the insurance benefit dominates the distortional effect of taxation. In order to maintain this property, we have to impose that the gain in lifetime utility that derives from implementing the innovative technology, is not decreasing in τ and τ'. After deriving the lifetime gain function $W(\tau, \tau', 1) - W(\tau, \tau', 0)$ following a similar procedure used to derive equation (15), it is enough to impose that the derivative of this function with respect to τ is negative. Analytically, this requires that for all τ

[9] This derives from the continuity of the function on the left-hand-side and the function on the right-hand-side, and from the fact that the inequality is satisfied in the limit $\gamma = 0$.

the following inequality is satisfied:

$$E\left\{(c_j(i=1))^{-\gamma}\left[Af(\theta+\omega)(1-\tau)-\frac{\partial T}{\partial\tau}\right]\right\} > E\left\{(c_j(i=0))^{-\gamma}\left[Af(\theta)(1-\tau)-\frac{\partial T}{\partial\tau}\right]\right\} \quad (27)$$

for $j \in \{1,2\}$. Because the inequality is satisfied when $\gamma = 0$, a continuity argument shows that there exists $\gamma > 0$ sufficiently small, for which the inequality is still satisfied.

Finally we want to assure that $\underline{\tau} < \tau^*$, where $\underline{\tau}$ and τ^* are derived as in section 4.2. The condition that guarantees this is:

$$E\left\{(c_2(i=1))^{-\gamma} f(\theta+\omega) \,\middle|\, \theta+\omega=\bar{\theta}\right\} > \frac{\int f(\theta+\omega)dF(\theta+\omega)\, f(\bar{\theta})\,(c_2(i=0))^{-\gamma}}{\int f(\theta)dF(\theta)} \quad (28)$$

where $c_2(i=1)$ is the consumption of the median voter in the steady state with growth and $c_2(i=0)$ is the consumption of the median voter in the steady state without growth. It can be shown that there exists $\bar{\gamma} > 0$ so that the above condition is satisfied for $\gamma \in [0, \bar{\gamma})$.

To summarize, the results obtained in the previous sections still hold when agents have a moderate degree of risk aversion. Alternatively, when insurance considerations play a major role—in investment as well as in voting decisions—high redistribution is not necessarily associated with low growth. However, as discussed in the next section, the empirical results of previous studies support the predictions of the model with risk neutral or moderately risk-averse agents.

7 Some empirical evidence

Barro (1991) provides evidence of a negative association between the growth rate of the economy and government consumption spending as a fraction of GDP.[10] This is a test of government expenditure affecting the growth rate of the economy and not vice versa, but it is also likely that the other causation could be found in the data. This is because data on government consumption

[10] However,Levine & Renelt (1992) find that the negative association between growth and government consumption is not robust to their testing procedure.

spending is not lagged respect to growth rates data. It must be pointed out, however, that, if both causations are important, then there is a simultaneity bias in the estimation of the growth equation.

The empirical study that is more directly related to this paper is Kristov et al. (1992). Using data for a subset of OECD countries, they estimate a regression equation in which the dependent variable is the value of social transfers (with and without pensions) as a fraction of GDP. Among the explanatory variables they include the growth rate of the economy and they find that this variable has a negative and statistically significant effect on social transfers. Therefore, the theorized negative effect of growth on redistributive policies is supported by the empirical results of this study.

Kristov, Lindert and McClelland also test the significance of several measures of inequality on the size of government transfers and they find that the ratio of average income to median income has a positive effect, even though not significant, which is consistent with the prediction of the model. The negative association between inequality and social transfers is also supported by the study of Rodriguez (1997) which uses a similar set of data.

The relationship between inequality and growth has been tested by Persson & Tabellini (1994), Alesina & Rodrik (1994) and Perotti (1996)[11] and the result seems to support a negative effect of inequality on growth. However, it must be pointed out that these studies test the effect of inequality on growth, while the model developed in this paper also provides predictions on the reverse causation, that is, the effect of growth on inequality.

In summary, although there are not empirical studies that allow us to detect the effect of growth on the distribution of income, some studies support the negative association between growth and transfers and between inequality and transfers. This is the prediction of the model economy developed in this paper when agents are characterized by a moderate degree of risk aversion.

[11] An excellent review of the empirical studies on inequality and growth is provided by Benabou (1996).

8 Conclusion

Mainstream theoretical results in the endogenous growth literature show that the level of taxation, and in particular the level of capital income taxes (to physical and human capital), affects the growth rate of the economy. This paper shows that the causal relationship between taxation and growth could also run in the opposite direction with the growth rate of the economy affecting the extent of redistributive policies. The main mechanism that in the model economy determines this result is the agents' lack of information regarding their position in the distribution of skills during periods of growth. There is a process of learning through which agents update their beliefs over the individual skill, but the noise associated with innovative activities reduces the ability to learn. Given the skewed distribution of skills, this implies that in a growing economy the expected income of the median voter is greater than the ex-post median income and, consequently, the median voter votes for less redistributive taxation.

The model economy allows for multiple steady state equilibria and it is shown that, under some conditions, the tax rate associated with a growing steady state is smaller than the tax rate associated with a steady state without growth. This is a direct consequence of the reduced informational structure (or learning) that characterizes an economy which is in a balanced growth path. The result of a negative impact of growth on redistributive policies found in the paper is supported by the empirical study of Kristov et al. (1992).

Another conclusion of the paper is that both greater inequality and greater mobility characterize growing economies. Therefore, while the ex-post inequality in the distribution of income is greater in economies that experience growth, at the same time this ex-post distribution is less dependent on ex-ante inequalities, that in the model are represented by the distribution of skills. Therefore, greater ex-post inequality and smaller ex-ante inequality are associated with growth.

A Appendix

A.1 Proof of lemma 4.1

The voter's problem, described in (19), is:

$$\begin{aligned} V(i, y_T, y_{NT}) &= \max_{\tau' \in [0,1]} \left\{ \frac{1}{2} A' x [1 + (1-\tau')^2] + \tau' Y' \right\} \qquad (29) \\ & \quad \text{subject to} \\ A' &= A(1 + \alpha\Psi) \\ Y' &= A'(1-\tau') \int f(\theta) dF(\theta) \left\{ 1 + \frac{1}{2}\alpha(\Psi + \Psi') \right\} \\ \Psi' &= H(\tau') \end{aligned}$$

where the variable x, defined in (20), identifies the voter type. If the tax rate does not affect the investment choice of the next young generation, *i.e.*, H is a constant function, then the solution of the voter's problem is unique (although it could be a corner solution). In fact, if $x < \int f(\theta)dF(\theta)[2+\alpha(\Psi+\Psi')]$, the objective is continuous and strictly concave in $\tau \in [0,1]$. If $x \geq \int f(\theta)dF(\theta)[2+\alpha(\Psi+\Psi')]$, then the objective is not strictly concave but it is strictly decreasing in $\tau \in [0,1]$ and the solution is $\tau = 0$. However, if the tax rate affects the investment choice of the next period young generation, through the function H, the solution of the voter's problem may not be unique.

Let's observe first that the innovation choice of the next young generation affects the voter's objective (29) only by affecting Y': if agents innovate, output and transfers will be greater, and growth is preferred.

Define $\tau_1(x)$ to be the tax rate preferred by agent x under the assumption that the next young generation will not innovate and the innovation choice of the next young generation is not affected by τ'. Moreover, define $\tau_2(x)$ to be the tax rate preferred by agent x under the assumption that the next young generation will innovate and the innovation choice of the next young generation is not affected by τ'. For all x, $\tau_1(x)$ and $\tau_2(x)$ are unique solutions of the voter problem (29) and they are decreasing functions of x (although not strictly). Moreover, the expected utility of the agent under $\tau_2(x)$ is strictly greater than the expected utility under $\tau_1(x)$. That is, growth is always preferred if the agent can choose the tax rate without affecting the growth of the economy. Let's assume now that for some $\tilde{x}$ the solution of the agent's voting problem is not unique and is given by two tax rates. The first tax rate, denoted by $\tau^g(\tilde{x})$, is such that the next young generation innovates. The second tax rate is $\tau_1(\tilde{x})$ but with this tax rate the next young generation does not innovate, because χ will be smaller than zero even in the case in which agents expect that other agents innovate. The following inequalities have to be satisfied: $\tau^g(\tilde{x}) < \tau_1(\tilde{x}) < \tau_2(\tilde{x})$. The first inequality must be satisfied because if the economy cannot grow under $\tau_1(\tilde{x})$, then any tax rate bigger than this prevents the economy from growing. The second inequality is satisfied because when the new young generation innovates, Y' is bigger and the voter prefers more taxes. Observe also that, if the voter is indifferent between the two tax rates, it must be the case that any tax rate τ, with $\tau^g(\tilde{x}) < \tau \leq \tau_2(\tilde{x})$ must induce the next young generation not to innovate. Otherwise a higher tax rate than $\tau^g(\tilde{x})$ is preferred.

I want to show now that for all agents with $x > \tilde{x}$ the solution of the voting problem is unique and it is characterized by a tax rate that is smaller or equal to $\tau^g(\tilde{x})$, and for all agents with $x < \tilde{x}$ the voting solution is also unique and it is characterized by a tax rate that is greater or equal to $\tau_1(\tilde{x})$. Consider first agents with $x > \tilde{x}$. A tax rate $\tau > \tau^g(\tilde{x})$ will prevent the economy from growing. If agents with $x = \tilde{x}$ are indifferent on whether the next young generation innovates or not, agents with $x > \tilde{x}$ will strictly prefer the growing tax rate because they have a smaller redistributive advantage from increasing taxes as can be seen by inspecting the objective (29). More specifically, for all $x > \tilde{x}$ for which $\tau_2(x) > \tau^g(\tilde{x})$, the preferred tax rate is $\tau^g(\tilde{x})$ while for all other agents the preferred tax rate is $\tau_2(x)$. Consider now agents with $x < \tilde{x}$. In order to induce the next young generation to innovate, these agents have to accept the same tax rate accepted by agents $\tilde{x}$, that is $\tau^g(\tilde{x})$. If for agents $\tilde{x}$ is indifferent to increase taxes and forcing the economy into a non growing path, for agents with $x < \tilde{x}$ it must be strictly preferred given that the advantage of redistributive taxation is greater than for agents $\tilde{x}$ and the optimal tax rate is $\tau_1(x)$. Consequently, there is only one value of x, $\tilde{x}$, for which preferences are not single-peaked. Because x is a continuous variable, the measure of agents with $x = \tilde{x}$ is zero.

In summary, tax preferences can be characterized by three regions in the range of the variable x. For $x < \tilde{x}$ the preferred tax rate is $\tau_1(x)$. For $\tilde{x} < x \leq \bar{x}$ the preferred tax rate is $\tau^g(\tilde{x})$ and for $x > \bar{x}$ the preferred tax rate is $\tau_2(x)$, where $\bar{x}$ is such that $\tau^g(\tilde{x}) = \tau_2(\bar{x})$. Finally for $x = \tilde{x}$ the preferred tax rates are $\tau^g(\tilde{x})$ and $\tau_1(\tilde{x})$. Because $\tau_1(x)$ and $\tau_2(x)$ are decreasing in x for all x, $\tau_1(\tilde{x}) > \tau^g(\tilde{x})$ and $\tau_2(\bar{x}) = \tau^g(\tilde{x})$, preferences are monotone decreasing in x, although not strictly. *Q.E.D.*

A.2 Proof of proposition 4.1

The proof follows three steps. The first step shows the existence of $\phi_1 > 0$ for which steady states without growth are possible only for $\phi \geq \phi_1$. The second step shows the existence of $\phi_2 > 0$ for which steady states with growth are possible only for $\phi \leq \phi_2$. The third step shows that $\phi_1 < \phi_2$, and therefore, there is a range of values of ϕ for which multiple steady state equilibria exist.

To check for the existence of steady state equilibria we have to check that, when the economy is in the steady state and all agents expect that this steady state will persist in the future, there is not incentive at the individual level to deviate from the action predicted by this equilibrium. Two are the conditions that need to be checked. First, in a steady state with growth it must be optimal for the new generation to innovate and in a steady state without growth it must be optimal not to innovate. The innovation decision depends on χ defined in (16) and it is given by:

$$\chi = [1 + (1-\tau)^2] + [1 + (1-\tau')^2](1+\alpha\Psi) - \phi \tag{30}$$

The second condition that needs to be checked is that the steady state tax rate is optimal for the median voter in the sense of optimizing the expected utility:

$$E(U_2|y_T, y_{NT}) = \frac{1}{2}Ax_{Med}[1 + (1-\tau')^2] + \tau'Y' \tag{31}$$

Proof of the existence of ϕ_1

In a steady state without growth $\Psi_t = 0$ for all t, and the equilibrium tax rate is determined by the first order conditions of the voting problem (19) for the median agent (under the assumption $\Psi = \Psi' = 0$). The solution is:

$$\tau^* = \frac{\displaystyle\int f(\theta)dF(\theta) - f(\bar{\theta})}{2\displaystyle\int f(\theta)dF(\theta) - f(\bar{\theta})} \tag{32}$$

In order to prove that a steady state without growth is in fact an equilibrium, we have to check that $\chi \leq 0$ and that τ^* is optimal for the median. For τ^* to be optimal there must not be other $\tau < \tau^*$ which is strictly preferred by the median. Of course, this depends on the cost parameter ϕ. Let's assume that ϕ is such that there exists $\tau < \tau^*$ for which:

$$\chi = [1 + (1-\tau^*)^2] + [1 + (1-\tau^*)^2] - \phi < 0 \tag{33}$$

but

$$\chi = [1 + (1-\tau)^2] + [1 + (1-\tau^*)^2] - \phi > 0 \tag{34}$$

This means that there is some $\tau < \tau^*$, for which it is optimal for the next young generation to deviate from the steady state action even though each of them expects that in the following period the economy is still in a steady state without growth (that is, other agents do not innovate). If this is the case, then there is some $\tau < \tau^*$ for which the median can induce the economy to move to an equilibrium with growth. Furthermore, if the change in growth induced by the change in τ provides higher expected utility to the median, then the steady state without growth is not an equilibrium. Define $U_{ss}(\tau^*)$ to be the median expected utility in a steady state without growth and $U_{dev}(\tau)$ the expected utility of the median when he or she chooses the tax rate $\tau < \tau^*$ and the next young generation innovates. The two utilities are given by:

$$
\begin{aligned}
U_{ss}(\tau^*) &= \frac{1}{2}Af(\bar{\theta})[1+(1-\tau^*)^2] + \tau^*(1-\tau^*)A\int f(\theta)dF(\theta) && (35)\\
U_{dev}(\tau) &= \frac{1}{2}Af(\bar{\theta})[1+(1-\tau)^2] + \tau(1-\tau)A\int f(\theta)dF(\theta)\left(1+\frac{1}{2}\alpha\right) && (36)
\end{aligned}
$$

It is easy to show that $U_{dev}(\tau^*) > U_{ss}(\tau^*) > U_{ss}(0)$ and $U_{dev}(\tau)$ converges monotonically to $U_{ss}(0)$, from $U_{dev}(\tau^*)$, as $\tau \to 0$. Therefore, there is a minimum value of τ that the median voter is willing to accept in order to induce growth. Let's call this level of tax rate τ_1. Then the equation

$$\phi_1 = [1+(1-\tau_1)^2] + [1+(1-\tau^*)^2] \tag{37}$$

defines the lower bound for the range of the cost parameter ϕ for which a steady state without growth is possible. Therefore, steady state without growth exist only for $\phi \geq \phi_1$.

Proof of the existence of ϕ_2

In a steady state with growth $\Psi_t = 1$ for all t. Let τ^{**} be the equilibrium tax rate of this steady state and τ_{foc} the tax rate determined by solving the first order conditions of the median voter when the economy is in a steady state with growth and the tax rate does not affect the innovation choice of the next young generation. The latter is given by:

$$\tau_{foc} = \frac{\int f(\theta+\omega)dF(\theta+\omega) - E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]}{2\int f(\theta+\omega)dF(\theta+\omega) - E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]} \tag{38}$$

It can be shown that $\tau_{foc} \leq \tau^*$. This is because the following inequalities are satisfied:

$$
\begin{aligned}
\tau_{foc} &= \frac{\int f(\theta+\omega)dF(\theta+\omega) - E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]}{2\int f(\theta+\omega)dF(\theta+\omega) - E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]} \\
&< \frac{\int f(\theta+\omega)dF(\theta+\omega) - \int f(\bar{\theta}+\omega)dF(\omega)}{2\int f(\theta+\omega)dF(\theta+\omega) - \int f(\bar{\theta}+\omega)dF(\omega)} \\
&\leq \frac{\int f(\theta)dF(\theta) - f(\bar{\theta})}{2\int f(\theta)dF(\theta) - f(\bar{\theta})} = \tau^*
\end{aligned}
$$

The first inequality comes from the convexity of f which implies that $E[f(\theta+\omega')|\theta+\omega=\bar{\theta}] > \int f(\bar{\theta}+\omega)dF(\omega)$. The second inequality comes from the particular conditions imposed on the function f in assumption 1.3.

In order to prove that a steady state with growth and tax rate τ^{**} is in fact an equilibrium, we need to check that $\chi \geq 0$ and τ^{**} is optimal for the median voter. If τ^{**} satisfies the condition:

$$\chi = [1 + (1-\tau^{**})^2] + [1 + (1-\tau^{**})^2](1+\alpha) - \phi \geq 0 \tag{39}$$

and $\tau^{**} = \tau_{foc}$, then of course τ^{**} is optimal for the median voter. If $\tau^{**} < \tau_{foc}$, then for τ^{**} to be optimal, condition (39) has to be satisfied with equality and there is not τ, with $\tau > \tau^{**}$, for which the expected utility of the median in the steady state equilibrium with growth is smaller than the expected utility under deviation from this equilibrium. The expected utility for the median in the growing steady state, denoted by $U_{ss}(\tau^{**})$, and in the non growing equilibrium, denoted by $U_{dev}(\tau_m)$, are given by:

$$
\begin{aligned}
U_{ss}(\tau^{**}) &= \frac{1}{2}AE[f(\theta+\omega')|\theta+\omega=\bar{\theta}][1+(1-\tau^{**})^2] + \tau^{**}(1-\tau^{**})A\int f(\theta)dF(\theta)(1+\alpha) \quad (40) \\
U_{dev}(\tau_m) &= \frac{1}{2}AE[f(\theta+\omega')|\theta+\omega=\bar{\theta}][1+(1-\tau_m)^2] + \tau_m(1-\tau_m)A\int f(\theta)dF(\theta)\left(1+\frac{1}{2}\alpha\right) \quad (41)
\end{aligned}
$$

where $\tau_m \in [0,1]$ is the tax rate that maximizes (41) without restrictions.

If (40) is smaller than (41), then the median voter has an incentive to deviate from the steady state tax rate, and therefore, a steady state with growth is not possible. For $\tau^{**} < \tau_{foc}$, $U_{ss}(\tau^{**})$ is increasing in τ^{**}. Define τ_2 to be the minimum τ^{**} the median is willing to accept in order to allow for growth, that is, τ_2 is defined by the condition $U_{ss}(\tau_2) = U_{dev}(\tau_m)$. Then the maximum level of ϕ compatible with a steady state with growth is given by the equation:

$$\phi_2 = [1 + (1 - \tau_2)^2] + [1 + (1 - \tau_2)^2](1 + \alpha) \tag{42}$$

and steady states with growth exist only for $\phi \leq \phi_2$.

Proof of $\phi_2 > \phi_1$

It is sufficient to prove that when $\phi = \phi_2$, a steady state equilibrium without growth exists. The cost parameter ϕ_2 is defined in (42) and it is given by:

$$\phi_2 = [1 + (1 - \tau_2)^2] + [1 + (1 - \tau_2)^2](1 + \alpha) \tag{43}$$

The tax rate τ_2 is determined by the condition $U_{dev}(\tau_m) = U_{ss}(\tau_2)$, that is:

$$\begin{aligned}
&\frac{1}{2}AE[f(\theta + \omega')|\theta + \omega = \bar{\theta}][1 + (1 - \tau_m)^2] + \tau_m(1 - \tau_m)A \int f(\theta)dF(\theta)\left(1 + \frac{1}{2}\alpha\right) = \\
&\frac{1}{2}AE[f(\theta + \omega')|\theta + \omega = \bar{\theta}][1 + (1 - \tau_2)^2] + \tau_2(1 - \tau_2)A \int f(\theta)dF(\theta)(1 + \alpha)
\end{aligned} \tag{44}$$

In a steady state without growth, the condition $U_{ss}(\tau^*) \geq U_{dev}(\tau_1)$ has to be satisfied, that is:

$$\begin{aligned}
&\frac{1}{2}Af(\bar{\theta})[1 + (1 - \tau^*)^2] + \tau^*(1 - \tau^*)A \int f(\theta)dF(\theta) \ \geq \\
&\frac{1}{2}Af(\bar{\theta})[1 + (1 - \tau_1)^2] + \tau_1(1 - \tau_1)A \int f(\theta)dF(\theta)\left(1 + \frac{1}{2}\alpha\right)
\end{aligned} \tag{45}$$

where τ_1 is determined by the condition:

$$\phi_2 = [1 + (1 - \tau_1)^2] + [1 + (1 - \tau^*)^2] \tag{46}$$

We want to show that when $\phi = \phi_2$, condition (45) is satisfied. First observe that the following relations between tax rates are satisfied: $\tau^* \geq \tau_m \geq \tau_2 \geq \tau_1$. This implies that the tax rate reduction when we switch from no growth to growth in a growing path, is smaller than in a non growing path ($\tau_m - \tau_2 < \tau_* - \tau_1$). Let's rewrite conditions (44) and (45) as:

$$E[f(\theta + \omega')|\theta + \omega = \bar{\theta}](1 - \tau_m)^2 + \tau_m(1 - \tau_m)(2 + \alpha) \int f(\theta)dF(\theta) \ = \tag{47}$$

$$E[f(\theta+\omega')|\theta+\omega=\bar{\theta}](1-\tau_2)^2+\tau_2(1-\tau_2)(2+\alpha)\int f(\theta)dF(\theta)+\tau_2(1-\tau_2)\alpha\int f(\theta)dF(\theta)$$

$$f(\bar{\theta})(1-\tau^*)^2+\tau^*(1-\tau^*)2\int f(\theta)dF(\theta)\ \geq \tag{48}$$

$$f(\bar{\theta})(1-\tau_1)^2+\tau_1(1-\tau_1)2\int f(\theta)dF(\theta)+\tau_1(1-\tau_1)\alpha\int f(\theta)dF(\theta)$$

Consider first the last term in equations (47) and (48). Because $\tau_1 \leq \tau_2$, this term in (47) is non smaller than in (48). Notice that the other two terms in the right hand side (RHS) have the same functional form (as a function of τ), of the left hand side (LHS). Therefore, we can determine how the utility of the agent changes with the reduction in τ by simply taking the derivative of the LHS and studying the pattern of this derivative. Of course, the derivative of the LHS in (47) when $\tau = \tau_m$, is equal to the derivative of the LHS in (48) when $\tau = \tau^*$, and they are equal to zero. This is because τ_m and τ^* are determined by solving for the first order conditions. (Unless the solution is not interior. In that case $\tau_m = 0$ and the proof is trivial). Now because the reduction in the tax rate in (47) is smaller than the reduction in (48), it is sufficient to show that for each τ, the second derivative of the LHS of (47) is greater than the second derivative of the LHS of (48). Because the second derivatives are negative, this just means that the first derivative falls faster in the LHS of (48). The second derivative of the LHS in (47) is given by $2E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]-2(2+\alpha)\int f(\theta)dF(\theta)$, and the second derivative of the LHS in (48) is given by: $2f(\bar{\theta})-4\int f(\theta)dF(\theta)$. Therefore, it is sufficient to show that:

$$\int f(\theta+\omega')dF(\theta+\omega')-E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]\leq\int f(\theta)dF(\theta)-f(\bar{\theta}) \tag{49}$$

To show this, assume that the variance of ω is zero. In this case the LHS and the RHS of equation (49) are equal. Now consider increasing the variance of ω. Both terms $\int f(\theta+\omega')dF(\theta+\omega')$ and $E[f(\theta+\omega')|\theta+\omega=\bar{\theta}]$ are increasing in the variance of ω. However, assumption 1.3 guarantees that the second term grows faster, and therefore, the LHS of (49) decreases. Because the RHS is not affected, as the variance of ω becomes positive, condition 49 is strictly satisfied. *Q.E.D.*

Acknowledgements

The author wishes to thank Hilary Appel, Joydeep Bhattacharya, Richard Boylan, Jacques Olivier, Richard Rogerson, José-Víctor Ríos-Rull for useful discussions and comments on an earlier version of this paper and seminar participants at Universitat Pompeu Fabra, 1997 Winter Meeting of the Econometric Society, Federal Reserve Bank of Minneapolis, University of Rochester, CODE conference at the Universitat Autonoma de Barcelona, 1997 Annual Meeting of the Society for Economic Dynamics. The author also wishes to thank two anonymous referees for helpful suggestions. Financial support from the European Community is gratefully acknowledged.

References

Aitchison, J. & Brown, J. (1969). *The Lognormal Distribution with Special Reference to its Uses in Economics*. Cambridge University Press, New York.

Alesina, A. & Rodrik, D. (1994). Distributive politics and economic growth. *Quarterly Journal of Economics*, *109*(2), 465–90.

Barro, R. J. (1990). Goverment spending in a simple model of endogenous growth. *Journal of Political Economy*, *98*, S103–S125.

Barro, R. J. (1991). Economic growth in a cross-section of countries. *Quarterly Journal of Economics*, *106*(2).

Benabou, R. (1996). Inequality and growth. In Bernanke, B. S. & Rotemberg, J. (Eds.), *NBER Macroeconomics Annual*. MIT Press, Cambridge, Massachusetts.

Bertola, G. (1993). Factor shares and savings in endogenous growth. *American Economic Review*, *83*(5), 1184–210.

Brennan, G. & Buchanan, J. (1977). Towards a tax constitution for leviathan. *Journal of Public Economics*, *8*, 255–73.

Diaz-Gimenez, J., Quadrini, V., & Ríos-Rull, J.-V. (1997). Dimensions of inequality: facts on the u.s. distribution of earnings, income and wealth. *Quarterly Review of The Federal Reserve Bank of Minneapolis*, *21*(2), 3–21.

Greene, W. H. (1990). *Econometric analysis.* MacMillan Publishing Company, New York.

Jones, L. E. & Manuelli, R. (1990). A convex model of equilibrium growth. *Journal of Political Economy*, *98*, 1008–38.

Jovanovic, B. & Nyarko, Y. (1996). Learning by doing and the choice of technology. *Econometrica*, *64*(6), 1299–310.

King, R. & Rebelo, S. (1990). Public policy and economic growth: developing neoclassical implications. *Journal of Political Economy*, *98*(5), S126–S150.

Kristov, L., Lindert, P., & McClelland, R. (1992). Pressure groups and redistribution. *Journal of Public Economics*, *48*, 135–63.

Krusell, P., Quadrini, V., & Ríos-Rull, J.-V. (1996). Are consumption taxes really better than income taxes?. *Journal of Monetary Economics*, *37*(3), 475–503.

Krusell, P., Quadrini, V., & Ríos-Rull, J.-V. (1997). Politico-economic equilibrium and economic growth. *Journal of Economic Dynamics and Control*, *21*(1), 243–72.

Levine, R. & Renelt, D. (1992). A sensitivity analysis of cross-country growth regressions. *American Economic Review*, *82*(4), 942–63.

Perotti, R. (1993). Political equilibrium, income distribution, and growth. *Review of Economic Studies*, *60*(4), 755–76.

Perotti, R. (1996). Growth, income distribution, and democracy: what the data say. *Journal of Economic Growth*, *1*, 149–87.

Persson, T. & Tabellini, G. (1994). Is inequality harmful for growth?. *American Economic Review*, *84*(3), 600–21.

Piketty, T. (1995). Social mobility and redistributive politics. *Quarterly Journal of Economics*, *CX*(3), 551–84.

Rebelo, S. (1991). Long-run policy analysis and long-run growth. *Journal of Political Economy*, *99*(3), 500–21.

Rodriguez, F. (1997). Inequality, redistribution and rent-seeking. Unpublished manuscript, Harward University.

Wright, R. (1996). Taxes, redistribution and growth. *Journal of Public Economics*, *62*, 327–48.

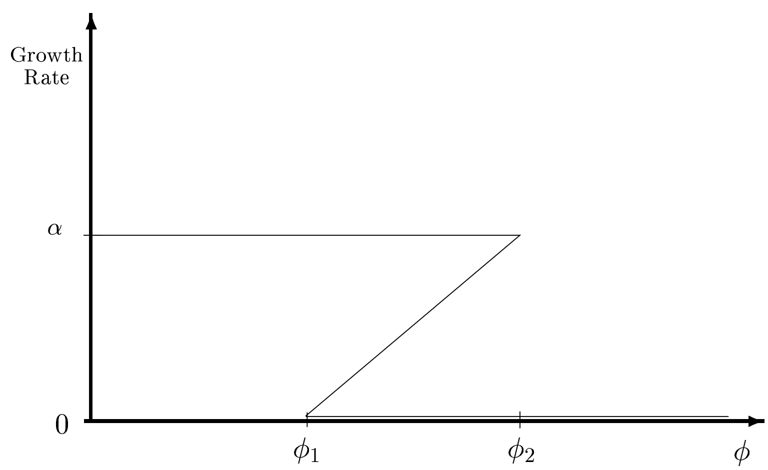

Figure 1: Equilibria with exogenous taxes

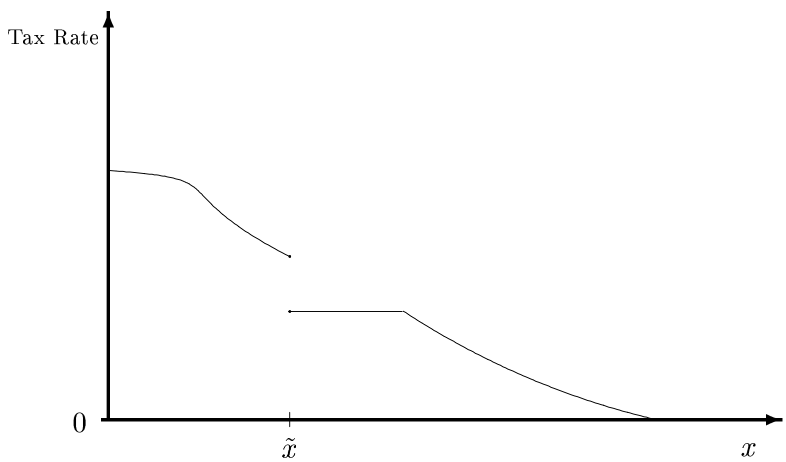

Figure 2: Tax preferences

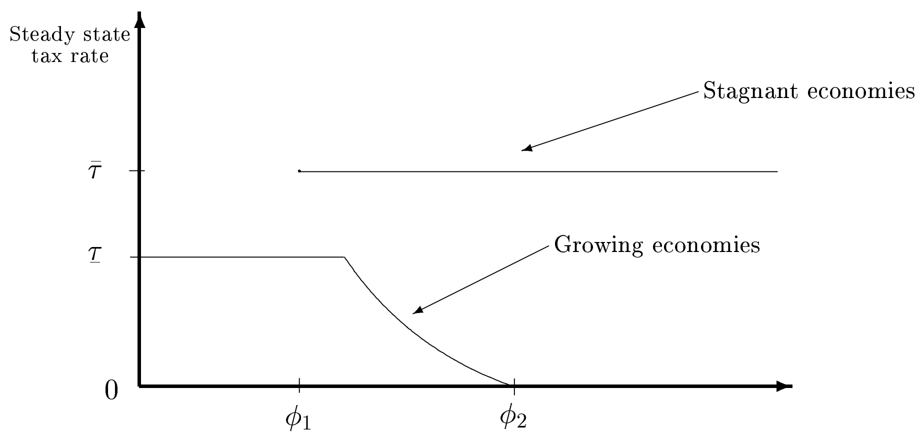

Figure 3: Steady state tax rates