The development of higher education in Europe as a “coordination game”

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The development of higher education in Europe as a "coordination game"

José Pedro Pontes and Ana Paula Buiše*

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Abstract

This paper tries to explain differences in high education growth across European countries by using a coordination game (Stag Hunt) played by n candidates to college education. The payoff of enrolling in the university is positive only if there is "unanimity", i.e. if all candidates engage in higher education, being zero otherwise. This coordination requirement follows from the specialized nature of skills acquired through higher education, which can only be made profitable if each graduate is matched with graduate complementary specialists. This game has two strict Nash equilibria, where either all youngsters enter the university or none does. We show that the assessment of the factors that explain the differential growth of universities across countries is related with alternative ways of selecting a Nash equilibrium in the coordination game. By using empirical data, we can conclude that demographic trends and a cumulative causation factor play a major role in tertiary education growth, while the "wage premium" associated with college attendance also matters but is relatively secondary. "Tuition fees" and other direct financial costs do not appear to be a significant cause or hindrance of university development.

Keywords: Higher Education; Regional Development; Coordination Games; Risk Dominance.

JEL classification: C72, I10, O12, R11.

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1. Introduction

Two main issues arise concerning the relationship between education and economic growth arise (REIS, 1993). Firstly, the investment in education means the accumulation of a specific kind of capital (namely human capital) so that it is assumed to help economic development. Secondly, the differential degree of success in the development of education across territories is influenced by economic factors. In this paper, we deal with the latter class of issues.

In the literature, the determinants of participation and attainment level in post-compulsory education are usually treated as individual features, which are mostly related with socioeconomic background of the family. For the university, SPIESS and WROLICH (2010) single out factors such as the education level of parents, the per capita income of the household of origin and the distance separating the parental home and the nearest university. The impact of distance seems to interact with the family socioeconomic background since it appears to be stronger for students coming from less favored families (see among others DICKERSON and MCINTOSH, 2013; FRENETTE, 2006).

Nevertheless, even if we regard the decision to attend the university as being mainly individual, it is undoubtedly influenced by region level variables. Among these, the financial costs of college attendance (the so called tuition fees) and the "wage premium" earned by workers with higher education matter effectively for decision by a youngster to enroll in the university. Furthermore, even the socioeconomic background seems to operate not only at the individual level but it appears to work also through externalities that operate at local area or region levels (see BENABOU, 1993, and LUCAS, 1988).
In this paper, we assess the economic factors that either help or hinder the development of post-compulsory education at the regional level through the framework of a coordination game. The suggestion of using such a framework is due to WYDICK (2008) and it was based on the fact that, when compared with basic education, higher education consists in the acquisition of specialized skills which can be made profitable only if each graduated specialist is matched during his professional life with other complementary highly educated specialists.

Since in many countries post-compulsory education is nowadays coincident with higher or "tertiary" education, the main emphasis will lie on the expansion of the university.
2. Modelling higher education development at the regional level with a coordination game

We assume that a country owns \( m \) regions, that are indexed by \( i = 1, 2, \ldots, m \). We may also interpret this setting as referring to countries within a regional integration area, such as the European Union. Henceforth, the subscript \( i \) will be dropped since we presuppose that the factors determining educational success are internal to the region concerned.

We assume that the region contains \( n \) families, each family being composed by an adult and a youngster who has the proper age (say 18 years old) to enroll in the university. There are two types of families

1. \( \bar{n} < n \) families where the adult has attended university with success.

2. \( n - \bar{n} \) families where the adult does not hold a university degree.

The youngsters belonging to the set of \( \bar{n} \) families with university background are predetermined to participate in higher education. The remaining \( n - \bar{n} \) youngsters play a symmetric coordination game (the so called *Stag Hunt* game), where each player has two pure strategies at his disposal, namely

\( \alpha \), which consists in refraining from enrolling in the university, thus deciding to take a job immediately. This strategy leads to a certain payoff \( x \).

\( \beta \), which consists in entering the university and completing a degree. This strategy entails a certain cost \( c \) and one of two possible rewards,

- \( y > 0 \), if all less favored \( n - \bar{n} \) youngsters decide to enter the university.
- \( 0 \), otherwise.
This is an *unanimity* game, where the investment in higher education has a positive return only if all potential students decide indeed to attend the university (see, for instance, VAN DAMME, 2002). Unanimity stands for a simple and standard approach to the *requirement of coordination* among the potential participants in higher education. As LUCAS (1988) emphasized, human capital is indeed a "social capital", so that individuals who engage in a training process "learn with each other" within a group of neighbors. Based upon further empirical evidence, BENABOU (1993) found that the effort cost for a candidate to enter the university decreases steadily with the proportion of people with higher education who live in the same local area.

A simple way of rationalizing the unanimity requirement, as expressed by \( n - \bar{n} \), can be found in DIAMOND (1982). Let us assume that there are \( n \) youngsters who face the decision to enter the university. If they decide to enter, each one incurs a cost \( 1 \) and obtains a specialized skill. In order to get a job after graduating, he must find another college educated worker who holds a complementary skill to his. If he succeeds, he gets a payoff \( 2 \) from higher education, otherwise his payoff is zero. During their professional lives, the workers are matched randomly. If a youngster decides to not to enter the university, his certain payoff is zero. If he attends a college, his expected payoff becomes

\[
2 \left( \frac{\text{number of youngsters who graduate}}{\text{total number of youngsters}} \right) - 1
\]  

(1)

It is clear that in (1), the numerator of the fraction increases with \( \bar{n} \), while the denominator rises with \( n \). An alternative way of expressing this, consists in requiring that all \( n - \bar{n} \) candidates enter the university in order that each one gets a positive payoff from graduating.
In what follows, we specify the rewards $x, y$ and the cost $c$. We bear in mind that, in this economy, a wage $w_y$ is paid to skilled labor which is earned by adults with a university degree. By contrast, a wage $w_u < w_y$, is received by unskilled workers, who lack college attendance.

The cost of attending university by a student with a less favored background is $\frac{w_u}{2}$, i.e. one half of his household income, in addition to the college tuition fee $f$.

By assuming that the time discount rate, is $r$, we can write the payoffs and cost as

$$x = w_u$$  \hspace{1cm} (2)

$$y = \frac{w_y}{1+r} - c \text{ where } c \text{ is given by}$$  \hspace{1cm} (3)

$$c = f + \left(\frac{w_u}{2}\right)$$  \hspace{1cm} (4)

While the reward of unskilled labor is received immediately, the payoff of skilled work is only received in the future after the completion of university in the future, hence it is discounted by rate $r$.

Then, we can simplify the game rules, while keeping invariant its best reply structure and set of Nash equilibria (see for this purpose WEIBULL, 1995). The steps of this transformation are:

1. We add $c$ to the payoffs of strategies $\alpha$ and $\beta$, which thus become

$$\tilde{x} = x + c = f + \frac{3w_u}{2}$$

$$\tilde{y} = y + c = \frac{w_y}{1+r}$$
2. We multiply each resulting payoff by the positive factor $\frac{1}{y}$ to obtain the simplified payoffs

\[
\bar{x} = \frac{x}{y} = \left( f + \frac{3w_u}{2} \right) \left( \frac{1 + r}{w_y} \right) \quad (5)
\]
\[
\bar{y} = 1 \quad (6)
\]

The rules of the game imply that $0 < \bar{x} < \bar{y}$, hence we have,

\[
0 < \left( f + \frac{3w_u}{2} \right) \left( \frac{1 + r}{w_y} \right) < 1 \quad (7)
\]

By defining

\[
w^* = \frac{w_y}{w_u} \quad (8)
\]
as the wage premium associated with university attendance and

\[
f^* = \frac{f}{w_u} \quad (9)
\]
as the relative price of higher education, as compared with the income of a less favoured household, the payoffs (5) and (6) become

\[
\bar{x} = \left( f^* + \frac{3}{2} \right) \left( \frac{1 + r}{w^*} \right) \quad (10)
\]
\[
\bar{y} = 1 \quad (11)
\]

From (10), the condition $\bar{x} < 1$ can be written as

\[
w^* > \left( f^* + \frac{3}{2} \right) (1 + r) \quad (12)
\]

Therefore, the rules of the coordination game imply that the wage premium of skill should be high in relation to the real price of higher education for a less
favored household, including the interest paid by the student on the loan that he contracts in order to cover the tuition fees.

Then, we can express exactly the simplified rules of this n person Stag Hunt game. Each player can either select,

Strategy $\alpha$, i.e., take a job immediately, and get a safe payoff $\bar{x} < 1$.

Strategy $\beta$, i.e., enter the university and obtain

- Either a payoff $\bar{y} = 1$, if all $n - \bar{n}$ less favored students decide to select $\beta$ as well.

- Or a zero payoff otherwise.

A well known result concerning the set of Nash equilibria in this game is recalled here (see CARLSSON and VAN DAMME, 1993).

**Proposition 1** The education game has two strict Nash equilibria in pure strategies, namely an equilibrium $\bar{\alpha}$ where all $n - \bar{n}$ low background students choose strategy $\alpha$, i.e. they opt to enter the labor market immediately, and an equilibrium $\bar{\beta}$ where each of them selects strategy $\beta$ and hence attends the university.

**Proof.** It is clear that an outcome where some candidates select $\alpha$ and other potential students select $\beta$ is not a Nash equilibrium. The reason is that a candidate of the latter type obtains a zero payoff, while he can get a positive payoff $\bar{x}$ if he switches to $\alpha$. It is straightforward to prove that the situations where each less favored candidate selects $\alpha$ and all potential students with low background choose $\beta$ are both strict Nash equilibria. ■
3. Selection of a Nash equilibrium in the coordination game

Since the education game has two strict Nash equilibria, namely "all candidates choose $\alpha$" and "all candidates select $\beta$", we try now to select a unique equilibrium through the specification of the beliefs that each player holds about the behavior of the other participants. Two methods for performing this selection will be successively used: the GÜTH (1992) approach; and the "risk dominance" method due to HARSANYI and SELTEN (1988) for symmetric games with $n$ persons.

3.1. The GÜTH (1992) approach - the role of individual costs and benefits of college attendance

We discuss first the selection of a Nash equilibrium based on the *maximal stability of unilateral deviation*, which was put forward by GÜTH (1992). We presuppose that each player $i$ believes that he is the single participant who ignores the true solution of the game. However, all players know that this solution is unique and that it is either $\vec{\alpha}$ or $\vec{\beta}$.

Then, any two players, $i$ and $j$, can describe their decision problem through a reduced game where each player $i$ believes that each player $k \notin \{i, j\}$ selects the same strategy a player $j$. Since the situation is fully symmetric, the reduced game does not depend upon the specific players whom are selected from the original player set. Hence, it can be described by the following matrix.

\[
\begin{array}{c|cc}
\text{Player } j & \alpha & \beta \\
\hline
\text{Player } i & \alpha & \tilde{x}, \tilde{x} & \tilde{x}, 0 \\
\beta & 0, \tilde{x} & 1, 1 \\
\end{array}
\]  

(13)
where $\bar{x}$ is given by (10). Then, with two players, this reduced game can be solved through HARSANYI and SELTEN (1988)'s concept of risk dominance, which amounts in this specific case to select the equilibrium with the larger Nash product, i.e. the equilibrium for which the product of deviation losses is higher. While the Nash product of equilibrium $(\alpha, \alpha)$ is $\bar{x}$, it is $(1 - \bar{x})$ for equilibrium $(\beta, \beta)$. Consequently, equilibrium $\beta$ will be selected if and only if $(1 - \bar{x}) > \bar{x} \Leftrightarrow \bar{x} < \frac{1}{2}$.

As it follows from (10), this equilibrium selection means that there will be coordination in attending the university if the wage premium of higher education $w^*$ is high and the real cost of attending $f^*$ it is low. Nevertheless, this kind of equilibrium selection has limitations both at the theoretical and empirical levels of analysis.

In theoretical terms, the number of players (n candidates to the university) has no influence here upon the outcome of the coordination game, which is rather not intuitive.

At the empirical level, we observe that there is convergence across the European countries both in rates of attendance of tertiary education and in real per head GDP. We estimated for 27 European countries (the 28 EU countries, excluding very small countries such as Cyprus, Luxembourg and Malta, while including two non EU countries, Norway and Switzerland) the following convergence equation by OLS.

$$\frac{1}{14} \log \left( \frac{s_{2018}}{s_{2004}} \right) \times 100 = \alpha + \beta \log s_{2004} + \varepsilon$$

(14)

where $s_{2004}$ and $s_{2018}$ are the schooling rates of higher education, as given by the share of population with higher education (ISCED 5-8) in total population aged between 25 and 34 years, the source being the Portuguese database PORDATA.
This model is very significant and it exhibits a high convergence speed with \( \hat{\beta} \approx -4.0 \).

For the sake of comparison, we also estimated by OLS a convergence equation of per head real GDP \( y \) across the same set of countries.

\[
\frac{1}{18} \log \left( \frac{y_{2018}}{y_{2000}} \right) \times 100 = \alpha + \beta \log y_{2000}^{PPS} + \varepsilon
\]  \hspace{1cm} (15)

In this equation, \( y_{2000} \) and \( y_{2018} \) are per head real GDP (in national currency) in 2000 and 2018, while \( y_{2000}^{PPS} \) is real per head GDP in 2000 expressed in PPS. The result is also highly significant. However, the estimated convergence speed showed a much lower value with \( \hat{\beta} \approx -2.3 \), almost one half of the estimated speed of tertiary schooling convergence. In some European countries, the gap between the annual growth rate of higher education growth rate (between 2004 and 2018) and the growth rate of real per head GDP (between 2000 and 2018) was indeed surprising, with Portugal exhibiting values of 4.5% and 0.6%, respectively.

These findings seem to invalidate any approach to Nash equilibrium selection in the educational coordination game which is only based on the costs and benefits faced by each candidate to the university. As a matter of fact, the wage premium of higher education, as given by (8), can be measured by the elasticity of labor income in relation to the tertiary schooling rate. It is clear that such elasticity is highly positively correlated with the elasticity of real per head GDP in relation to the same variable. The fact that the speed of convergence in tertiary schooling largely exceeds the speed for real per head GDP is inconsistent with any explanation of the progress of universities that is exclusively founded on the magnitude of the "wage premium" earned by college graduates.

In order to shed further light on this issue, we estimated the following OLS
model across the same 27 European countries.

\[
\dot{s} = \alpha + \beta_1 w^* + \beta_2 f^* + \epsilon
\]  \hspace{1cm} (16)

where the meaning of variables is,

\[ s = \frac{1}{14} \log \left( \frac{s_{2018}}{s_{2004}} \right) \times 100 \], is the growth rate in tertiary schooling, that was defined above in (14).

\[ w^* \equiv \text{country "wage premium" in higher education, as a mean for the period 2004 – 2013. The source is MYSÍKOVÁ and VECERNÍK (2019).} \]

\[ f^* \equiv \text{Country average annual tuition fee as a % of average wage.} \]

The estimated model thus obtained was,

\[
\dot{s} = 1.29 + 10.184w^* + 0.001f^* \]  \hspace{1cm} (17)

with the t-statistics in parentheses. The overall quality of the adjustment is given by

\[
R^2 \approx 0.24 \]  \hspace{1cm} (18)

\[
F \approx 3.882
\]

The model as a whole and the \( \beta_1 \) coefficient are significant at the 5% confidence level, while coefficient \( \beta_2 \) is clearly not significant.

We can infer from this estimation that the "wage premium" shows some explanatory power of higher education growth, although it is rather limited. Consequently, we will try a different method to select a Nash equilibrium in the educational coordination game.
3.2. The HARSANYI and SELTEN (1988)'s risk dominance approach - the role of the number of players in the educational game

In order to account for the influence of the number \(n - \pi\) of players upon the selection of an equilibrium in the educational coordination game, we will use the concept of risk dominance, which was put forward by HARSANYI and SELTEN (1988) and carefully explained again by VAN DAMME (2002). In the case of an \(n\) person coordination game, which is outlined in this paper, the specification by each player of the beliefs about opponents in the context of the risk dominance procedure implies the following steps.

Firstly, we determine for each player \(i\) the prior expectation he holds about any other player selecting a given pure strategy, let us say, strategy \(\beta\). We name this prior belief as probability \(p_i(\beta)\). Player \(i\) assumes that every other player knows the true Nash equilibrium of the game. Hence, he has a subjective probability \(z_i\) that every other player selects \(\beta\) and a probability \(1 - z_i\) that the other players choose \(\alpha\). Hence, \(z_i\) is a belief about the opponents’ correlated behavior.

The players other than \(i\), whom we label collectively as "_i", do not observe the value of \(z_i\). According to the principle of "insufficient reason", they assume that \(z_i\) is a random variable, that is uniformly distributed in \([0, 1]\).

From the viewpoint of players "_i" (who behave here as some kind of external observer of \(i\)'s actions), for each realization of random variable \(z_i\) player \(i\) will take the best reply to it. Let \(b_i(\beta)\) label \(i\)'s best reply to subjective probability \(z_i\) in terms of the probability that he assigns to playing pure strategy \(\beta\).

\[
b_i^*(\beta) = \begin{cases} 0 & \text{if } z_i < \hat{z} \\ 1 & \text{if } z_i > \hat{z} \end{cases}
\]  

(19)
Consequently, players "i" will compute the prior expectation that player i holds about them selecting pure strategy \( \beta \)

\[
p_i(\beta) = \int_0^1 b_i^{\alpha_i}(\beta) \, dz_i
\]

\[
p_i(\beta) = \int_0^{\beta} b_i^{\alpha_i}(\beta) \, dz_i + \int_{\beta}^1 b_i^{\alpha_i}(\beta) \, dz_i
\]

\[
p_i(\beta) = \int_0^{\beta} 0 \cdot dz_i + \int_{\beta}^1 1 \cdot dz_i
\]

\[
p_i(\beta) = 1 - \bar{x}
\] (20)

Secondly, each player computes the expected payoff of each one of his pure strategies and defines a plan which consists in selecting the best reply to his prior expectation \( p_i(\beta) \). Since the game is symmetric, the players’ plans of action will be identical. With the prior expectation derived in (20), the probability that every other "less favored" candidate chooses \( \beta \) is simply \((1 - \bar{x})^{(n-\pi-1)}\). As the payoff of an unanimous choice of strategy \( \beta \) is 1, the associated expected payoff is also \((1 - \bar{x})^{(n-\pi-1)}\). Recalling that \( \bar{x} \) is the certain payoff of strategy \( \alpha \), the optimal plan of action will be to play \( \beta \) iff

\[(1 - \bar{x})^{(n-\pi-1)} > \bar{x}\] (21)

To play \( \alpha \) will be the optimal course of action if the reverse of (21) is satisfied.

Thirdly, since the game is symmetric, the plans of action selected by all players will be identical (either all players choose \( \alpha \) or \( \beta \)). In any case, according to Proposition 1, each set of plans is coincident with one strict Nash equilibrium of the original game. Hence, following HARSANYI and SELTEN (1988), each one is robust to any further updating of expectations and can be viewed as the unique solution of the game, the risk dominant solution to be more precise.
We now assess the meaning of condition (21). By taking logs in both sides, it becomes

\[(n - \bar{n} - 1) \ln (1 - \hat{x}) > \ln \hat{x} \text{ or} \]
\[n - \hat{n} < 1 + \gamma (\hat{x}) \text{ where } \gamma (\hat{x}) = \frac{\ln \hat{x}}{\ln (1 - \hat{x})} \]  \(22\)

It can be checked through direct calculation that \(\gamma (\hat{x})\) is a strictly decreasing function.

We try now to rationalize the situation of coordination failure, where the solution of the game implies that no candidate enrolls in the university. The necessary and sufficient condition for this failure to take place is just the reverse of inequality (23),

\[n - \bar{n} > 1 + \gamma (\hat{x}) \]  \(24\)

In order to assess the value added of including \(n - \bar{n}\) as an explaining factor of higher education growth, we estimated the following OLS model across the same set of 27 European countries as before.

\[\dot{s} = \alpha + \beta_1 w^* + \beta_2 f^* + \beta_3 (n - \bar{n}) + \varepsilon \]  \(25\)

The variables in (25) have the following meaning

\[\dot{s} \equiv \frac{1}{13} \log \left( \frac{s_{2017}}{s_{2004}} \right) \times 100 \equiv \text{annual growth rate of tertiary schooling between 2004 and 2017.}\]

\(w^*\) and \(f^*\) have the same meaning as in regression (16).

We define \(n_{2004}\) and \(n_{2017}\) as a country total population with age between 25 and 34 years in 2004 and 2017, respectively. Then, variable \((n - \bar{n})\) stands for the growth rate of population with age between 25 and 34 years that shows no
university attendance. More precisely, we define,

\[
(n - \bar{\pi}) = \frac{1}{13} \log \left[ \frac{n_{2017}(1 - s_{2017})}{n_{2004}(1 - s_{2004})} \right] \times 100
\]

The estimated structure thereby obtained is (the t-statistics are in parentheses)

\[
\hat{s} = 1.146 + 4.831 w^* - 0.012 f^* - 0.655(n - \bar{\pi})
\]

(26)

The overall measures of the quality of fit are,

\[
R^2 \approx 0.40
\]

(27)

\[
F \approx 5.096
\]

These results are clearly better than those of the former regression (17). The \(R^2\) is much higher and the model becomes significant at a 1% confidence level.

Only the coefficient \(\beta_3\) of the growth rate of population without college education is significant (at a 5% confidence level), but the model exhibits the desirable feature that the signs of \(w^*\) (the "wage premium of higher education") and \(z\) (the the real cost associated with "tuition fees") are theoretically expected.

In whole, the inclusion of demographic trends and the cumulative effect of the expansion of the universities clearly improved the rationale for the differences in higher education across the European countries.
4. Discussion and concluding remarks

In this paper, we used the framework of a coordination game in order to explain the differential growth of higher education across European countries. The rationale for employing this framework lies in that higher education is a group process, where neighboring students learn with each other. In addition, college attendance usually leads to the acquisition of a relatively specialized skill, which is made profitable only if each graduate is matched with complementary specialists who work within the same local area. This perspective is also founded on the well known empirical regularity that the effort cost for a student to attend the university decreases with the proportion of highly educated people living in the same neighborhood.

If we label as $n$ the number of potential students (i.e. youngsters with 18 years old) and as $\bar{n}$, the number of youngsters whose parents have already acquired university education, we can model the game as a Stag Hunt unanimity game with $n - \bar{n}$ players. It is well known that such a game has two symmetric strict Nash equilibria, namely an equilibrium where all players decide to enter the university, and an equilibrium where none does it.

Differences in growth rates of higher education across European countries can be explained in alternative ways, according to the specific method adopted for selecting a Nash equilibrium in the coordination game.

GÜTH (1992) explains the arise of coordination exclusively by the costs and benefits (mainly the "wage premium" earned by workers with tertiary education) that are faced by a youngster when he decides to enter a college. No influence is attached here to the number of players $n - \bar{n}$ in the coordination game. This ap-
proach is of limited usefulness as it contradicts the well known empirical regularity that the cross country convergence in tertiary schooling rates far outweighs the convergence in per head GDPs. Although the "wage premium" of workers with higher education appears to have some capacity to explain the evolution of higher education, such a rationale seems rather insufficient.

Hence, we tried an alternative method to select a Nash equilibrium in the education game, namely the "risk dominance" approach due to HARSANYI and SELTEN (1988). In addition to individual costs and benefits of college attendance, such an approach takes in consideration the number \( n - \pi \) of candidates without a university background. If such a number is low, the coordination requirement (the unanimity of players) becomes less stringent and each player will likely expect the other candidates to enter the university. The number of potential students without a college background appears to be highly significant in explaining the progress of higher education, with a secondary role being assigned to individual costs and benefits of graduation.

Hence, differential growth of higher education across European countries seems to be mainly related with adverse demographic trends, that diminish the number of candidates to the university, and by a cumulative causation factor. In this regard, the "wage premium" earned by workers with college education seems to play only a secondary role. The direct financial costs of attending the university appear as neither a significant cause nor an hindrance of higher education growth.
References


Appendix: Empirical Data
1. Per head real GDP

<table>
<thead>
<tr>
<th>European countries</th>
<th>$y_{2000}$</th>
<th>$y_{2018}$</th>
<th>$y_{2000}^{PPS}$</th>
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Meaning of variables.

$y_{2000}$ ≡ per head GDP in 2000 at constant prices of 2010; unit: national currency (Source: AMECO).

$y_{2018}$ ≡ per head GDP in 2018 at constant prices of 2010; unit: national currency (Source: AMECO).

$y_{2000}^{PPS}$ ≡ per head GDP in 2000; unit: PPS (Source: AMECO).
2. Schooling rate of higher education

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</table>
Meaning of $s_t$, $t = 2000, 2017, 2018$ 

≡ Population with Higher Education (ISCED 5-8) in % of population with age between 25 and 34 years. Source: Portuguese database *PORDATA.*
3. Resident population.

<table>
<thead>
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<th>European countries</th>
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<th>$n_{2017}$</th>
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Meaning of $n_t, t = 2004, 2017 \equiv$ resident population with age between 25 and 34 years; unit: million of people. Source: Portuguese database PORDATA.
4. Individual cost and benefit of attending tertiary education.

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Meaning of variables.

\( w^* \equiv \text{wage premium of tertiary education. Source: MYSÍKOVA and VECERNÍK (2019).} \)

\( f \equiv \text{Average annual tuition fees for undergraduate studies, excluding medical schools, in 2018. Unit: 1000 euros.} \)

\( w_u \equiv \text{nominal compensation per employee in 2018. Source: AMECO. Unit: 1000 euros.} \)