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Educational Spread as a 'Coordination Game' – Theory and Application to Portugal

José Pedro Pontes[1] and João Dias[2]

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Abstract: This paper examines the recent evolution of higher education in Portugal under the light of an n-person coordination game. We feature two alternative coordination requirements, namely "unanimity", which expresses a cooperative agreement, and "k-coordination", which is driven by efficiency considerations.
We find that public policy has driven higher education to fully cover the territory and in particular individuals living in sparsely populated areas. This orientation might have brought about a loss of scale economies in teaching and, consequently, in the efficiency of tertiary education. This is a plausible explanation for the disconnection between higher education spread and economic growth during the more recent period.

Keywords: Education, Regional Development, Coordination Games, Risk Dominance.

JEL Classification: C72, I20, O12, R11

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1. Introduction

Compulsory education levels in Portugal progressed fast since the establishment of a democratic regime in 1974. At that time, it involved only six schooling years. In the aftermath, it increased to nine years from 1985 on and it was eventually set at twelve years after 2008.

Tertiary schooling (ISCED 5-8) stands now for post-compulsory education, and it is the core signal of progress in overall education. Table 1 shows growth rates in percentage of tertiary-educated people and in real per head GDP during the periods 1981-2001 and 2001-2021.

Table 1

Time period	(1)	(2)	(1)−(2)
1981−2001	6.4	3.0	3.4
2001−2021	4.8	0.4	4.4

(1) ≡ average annual growth rate in the share of people older than 15 with a complete higher education degree according to the Censuses.

(2) ≡ average annual growth rate of real per head GDP.

Source: PORDATA. INE

While there was a steady progress in college attendance rates, the positive correlation between higher education spread and economic growth, which was clear in the first period, vanished during the last twenty years.

The evolution in Portugal matches the global one. Hanushek (2016) and Holmes (2013) regressed economic growth rates over a long period of time on tertiary schooling rates across many countries and found that it is the *quality* rather than the quantity of higher education that explains country economic performance. That is to say, the share of individuals endowed with a university degree is a far less influential factor of economic growth than the cognitive skills such as reading and mathematical ability, which are shown by students in international standardized tests *before* they actually join the university.

This paper tries to assess the driving forces behind the expansion of universities to measure the level of efficiency in this process. Such an analysis might enable us to explain why higher education spread and aggregate productivity growth became apparently unrelated in the more recent past.

Since tertiary education is non-compulsory, the decisions to enrol in a university and the student's performance have an individual character, which is mostly related with the socioeconomic background of the family. For the university, Spiess and Wrolich (2010) single out factors such as the education level of parents, the per head income of the household and the distance separating the parental home and the nearest university. The impact of distance interacts with the family socioeconomic background as it seems stronger for students coming from less favoured families (see, among others, Dickerson and McIntosh, 2013, and Frenette, 2006).

However, the individual decision to join a university is strongly affected by region-level economic factors such as the wage premium of tertiary-educated workers in relation to unskilled ones. Since in this paper we will assume that labour is perfectly mobile, the wage premium is not considered a possible source of discrimination across regions. Instead, we focus here the determinants associated with the "group process" nature of education, which is based on three different grounds.

First, as Lucas (1988) emphasized, human capital is effectively a "social capital", so that individuals who engage in a training process "learn with each other" within a group of neighbours. As Benabou (1993) emphasized, the effort cost for a candidate to join a university decreases steadily with the share of people with higher education living in the same local area. Second, the operation of a college is feasible only if a minimum number of students "share" a set of fixed inputs, such as "buildings", "professors", "laboratories", "libraries" and so on. Finally, tertiary education is specialized by nature. Diamond (1982) argued that a graduate may use his training period profitably only if he is matched with complementary specialists within a work organization. In the same line of reasoning, Helsley and Strange (1990) said that a minimum population density is required to allow a sufficiently dense network of colleges to break even, thus ensuring that each student's residence lies within an acceptable travel distance to the closest university.

In this paper, we model the tertiary schooling process as a simultaneous coordination – *Stag Hunt* – game, where a set of players (i.e., youngsters) decide whether to enrol in the university or to engage in work immediately. The latter option guarantees the lower wage of unskilled labour. The former choice gives the higher wage of skilled labour, as long as a "critical mass" of k youngsters decide to engage in college. Otherwise, the student becomes unemployed at the end of the graduation period and thus receives a zero reward.

The existence of a $k-\text{coordination}$ requirement adds a "group process" nature to learning in a university. But the "critical mass" in the coordination game may be described in two different ways. Either the u*nanimity* of players is required for each student to obtain the wage premium, or only a subset of individuals is necessary. In the latter case, the size of the students' "critical mass" is determined to allow the group effects of learning to take place effectively. These alternative specifications of the coordination requirement have opposite meanings.

As Nash (1950, 1953) remarked, the selection of an equilibrium in a coordination game by requiring a *unanimous* choice by the players models in fact the negotiation of a cooperative agreement. In the case of an educational game, the aim is to cover all individuals in every region regardless of "efficiency" or "quality" concerns.

By contrast, if a subset of individuals is required as a "critical mass", then a minimum group of students is necessary so that teaching takes place under reasonable levels of efficiency or quality, which may be attained only if economies of scale are fully used.

2. Modelling decisions to join a university by means of a n-person *Stag Hunt* game.

2.1. Assumptions

We feature an economy along two consecutive periods. In each period $t = 0,1$, the economy is composed by n_t families.

Let s_t be the share of youngsters in period t who complete a college degree. We assume that in the next period $t+1$ these youngsters become parents and they will predetermine their children to enrol in the university. Consequently, in each period t, only $n_t - s_{t-1}n_t$ youngsters are free to decide whether to engage in higher education.

We presuppose that that the values n_0 and s_0 in period 0, and n_1 in period 1 are exogenously determined. Then we try to explain the value of s_1. For that purpose, we assume that in period 1 each youngster either enters immediately the labour market (pure strategy α) or enrols in college (pure strategy β) thus postponing one period his participation in the labour market. These decisions are made simultaneously by all players.

The payoffs of the youngsters' pure strategies are as follows. If a youngster play α , i.e., he decides to find a job immediately, he obtains the wage of unskilled labour w_U as a certain payoff. Otherwise, if he plays β , i.e., he decides to join a university, he might obtain one of two possible rewards.

If at least k of the n_1 youngsters decide to join a university, then each student obtains the payoff $\frac{w_S}{1+r}$, the discounted value of the wage of skilled labour with $w_S > w_U$. For simplicity, we assume that the discount rate r is close to zero, so that the payoff of higher education under $k-\text{coordination}$ among candidates might be approximated by w_S , the wage of skilled labour. The $k-\text{coordination}$ requirement stems from the group nature of higher education as we stressed above in the introduction.

Otherwise, if the coordination requirement is not satisfied, then the graduate is assumed to become unemployed, and his payoff is zero.

2.2. The set of strict Nash equilibria in the n-person *Stag Hunt*

The n-person *Stag Hunt* game was well described by Carlsson and van Damme (1993) and van Damme (2002). They prove that this game has two Nash equilibria in pure strategies, namely $\overline{\alpha} \equiv$ all players select the pure strategy α, and $\overline{\beta} \equiv$ all players select the pure strategy β, a result that is quite intuitive.

This game involves the selection of a Nash equilibrium, which amounts to the specification for each player of beliefs about the opponents' behaviour. Such beliefs enable everyone to deal with the situation of strategic uncertainty.

It is well known that Harsanyi and Selten (1988) define two criteria for ranking multiple Nash equilibria, namely *payoff dominance* and *risk dominance*. While the former concept is related with collective rationality, the latter expresses the individual attitude of each player while dealing with the strategic uncertainty about the opponent's behaviour.

In theoretical terms, Harsanyi and Selten (1988) contend that, when the two criteria conflict each other, payoff dominance should prevail over risk dominance. This is so because the criterion of payoff dominance is *focal*. Even though the players are not allowed to bargain before the game, there is common knowledge that, *if they might*, then they would settle in the Pareto dominant equilibrium. Consequently, they will tacitly coordinate in the payoff dominant equilibrium.

This assertion has been widely debated in experimental economics. Earlier results with coordination games, such as those by Cooper et al. (1990) and Van Huyck, Battalio and Beal (1990, 1991) stressed that Pareto dominant outcomes failed to be observed in many instances. Most recent laboratory studies with two-person *Stag Hunt* such as

Straub (1995) and Schmidt et al. (2003) emphasize risk dominance considerations in relation to those Pareto dominance. In situations where the two criteria choose different equilibrium points, Schmidt et al. (2003) argue that, even though the payoff dominant strategy is selected more often than not, players appear to be quite responsive to changes in risk dominance levels, whereas they seem not ready to react to variations in payoff dominance levels.

The importance of the risk dominance criterion derives not only from that it is purely based on individual rationality in a situation of strategic uncertainty, but also from that it takes into account more information about the payoff functions than payoff dominance on two different grounds. First, while payoff dominance in 2×2 *Stag Hunt* games is based only on Nash equilibrium payoffs, risk dominance takes additionally into account payoffs related with out-of-equilibrium outcomes. Second, while payoff dominance in $n-$ person *Stag Hunt* only compares individual payoffs, risk dominance is also influenced by the *size* of the group of players.

2.3. Checking risk dominance in the n-person *Stag Hunt* educational game.

In the $n-\text{person}$ *Stag Hunt* game applied to simultaneous decisions to join a college, Harsanyi and Selten (1988)'s risk dominance can be checked in two steps. First, we need to specify for each player a *belief* about another player deciding to join a university, i.e., that he selects his pure strategy β. Since the game is fully symmetric, this belief should be the same across players and might be expressed by the probability $p\in(0,1)$.

Second, we need to compute each player's best reply against his belief p. As we will realize ahead, the profile of players' best replies is necessarily one of the two pure strategy Nash equilibria of the coordination game, i.e., it is either $\overline{\alpha}$ (all individuals decide to work immediately), or $\overline{\beta}$ (all youngsters decide to join a university). Hence, no further adjustment of beliefs and strategies is required. The emerging profile of best replies to beliefs is indeed the risk dominant Nash equilibrium of the game.

While in the 2×2 *Stag Hunt* the specification of players' beliefs compatible with the determination of the risk dominant equilibrium is unique, Carlsson and van Damme (1993) showed that in the n-person version of the game there might be several different forms of specifying them.

The basic assumption underlying the specification of $p\in(0,1)$ is the so-called *principle of insufficient reason*. If a player is uncertain about the alternative of action that an opponent might take and he has no additional information allowing him to discriminate, then he should assign the same probability to each one of the other player's pure strategies. In this context, each player should expect an opponent to select pure strategy β with probability $p=\frac{1}{2}$, an idea that was put forward by Güth and Kalkofen (1989).

In a different line of reasoning, Harsanyi and Selten (1988) propose for the n-person educational game $p=\tilde{w}$, where $\tilde{w}$ stands for the "wage premium" of higher education, i.e., $\tilde{w}\equiv\frac{w_S-w_U}{w_S}\in(0,1)$. The latter specification of p is intuitive since the expectation that an opponent joins a university should be directly proportional to the wage premium he might earn by behaving in this way. Hence, we adopt here the specification $p=\tilde{w}$.

There is more than one form to model the n-person *Stag Hunt* educational game, depending on the specification of the $k-$ coordination requirement. We examine two ways of stating this requirement. Under the first alternative statement (see van Damme, 2002), a student may reap the benefits of completing higher education only if the n neighbouring youngsters decide *unanimously* to join the university. Under the second specification (see Heinemann et al., 2009), we only require that $k<n$ candidates decide to enrol in college. This subset of k individuals is considered a

"critical mass", i.e., the minimum number of students that allow complementarities and "group effects" to take place across individuals.

In what follows, we will realize that these two ways of stating the coordination requirement give contrasting meanings to the educational game.

2.3.1. The *unanimity* game

Following van Damme (2002), the decision by participants in this game to attend higher education is profitable only if it is taken *unanimously* by the candidates. Since $n_t s_{t-1}$ youngsters are constrained to join the university by parental orientation, the required *unanimity* concerns in fact only $n_t\left(1-s_{t-1}\right)$ players.

As van Damme (2002) argued, action β will be a risk dominant equilibrium strategy if

$$\tilde{w}^{\left[n_t\left(1-s_{t-1}\right)-1\right]} w_S > w_U \qquad (1)$$

In inequality (1), $\tilde{w}$ is the probability that a youngster expects another player to enrol in college. Since each individual faces other $n_t\left(1-s_{t-1}\right)-1$ freely deciding youngsters and he expects these individuals to take independent choices, the chance that the coordination requirement is met is $\tilde{w}^{\left[n_t\left(1-s_{t-1}\right)-1\right]}$. Consequently, the expected payoff of pure strategy β is just the left-hand side of (1).

Inequality (1) may be written as,

$$\tilde{w}^{\left[n_t\left(1-s_{t-1}\right)-1\right]} + \tilde{w} > 1 \qquad (2)$$

Inequality (2) may be solved for n_t to give,

$$n_t < \left(\frac{1}{1-s_{t-1}}\right)\left[\frac{\ln(1-\tilde{w})}{\ln \tilde{w}}+1\right] \tag{3}$$

Since the ratio $\frac{\ln(1-\tilde{w})}{\ln \tilde{w}}$ is a strictly increasing function of $\tilde{w}$, the $\overline{\beta}$ equilibrium point will be likelier if $\tilde{w}$ and s_{t-1} are high.

Furthermore, a low n_t makes the inequality easier to be satisfied. In other words, the *unanimity* constraint becomes less binding when the number of players is reduced.

To understand this, we should realize in line with John Nash (1950, 1953) that, even though the selection of an equilibrium point is achieved within a formally *noncooperative* unanimity game, it is just in fact an implicit way of representing a cooperative situation where players discuss to reach a binding agreement. It is not surprising that a cooperative agreement becomes harder to achieve when the number of participants in the bargaining increases.

2.3.2. The k – coordination game

While there exist different kinds of complementarity among candidates to the university, we assume here that the "critical mass" is determined only by the constraint that the number of students should sufficient for a college to break even. This means that the group interaction follows from the fact that students must share fixed inputs, such as "professors", "buildings", "libraries", "laboratories" and so on, thereby benefiting from economies of scale.

We assume that there is a university in each region, whose cost F is utterly fixed. This university is fully financed by a tuition fee c, which is contributed by each student.

Even though there exist n_t students in period t, a subset of $n_t s_{t-1}$ youngsters have their enrolment decision determined by parents, so that they are not effective players in the coordination game. Let y_t be the number of youngsters who decide freely to join a university in period t. Then, the *k - coordination* requirement may be expressed by the inequality,

$$\left(y_t + n_t s_{t-1}\right)c \geq F \tag{4}$$

By solving (4) in relation to y_t, we obtain the *k – coordination* requirement in period t, i.e., k_t.

$$y_t \geq \frac{F}{c} - n_t s_{t-1} \equiv k_t \tag{5}$$

For a given tuition fee, the breakeven point of higher education increases with the college fixed cost and decreases with the number of students in period t and with the share of tertiary-educated people in the previous period $t-1$.

Following Heinemann, Nagel and Ockenfels (2009), we can use a Bernoulli (or binomial) distribution to write the probability that the k_t - coordination requirement in (5) is satisfied as,

$$\begin{gathered}\sum_{x=k_t-1}^{n_t-1} \binom{n_t-1}{x} \tilde{w}^x \left(1-\tilde{w}\right)^{\left[(n_t-1)-x\right]} \\ \text{where } k_t \equiv \frac{F}{c} - n_t s_{t-1}\end{gathered} \tag{6}$$

The expression in (6) is just the probability that *at least* $k_t - 1$ out of $n_t - 1$ players select the pure strategy β. Then, the condition that β is a risk dominant Nash equilibrium strategy is just,

$$\sum_{x=\frac{F}{c}-n_t s_{t-1}-1}^{n_t-1} \binom{n_t-1}{x} \tilde{w}^x \left(1-\tilde{w}\right)^{\left[(n_t-1)-x\right]} w_S > w_U \tag{7}$$

which may also be written as,

$$\sum_{x=\frac{F}{c}-n_t s_{t-1}-1}^{n_t-1} \binom{n_t-1}{x} \tilde{w}^x (1-\tilde{w})^{[(n_t-1)-x]} + \tilde{w} > 1 \tag{8}$$

Clearly, Nash equilibrium selection corresponds here to a noncooperative situation. Youngsters living in a region will decide to join the university if they are numerous enough to allow college fixed costs to be covered by tuition fees.

Let us define as $\mathrm{Bin}(n,k,p)$ the cumulative Bernoulli (or binomial) distribution function.

$$\mathrm{Bin}(n,k,p) \equiv \sum_{x=0}^{k} \binom{n}{x} p^x (1-p)^{(n-x)} \tag{9}$$

Let p be the probability of success in each trial. Then, $\mathrm{Bin}(n,k,p)$ stands for the probability that that a number of successes equal to or smaller than k arise in n trials.

It is clear that $\mathrm{Bin}(n,k,p)$ decreases with n and p, and increases with k.

Hence, we may write condition (8) that β is a risk dominant equilibrium pure strategy in terms of $\mathrm{Bin}(n,k,p)$ as,

$$\left[1-\mathrm{Bin}\left(n_t-1, \frac{F}{c} - n_t s_{t-1} - 2, \tilde{w}\right)\right] + \tilde{w} > 1 \tag{10}$$

Hence, $\overline{\beta}$ will be the risk dominant Nash equilibrium in period t in case that,

- n_t, the total number of youngsters in period t, is high.
- s_{t-1}, the share of college educated people in the former period $t-1$, is high.
- $\tilde{w}$, the wage premium of skilled labour, is high.

If we compare these conditions with those yielded by the game under the *unanimity* requirement, we can draw two main conclusions. First, variables s_{t-1} and $\tilde{w}$ have the same kind of influence on the decision to enrol in college in both game specifications, i.e., they favour this decision. Second, variable n_t has a contrasting influence on tertiary schooling rate in the two models, i.e., while it hinders the spread of higher education in the context of the *unanimity* game, it helps it to develop in the *k – coordination* situation.

In the following section, we seek to determine which kind of coordination requirement fits better the evolution of college attendance across the Portuguese regions (NUTS3 in the mainland and NUTS1 insular regions).

3. Testing the coordination requirement implicit in higher education spread

We now try to find out which kind of coordination requirement – either *unanimity* or $k-$ coordination - better explains the expansion of universities in Portugal between 2001 and 2021.

In Table 1 in the appendix, we gather data on higher education (ISCED 5-8) schooling rates in 2001, s_{t-1}, and 2021, s_t, across NUTS3 regions in mainland Portugal and the NUTS1 insular regions of Azores and Madeira. More precisely, s_t is the share of population aged over 15 with a complete higher education degree as it is recorded through a population census. We also record n_t, the resident population in each region in 2021, from the same statistical source and measured in thousand people.

The choice of NUTS3 as the basic territorial unit allows for a high enough number of regions, while each of them is sufficiently large to avoid significant interactions in college attainment across neighbouring regions. Such interactions are not accounted for in our theoretical model, so that we seek to minimize their influence in the selected sample data.

We use a cross-section OLS model to assess the kind of coordination requirement that describes more accurately how universities spread out in Portugal. We selected above the causes that might account for the fact that joining a university (pure strategy β) is risk dominant in period t, namely population in period t, n_t, the share of college educated people in the previous period $t-1$, s_{t-1}, and the wage premium of skilled labour, $\tilde{w}$. From these factors, we only retain n_t and s_{t-1}, which amounts to assume that workers are freely mobile so that the wage premium $\tilde{w}$ is equalized across regions.

We consider first the *unanimity* game. Condition (3) of risk dominance of strategy β might be written as,

$$n_t\left(1-s_{t-1}\right)<\left[\frac{\ln\left(1-\tilde{w}\right)}{\ln\tilde{w}}+1\right] \tag{11}$$

The fact that this inequality is satisfied may be checked by estimating the decreasing function,

$$s_t=f\left[n_t\left(1-s_{t-1}\right)\right] \tag{12}$$

We turn now to the condition of risk dominance of strategy β in the k – coordination game. Basically, for a given wage premium $\tilde{w}$, the left-hand side of (10) increases with the population of youngsters in period t, n_t, and it decreases with the coordination requirement $k_t\equiv\frac{F}{c}-s_{t-1}n_t$. Hence, it can be approximately described by the difference n_t-k_t, which is given by,

$$\begin{aligned}n_t-k_t&=n_t-\left(\frac{F}{c}-s_{t-1}n_t\right)\\&=n_t\left(1+s_{t-1}\right)-\frac{F}{c}\end{aligned} \tag{13}$$

As the price and cost parameters F and c are supposed to be invariant across regions, the *k – coordination* requirement may be checked by estimating in cross-section the increasing function,

$$s_t=g\left[n_t\left(1+s_{t-1}\right)\right] \tag{14}$$

Thus, we should estimate jointly the functions $f(\cdot)$ and $g(\cdot)$ in the cross-section model,

$$s_t = \beta_1 + \beta_2 \left[n_t \left(1 - s_{t-1}\right) \right] + \beta_3 \left[n_t \left(1 + s_{t-1}\right) \right] + u_t \tag{15}$$

where u_t is an error term and the coefficients have expected signs $\beta_2 < 0$ and $\beta_3 > 0$.

By collecting terms, we may write the model (15) as,

$$s_t = \beta_1 + \left(\beta_2 + \beta_3\right) n_t + \left(\beta_3 - \beta_2\right)\left(s_{t-1} n_t\right) + u_t$$

or

$$s_t = \alpha_1 + \alpha_2 n_t + \alpha_3 \left(s_{t-1} n_t\right) + u_t \tag{16}$$

where we define,

$$\alpha_1 \equiv \beta_1$$
$$\alpha_2 \equiv \beta_2 + \beta_3$$
$$\alpha_3 \equiv \beta_3 - \beta_2$$

The expected signs of the coefficients in (16) are $\alpha_3 > 0$, while the sign of α_2 is ambiguous. $\alpha_2 > 0$ indicates a prevailing “k-coordination” requirement, whereas $\alpha_2 < 0$ is a sign for the existence of a “unanimity” requirement.

The estimated structure of (16) across the regions in Portugal shown in Table 1 in the appendix (with p-values in parenthesis) is,

$$\hat{\alpha}_1 = 0.150303$$
$$\hat{\alpha}_2 = 4.2\text{E-}06 \quad (0.919)$$
$$\hat{\alpha}_3 = 0.000332 \quad (0.352)$$
$$R^2 = 0.59$$
$$F = 15.784 \quad (0.000)$$

This is clearly a case of high multicollinearity.

To overcome this problem, we estimate the model again by substituting separate data for the municipalities within the metropolitan areas of Lisbon and Oporto for the aggregate data. We keep in the sample only those municipalities that are comparable in size to the NUTS3, i.e., that contain a population in 2021 not lower than the population living in the smallest NUT3, which is *Beira Baixa* with about 81000 inhabitants. Data for the larger urban municipalities are collected in Table 2 in the appendix.

The sample of regions now includes 44 observations, i.e., 23 regions outside the metropolitan areas shown in Table 1, plus 21 larger municipalities belonging to these metropolitan areas depicted in Table 2.

The results of the estimation are (with p-values in parenthesis),

$$\hat{\alpha}_1 = 0.191723$$
$$\hat{\alpha}_2 = -0.000332 \ (0.000)$$
$$\hat{\alpha}_3 = 0.004576 \ (0.000)$$
$$R^2 = 0.66$$
$$F = 39.385 \quad (0.000)$$

We can draw two main conclusions from the latter regression.

First, the coordination game framework is indeed suitable to explain higher education spread across regions. Clearly, variable $s_{t-1}n_t$, the number of individuals whose choice to join a university is predetermined by parental orientation, increases the share of tertiary-educated people in the region.

Second, the negative and highly significant coefficient $\hat{\alpha}_2$ of the regional population in 2021 clearly means that the higher education spread was planned to meet a "unanimity" requirement, i.e., to effectively cover all regions and reach all potential candidates on an even ground.

4. Concluding remarks

This paper examines the evolution of higher education in Portugal under the light of an n-person (*Stag Hunt*) coordination game. Such a game exhibits two strict Nash equilibrium points, namely $\overline{\alpha}$ when all youngsters decide to work immediately, and $\overline{\beta}$ when they all decide to join a university. Harsanyi and Selten (1988)'s risk dominance concept is used to select the $\overline{\beta}$ Nash equilibrium.

We consider two alternative coordination requirements in the n – person *Stag Hunt*, namely *unanimity* and the *k – coordination* requirement, that allows the university to break even. Even though the *unanimity* game is formally noncooperative, it represents in fact the result of a cooperative agreement as was emphasized by John Nash (1950, 1953). By contrast, the *k – coordination* game is purely noncooperative and it is driven by efficiency considerations.

While there is an effective concentration of the higher education sector in the main metropolitan areas of Lisboa and Porto, we found that public policy was directed to covering the whole territory, especially people living in sparsely populated areas, both at the regional level, across the NUTS3, and within the main metropolitan areas.

This policy orientation might have caused a loss of scale economies in teaching and an insufficient level of efficiency or quality in the operation of the college system. These limitations likely explain why higher education spread appears to be disconnected from economic growth in the more recent period.

REFERENCES

BENABOU, ROLAND (1993), "WORKINGS OF A CITY: LOCATION, EDUCATION AND PRODUCTION", *QUARTERLY JOURNAL OF ECONOMICS*, 108, AUGUST, PP. 619-652.

CARLSSON, HANS AND ERIC VAN DAMME (1993), "EQUILIBRIUM SELECTION IN STAG HUNT GAMES" IN *FRONTIERS OF GAME THEORY* EDITED BY KEN BINMORE, ALAN KIRMAN AND PIERO TANI, CAMBRIDGE MASS. AND LONDON, MIT PRESS.

COOPER, RUSSELL, DOUGLAS DE JONG, ROBERT FORSYTHE AND THOMAS ROSS (1990), "SELECTION CRITERIA IN COORDINATION GAMES", *AMERICAN ECONOMIC REVIEW*, 80(1), MARCH, PP. 218-233.

DIAMOND, PETER (1982), "AGGREGATE DEMAND MANAGEMENT IN SEARCH EQUILIBRIUM", *JOURNAL OF POLITICAL ECONOMY*, 90(5), PP. 881-894.

DICKERSON, ANDY AND STEVEN MCINTOSH (2013), "THE IMPACT OF DISTANCE TO NEAREST INSTITUTION ON THE POST-COMPULSORY PARTICIPATION DECISION", *URBAN STUDIES*, 50(4), PP. 742-758.

FRENETTE, MARC (2006), "TOO FAR TO GO ON? DISTANCE TO SCHOOL AND UNIVERSITY PARTICIPATION", *EDUCATION ECONOMICS*, 14(1), PP. 31-58.

GÜTH, WERNER AND BRIGITTE KALKOFEN (1989), *UNIQUE SOLUTIONS FOR STRATEGIC GAMES*, LECTURE NOTES IN ECONOMIC AND MATHEMATICAL SYSTEMS, VOL. 328. BERLIN, SPRINGER.

HANUSHEK, ERIC (2016), "WILL MORE HIGHER EDUCATION IMPROVE ECONOMIC?", *OXFORD REVIEW OF ECONOMIC POLICY*, 32(4), PP. 31-58.

HARSANYI, JOHN AND REINHARDT SELTEN (1988), *A GENERAL THEORY OF EQUILIBRIUM SELECTION IN GAMES*", LONDON AND CAMBRIDGE/MASS., MIT PRESS.

HEINEMANN, FRANK, ROSEMARIE NAGEL AND PETER OCKENFELS (2009),"MEASURING STRATEGIC UNCERTAINTY IN COORDINATION GAMES", *REVIEW OF ECONOMIC STUDIES*, 76, PP. 181-221.

Holmes, Craig (2013), "Has the expansion of higher education led to greater economic growth?", *National Institute Economic Review*, 224(1), pp. R29-R47.

Lucas, Robert (1988), "On the mechanics of economic development", *Journal of Monetary Economics*, 22, pp. 3-42.

Nash, John (1950), "The bargaining problem", *Econometrica*, 18(2), pp. 155-162.

Nash, John (1953), "Two person cooperative games", *Econometrica*, 21(1), January, pp. 128-140.

Schmidt, David, Robert Shupp, James Walker and Elinor Ostrom (2003), "playing safe in coordination games", *games and Economic Behavior*, 42, pp. 281-289.

Spiess, C. Katharina and Katharina Wrolich (2010), "Does distance determine who attends university in Germany?", *Economics of Education Review*, 29, pp. 470-479.

Straub, Paul (1995), "Risk dominance and coordination failures in static games", *Quarterly Review of Economics and Finance*, 35(4), Winter, pp. 339-363.

van Damme, Eric (2002), "strategic equilibrium" in R. J. AUMANN and S. HART (organizers), *Handbook in Game Theory, Volume 3, Elsevier Science B.V.*

Van Huyck, John, Raymond Battalio and Richard Beil (1990), "Tacit coordination games, strategic uncertainty and coordination failure", *American economic Review*, march, 80(1), pp. 234-248.

Van Huyck, John, Raymond Battalio and Richard Beil (1991), "strategic uncertainty, equilibrium selection and coordination failure in average opinion games", *Quarterly Journal of Economics*, August, pp. 885-910.

Appendix: Data on higher education schooling rates and resident population across Portuguese regions

Meaning of variables

$s_t \equiv$ share of regional population aged over 15
with a complete higher education (ISCED 5 -8) degree in time period t

$n_t \equiv$ resident population in the region in time period t (unit: 1000 people)

Time periods

$t-1 \equiv 2001$

$t \equiv 2021$

Statistical sources: PORDATA. INE. Censuses of 2001 and 2021

Table 1: Portuguese Regions (NUTS3)

Portuguese Regions	s_t	s_{t-1}	n_t
Alto Minho	0.147	0.047	231
Cávado	0.199	0.062	417
Ave	0.141	0.039	418
Oporto Metropolitan Area	0.21	0.081	1736
Alto Tâmega	0.118	0.042	84
Tâmega e Sousa	0.104	0.027	409
Douro	0.148	0.051	184
Terras de Trás-os-Montes	0.166	0.056	107
Oeste	0.155	0.049	364
Região de Aveiro	0.186	0.067	367
Região de Coimbra	0.214	0.083	437
Região de Leiria	0.169	0.052	287
Viseu, Dão, Lafões	0.162	0.055	253
Beira Baixa	0.169	0.054	81
Médio Tejo	0.153	0.053	228
Beiras e Serra da Estrela	0.154	0.052	211
Lisbon Metropolitan Area (NUT2)	0.266	0.12	2870
Alentejo Litoral	0.124	0.039	96
Baixo Alentejo	0.139	0.046	115
Lezíria do Tejo	0.151	0.053	236
Alto Alentejo	0.140	0.047	105
Alentejo Central	0.164	0.059	152
Algarve	0.173	0.065	467
Região Autónoma dos Açores (NUT2)	0.147	0.052	236
Região Autónoma da Madeira (NUT2)	0.165	0.056	251

Table 2: Larger Municipalities within Metropolitan Areas

Municipalities	s_t	s_{t-1}	n_t
Porto Metropolitan Area	–	–	–
Gondomar	0.166	0.062	164
Maia	0.255	0.099	135
Matosinhos	0.247	0.093	172
Paredes	0.121	0.03	84
Porto	0.353	0.161	232
Santa Maria da Feira	0.157	0.043	137
Valongo	0.176	0.058	95
Vila do Conde	0.176	0.054	81
Vila Nova de Gaia	0.214	0.081	304
Lisbon Metropolitan Area	–	–	–
Almada	0.243	0.103	177
Amadora	0.219	0.095	171
Cascais	0.325	0.071	214
Lisboa	0.412	0.191	546
Loures	0.208	0.087	202
Mafra	0.232	0.066	86
Odivelas	0.234	0.078	148
Oeiras	0.378	0.204	172
Seixal	0.2	0.077	166
Setúbal	0.209	0.09	123
Sintra	0.198	0.094	386
Vila Franca de Xira	0.197	0.07	138