THE ROLE OF HIGHER EDUCATION INSTITUTIONS IN SUSTAINABLE DEVELOPMENT: A DSGE ANALYSIS

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1. Introduction

This paper explores the role of higher education institutions in achieving sustainable development, employing a Dynamic Stochastic General Equilibrium (DSGE) model extended to consider the European Union (EU) educational system and households' environmental awareness. In particular, this paper addresses the following fundamental questions: (i) how HEIs productivity affect households' environmental awareness? (ii) how human capital and environmental awareness interact with the business cycle?

Economic theory on sustainable development mainly focuses on the incentives to reduce Greenhouse Gases (GHGs) emissions, but it is very important to analyze the processes of the definition of preferences of individuals and households to define a real change. In opposition to a large managerial and organizational literature on this topic, economic analysis has few contributions.

In order to fill this gap in the literature, this paper extends previous studies applying environmental DSGE models, embedding human capital accumulation, environmental variables, and households' environmental awareness.

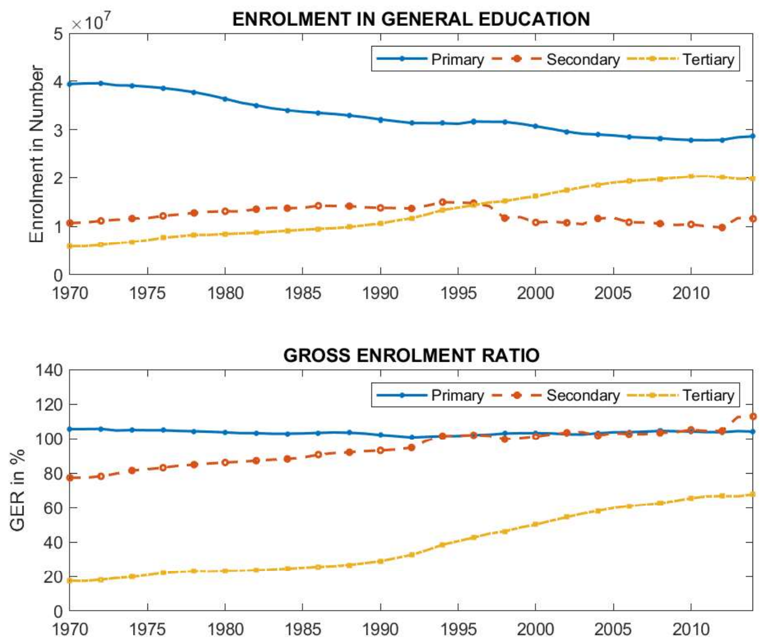
Our results can be summarized as follows. First, enrollment in tertiary education and environmental awareness are procyclical. Second, households become more sensitive to environmental issues during a positive technology shock. Finally, higher academic institutions play a key role in reinforcing the above mechanism, allowing sustainable development.

This paper is structured as follows: Section 2 discusses the main stylized facts in global and EU-27 education. Section 3 presents a DSGE model embedding time in education and household environmental awareness. Section 4 presents the model calibration. Finally, Section 5 presents the impulse response analysis. Finally, section 6 concludes.

2. Education: Empirical Evidences

This section provides an overview of long-run changes in education outcomes and outputs worldwide, focusing on the EU-27. From a historical perspective, the world went through a great expansion in education over the past two centuries. Global literacy rates have been climbing over the last two centuries, mainly through increasing enrollment rates in primary education. Secondary and tertiary education have also seen drastic growth, with the global average years of schooling being much higher than a hundred years ago. Fig. 1 displays the evolution of the European Union 27 (UE-27) education from 1970 to 2014. We consider two indicators of human capital: total enrollment and the enrollment ratio (GER) in primary, secondary, and tertiary education, all courses, and both sexes. These data are obtained from the World Bank indicator database. From Fig. 1, it is possible to identify a clear positive trend for secondary and tertiary education in the sample period. In particular, starting from 1990, the enrolment in tertiary education has increased drastically (about 40 percentage points in 1970-2014).

Figure 1 – *Enrolment and the GER in all courses, both sex, EU-27- 1970-2014*



3. The Model

This section presents a DSGE model to examine the role of higher education institutions in achieving sustainable development. This model presents three agents: a representative household, a representative higher academic institution, and a representative firm. We configure the model in the following way. Households maximize expected utility defined over to consumption, environmental quality, labor effort, and education. They can invest in abatement activity and physical capital. The representative firm produces goods employing effective labor and capital. Academic institutions transform education into new human capital. In detail, we expand a standard *Real Business Cycle* (RBC) model with human capital considering two significant features that have non-trivial implications for sustainable development analysis. First, our model embeds the environmental sector and carbon emissions dynamics. Second, households are environmentally aware and use part of their resources to protect the environment. The unique source of uncertainty is a technology shock on output.

3.1. Higher Academic Institutions

The higher academic institutions transform time devoted to education from households into new human capital. The new human capital assumes the following functional form:

$$i_t^h = A_{h,t}(h_t e_t)^{\varphi_e}[(1 - v_t k_t)]^{1-\varphi_e} \tag{1}$$

where $(1 - v_t)$ is the remaining fraction of physical capital allocated to the human capital investment sector; and $A_{h,t}$ is the human capital technology productivity. According to literature in this filed, we assume diminishing return to education; it is added to the model by the assumption that φ_e takes a value in the interval (0,1). In line with Ben-Porath (1967), an agent forms new human capital stock by combining time (e_t), talent, and current human capital stock (h_t). In addition, we assume that new human capital is linked to physical capital (k_t). Agents in the economy are investing in themselves to maximize their expected lifetime returns. In detail, households make a human capital investment to the point that the marginal return of a unit investment is equal to the alternative marginal return they can earn with the time they use for acquiring human capital.

3.2. Firms

In the model, input markets are perfectly competitive. Firms, which take factor prices as given, rent physical capital and employ labor force in order to maximize profits. The representative firm maximize their profits by choosing the optimal quantity of capital and labor:

$$max_{k_t,l_t} \Pi_t = y_t - v_t r_t k_t - w_t n_t h_t \quad (2)$$

s.t

$$y_t = A_t (v_t k_t)^{\alpha} \left(h_t\ n_t\right)^{1-\alpha} \quad (3)$$

where A_t is the total factor productivity shock and follows an AR (1) stochastic processes:

$$log(A_t) = \rho_a log(A_{t-1}) + (1-\rho_a) A_{ss} + \varepsilon_t^a \quad (20)$$

where A_{ss}, is a constant and represents the steady-state values; $0 < \rho_a < 1$ is the autoregressive parameters; ε_t^a, is Gaussian i.i.d. shocks with zero means and known variances, σ_a^2. The first order conditions for the firms are:

$$r_t = \alpha \frac{y_t}{v_t k_t} \quad (4)$$

$$w_t = (1-\alpha) \frac{y_t}{h_t\ n_t} \quad (5)$$

The representative firm hires labor until the marginal product of effective labor is equal to the wage rate, w_t, and rent capital until the marginal product of physical capital is equal to the rental rate, r_t.

3.3. Households

Households maximize expected utility defined over to consumption, leisure, and the environment investment ratio. The period utility function is:

$$U_t(c_t, l_t, m_t) = \sum_{t=0}^{\infty} \beta^t [log(c_t) + \varkappa log(l_t) + \mu log(m_t)] \quad (6)$$

where c_t is consumption per capita, l_t denotes leisure, β is the discount factor, $\varkappa$ leisure weight, μ is the environmental quality weight. As in Zhang *et al.* (2019), we consider that the environment investment ratio $m_t$affects positively the household's utility function. We use the environmental investment as a proxy of the environmental awareness. The representative agent is confined by a unitary time endowment constraint for every period:

$$l_t + n_t + e_t = 1 \tag{7}$$

where n_t is the labor employed in goods production, and e_t is time spent in education. Households maximize expected utility subject to the flow budget constraint:

$$c_t + i_t + m_t = h_t \ w_t n_t + v_t r_t k_t \tag{8}$$

Households consume goods, invest in the production sector (i_t) and in the abatement activity (m_t). Households finance these expenditures through effective wage $(h_t \ w_t)$ income from the production firms, and the return they receive from the investments in the previous period (v_t is the fraction of capital devoted to goods production). The human capital stock $(h_t \ )$ evolves according to the following law of motion:

$$h_{t+1} = i_t^h + (1 - \delta_h) h_t \tag{9}$$

where i_t^h define the new human capital and δ_h is the depreciation rate of human capital. The stock of capital is usual and evolve according to the following law of motion:

$$k_{t+1} = (1 - \delta) k_t + i_t \tag{10}$$

where δ is capital depreciation rate.

Households maximize their lifetime utility. The choice variables in the maximization problem are the consumption level, the investment level, the environmental investment level, the education time, the work time, the physical, and the human capital that they plan to invest for the next period.

The following set of equations characterize the intertemporal maximization problem:

$$max_{c_t, n_t, m_t, k_{t+1}, h_{t+1}, e_t, v_t} \sum_{t=0}^{\infty} \beta^t [log(c_t) + \varkappa log(l_t) + \mu log(m_t)]$$

s.t:

$$l_t + n_t + e_t = 1$$

$$c_t + i_t + m_t = h_t \ w_t n_t + v_t r_t k_t$$

$$h_{t+1} = A_{h,t} (h_t e_t)^{\varphi_e} [(1 - v_t k_t)]^{1-\varphi_e} + (1 - \delta_h) h_t$$

$k_{t+1} = i_t + (1 - \delta)k_t$

$$given\ k_0 , h_0 > 0, \forall t$$

The first order conditions for consumption, environmental investments, labor, education, fraction of capital in goods production, physical capital and human capital are the follows:

$\frac{1}{c_t} = \lambda_t$ (11)

$\frac{\mu}{m_t} = \lambda_t$ (12)

$\frac{\varkappa}{l_t} = \lambda_t w_t h_t$
(13)

$\frac{\varkappa}{l_t} = \varrho_t A_{h,t}(\varphi_e)(h_{t+1}e_t)^{\varphi_e}[(1 - v_t k_t)]^{1-\varphi_e} h_t$ (14)

$r_t \ \lambda_t = \varrho_t(1 - v_t)A_{h,t}(1 - \varphi_e)(h_t e_t)^{\varphi_e}[(1 - v_t k_t)]^{-\varphi_e}$ (15)

$\lambda_t = \beta\big[r_{t+1}v_{t+1}\lambda_{t+1} + \varrho_{t+1}(1 - v_{t+1})A_{h,t+1}(1 - \varphi_e)(h_{t+1}e_{t+1})^{\varphi_e}[(1 - v_{t+1}k_{t+1})]^{-\varphi_e} + 1 - \delta\big]$ (16)

$\varrho_t = \beta\big[\varrho_{t+1}e_{t+1}A_{h,t+1}(\varphi_e)(h_{t+1}e_{t+1})^{\varphi_e}[(1 - v_t k_{t+1})]^{1-\varphi_e} + \lambda_{t+1}w_{t+1}n_{t+1} + 1 - \delta_h\big]$ (17)

where λ_t and ϱ_t are the Lagrangian multipliers associated to the budget constraint and the law of motion of human capital, respectively. Eq. 11, 12, 13 14, represent marginal utility for consumption, environmental protection, labor and education, respectively; Eq. 15 equates weighted factor intensities across sectors; Eq. 16 and 17 are the Euler equations for physical and human capital.

3.4. Natural Resources and Carbon Emissions

One of the novelties of this study is to consider environmental variables in a standard RBC model with human capital. As in previous studies, we assume that production activity emits carbon dioxide in the atmosphere. In particular, emissions per firm (em_t) are by-product of output:

$em_t = (\epsilon - m_t)y_t$ (18)

Emission intensity ($e\, m_t/y_t$ depends on the abatement technology ($\epsilon - m_t$), where ϵ defines the emissions for unit of output. This study considers also environmental quality dynamics. As in Angelopoulos *et al.* (2013), environmental quality evolves according to the following law of motion:

$$q_t = (1 - \delta_q)eq + \delta_q q_{t-1} - em_t \quad (19)$$

where the parameter eq represents environmental quality without pollution, and $0 \leq \delta_q \leq 1$ is a parameter measuring the degree of environmental persistence.

4. Calibration

The model is calibrated for the EU 27 and time is measured in quarters. Table 1 lists all the parameters of the model. For conventional parameters, we use the standard estimates used in the business cycle literature (e.g., Smets and Wouters, 2003). The discount factor is set at a value consistent with a real interest rate of 4% per year, that is 0.99. The depreciation rate of capital is set at 0.025 and the capital share at 1/3. Regarding the environmental part of the model, we refer to previous environmental DSGE models for climate change to obtain plausible values for environmental parameters. As in Heutel (2012), we set the emission intensity parameter to 0.45. For the environmental quality dynamics, we refer to Angelopoulos *et al.* (2013).

Table 1 – *Baseline Parameter Calibration.*

Parameter	Description	Value	Source
χ	Leisure Weight	2.00	Endogenous Calibration
μ	Environmental Quality Weight	0.14	Endogenous Calibration
δ	Capital Depreciation Rate	0.02	Smets and Wouters (2003)
δ_h	Human Capital Depreciation Rate	0.01	Kim and Lee (2007)
α	Capital Share in Production	0.33	Smets and Wouters (2003)
φ_e	Education Technology	0.8-0.9	Kim and Lee (2007)
ϵ	Emissions Intensity	0.45	Heutel (2012)
δ_q	Natural Depreciation Rate	0.90	Angelopoulos et al. (2013)
ρ_a	Persistence of TFP shock	0.95	Smets and Wouters (2003)

More precisely, we define the persistence of environmental quality as equal to 0.95. In contrast to the other parameters, there is relatively little econometric evidence on the parameter in the human capital formation equation. Achieving effectiveness and efficiency in higher education depends on public authorities creating the right framework within which higher education institutions can operate. For this reason, we assume two alternative calibrations for education productivity in the HEI production function. The two alternative calibrations are in line with the literature (e.g., Heckman, 1976) and allow us to explore the role of higher institutions with different educational structures. The depreciation rate of the human capital is equal to 0.01, as in previous studies in this field. Finally, for the stochastic processes of the model, we assume a high degree of autocorrelation for the exogenous shocks by setting at 0.95.

5. Results

In order to assess the role of higher education institutions on carbon emissions and the business cycle, we analyze the dynamic properties of the model under two alternative calibrations of education productivity parameters: $\varphi_e = 0.8, 0.9$. We can think of this different calibration as national reform in tertiary school education improving study quality and increase returns to the education received[1].

5.1. Impulse Response Analysis

Figure 2 shows the impulse response functions for a technology shock in the goods production sector.

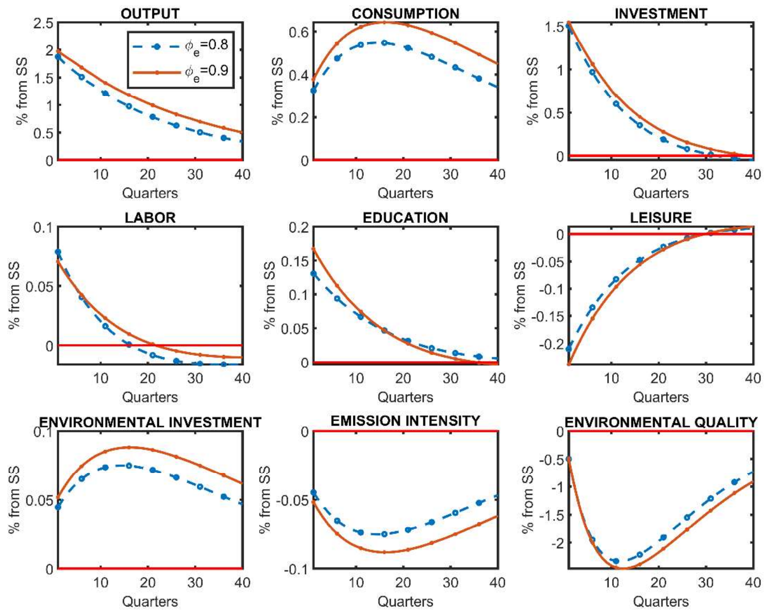
Following a positive technology innovation, both calibration, output, consumption, investment, and labor all rise persistently. Households find optimal increase investments, work harder and increase education during the early phases of the adjustment process when productivity is higher. Households allocate more time to education in order to increase their future human

capital. We find a pro-cyclical pattern for time spent in education. This finding contrasts with the results of a strand of research considering countercyclical fluctuations for the human capital (Kim and Lee, 2007, among others). However, our finding is in line with Malley and Woitek (2011) and King and Sweetman (2002), investigating the empirical relationship between college enrollment and output and evidence in favor of procyclicality. Consequently, the increase in time spent in education and improvement in firm productivity affect the household's

[1] The simulations have been obtained using numerical analysis and perturbation methods to simulate the economy and compute the equilibrium conditions outside the steady-state. We solve the model using a second-order Taylor approximation around its steady state. All results are reported as percentage deviations from the steady-state.

environmental awareness, increasing investments in environmental protection. This latter occurs for two main reasons. First, the increase in productivity induces a corresponding increase in emissions, worsening the environmental quality. Hence, households respond by increasing the abatement effort to preserve their well-being. Second, after this shock, their income increase.

Figure 2 – *Impulse response functions to a one percent technology shock*.



As a consequence, households use part of their resources to preserve the environmental quality. Our finding is in line with recent literature investigating the role of the business cycle in changing people's environmental concerns. Scruggs and Benegal (2012) find that public opinion about global warming is variable and driven by the business cycle and economic insecurity. Kahn and Kotchen (2010) find that an increase in a state's unemployment rate is associated with a decrease in the probability that residents think global warming is happening and a reduced investment in environmental protection. Turning to the national reforms in school education scenario, positively affecting returns to the education received, this study presents interesting results. In detail, when the education productivity increase households prefer to reduce their leisure and increase their investment in education. Households' education choices affect business cycle dynamics in two ways. First, it positively affects firms' productivity, amplifying beneficial effects from productivity shock on output. Second, investment in education affects workers' skills, allowing them to earn greater wages. Consequently, households increase consumption, investments in physical capital, and environmental protection. In conclusion, a better structure of educational institutions allows achieving sustained growth economic with a lower impact on the environment. The rise in environmental protection associated with economic growth contributes to a reduction in emission intensity.

6. Conclusions

This paper provides selected insights to reason on the role of higher academic institutions in achieving sustainable development, while households choose between consumption, education, and labor and decide how to allocate their saving between environmental protection and goods production. To investigate this question (and possibly many others), this manuscript designs an equilibrium model capable of capturing the trade-off between environmental-compliant choices and those based only on crude economic drivers, focusing on how investment in education can affect it. This document is motivated by the recent rise in awareness about climate change issues and their consequences (e.g., "Fridays for Future" Climate Strike implications). However, most of the existing literature on environmental policy analysis (e.g., Fischer and Springborn, 2011; Heutel, 2012; Annicchiarico and Di Dio, 2015) neglects the role of the household in this story. Since households' behavioral changes are one of the key factors of sustainable economic development, neglecting their preferences could result in a biased calculation of environmental policies performances. Therefore, ignoring education and awareness aspects in theoretical models means disregarding an important channel for macroeconomic fluctuations and suggesting misleading policy recipes. This study suggests that time devoted to education and investment in abatement activity are pro-cyclical. First, households are willing to reduce their leisure during the economic growing phases, increasing time devoted to labor and education. Second, as documented in the literature, environmental concern is linked to the business cycle in this study. Short-term economic conditions and environmental quality anomalies affect opinions and concerns about climate change. Consequently, households become more sensitive to environmental issues during a positive technology shock. The mechanism is reinforced when higher academic institutions become more efficient in their educational activity. Tertiary education plays a strategic role in the processes of sustainable development. Some points in our future research agenda will be related to the dynamics of accumulation of a specific green human capital affecting households' choices and the impact of HEIs policies on students and households' pro-environmental attitude and their effect on sustainability, providing a welfare analysis.

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SUMMARY

The role of higher education institutions in sustainable development: a DSGE analysis

The higher education sector is recognized as one of the major players in advancing sustainability through its research, education, and societal engagement. In order to investigate the role of higher education in achieving sustainable development, this study proposes a *Dynamic Stochastic General Equilibrium* (DSGE) model embedding human capital accumulation, environmental variables, and households' environmental awareness (i.e., investments in environmental protection). This paper studies the dynamic behavior of education and its link to environmental awareness, considering different higher education institution productivity parameters and a technology shock. This paper offers three main results. First, enrollment in tertiary education and environmental awareness are procyclical: households are willing to reduce their leisure during positive economic phases, increasing time devoted to labor and education. Second, as documented in the literature, environmental concern is linked to the business cycle in this study. Concerns about climate change are affected by short-term economic conditions and environmental quality anomalies. Consequently, households become more sensitive to environmental issues during a positive technology shock. Third, this mechanism is reinforced when the higher academic institutions become more efficient in their education activity, amplifying the beneficial effects of a technology shock on output and investments in environmental protection.

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