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Public policy and the spatial asymmetries in (higher) education growth

by

José Pedro Pontes[1]

Date: May 2026

Abstract: This paper seeks to provide a reasonable explanation for why private colleges display a much higher elasticity of schooling rates with respect to population density than public universities. It also accounts for the fact that, although private universities played an important role in the early stages of the expansion of higher education in Portugal, their relative weight declined considerably in more recent times.

While the higher level of subsidisation of fixed costs in public universities is undoubtedly an important factor behind this pattern, but it is far from the only one. Public universities also tend to internalise spatial knowledge externalities, a behaviour that private institutions do not typically replicate.

Consequently, schooling rates in private universities are consistently lower than those in public institutions and this gap narrows as regional accessibility and demographic density increase. Moreover, the evolution of higher education exhibits rising spatial inequalities at earlier stages and diminishing inequalities at later stages.

Keywords: Higher Education Growth, Population Density, Spatial Inequalities in Schooling, Knowledge Spillovers, Public and Private Universities.

JEL Classification: I20, O15, O18, R11

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1. Introduction

This paper examines the pronounced inequalities in schooling rates that persist across regions, particularly in higher education attainment. According to Moretti (2004), population density is a major driver of these asymmetries, thereby generating a substantial gap in schooling rates between urban and rural areas. In addition, significant differences exist across metropolitan areas, stemming from industrial structure. While a higher share of agriculture in the economy tends to depress educational levels, a greater proportion of high-tech sectors in employment favours university attendance (see Karahasan and Lopez-Bazo, 2013).

The concept of *Market Potential,* introduced by Harris (1954), is widely used to explain the spatial variation in educational attainment. According to this concept, demand addressed to firms in a region derives not only from the internal market, but also from external ones. The demand originating from each external market should be discounted by a spatial decay factor, which is usually decreasing and convex in distance. Hence, the market size of a region derives mainly on demand originated in nearby locations. Moreover, a decreasing and convex distance-decay factor also characterises knowledge spillovers (see Fujita and Ogawa, 1982; Adam, Trajtenberg and Henderson, 1993).

Market Potential is a crucial concept for sectors with significant economies of scale. While it often applies to manufacturing, education – especially higher education - also operates under increasing returns to scale as schools also incur high fixed costs.

Differences in *Market Potential* can often explain the empirical distribution of tertiary schooling rates across regions (Lopez-Rodriguez, Faina and Lopez-Rodriguez, 2007; Diebolt and Hippe, 2018; Karahasan and Bilgel, 2020). A theoretical rationalization of this dependence is provided by Redding and Schott (2003). These authors argue that central areas with easy access to markets tend to specialise in the production of goods with high transport costs such as manufacturing, which are intensive in skilled, well-trained labour. This specialisation raises the wage premium of education and the level of university attendance in accessible regions. A converse negative effect applies to remote areas.

While the *Market Potential* concept has strong explanatory power for educational attainment across nations, it shows no clear advantage over population density in accounting for differences in university attendance across smaller geographic units such as the European NUTS2 (Brakman, Garretsen and Marrewijk, 2009).

In this paper, we model regional variation in formal education levels as arising from asymmetries in population density. The economy produces a composite consumer good under constant returns with labour as the sole production factor. Each worker faces a trade-off when maximizing individual output and wages. He may either devote most of his time to work and only a small share to schooling, thereby becoming a low-skilled worker, or he may choose the opposite allocation. The outcome of this decision depends on the relative efficiency of the educational technology at his location.

We model the economy as consisting of two successively related sectors: formal education, which operates through a network of colleges, and the production of a final good. While formal education is supposed to be a non-tradable good – meaning that everyone must attend school in the location where they live and work - the consumer composite good is assumed to be tradable.

This sectoral structure closely follows the endogenous growth literature, in which knowledge externalities are essential to the functioning of the economy. Although spillovers may operate at the final production stage, we follow instead Azariadis and Drazen (1990) and Benabou (1993), who consider that they directly affect educational technology.

Lucas (1988) argued that education operates through two complementary mechanisms.

> “Most of what we know we learn from other people. We pay tuition to a few of these teachers, either directly or indirectly by accepting lower pay so we can hang around them, but most of it we get for free, and often in ways that are mutual – without a distinction between student and teacher. Certainly, in our profession, the benefits of colleagues from whom we hope to learn are tangible enough to lead us to spend a considerable fraction of our time fighting over who they shall be, and another fraction travelling to talk with those we wish we could have as colleagues but cannot.” (Lucas, 1988:38)

Firstly, education works through a system of schools, where students meet teachers in the context of prearranged lectures, which have an opportunity cost in terms of lost working hours. The quality of a school depends critically on the local population density, which allows economies of scale to emerge so that *more* and *better* schools can break even (Black and Henderson, 1999).

Secondly, educational efficiency is enhanced by random face to face contacts that enable each worker to learn informally with more skilled or better-trained colleagues (Glaeser, 1999; Jovanovic and Rob, 1989). As Rauch (1993) observed, the probability of such instructive encounters increases with the average level of human capital prevailing in the metropolitan area. In addition, informal meetings usually incur travel costs, making them unlikely when agents are far apart. According to Conley, Flyer and Tsiang (2003), most knowledge spillovers dissipate when exceeds 90 minutes.

We argue that, while schooling is more available and of better quality in densely populated areas, informal learning contributes to the convergence of educational attainment across regions. Furthermore, although the spread of higher education initially exhibits rising spatial inequalities, it tends to become more even at a later stage.

This article is organised as follows. Section 2 presents the empirical motivation of the paper, while Section 3 develops the theoretical model. Section 4 concludes.

2. Motivation

We are motivated by the fact that, although educational attainment across regions is positively correlated with population density, the impact of the latter differs considerably between public and private colleges.

In the Appendix, we compile data on population density, higher education (ISCED 5-8) attainment levels, and the share of college students enrolled in public institutions across Portuguese NUTS2 regions in year 2021.

We compute the elasticities of tertiary schooling rates with respect to population density for the entire higher education system, as well as for the public and private subsystems separately, by fitting the multiplicative model $y = \alpha x^{\beta}$ to the data in Table 1 using OLS. The scatter plot of total schooling rates is shown in Figure 1.

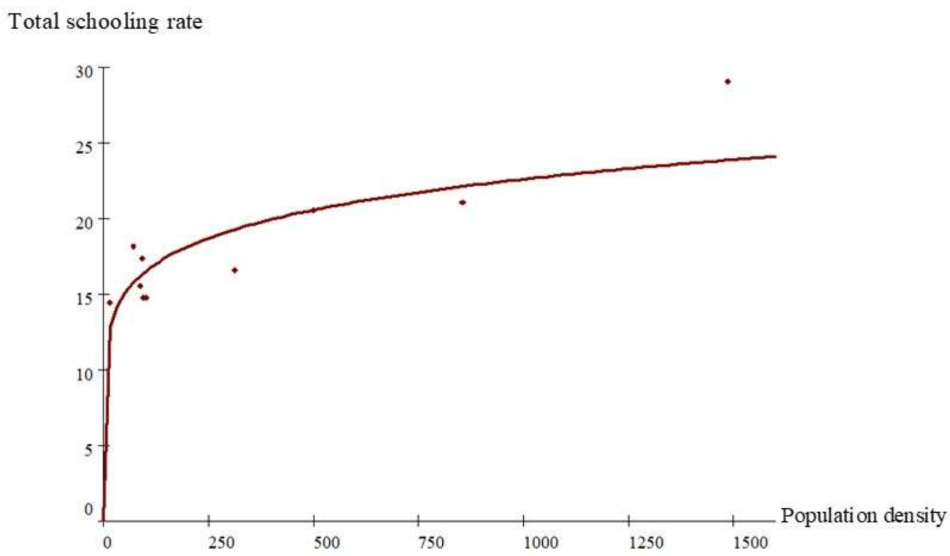

Figure 1: Total schooling rate as a function of population density

The estimated elasticity is $\hat{\beta} \approx 0.136$ and the R^2 of this regression is 0.70. In addition, the region of *Grande Lisboa*, which hosts the capital city, is an outlier, as it exhibits a tertiary schooling rate far above the expected value. This result stems from the fact that higher education involves significant fixed costs. For instance, a skilled professor represents a fixed cost, as he can teach a group of students of varying size. Hence, high population density not only allows more colleges to break-even but also ensures that these institutions tend to be higher quality, as they are located on average closer to students' residences. Furthermore, strong demand for education makes it possible to offer more diverse and specialised training programs.

In Figure 2, we present a scatter plot considering only the public higher education subsystem.

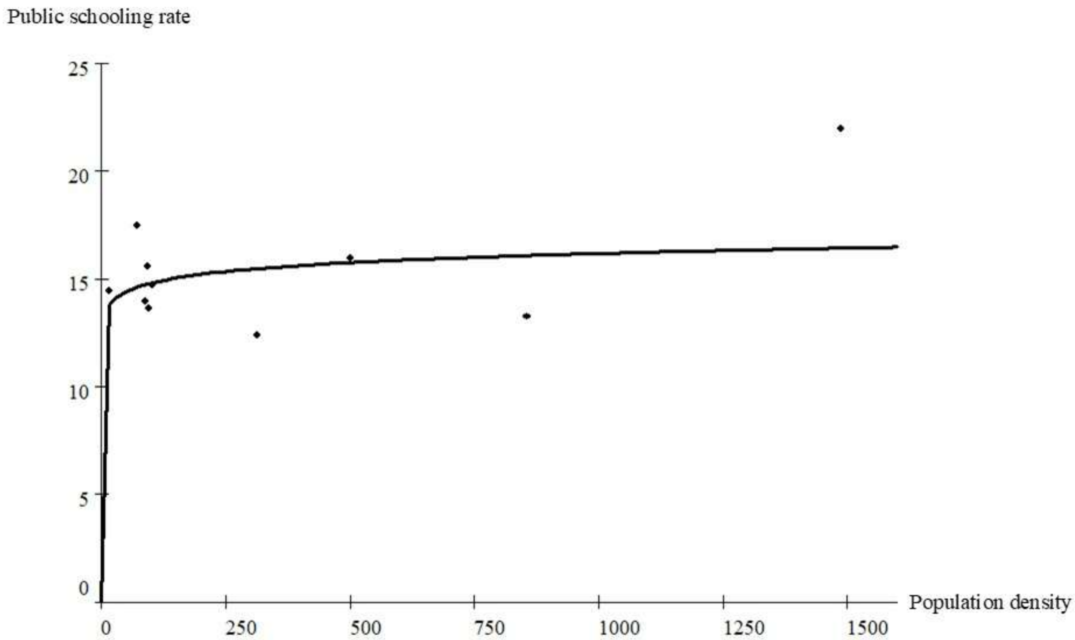

Figure 2: Public schooling rates as a function of population density

The elasticity is now $\widehat{\beta} \approx 0.038$, a relatively low figure that falls within the standard range of elasticities of per capita income in relation to population density (Pontes, 2025). Moreover, the R^2 is only 0.10, indicating that population density is not a significant determinant of the spatial distribution of public higher education. Instead, this distribution appears to be driven instead by the objective of ensuring even territorial coverage across the country. *Grande Lisboa* is again an outlier.

Figure 3 displays the scatter plot of schooling rates for private universities.

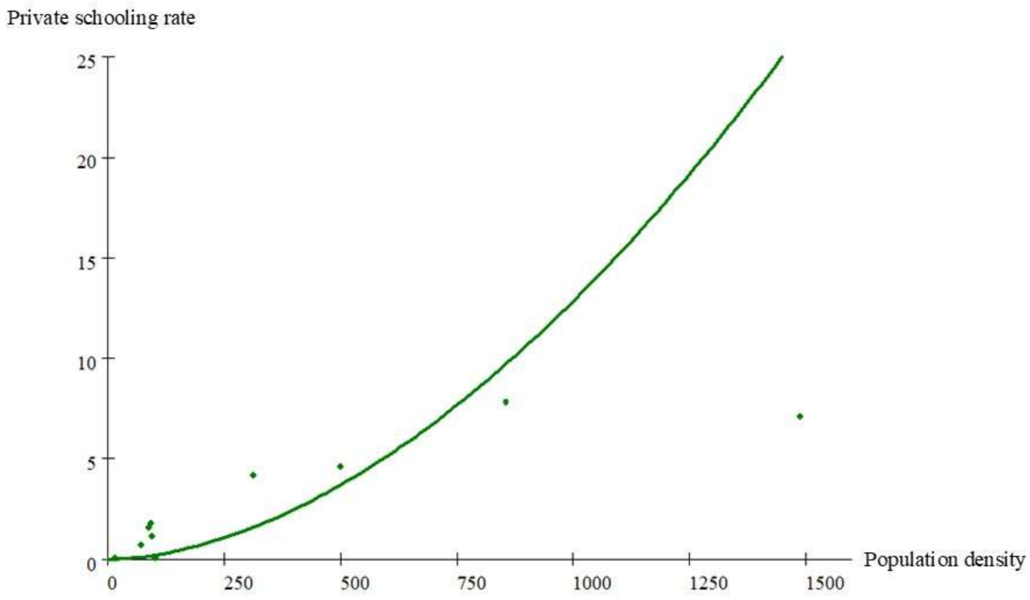

Figure 3: Private schooling rates as a function of population density

The elasticity of private schooling in relation to population density is $\hat{\beta} \approx 1.794$, greater than 1 and far higher than those implicit in Figures 1 and 2. The region of *Grande Lisboa* is again an outlier.

These findings are consistent with those of Queiró (2017), who examined the evolution of higher education in Portugal. According to this author, private colleges can break even only in major urban centres with high population density. The private sector accounted for about 5 percent of total enrolled students in 1977 and expanded rapidly to reach roughly one third in 1997. Since then, it has declined sharply to around 15 percent in 2017.

This evolution reflects the fact that the higher education system expanded firstly in dense areas and only later spread to more sparsely populated regions. Although the private college schooling rate is comparatively small – always below 8 percent – it explains why the overall share of educated individuals increases significantly with population density.

In Figure 4, we superimpose the estimated schooling rates in relation to density in Figures 1,2 and 3.

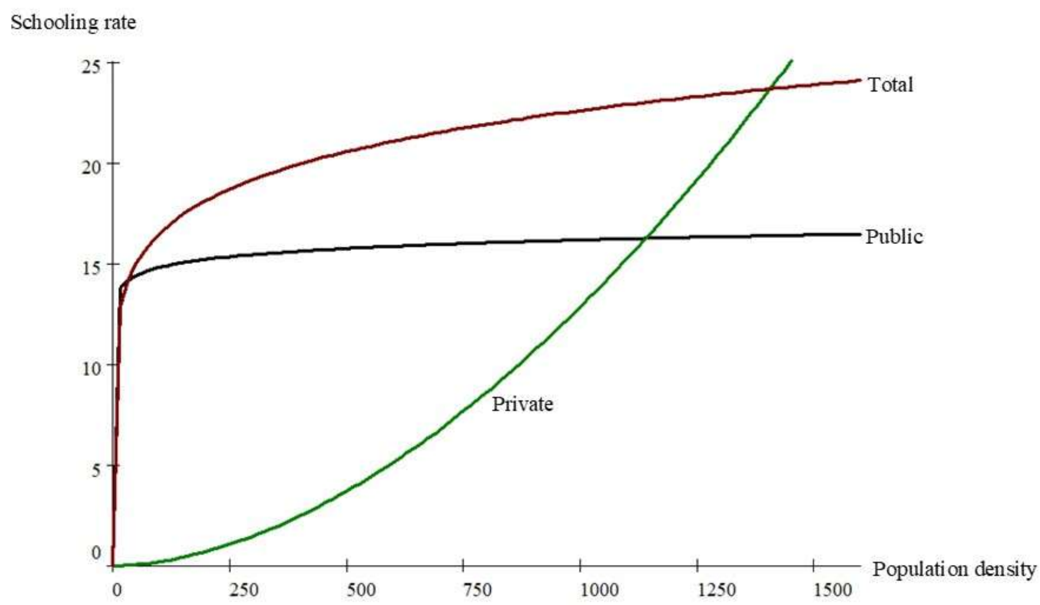

Figure 4: Total, public and private schooling rates in relation to demographic density

Beyond the fact that the elasticity is much higher for private universities than for public ones, we have not yet provided a satisfactory explanation for the convergence of schooling rates – excluding the capital region – for highly populated areas. The fact that the fixed costs of public institutions are more heavily subsidised than those of private institutions is only a *necessary* condition for this pattern to emerge. In addition, we must theoretically characterise the behaviour of public universities regarding their location choices.

3. The model

We assume a spatial economy described by the interval $[0,1]$. The population distribution is given by a density function $L(r)$ that satisfies two assumptions, namely $L(r) \geq 1$ and $L'(r) < 0$. Hence, the origin $r = 0$ is the mode of the spatial distribution of population.

Each individual living in location r performs two successive activities. First, he becomes educated. We assume that formal education is a non-tradable service, so he must be trained in the same location where he lives and works. For this purpose, the worker allocates a share $s(r) \in [0,1)$ of his time to attending school.

Second, the individual takes part in the production of a composite, fully tradable consumer good. Such productive activity operates under constant returns to scale and perfect competition. Composite good production in point r is described by a Cobb-Douglas function:

$$Y(r) = A\left[\left(1 - s(r)h(r)L(r)\right)\right]^{\alpha} K(r)^{(1-\alpha)} \quad (1)$$

where, for location r, we define:

$Y(r)$ output produced

$h(r) > 0$ worker skill

$K(r)$ capital stock

In addition, A is an aggregate Hicks-neutral productivity term.

For simplicity, we assume that capital input is identical across locations, so that $K(r) = \bar{K}$. The issue of imperfect substitution between skilled and unskilled labour - where an increase in skilled labour is assumed to reduce *per se* its relative wage, is not relevant to our model.

Consequently, production function in (1) becomes,

$$Y(r) = A'\left[\left(1 - s(r)h(r)L(r)\right)\right]^{\alpha} \tag{2}$$

where $A' \equiv A\overline{K}^{(1-\alpha)}$.

Since composite good production is competitive, the wage prevailing in point r $w(r)$ is determined by the marginal productivity of labour.

$$w(r) = \frac{\partial Y(r)}{\partial L(r)} = A'\alpha\left[\left(1 - s(r)\right)h(r)\right]^{\alpha} L(r)^{(\alpha-1)}$$

This may alternatively be written as

$$w(r) = A''\left[\left(1 - s(r)\right)h(r)\right]^{\alpha} L(r)^{(\alpha-1)}$$

where $A'' \equiv A'\alpha$. Through an appropriate choice of the output unit measure, we may write $A'' = 1$, so that the wage becomes,

$$w(r) = \left[\left(1 - s(r)\right)h(r)\right]^{\alpha} L(r)^{(\alpha-1)}$$

Henceforth, we assign variables to a specific time t, so that the wage is written as

$$w_t(r) = \left[\left(1 - s_t(r)\right)h_t(r)\right]^{\alpha} L(r)^{(\alpha-1)} \tag{3}$$

We now define the technology of education, which is described for location r and time t by

$$h_t(r) = 1 + \gamma_t(r)s_t(r) \tag{4}$$

where $\gamma_t(r)$ denotes the efficiency of formal education at a given time and location.

We assume as an initial condition that in time 0 $s_0(r) = 0$ and $h_0(r) = 1$ for every location r.

We make the following assumptions about schooling efficiency $\gamma_t(r)$,

1. $\gamma_t(r) > 1$
2. $\gamma_t(r)$ does not depend on $s_t(r)$, although it may depend on $s_{t-1}(r)$.

Substituting (4) in (3), then the wage equation becomes

$$w_t(r) = \left[\left(1 - s_t(r)\right)\left(1 + \gamma_t(r)s_t(r)\right)\right]^{\alpha} L(r)^{(\alpha-1)} \tag{5}$$

From (5), it follows that the worker living at point r maximises the earnings at time t if he allocates a share $s_t^*(r)$ of his time to schooling defined by

$$s_t^*(r) = \frac{1}{2}\left(1 - \frac{1}{\gamma_t(r)}\right) \tag{6}$$

The wage-maximizing schooling rate $s_t^*(r)$ strictly increases with the efficiency of learning. It varies between 0, when $\gamma_t(r) = 1$, and $\frac{1}{2}$ when $\gamma_t(r)$ becomes arbitrarily high.

We now determine the schooling efficiency at point r and time t as

$$\gamma_t(r) = L(r)^{\phi}\left[1 + \left(s_{t-1}(0) - s_{t-1}(r)\right)e^{-\tau r}\right]^{\psi} \tag{7}$$

where ϕ and ψ are positive elasticities and τ is a positive term of spatial decline.

The efficiency of learning is determined by two complementary factors, multiplicatively related.

The first factor is the efficiency of schooling, expressed by $L(r)^{\phi}$. Teaching operates under economies of scale because it involves sharing of fixed inputs such as professor training, buildings, laboratories and libraries. The higher the population density $L(r)$, the more numerous and higher-quality colleges will be. In a region with a large population, colleges will on average be closer to students' residences and able to supply a more diverse range of specialised programs.
The second factor is the efficiency of *informal* learning, expressed by $\left[1+\left(s_{t-1}(0)-s_{t-1}(r)\right)e^{-\tau r}\right]^{\psi}$. It is intuitive - and will be formally proved below - that the equilibrium schooling rate $s_t(r)$ strictly decreases with population density $L(r)$. Hence, it also strictly decreases with distance r from the origin, which is by assumption the mode of the spatial distribution of population.
We assume that each worker learns informally by interacting with colleagues who have a higher schooling level than himself. Consequently, the amount of learning at time t by a worker living at point r increases with the difference, in the previous period $t-1$, between his educational attainment and that of the more skilled worker living in point $r=0$. Since these informal contacts are random, we assume that their probability decreases with the distance separating the two agents. This expressed by the exponential decline term $e^{-\tau r}$.
If we substitute $\gamma_t(r)$ from (7) into (6), we obtain the following first-order difference equation that concerns the workers living in point r,

$$s_t(r)=\frac{1}{2}\left\{1-\frac{1}{L(r)^{\phi}\left[1+\left(s_{t-1}(0)-s_{t-1}(r)\right)e^{-\tau r}\right]^{\psi}}\right\} \tag{8}$$

Equation (8) is homogeneous because t is not an argument on the right-hand side. We may express it as

$$s_t(r)=f\left(s_{t-1}(r),r\right) \tag{9}$$

We now define the solution of the dynamic process defined by (8) or (9). Dropping the subscript t in (8), we can define function $f\left(s\left(r\right)\right)$ as,

$$f\left(s\left(r\right)\right)=\frac{1}{2}\left\{1-\frac{1}{L\left(r\right)^{\phi}\left[1+\left(s\left(0\right)-s\left(r\right)\right)e^{-\tau r}\right]^{\psi}}\right\} \tag{10}$$

Clearly, function $f\left(s\left(r\right)\right)$ has the following properties on domain $\left[0,1\right]$.

1. It is defined.
2. It has an image set contained in $\left[0,1\right]$.
3. It is continuous.

Brouwer's Theorem ensures the existence of at least one fixed point of $f\left(s\left(r\right)\right)$, i.e., of a $s\left(r\right)$ such that $s\left(r\right)=f\left(s\left(r\right)\right)$.

The first derivative of $f\left(s\left(r\right)\right)$ is,

$$f'\left(s\left(r\right)\right)=-\frac{1}{2}\psi e^{-\tau r}L\left(r\right)^{-\phi}\left(1+\left(s\left(0\right)-s\left(r\right)\right)e^{-\tau r}\right)^{-(1+\psi)} \tag{11}$$

Clearly, $f'\left(s\left(r\right)\right)$ is negative. Hence, $f\left(s\left(r\right)\right)$ has a unique fixed point.

Furthermore, since the term $e^{-\tau r}L\left(r\right)^{-\phi}\left(1+\left(s\left(0\right)-s\left(r\right)\right)e^{-\tau r}\right)^{-(1+\psi)}$ is smaller than 1, we can determine an upper bound for the modulus of $f'\left(s\left(r\right)\right)$.

$$\left|f'\left(s\left(r\right)\right)\right|<\frac{1}{2}\psi \tag{12}$$

Consequently, a sufficient condition for $\left|f'\left(s\left(r\right)\right)\right|<1$ is $\psi<2$. If the elasticity of learning efficiency with respect to informal personal interactions is not too high, then the unique equilibrium $s^*\left(r\right)$ will be globally stable in $\left[0,1\right]$. The dynamic process will converge to $s^*\left(r\right)$ for every initial spatial schooling curve $s_0\left(r\right)$.

Although the equilibrium condition $s^*\left(r\right)=f\left(s^*\left(r\right)\right)$ is difficult to solve explicitly, we can easily find through implicit differentiation that $\frac{d}{dr}s^*<0$. The equilibrium schooling rate $s^*\left(r\right)$ strictly decreases with distance from the origin.

This framework may be used to account for the difference between the spatial schooling curves of public and private colleges plotted in Figures 2, 3 and 4. While privately owned higher-education institutions are unlikely to consider informal learning spillovers when deciding whether to establish a college, public universities are expected to be influenced by such knowledge externalities. Hence, we derive the spatial schooling curve associated with private universities simply by setting the spillover elasticity ψ equal to 0, obtaining $s^*\left(r\right)$ from (8).

$$s^*\left(r\right)=\frac{1}{2}\left[1-\frac{1}{L\left(r\right)^{\phi}}\right] \tag{13}$$

We thus obtain a static schooling curve in private universities, positively correlated with regional population density. However, we must still explain the empirical evidence that the share of students enrolled in private universities rises in the early stages of higher education expansion and then declines in the later period. Moreover, we have not yet derived the equilibrium distribution of schooling in space of all higher education institutions – both public and private – which is essential to draw a comparison with the curve in (13).

A straightforward way to address these issues is simply to solve numerically the recursion in (8), using as initial condition the situation where schooling rates are zero everywhere, i.e., if $s_0(r)=0$ for all r.[2] Then, no informal learning takes place at time 0, so that at time 1 the schooling curve is identical to (13), corresponding to the operation of private universities only. From this period onwards, the recursion converges the unique stable equilibrium defined by the fixed point of $f(s(r))$ in (10).

We perform these calculations and show them in Figure 5. We specify the population density and parameter values as follows:

$$L(r)=2-r,\ \phi=\psi=1,\ \tau=0.1$$

Since τr is close to zero, we use for computational ease the linear approximation $1-\tau r$ of the exponential decline factor $e^{-\tau r}$. We perform four iterations and it results that the curve $s_4(r)$ approximates closely the equilibrium curve $s^*(r)$.

[2] The choice of $s_0(r)=0$ as the initial condition does not entail a loss of generality as the difference equation in (8) has a unique and globally stable equilibrium.

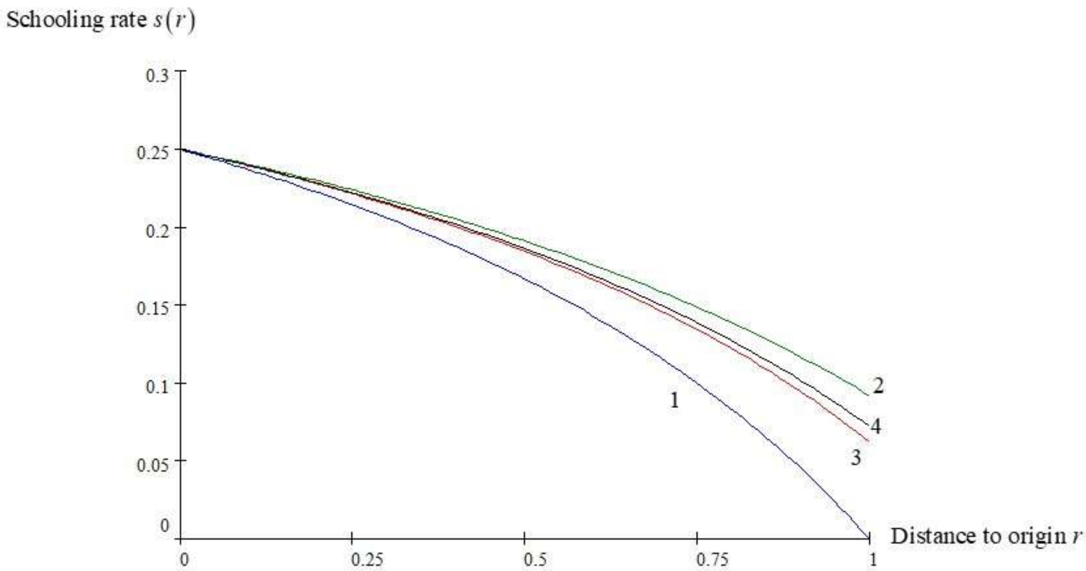

Figure 5: Evolution of spatial schooling curves.

By comparing schooling curves $s_1(r)$ and $s_4(r)$, we find that when universities take into account externalities in human-capital formation, the equilibrium share of educated people substantially exceeds the share merely explained by economies of scale in teaching. Furthermore, this difference increases with the distance between the worker's location and the point with maximal population density.

The main conclusion from Figure 5 consists in that the public authority should subsidize the fixed costs of education in remote, sparsely populated areas.

To rationalize the empirical schooling curves of public and private universities plotted in Figure 4, we redraw curves $s_1(r)$ and $s_4(r)$ of Figure 4 using population density rather than location as the argument. This change of variable poses no difficulty. Since population density $L(r)$ is strictly decreasing, it admits an inverse function L^{-1} everywhere. The two curves $s_1(L)$ and $s_4(L)$ are plotted in Figure 6 and match qualitatively the estimated curves drawn in Figure 4.

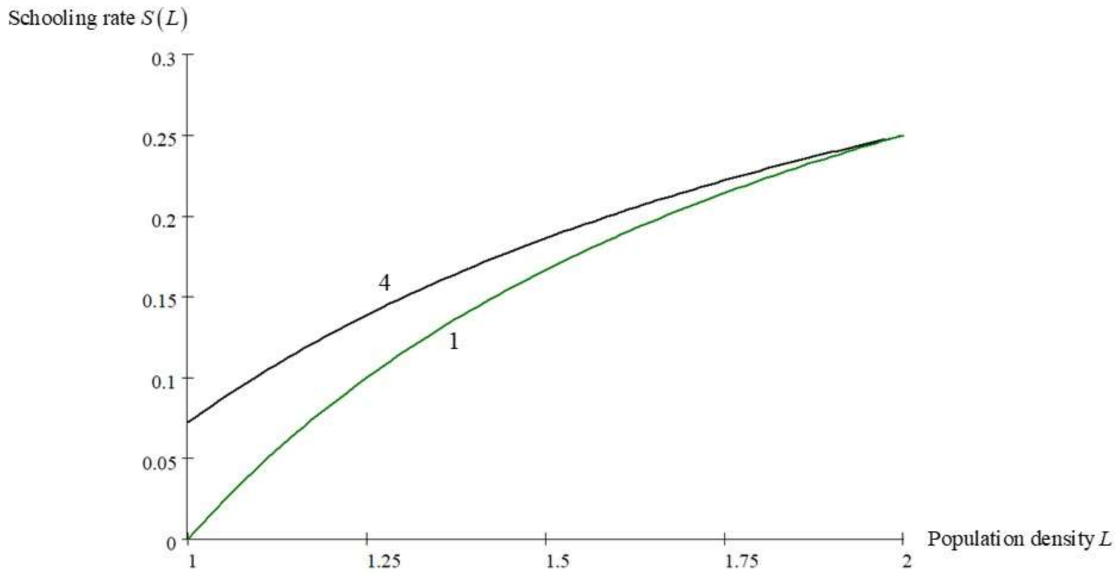

Figure 6: Theoretical schooling rate curves and population density

Figure 6 shows that schooling rates are consistently higher for public universities than for their private counterparts and this gap decreases with population density.

4. Concluding remarks

In this paper, we have sought to rationalise two stylised facts concerning the spread of universities in Portugal in the recent past. The first fact is that private universities display an elasticity of the schooling rate with respect to population density that far exceeds the elasticity observed in public institutions. The second fact is that private colleges expand rapidly in the earlier stages of higher education spread and then tend to decline in the thereafter.

A key factor behind this pattern is that the fixed costs of higher education are typically subsidised to a greater extent in public universities than in private institutions. Moreover, the expansion of higher education follows a spatial diffusion process, beginning in major urban centres and gradually extending to less populated areas.

While the subsidisation of fixed costs is an important source of disparity between the public and private higher education subsystems, it is not the only one. Unlike private institutions, public universities view the establishment of colleges in low-density areas as a potentially efficient instrument for fostering local economic development, even if such decentralised schools may fail to exploit significant scale economies. This belief rests on the idea that less educated individuals in low-density regions can learn informally from more skilled workers in major urban centres. The scope for this kind of informal learning increases with the dispersion of educational levels across regions and improvements in transport and communication networks.

Consequently, in the earlier stages of university expansion, schooling rates are generally low and opportunities for informal learning across regions are limited. During this period, colleges are primarily driven by high-density areas, where they can benefit from scale economies, thereby generating substantial asymmetries in educational attainment across regions. At this stage, private colleges may play an important role in the expansion of higher education.

At a later stage, universities spread beyond major urban centres to enrol workers in less accessible areas, who may benefit from learning interactions with centrally located, educated workers. Public universities can internalise such externalities, whereas this opportunity is not readily available to private institutions. The evolution of higher education thus exhibits rising spatial inequalities at an earlier stage and diminishing inequalities at a later stage.

As a result, schooling rates in public universities are consistently higher than those in private institutions, and this gap is particularly pronounced in peripheral, sparsely populated regions. Indeed, public policies explicitly support the development of higher education in such areas.

A crucial assumption of our analysis is that individuals do not migrate, so that a young person is constrained to study and work in the same location. While this assumption does not appear excessively restrictive (see Lopez-Rodriguez, Faina and Lopez-Rodriguez, 2007, Diebolt and Hippe, 2018), a promising avenue for future research would be to incorporate labour mobility into the model.

Declaration: The author declares that this paper does not incur any conflict of interest.

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Appendix

The following table contains data on population density, higher education attainment levels, and the share of students in *public* institutions across Portuguese NUTS2 regions in year 2021. We include the *Área Metropolitana do Porto*, although it is not a NUTS2 region and remove its data from the *Norte* region. We also consider the island regions of the Azores and Madeira, which are technically NUTS1. These data are drawn the PORDATA database.

Table 1

Region	(1)	(2)	(3)
Norte	97	14.7	92.4
Porto Metropolitan Area	857	21.0	62.9
Centro	72	18.1	96.4
Oeste e Vale do Tejo	89	15.5	90.0
Grande Lisboa	1489	29.0	75.7
Península de Setúbal	501	20.5	77.8
Alentejo	17	14.4	100.0
Algarve	94	17.3	90.0
Azores (Islands NUTS1)	103	14.7	100.0
Madeira (Islands NUTS1)	315	16.5	75.0

Meaning of variables:

(1) Population density, (inhabitants per km^2)
(2) Higher education attainment: percentage of the resident population aged 15 or older holding a completed tertiary degree (ISCED 5-8), according to the 2021 Census.
(3) Percentage of tertiary education students enrolled in public universities and colleges in 2021.

In addition to the overall regional schooling rates, the shares in column (3) allow us to compute separate schooling rates for the public and private universities subsystems.