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Federalism, Education-Related Public Good and Growth when Agents are Heterogeneous

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Abstract

In this paper we use an endogeneous-growth model with human capital and heterogeneous agents to analyse the relationship between fiscal federalism and economic growth. Results show that federalism, which allows education-related public good levels to be tailored on the human capital of heterogeneous agents, increases human capital accumulation. This in turn leads to higher rates of growth. The benefits of federalism are stronger the larger the intra-jurisdiction variance of agents' human capital.

Keywords: Fiscal Federalism, Endogenous Economic Growth, Overlapping Generations, Heterogeneous Agents

JEL Codes: H77, J24, O41

1 Introduction

More than forty years have passed since economists formally addressed the theory of fiscal federalism. Richard Musgrave, in 1959, gave a definition of fiscal federalism as a system whose purpose "is to permit different groups living in various states to express different preferences for public services; and this inevitably leads to differences in the levels of taxation and public services" (Musgrave, 1959, p. 179). So, what this means is that the more heterogeneous the federal population, the higher the necessity of decentralization. This argument was underpinned in the seminal works of Tiebout (1956), Olson (1969) and Oates (1972). As Brueckner (2006, p. 2107) points out: the "beneficial outcome (of federalism)...is achieved via sorting individuals into demand-homogeneous jurisdictions, each of which provides a different amount of the public good".

Following these seminal studies, in the theoretical literature we have seen a huge amount of papers (for a survey see Oates, 1999) which confirm this first insight that is: with varying tastes and incomes of all citizens in a country, public and uniform provision - as opposed to private provision - may result in a loss of welfare as the distance between the deciders and beneficiaries of the public goods increases.

More recently, economists are also exploring this strong argument in favour of federalism within a dynamic setting. In other words economists are now trying to explain the link between fiscal decentralization and economic growth by developing endogenous growth models (see Koethenbuerger and Lockwood 2007). It is also worth saying that as far as the decentralization-growth nexus is concerned, the empirical research has been more intense than the theoretical one and, most important, robust evidence of decentralization and growth has been found (see Thiessen 2003).

In this paper we intend to make a contribution on the theoretical side to explore further this link and we start from an endogenous-growth model with overlapping generations. In our model agents invest in human capital while young to enhance their earning power when they are old.

Our paper is related to a model recently published by Brueckner (2006) who shows that federalism, which allows public good levels to be tailored to suit the different demands of young and old individuals, who live in different jurisdictions, increases the incentive to save. This strong incentive in turn leads to an increase in investment in human capital, and a by-product of this higher investment economic growth is faster .

We modify Brueckner's analysis since in our model we assume that i) the public good enhances the human capital; ii) human capital is heterogeneously distributed across individuals. In other words, differently from Brueckner's analysis, we consider a publicly provided public good which is related to the educational process or investment in human capital. For instance let us think of such public good as training programmes which may be chosen by governments to improve the educational process in the economy or stated differently the human capital of a country.

Secondly, in Brueckner, heterogeneity across individuals - and therefore

across jurisdictions - is only age-related. The young and the old live in separate jurisdictions and therefore there are only two jurisdictions. This sorting assumption is crucial for the results in Brueckner's paper.

In our work instead agents are completely heterogeneous to one another according to the different endowment of human capital they may have. So, to the best of our knowledge, our paper is the only one that studies the relationship between fiscal federalism and growth in a set-up where there is complete heterogeneity among all individuals in the economy and notably our results are independent on any sorting assumption.

Preliminary results of our analysis show that federalism, which allows education - related public good levels to be tailored on the human capital of heterogeneous agents, increases human capital accumulation. This in turn leads to higher rates of growth. The benefits of federalism are stronger the larger the intra-jurisdiction variance of agents' human capital.

The paper is organized as follows. Section 2 introduces the model. Section 3 describes an idealized economy which is composed of a complete array of heterogenous jurisdictions. Sections 4 and 5 present respectively the unitary and the federalist system. Section 5 concludes.

2 The set-up

We set up a model that relies on Brueckner (2006), modified in order to explicitly consider an education-related public good.

The economy consists of overlapping generation (OLG) of a continuum of two-period lived agents with mass equal to 1. There is no population growth.

In the economy there exists a unique non-perishable good, the output good (Y). At any time the output good can be consumed (X), or purchased by the Government. The Government then uses these purchases to provide public good (or services) (Z) to individuals.

At any time t, the following equation holds:

$$Y_t = X_t + Z_t \tag{1}$$

In this economy there exists a unique production factor, human capital (H), which is heterogeneously distributed across individuals. H_t indicates aggregate human capital at time t. Individual variables (lowercase letters) are indexed both by a time subscript (like the aggregate ones), and by an individual (i) subscript and by a superscript, that indicates the agent's generation, or date of birth. Therefore h_{it}^t indicates the human capital of agent i, of generation t, at time t. Human capital heterogeneity implies $h_{it}^t \neq h_{jt}^t \ \forall i \neq j$. Notice that this hypothesis is different from Brueckner (2006) who assumes a young representative agent and a old representative agent. In other words the young agents are identical to one another, and the old agents also are identical to one another. Therefore heterogeneity across individuals - and therefore across jurisdictions - is only age-related. The young and the old live in separate jurisdictions and as a consequence there are only two jurisdictions.

We assume a constant marginal product, such that, the production function becomes

$$Y_t = F(H_t) \tag{2}$$

with $F' = const$

Profit $(F(H_t) - w_t H_t)$ maximization and the zero-profit condition imply

$$w_t = F'(H_t) \tag{3}$$

Therefore the wage rate is constant over time:

$$w_t = w \tag{4}$$

Following Brueckner (2006), we assume that young individuals fully inherit the human capital of their "old" parents, therefore the intergenerational transmission mechanism of human capital is the following:

$$h_{it}^t = h_{it}^{t-1} \tag{5}$$

This hypothesis is unusual. Actually the literature that studies the intergenerational accumulation/transmission of human capital either assumes a genetic mechanism, that is the young's human capital is equal to his father's one when young (we could define this as a *Darwinian* transmission mechanism), or assumes a stochastic mechanism, that is Nature extracts each generation's human capital from a time invariant distribution. Our hypothesis may seem *Lamarkian* at first sight, but captures the fact that parents' human capital affects the environment where the new born lives and, by this token, affect his human capital.

The public good (z) is education-related and enhances human capital of young individuals. In other words individual human capital technology is human capital intensive and positively depends on the education-related public good:

$$h_{it+1}^t = \phi(z_t)\, h_{it}^t \tag{6}$$

where $\phi(0) = 1$, indicating that human capital remains constant over the life cycle if no education is undertaken, whereas on the contrary $\phi(z_t) > 1 \ \forall z_t > 0$. Moreover we assume diminishing returns from education, that is $\phi'(z_t) > 0$ and $\phi''(z_t) < 0$.

Hereafter, in order to study explicit functional forms, we assume

$$h_{it+1}^t = \left(1 + (z_t)^{1/2}\right) h_{it}^t \tag{7}$$

We assume preferences are captured by the following lifetime utility function[1]:

$$U_i = \lg x_{it}^t + \lg x_{it+1}^t \tag{8}$$

[1] This function is identical to Yakita (2003), but for the discount rate, that we assume equal to 0. Actually, as explained below, we assume that in the economy there exists unlimited access to credit at an exogenous interest rate equal to 0.

where x_{it}^t is consumption while young and x_{it}^t is consumption while old of the i-th agent of generation t.

When young agents consume, pay the cost of the public good in order to get educated, work and store inventories. Since preferences do not depend on leisure, agents supply their entire endowment of human capital. Human capital heterogeneity across agents also implies income heterogeneity across agents, since individual income is the product of the wage rate times individual human capital (wh_{it}^t).

As in Brueckner (2006) we assume that the cost per-capita per unit of public good is equal to c, with the cost recovered via a head tax (cz_t) . Young agent's disposable income is therefore $wh_{it}^t - cz_t$. Furthermore we assume unlimited access to credit (l) at an exogenous interest rate, that we assume, for the sake of simplicity, equal to 0 [2].. The i-th young agent's budget constraint therefore becomes:

$$x_{it}^t = wh_{it}^t + l_{it} - cz_t \tag{9}$$

When old agents get return on human capital, work, refund the debt and consume therefore the old agent's budget constraint is [3]:

$$x_{it+1}^t = wh_{it+1}^t - l_{it} \tag{10}$$

Substituting eq. (7) into eq. (10) we get:

$$x_{it+1}^t = w\left(1 + (z_t)^{1/2}\right) h_{it}^t \tag{11}$$

Solving eq (9) for s_{it} and substituting it into eq. (11) we get the intertemporal budget constraint (IBC), that is

$$x_{it}^t + x_{it+1}^t = wh_{it}^t - cz_t + w\left(1 + (z_t)^{1/2}\right) h_{it}^t \tag{12}$$

The interpretation of the eq. (12) is straightforward: lifetime consumption is equal to lifetime disposable income.

Therefore the maximization problem becomes:

$$\begin{aligned} &\underset{x_{it}^t, x_{it+1}^t}{Max}\ U_i \\ &\text{subject to the IBC:} \\ &x_{it}^t + cz_t + x_{it+1}^t - w\left(1 + (z_t)^{1/2}\right) h_{it}^t = wh_{it}^t \end{aligned} \tag{13}$$

The first order conditions for a maximum are the following:

[2] In the model we voluntarily neglect any consideration about how the financial markets affect growth. This hypothesis therefore allows us to get rid of any credit maket microfundation.

[3] If the labour income was high enough for consumption and investment in human capital through the education-related public good, l_{it} would be negative. This would be the case of an economy that stores inventories, whose return is equal to 0. It is easy to verify this is not the case in our model (see footnote 3).

$$\frac{1}{x_{it}^t} = \lambda \tag{14}$$

$$\frac{1}{x_{it+1}^t} = \lambda \tag{15}$$

$$x_{it}^t + cz_t + x_{it+1}^t - w\left(1 + (z_t)^{1/2}\right) h_{it}^t = wh_{it}^t \tag{16}$$

From eqq. (14-16) we get :

$$x_{it}^{t*} = \frac{1}{2}\left[w\left(2 + (z_t)^{1/2}\right) h_{it}^t - cz_t\right] \tag{17}$$

and

$$x_{it+1}^{t*} = \frac{1}{2}\left[w\left(2 + (z_t)^{1/2}\right) h_{it}^t - cz_t\right] \tag{18}$$

In this setting the credit market allows individuals to smooth consumption along lifetime, therefore $x_{it}^{t*} = x_{it+1}^{t*}$.

Notice that with this set-up, as it will be more clear in the following sections, it is possible to consider heterogeneity along two dimensions: heterogeneity across individuals and heterogeneity across jurisdictions

3 The atomistic economy

Let us assume now that the economy is like an extreme Tiebout world (one individual in each jurisdiction). This implies $z_{it} \neq z_{jt}$ for $i \neq j$. Obviously in such economy heterogeneity across individuals coincides with heterogeneity across jurisdictions.

We index the public good with the subscript i, since in each i-th jurisdiction, the public good is tailored to solve the i-th agent's optimization problem.

Therefore, as far as each i-th jurisdiction is concerned, the atomistic solutions of the utility maximization problem are eqq. (17-18) rewritten[4]:

$$x_{it}^{tA} = \frac{1}{2}\left[w\left(2 + (z_t)^{1/2}\right) h_{it}^t - cz_{it}\right] \tag{19}$$

$$x_{it+1}^{tA} = \frac{1}{2}\left[w\left(2 + (z_t)^{1/2}\right) h_{it}^t - cz_{it}\right] \tag{20}$$

The Government/agent of the atomistic jurisdiction therefore chooses to provide the level of public good that maximizes $U_i\left(x_{it}^{tA}, x_{it+1}^{tA}\right)$, that is:

$$U_i\left(x_{it}^{tA}, x_{it+1}^{tA}\right) = 2\lg\left\{\frac{1}{2}\left[w\left(2 + (z_t)^{1/2}\right) h_{it}^t - cz_{it}\right]\right\} \tag{21}$$

[4] The superscript A stands for "atomistic".

The first order condition for a maximum gives the optimal level of public good provided in each atomistic jurisdiction:

$$z_{it}^{A} = \left(\frac{wh_{it}^{t}}{2c}\right)^{2} \tag{22}$$

From eq. (22) it is clear that the provision of public good is optimal when the per-capita marginal cost (c) of education equals the marginal gain from education, that is the product of the wage rate times the marginal return on education $\left(w\frac{z_{it}^{-1/2}}{2}h_{it}^{t}\right)$. Moreover, since the marginal return on education increases as the young agents' human capital (h_{it}^{t}) increases, the optimal level of public good is increasing and convex in h_{it}^{t} [5]. This is summarized in the proposition that follows.

Proposition 1 *The higher the level of human capital in a jurisdiction, the higher the provision of the education-related public good tailored to suite the preferences of i-th individual's, who constitutes the jurisdiction itself.*

This is basically the engine of a virtuous circle that, as shown in the following section and summarized in propositions 2 and 3, makes a jurisdiction growing at an increasing rate and, by the same token, allows a jurisdiction with a higher level of human capital to grow faster than another jurisdiction with less human capital

3.1 Dynamics

In order to study the dynamics in the atomistic economy, let us first focus on figure 1. Panel (a) describes equation (22), that is the atomistic optimal level of public good, increasing and convex in h_{it}^{t}. Panel (b) only transfers z_{it}^{A} from the vertical to the horizontal axes. Both panel (c) and the straight lines in panel (d) sketches eq. (7) as far as the atomistic economy is concerned, that is

$$h_{it+1}^{tA} = \left(1 + \left(z_{it}^{A}\right)^{1/2}\right) h_{it}^{t} \tag{23}$$

[5] Substituting eq. (22) into eqq. (19-20), we get

$$\begin{aligned} x_{it}^{tA} &= \frac{1}{2}wh_{it}^{t}\left(2 + \frac{wh_{it}^{t}}{4c}\right) \\ x_{it+1}^{tA} &= \frac{1}{2}wh_{it}^{t}\left(2 + \frac{wh_{it}^{t}}{4c}\right) \end{aligned}$$

Substituting $x_{it}^{tA}, x_{it+1}^{tA}$ and z_{it}^{tA} into eq. (12) and solving for l_{it}, we get

$$l_{it} = wh_{it}^{t}\left(\frac{1}{2}\left(2 + \frac{wh_{it}^{t}}{4c}\right) + \frac{wh_{it}^{t}}{4c} - 1\right)$$

For any positive level of human capital $l_{it} > 0$.

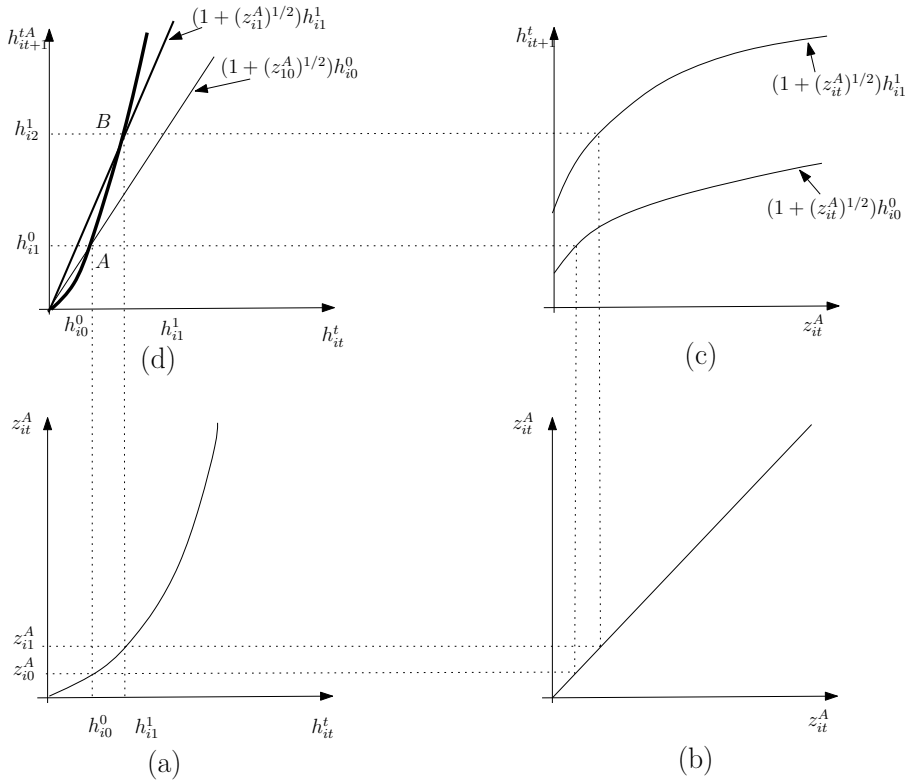

Figure 1: The increasing returns on human capital thanks to the provision of the education-related public good

h^t_{it+1} is linearly increasing in h^t_{it} (given z^A_{it}) (see the increasing straight lines in panels (d)), and is increasing and concave in z^A_{it} (given h^t_{it}). This means that human capital technology enhances/multiplies the young's human capital and there are decreasing returns in education. Once the public good is optimally chosen, the resulting relation between h^t_{it+1} and h^t_{it} becomes increasing and convex: the higher h^t_{it}, the higher the public good, the higher h^t_{it+1}.

Formally, from eqq. 7 and 22, we get the individual human capital law of motion:

$$h^{tA}_{it+1} = h^t_{it} + \frac{w\left(h^t_{it}\right)^2}{2c} \tag{24}$$

Note that this is both the individual lifetime accumulation of human capital and the intergenerational accumulation of human capital (remind the intergenerational transmission mechanism $h^{t+1}_{it+1} = h^t_{it+1}$). Therefore eq. (24) describes also the dynamics of the human capital of the i-th jurisdiction, as shown in the i-th jurisdiction phase diagram depicted in figure 2.

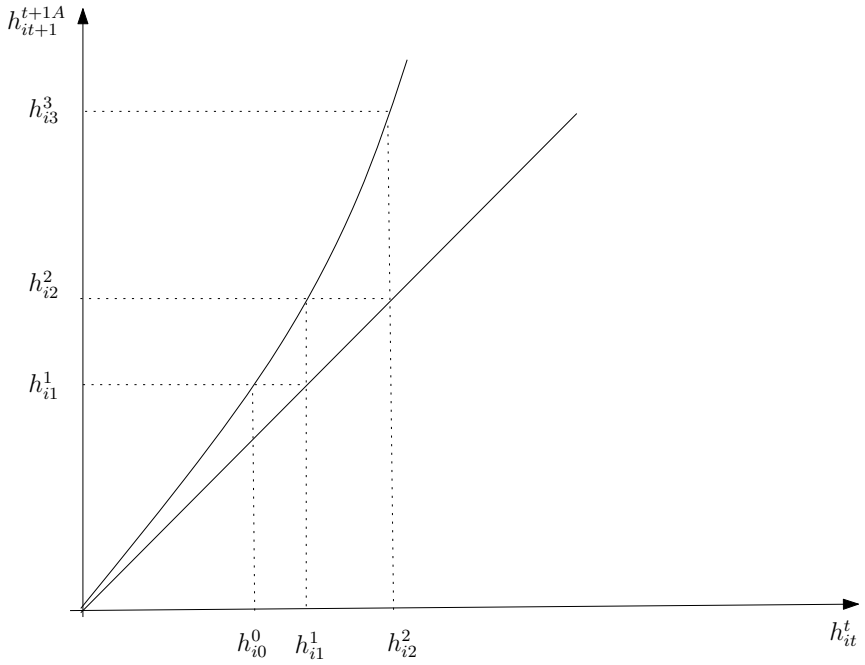

Figure 2: The phase diagram for an atomistic jurisdiction

Proposition 2 *An atomistic jurisdiction grows at an increasing rate.*

Proof. From eq. (24), we derive that the rate of growth for a jurisdiction i is increasing in h_{it}^t:

$$\gamma_{it+1}^A \equiv \frac{h_{it+1}^t - h_{it}^t}{h_{it}^t} = \frac{wh_{it}^t}{2c} \tag{25}$$

Therefore during the human capital accumulation process, the rate of growth increases. The rationale for this result comes from proposition 1. ■

Proposition 3 *The higher the level of human capital in a jurisdiction, the higher the rate of growth performed by the jurisdiction itself.*

Proof. The proof follows from eq. (25) referred to two different jurisdictions: $\frac{h_{jt+1}^t - h_{jt}^t}{h_{jt}^t} > \frac{h_{it+1}^t - h_{it}^t}{h_{it}^t}$ if and only if $h_{jt}^t > h_{it}^t$ ■

3.2 The economy: aggregating atomistic jurisdictions

Let us pass now to analyze the performance of the entire economy, which consists of the aggregation of all the atomistic jurisdictions. First of all, notice that, since each generation has mass equal to 1, aggregate and average levels of variables are identical. Let us denote denote by $\overline{h}_{t+1}^t \left(\equiv \overline{h}_{t+1}^{t+1} \right)$ the average human capital of generation t while old (or equivalently of generation $t+1$ while young), and by $\overline{h}_t^t$ the average human capital of generation t while young. Taking the mean of eq. (24), we get:

$$\overline{h}_{t+1}^{tA} = \overline{h}_t^t + \frac{w\left(Var\left(h_{it}^t\right) + \left(\overline{h}_t^t\right)^2 \right)}{2c} \tag{26}$$

Proposition 4 *The aggregate dynamics of an atomistic economy is positively affected both by the average human capital and by the variance of the distribution of human capital.*

The rationale for the relevance of the variance is based on the increasing returns on human capital thanks to the provision of the education-related public good and on the deriving convexity of the phase diagram. To have a graphic intuition of this result let us analyze the following figure. The figure represents two economies with the same mean and two agents/jurisdictions each but with different variance of human capital. One economy has a higher variance than the other. The resulting average human capital $\left(\overline{h}_{t+1}^{tA}\right)$ is higher for the atomistic economy with a higher variance.

Proposition 5 *The rate of growth of an atomistic economy is higher the higher the variance of the distribution of human capital with respect to its mean.*

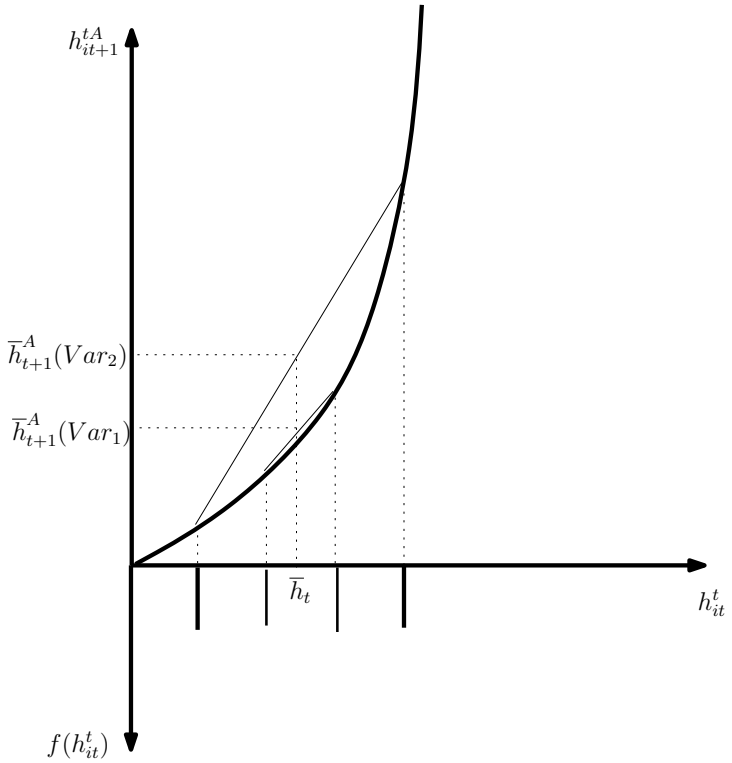

Figure 3: The effects of the variance in the aggregate atomistic economy

Proof. From eq. 26 it follows:

$$\gamma_{t+1}^{A} \equiv \frac{\overline{h}_{t+1}^{tA} - \overline{h}_{t}^{t}}{\overline{h}_{t}^{t}} = \frac{w\left(\frac{Var\left(h_{it}^{t}\right)}{\overline{h}_{t}^{t}} + \overline{h}_{t}^{t}\right)}{2c} \tag{27}$$

■

4 The Unitary System

If the economy is a unitary system, at any time t a common public good level z_t is provides regardless the heterogeneity across agents. Therefore $z_{it} = z_t$ for any i. The level of z_t is chosen according to the average of the preferences across agents, therefore taking the mean of all z_{it}^{A} (eq. **??**), we get $z_t = E\left[\left(\frac{wh_{it}^{t}}{2c}\right)^2\right]$, that is

$$z_{t}^{U} = \left(\frac{w}{2c}\right)^2 \left(Var\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t}\right)^2\right) \tag{28}$$

Proposition 6 *The Government of a unitary economy would supply a level of public good that increases both in the first and in the second moment of the distribution of human capital.*

Proposition 7 *If* $Var\left(h_{it}^{t}\right) = 0$ *then* $z_{it}^{A} = z_{t}^{U}$.
Proof. *This would be the case of a representative agent economy with absence of heterogeneity.* ■

Proposition 8 *In a unitary economy the provision of the education-related public good is inefficient at the individual level, that is if* $\left(h_{it}^{t}\right)^2 > \left(Var\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t}\right)^2\right)$ *then* $z_{it}^{A} > z_{t}^{U}$ *viceversa if* $\left(h_{it}^{t}\right)^2 < \left(Var\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t}\right)^2\right)$ *then* $z_{it}^{A} < z_{t}^{U}$
Proof. *The proof follows by comparing eq. 22 with eq. 28.* ■

4.1 Dynamics

Substituting eq. 28 into eq. 7, we get the individual law of motion of human capital in a unitary economy:

$$h_{it+1}^{tU} = \left(1 + \left(\frac{w}{2c}\right)\sqrt{Var\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t}\right)^2}\right) h_{it}^{t} \tag{29}$$

Proposition 9 *In a unitary economy the accumulation of individual human capital is inefficient, that is if* $\left(h_{it}^{t}\right)^2 > \left(Var\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t}\right)^2\right)$ *then* $h_{it+1}^{tA} > h_{it+1}^{tU}$ *viceversa if* $\left(h_{it}^{t}\right)^2 < \left(Var\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t}\right)^2\right)$ *then* $h_{it+1}^{tA} < h_{it+1}^{tU}$

Proof. *The proof follows from proposition 8.* ■

Aggregating, we get the unitary economy accumulation of human capital:

$$\overline{h}_{t+1}^{tU} = \overline{h}_t^t + \left(\frac{w}{2c}\right)\sqrt{Var\left(h_{it}^t\right) + \left(\overline{h}_t^t\right)^2}\overline{h}_t^t \tag{30}$$

From eq. 30, we get the unitary economy rate of growth:

$$\gamma_{t+1}^U \equiv \frac{\overline{h}_{t+1}^{tU} - \overline{h}_t^t}{\overline{h}_t^t} = \left(\frac{w}{2c}\right)\sqrt{Var\left(h_{it}^t\right) + \left(\overline{h}_t^t\right)^2} \tag{31}$$

First of all notice that the increasing marginal returns on human capital disappears, since the provision of public good is not tailored on individual human capital.

Proposition 10 *The atomistic economy accumulates more human capital and grows at a faster rate than the unitary economy.*
Proof. *Comparing eq. 26 with eq. 30 and eq. 27 with eq. 31, since* $\left(Var\left(h_{it}^t\right)\right)^2 + Var\left(h_{it}^t\right)\left(\overline{h}_t^t\right)^2 > 0$, $\overline{h}_{t+1}^{tA} > \overline{h}_{t+1}^{tU}$ *and* $\gamma_{t+1}^A > \gamma_{t+1}^U$ ■

5 The Federalist System

Let us consider now the federalist system. For the sake of simplicity let us assume that the economy is composed by two jurisdictions Ω and Γ. Notice that this sorting assumption is very general. In other words, we do not consider a rich versus a poor jurisdiction as an assumption.

In each jurisdiction at any time t a common public good level z_t. Therefore $z_{it} = z_t^\Omega$ for any $i \in \Omega$ and $z_{it} = z_t^\Gamma$ for any $i \in \Gamma$. The level of z_t is chosen according to the average of the preferences across agents, therefore taking the mean of eq. **??** as far as each jurisdiction is concerned, we get

$$z_t^\Omega = \left(\frac{w}{2c}\right)^2\left(Var^\Omega\left(h_{it}^t\right) + \left(\overline{h}_t^{t\Omega}\right)^2\right) \tag{32}$$

and

$$z_t^\Gamma = \left(\frac{w}{2c}\right)^2\left(Var^\Gamma\left(h_{it}^t\right) + \left(\overline{h}_t^{t\Gamma}\right)^2\right) \tag{33}$$

Proposition 11 *The Federalist Government would supply a level of public good that increases both in the first and in the second moment of the distribution of human capital in each jurisdiction.*

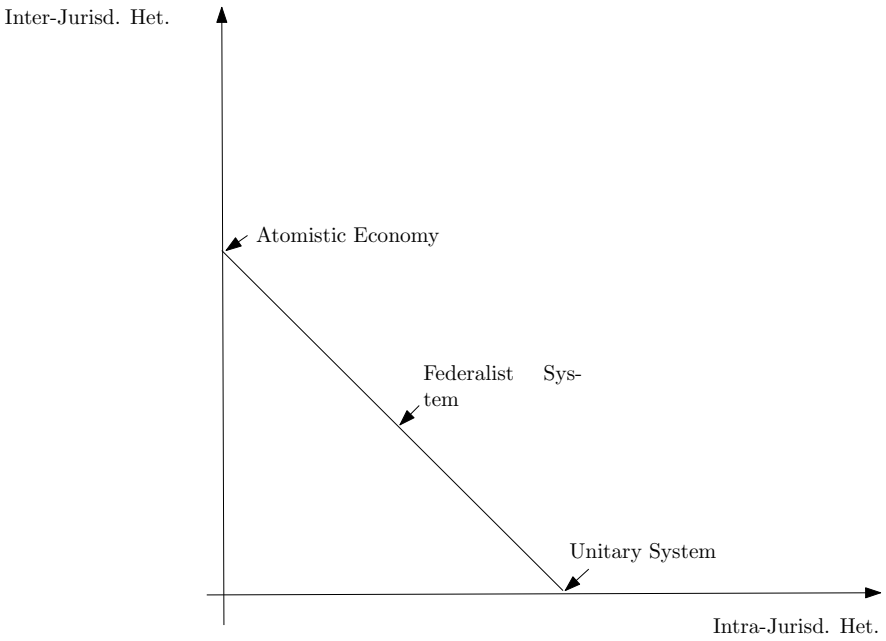

Figure 4: Intra and inter jurisdiction heterogeneity

Notice that the literature on fiscal federalism typically analyzes heterogeneity only along one dimension -that is inter-jurisdictions heterogeneity - in other words a rich versus a poor jurisdiction. Since in our model there exists complete heterogeneity across agents, this implies that exists heterogeneity even inside each jurisdiction (Ω and Γ), that we call *intra-jurisdiction* heterogeneity. This is captured by $Var^{\Omega}\left(h_{it}^{t}\right)$ and $Var^{\Gamma}\left(h_{it}^{t}\right)$.

To sum up, the two dimensions heterogeneity can be sketched by the following figure.

5.1 Dynamics

Aggregating for each jurisdiction, we get the following laws of human capital accumulation:

$$h_{it+1}^{t\Omega}=\left(1+\left(\frac{w}{2c}\right)\sqrt{Var^{\Omega}\left(h_{it}^{t}\right)+\left(\overline{h}_{t}^{t\Omega}\right)^{2}}\right)h_{it}^{t} \tag{34}$$

for jurisdiction Ω, and

$$h_{it+1}^{t\Gamma}=\left(1+\left(\frac{w}{2c}\right)\sqrt{Var^{\Gamma}\left(h_{it}^{t}\right)+\left(\overline{h}_{t}^{t\Gamma}\right)^{2}}\right)h_{it}^{t} \tag{35}$$

for jurisdiction Γ.
Averaging in each jurisdiction:

$$\overline{h}_{t+1}^{t\Omega} = \left(1 + \left(\frac{w}{2c}\right)\sqrt{Var^{\Omega}\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t\Omega}\right)^{2}}\right)\overline{h}_{t}^{t} \tag{36}$$

for jurisdiction Ω, and

$$\overline{h}_{t+1}^{t\Gamma} = \left(1 + \left(\frac{w}{2c}\right)\sqrt{Var^{\Gamma}\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t\Gamma}\right)^{2}}\right)\overline{h}_{t}^{t} \tag{37}$$

for jurisdiction Γ.
Therefore each jurisdiction grows at the following rates:

$$\gamma_{t+1}^{\Omega} \equiv \frac{\overline{h}_{t+1}^{t\Omega} - \overline{h}_{t}^{t}}{\overline{h}_{t}^{t}} = \left(\frac{w}{2c}\right)\sqrt{Var^{\Omega}\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t\Omega}\right)^{2}} \tag{38}$$

as far as jurisdiction Ω is concerned, and

$$\gamma_{t+1}^{\Gamma} \equiv \frac{\overline{h}_{t+1}^{t\Gamma} - \overline{h}_{t}^{t}}{\overline{h}_{t}^{t}} = \left(\frac{w}{2c}\right)\sqrt{Var^{\Gamma}\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t\Gamma}\right)^{2}} \tag{39}$$

as far as jurisdiction Γ is concerned.

Proposition 12 *Each jurisdiction J benefits from federalism as long as*

$$Var^{J}\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{tJ}\right)^{2} > Var\left(h_{it}^{t}\right) + \left(\overline{h}_{t}^{t}\right)^{2}$$

This proposition tells us that the benefits from federalism are independent on any sorting assumption of individuals into jurisdictions. Moreover the benefits are larger the larger the variance in agents' endowment of human capital.

6 Conclusions

We have developed a theoretical model in order to explore the relationship between federalism and economic growth. The model is an endogenous-growth model with overlapping generations of two-period lived, heterogeneous agents.

To sum up, building on Brueckner's work (2006) in our paper we have explicitly considered an education-related public good that enhances individual human capital; moreover we have considered complete heterogeneity among all the agents living in this economy. Therefore, it is worth of note that this set-up allowed us to study the effects of heterogeneity which is then twofold: inter-jurisdictions and intra-jurisdiction.

Intra-jurisdiction heterogeneity is proxied by the variance of the intra- jurisdiction distribution of human capital. The provision of an education-related public good, both in the unitary and in the federalist system, is tailored to suit

the characteristics of the distribution of human capital respectively within the economy as a whole and within each jurisdiction. More precisely the provision of the public good in the federalist system (unitary system) increases as the intra- jurisdiction (economywide) first and second moments of the distribution of human capital increase. For a given level of the average human capital, the higher the intra-jurisdiction (economywide) heterogeneity, the higher the provision of the education-related public good, and the higher the accumulation of human capital. This virtuous circle boosts economic growth.

Preliminary results of our analysis also show that, for a given level of the average human capital in the jurisdiction and in the economy, the benefits of federalism are stronger the larger the intra-jurisdiction heterogeneity with respect to the economywide heterogeneity. Notably our results are independent on any sorting assumption.

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