The business cycle human capital accumulation nexus and its effect on labor supply volatility

(Preliminary)

Diana Alessandrini*, Stephen Kosempel, Thanasis Stengos

Department of Economics and Finance, University of Guelph

Abstract

This paper studies the cyclicality of human capital accumulation by using a lifecycle RBC model with two types of heterogeneity: age and productivity in learning. Results show that individuals invest more in human capital during economic downturns. In particular, schooling acts as a buffer sector and allows agents to compensate for the shock by accumulating more human capital. However, human capital accumulation is more countercyclical for young and low-productivity individuals because they face lower opportunity costs of education. These results are confirmed empirically using US data from the Current Population Survey.

KEYWORDS: human capital accumulation, business cycles, labor supply.

JEL CLASSIFICATION: J24, E32, J22

1 Introduction

Among US high-school students age 16 to 24 who graduated in 2009, 70.1% enrolled in college in October 2009. This is the historical high for college enrollment rate since 1959. At the same time, unemployment rate has reached the level of 10% in October 2009 which is also the maximum level for unemployment in the recent financial crisis[1]. This seems to be consistent with several studies in the literature regarding the cyclicality of schooling decisions. Enrollment in post-secondary education (PSE), in fact, is mainly affected by opportunity costs and financial costs of education. These, in

*Corresponding Author. Department of Economics and Finance, University of Guelph, Guelph, Ontario, N1G 2W1, Canada, e-mail: dalessan@uoguelph.ca

[1]Source: US Bureau of Labor Statistics.

turn, are affected by business cycle fluctuations. On one hand, during a recession high unemployment decreases opportunity costs of education and people substitute work for school. On the other hand, family income is lower and students may not be able to afford costs of education (Christian, 2007). If liquidity constraints are not too tight, the first effect dominates and enrollment is countercyclical. This is more likely to happen in OECD countries compared to non-OECD countries (Sakellaris and Spilimbergo, 2000).

From a theoretical point of view, several macroeconomic models have been developed to study the countercyclicality of human capital accumulation. Canton (2002), for example, used a discrete time stochastic version of the endogenous growth model developed by Lucas (1988) and Uzawa (1965). He showed that uncertainty leads agents to accumulate more human capital to compensate for future income losses. DeJong and Ingram (2001), instead, developed a Real Business Cycle (RBC) model with skill acquisition. In the presence of a positive TFP shock, in particular, human capital is more expensive than physical capital. Thus agents decrease study hours and accumulate less human capital. Within an overlapping generations framework, instead, Heylen and Pozzi (2007) proved that the optimal amount of education depends negatively on the ratio between current and future real wage. Since this ratio is more likely to decrease during recessions, investment in education is countercyclical.

Empirically, the results are more controversial. Mattila (1982), Polzin (1984), Kane (1994), Edwards (1976) and Christian (2007) found no impact of business cycles on enrollment decisions. Betts and McFarland (1995), Dellas and Sakellaris (1996), and Dellas and Koubi (2003) found evidence in favor of coutercyclicality. Finally, Sakellaris and Spilimbergo (2000) found a positive relationship between GDP growth and enrollment rates in non-OECD countries, and a negative relationship in OECD countries.

The cyclicality of schooling decisions has received particular attention in the literature because of its interesting implications. Economic downturns are bad for the economy. However, if enrollment rates are countercyclical, then crises are also the most efficient time to accumulate human capital and produce more skilled workers. This paper, in particular, further investigates the relationship between crises and human capital accumulation by looking at heterogeneity among agents. The main result is that crises impact different types of agents in different ways: young and low-productivity individuals are more likely to enroll in PSE. This is because it is cheaper for them to leave the labor market and go to school. In contrast, high-productivity agents and old people with work experience earn higher wages and are less likely to leave the market.

The countercyclicality of human capital accumulation has also important implications regarding the volatility puzzle in RBC models. One of the main shortcomings of these models, in fact, is the inability to predict labor supply volatility, which is lower than the empirical estimates. Several solutions have been proposed in the literature, including the introduction of indivisible labor (Hansen, 1985) or alternatives to market production (e.g. home production and education). The countercyclicality of human capital accumulation, for example, can be used to increase labor supply volatility because agents reduce more hours worked in order to study.

These solutions assume that the RBC model systematically underestimates the volatility by excluding important factors that influence labor supply. Recent papers (e.g. Hansen and İmrohoroğlu, 2009; Gomme *et al.*, 2004), instead, have looked at the volatility puzzle from a different perspective. According to them, the RBC model underestimates the volatility only for certain groups of individuals. In reality, for example, labor supply is more volatile for young compared to middle-age individuals. This fact cannot be captured by the baseline RBC model because of the representative-agent assumption. Therefore, introducing heterogeneity in the model may help to explain the volatility puzzle. Previous papers in the literature focused on heterogeneity by age and tried to explain the puzzle especially for young agents (Gomme *et al.*, 2004; Hansen and İmrohoroğlu, 2009; Jaimovich *et al.*, 2009). Their results confirm that the volatility is underestimated for young, and it is overestimated for old if the model includes mandatory retirement. This paper, instead, shows how heterogeneity by productivity type rather than by age plays an important role in explaining the puzzle. In particular, the model is presented in Section 2. Section 3 presents the theoretical results and the implications about labor supply volatility. These results are tested empirically in Section 4 by using US data. Finally, Section 5 concludes.

2 The Model

Every year a new generation of equal size is born. Households live for 60 periods. Period 1 represents the 20-year-old cohort in reality. This is to exclude from the model the period of mandatory education because the focus is on enrollment decisions and people do not choose to enroll in mandatory education. Further, all agents die at age 80, which implies a 60 years lifetime. Individuals are endowed with one unit of time they can allocate among leisure, work and education. Agents can work and study at the same time during their working life. At age 41 retirement is mandatory. During retirement, labor supply and education are absent and the time endowment is completely allocated to leisure. In any period, there are two types of capital: physical and human capital. Agents start their life with no physical capital and leave no bequests at the end of their life. The initial human capital stock, instead, is positive. This is to account for the amount of human capital accumulated during mandatory education[2]. Physical capital is accumulated during life through investment, while the human capital stock increases by allocating time to education.

At the beginning of their life, agents maximize their lifetime utility:

$$E_t \sum_{s=1}^{60} \beta^{s-1} \left[\frac{\left(c_{t+s-1,s} l_{t+s-1,s}^{\gamma}\right)^{1-\eta}}{1-\eta} \right],$$

by choosing consumption, investment in human and physical capital, and time spent working and studying. The subscripts t and s refer to time period and age, respectively. Further, c is consumption, l is leisure, E is the expectation operator, β is the discount factor, γ is the disutility of non-leisure activities (i.e. working and studying), and η is the coefficient of relative risk aversion.

During the working period, the sources of income are labor and asset wealth accumulated from investment in physical capital. Labor income, in turn, depends on efficiency units of labor $n_{t,s}h_{t,s}$. In the retirement period agents receive a public pension and interest on the investment in physical capital. Therefore, the budget constraints are given by the following equations:

$$\begin{aligned}
k_{t+1,s+1} &= (1 + r_t - \delta)k_{t,s} + (1 - \tau)w_t n_{t,s} h_{t,s} - c_{t,s} && \text{for s} = 1, ..40\,, \\
k_{t+1,s+1} &= (1 + r_t - \delta)k_{t,s} + b - c_{t,s} && \text{for s} = 41, ..59, \\
c_{t,s} &= (1 + r_t - \delta)k_{t,s} + b && \text{for s} = 60,
\end{aligned}$$

where k is physical capital, h is human capital, n is labor supply, r is the rental rate of physical capital, δ is the physical capital depreciation rate, w is the wage rate, τ is the tax on labor income and b is the annual public pension benefit level.

Within the same cohort, agents are heterogeneous because of different levels of productivity in learning: high and low. High types are more productive in learning compared to low types. Therefore, they can accumulate more human capital given the same amount of time spent in education. In particular, human capital accumulation follows:

$$h_{t+1,s+1}^{i} = (1 - \delta_h)h_{t,s}^{i} + \Omega_s^i h_{t,s}^{i} e_{t,s}^{i\,\phi_i},$$

[2]Note that age one in the model refers to age 20 in the real world.

where $i = \{high, low\}$. The parameter ϕ_i determines how many units of time spent in education effectively contribute to human capital accumulation. This is to capture the quality of education (e.g. number of books in the university library, the student/teacher ratio and the number of laboratories in the university). This parameter depends on i because high types are more able to take advantage (in terms of human capital accumulation) of the quality of education compared to low types. Therefore, $\phi^{high} > \phi^{low}$. Further, δ_h is the depreciation rate of human capital and Ω_s^i refers to the productivity in learning which depends on age s. In particular, the productivity in learning declines as the agent becomes older because of the negative impact of aging on learning abilities. Further, as already mentioned, $\Omega_s^{high} > \Omega_s^{low}$ for any s.

Although Ω_s^i refers to the productivity in learning, it also affects the productivity in working. This is given by the fact that a higher productivity in learning implies more human capital accumulated in the next period, which determines the efficiency at work. Therefore, high types are more productive in both learning and working compared to low types.

In this model, individuals acquire human capital through education only. Therefore, the model does not account for learning by doing and on-the-job training. Moreover, since education does not affect utility, agents invest in education only to increase their human capital stock and earn a higher labor income. For this reason, in the retirement period there is no incentive to spend time in education and accumulate human capital, which progressively depreciates as the agent becomes older.

The production sector is given by competitive firms that produce output using efficiency units of labor L_t and physical capital K_t. The production function for the representative firm is Cobb-Douglas:

$$Y_t = Z_t K_t^{\alpha} L_t^{1-\alpha} \ ,$$

where Z_t is the aggregate technology level which follows an AR(1) process: $ln(Z_t) = \rho ln(Z_{t-1}) + \varepsilon_t$ with $\varepsilon_t \sim N(0, \sigma^2)$. In equilibrium, the prices of the production factors are equal to the marginal products:

$$w_t = (1-\alpha) Z_t K_t^{\alpha} L_t^{-\alpha},$$

$$r_t = \alpha Z_t K_t^{\alpha-1} L_t^{1-\alpha},$$

where α is the physical capital share of output.

Finally, the government collects labor income taxes, τ_t, from the workers and provides public pensions, b, to the retired agents using a pay-as-you-go system. Public expenditure must be completely financed by tax revenue in every period, therefore the budget balanced constraint for the government is given by:

$$\tau w_t L_t = b\tfrac{1}{3},$$

where 1/3 is the fraction of the population receiving pension benefits at each date.

2.1 The equilibrium

Given the government policy b and τ_t, the initial physical and human capital stocks distributions, and the productivity sequence Ω_s^i, the equilibrium is a collection of policy rules for each ability type i, $c_s^i(k_{s,t}^i, h_{s,t}^i, K_t, L_t)$, $n_s^i(k_{s,t}^i, h_{s,t}^i, K_t, L_t)$, $e_s^i(k_{s,t}^i, h_{s,t}^i, K_t, L_t)$, $h_{s+1}^i(k_{s,t}^i, h_{s,t}^i, K_t, L_t)$ and $k_{s+1}^i(k_{s,t}^i, h_{s,t}^i, K_t, L_t)$, and the prices of production factors $\{w_t, r_t\}$ such that:

1. The individual policy rules solve the household's maximization problem.

2. Prices $\{w_t, r_t\}$ solve the representative firm's maximization problem.

3. The government balanced-budget constraint is satisfied.

4. The market-clearing condition is satisfied:

$$Z_t K_t^\alpha L_t^{1-\alpha} = C_t + K_{t+1} - (1-\delta)K_t.$$

5. Individual decisions are consistent with aggregate outcomes:

$$L_t = \textstyle\sum_{s=1}^{60} \frac{\left(n_{s,t}^{high} \times h_{s,t}^{high} + n_{s,t}^{low} \times h_{s,t}^{low}\right)}{120},$$

$$K_t = \textstyle\sum_{s=1}^{60} \frac{k_{s,t}^{high} + k_{s,t}^{low}}{120}.$$

2.2 Calibration

The calibration is consistent with the standard practice in the RBC literature. In particular, one model period corresponds to one year in reality. Table A1 in the Appendix reports the calibrated values. The capital share of output, α, is chosen such that the annual interest rate is 12% and the average physical capital to output ratio is 3. The depreciation rate of physical capital is set to 6%. The discount factor is determined by the Euler Equation for physical capital. The disutility of non-leisure activities, γ, is chosen to target the average time spent working to 0.33. The coefficient of relative risk aversion, η, is taken to be 2. The tax rate, τ, is calibrated based on a replacement ratio of 30%. Finally, the parameters for the Solow residual are chosen to be ρ =0.814 and σ =0.0142. These parameters are equivalent to the values estimated by Prescott (1986) for quarterly frequencies[3].

Regarding the human capital accumulation function, three parameters must be calibrated: the depreciation rate of human capital δ_h, the parameter ϕ_i, and the productivity sequence Ω_s^i. In particular, the depreciation rate is set to 0.5% following DeJong and Ingram (2001). The parameter ϕ_i is calibrated using the first order condition with respect to time spent in education and the Euler equation for human capital. This combination gives:

$$\phi_i = \left(\frac{1}{\beta} - 1\right)\frac{e_i^*}{n_i^* \delta_h},$$

where $\frac{e_i^*}{n_i^*}$ is the ratio between the time spent in education and the time spent working averaged across all ages. Both e_i^* and n_i^* are calibrated using data from the "American Time Use survey" (ATU) 2003-2010[4]. Empirically, low types are defined as those individuals who has a high school diploma or a lower schooling level, while high types are those enrolled in or graduated from any post-secondary education program[5]. The calibrated ratio is equal to 0.0139 for low types and 0.04 for high types. This implies $\phi^{high} = 0.16$ and $\phi^{low} = 0.0556$.

The productivity sequence is calibrated using the human capital accumulation function:

$$\Omega_s^i = \frac{h_{s+1}^{i*} - (1-\delta_h)h_s^{i*}}{h_s^{i*} e_s^{i*\phi_i}},$$

where e_s^{i*} is the average time spent studying for each age s and it is computed using annual data from ATU. The efficiency weights h_s^{i*}, instead, are calibrated following the methodology proposed by Hansen (1993) and using annual data from the "Current Population Survey, March Supplement"(1986-2010)[6]. In particular, the averages of e_s^{i*} and h_s^{i*} are first obtained for eight different age groups (20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59) and the two productivity types. These values are then interpolated to obtain one value for each single age and type. It is worth mentioning that Hansen (1993) did not distinguish between high and low types. His methodology produces one sequence of h_s^*

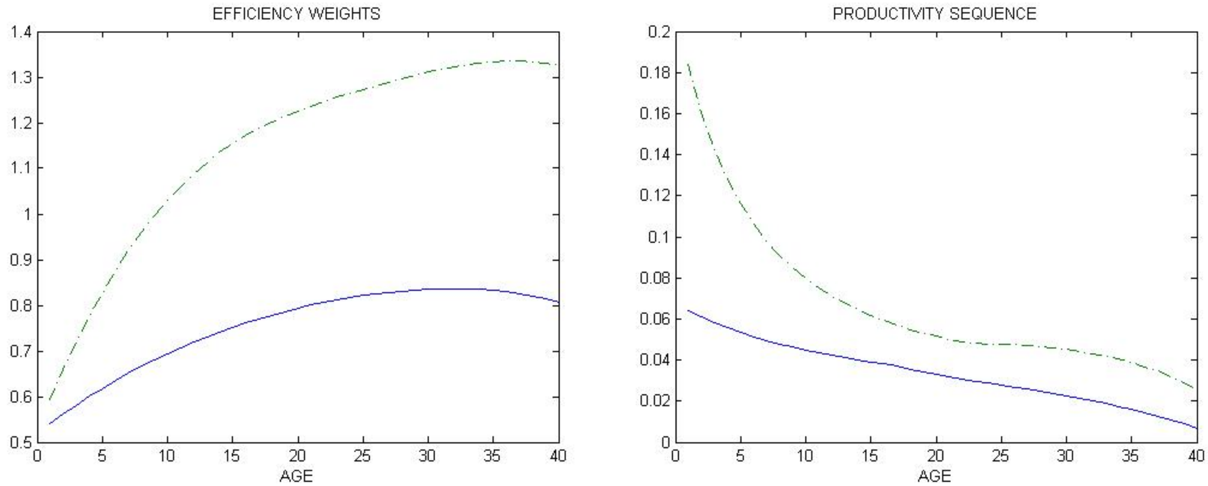
[3] See Heer and Maussner (2009), page 549.

[4] The survey started in 2003 so it is not possible to calibrate the parameters using a larger time period.

[5] This includes individuals with some college but no degree and individuals with an associate degree, college degree, Bachelor's degree, Master's degree, professional school degree or Doctoral degree.

[6] Earlier data cannot be used because one of the main education variables is available starting from 1986 only.

Figure 1: Calibrated efficiency weights and productivity sequences during the working life



The dashed line represents the high type, while the solid line represents the low type.

for the whole economy. However, the procedure has been extended in order to include the two types which are empirically defined as before. Finally, the sequence for h_s^{i*} is also used to calibrate the initial levels of human capital for high and low types (i.e. h_1^{i*}).

Figure 1 shows the calibrated efficiency weights and the productivity sequences during the working life. In particular, the efficiency at work increases when agents are young, has a peak around the middle age and then it starts to decline. Further, at any age high types are more efficient at work than low types. The productivity in learning, instead, determines the human capital stock each agent can accumulate given the human capital stock previously acquired and the amount of time spent in education. Clearly, this depends on age. In particular, the productivity decreases as the agent becomes older because of the negative impact of aging on learning abilities. Further, the productivity is higher for high types than for low types independently of age. The difference is minimized around age 20, which corresponds to age 40 in reality. In fact, while the productivity for low types declines at an approximately constant rate, the productivity of high types declines faster early in life. This is due to the fact that starting from age 1, high types gradually enter the labor market and loose productivity in learning (which decreases if unused). Low types, instead, are already in the labor market. Therefore, there is no sharp decline for them.

Table 1: Steady-state aggregate values

Aggregate values:	L^*	K^*	Y^*	w^*	r^*	b	τ^*
	0.32	0.68	0.38	0.83	0.16	0.095	0.13

Household problem:	$\sum_{s=1}^{40} \frac{n_s^*}{40}$	$\sum_{s=1}^{60} \frac{k_s^*}{60}$	$\sum_{s=1}^{60} \frac{h_s^*}{60}$	$\sum_{s=1}^{39} \frac{e_s^*}{39}$
high type	0.34	0.69	1.15	0.02
low type	0.31	0.66	.72	0.003

2.3 Solution method

The non-stochastic steady state (i.e. $Z = 1$) in the 60-period Overlapping Generations model has been computed using a guess and verify method. The algorithm can be summarized as follows:

1. Guess the steady-state aggregate values for labor in efficiency units L and physical capital K .

2. Compute the factor prices w and r , and the tax rate τ .

3. Solve the household maximization problem for the two types separately by using backward induction.

4. Compute the aggregate values for labor in efficiency units L and physical capital K .

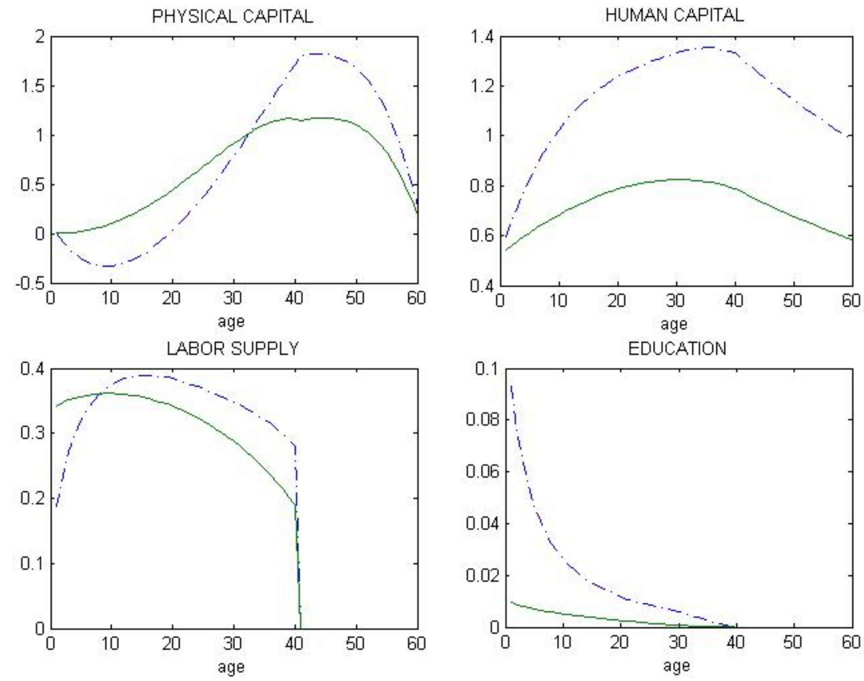
5. Update the initial guesses if they are different from the computed aggregate values in step 4. Repeat from step 2 until convergence.

In order to analyze the effect of business cycles on human capital accumulation, a negative technology shock has been introduced in the model. The transitional dynamics are computed by log-linearizing the first order conditions around the non-stochastic steady state. The impulse response functions are then obtained to describe the dynamics that lead the economy to the steady state after the shock. The results are discussed in the next session.

3 Results

The non-stochastic steady state is described in Table 1. Figure 2, instead, shows the steady-state levels for the main variables by age and productivity type. Since high types are very productive in learning, in the steady state they spend more time in education and accumulate more human capital. At the end of the working life, they have accumulated a level of human capital that is twice the level accumulated by low-productivity agents. Since they study more, high types work less at the beginning of their life

Figure 2: Steady-state values by age and type

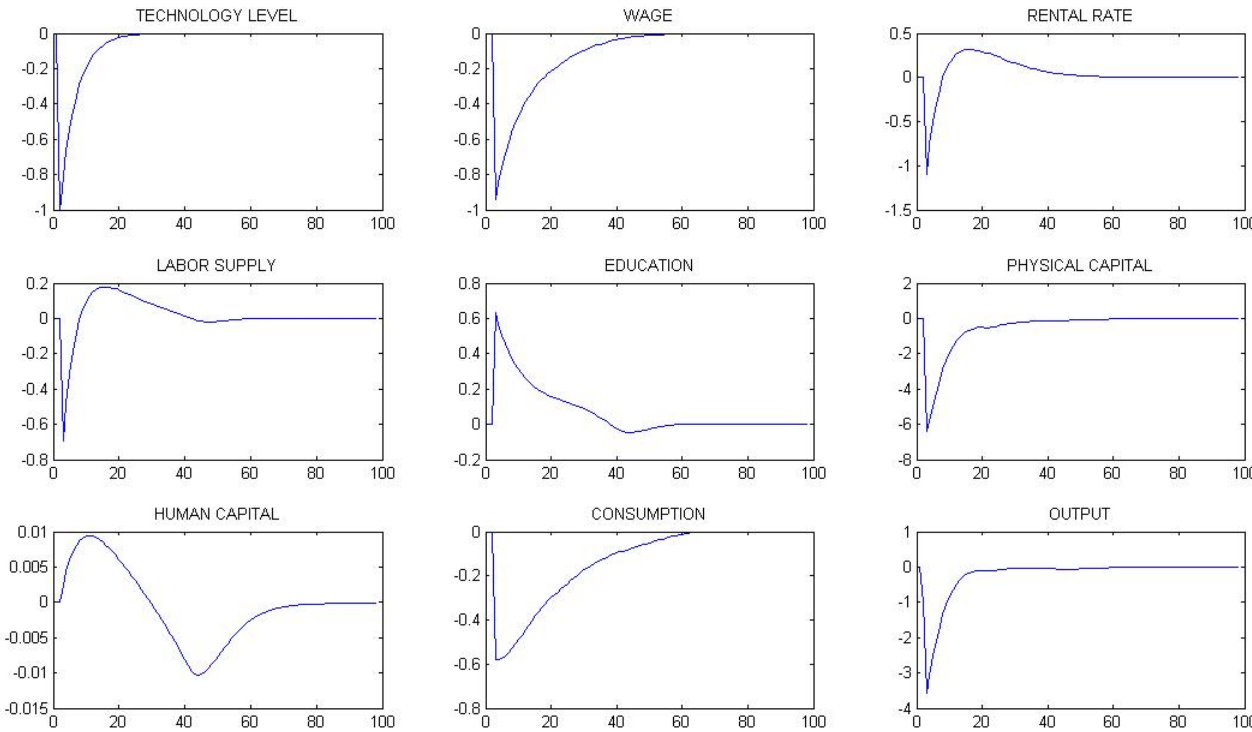


The dashed line represents the high type, while the solid line represents the low type.

and borrow physical capital to "finance" education. Although there are no direct monetary costs for education, in order to study the agent must spend less time working and forgo part of her labor income. Therefore, the young high-type borrows physical capital to smooth consumption over time. Around age 20, the time spent studying is significantly reduced and the agent starts to invest in physical capital. Since labor is more efficient for the high type, labor income and the physical capital accumulated in the lifetime are higher compared to the low type.

In order to analyze how agents' decisions are affected by business cycles, a negative one-standard deviation technology shock has been introduced in the model. Figure 3 shows the impulse responses for the aggregate economy. The graphs represent the percent deviation of each variable from the steady state after the shock. The curves show that physical capital, investment, consumption and hours worked are procyclical. Time spent in education and human capital accumulation, instead, are countercyclical. In particular, when the economy is hit by a negative technology shock, the marginal productivity of labor and physical capital decreases. Thus, both wage and rental rate of physical capital drop. Agents invest less in physical capital and reduce hours worked. Output and consumption decrease. Further, individuals invest more in education to accumulate more human capital and compensate for the reduction in labor income due to the wage contraction. This is manly due to the decrease in opportunity costs of education. During a crisis, in fact, the decrease in the wage rate reduces the opportunity cost

Figure 3: Impulse responses for the aggregate economy



The x-axis represents the number of periods after the shock. The y-axis indicates the percent deviation from the steady state for each variable.

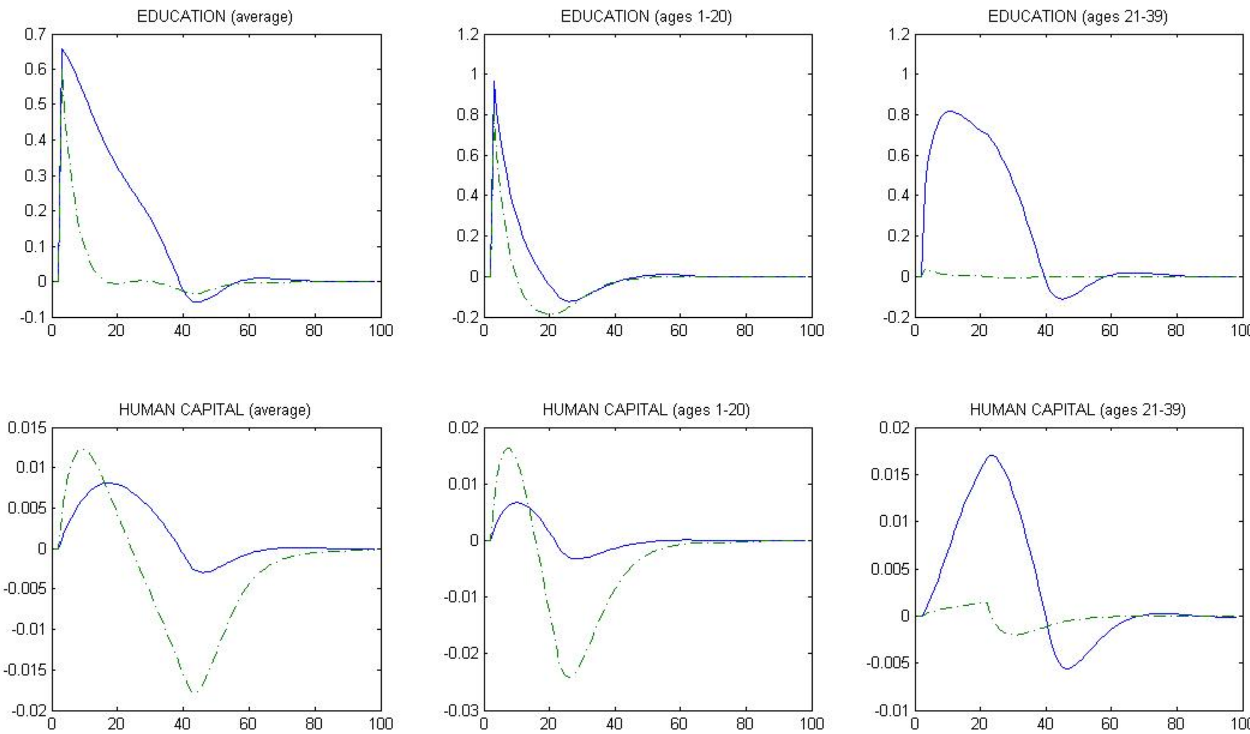
of education, which becomes more attractive compared to labor. Individuals substitute time spent working for time spent studying[7]. As a consequence, human capital accumulation increases in contrast with the decrease in physical capital accumulation. Agents substitute physical capital for human capital because the shock reduces the rate of return to physical capital investments compared to the rate of return to human capital investments. This implies that the education sector acts as a buffer sector. In particular, it allows agents to compensate for the reduction in labor income by increasing the human capital stock. However, as human capital increases, its marginal product decreases. Therefore, after approximately six periods agents start to substitute back human capital for physical capital and the economy starts to converge to the original steady state.

3.1 Differences by ability type and age

Figure 4 shows the impulse responses for education and human capital by productivity type and age group. The first column shows the behavior of the average high and low type. In general, the deviation from the steady state of time spent in education is higher for low types rather than high types. This

[7]A similar argument applies for leisure.

Figure 4: Impulse responses by ability type and age group



The x-axis represents the number of periods after the shock. The y-axis indicates the percent deviation from the steady state for each variable. The dashed line represents the high type, while the solid line represents the low type.

is due to the fact that high-productivity agents have already accumulated a higher amount of human capital before the crisis, compared to low types. Therefore, it is more expensive for them to reduce hours worked and study more to accumulate human capital. In other words, their efficiency at work is already high and the reduction in the opportunity cost of education is not enough to incentivize the reduction in hours worked. Regarding human capital, the average deviation of low types is higher than the average deviation of high types. Since high types have a higher human capital stock in the steady state, the marginal product is lower and they benefit less by substituting physical for human capital.

The second and third columns show the impulse responses by type for two age groups: young and old. The young group corresponds to age 1-20, while the old group refers to age 21-39. In particular, young types increase more time spent in education and human capital compared to older types. This is especially true for high-productivity individuals. Old high-types, in fact, have accumulated more human capital during their working life. They are more productive at work, thus less willing to reduce hours worked and accumulate more human capital. Among low types, instead, the difference between young and old is less noticeable. The human capital accumulated by young and old low-types is almost the same. Thus, the benefits they receive from substituting physical capital for human capital are almost the same. For this reason, the deviation of old high-types is very close to zero in contrast to that for old low-types, which is still positive.

These results become more intuitive if related to the real world. During a crisis, labor market conditions are worse: it is harder to find a job or receive a high labor income. However, certain categories of individuals are more affected than others. Young and low-productivity individuals face even harder labor market conditions. Young people do not have experience in the labor market yet. Low types are less efficient at work than high types because of the lower human capital stock. Therefore, when the crisis hits the economy, these categories benefit more from the education sector and the substitution between physical and human capital.

3.2 Implications for labor supply volatility

Table 2 shows the business cycle statistics computed from 500 simulations of the model along with statistics from US data. The data about labor supply are from CPS, March Supplement (1986-2010). Hours worked are obtained using the answer to the question "How many hours did you actually work last week?". Data for output, consumption and investment are from US Bureau of Economic Analysis. Output, in particular, is measured by real GDP from 1986 to 2010. Both the actual and the simulated series are transformed by taking natural logarithms and detrended using the Hodrick-Prescott filter. The smoothing parameter is equal to 100.

In the model all variables tend to be less volatile and more correlated with output compared to the data. Further, education is negatively correlated with output which empirically supports the countercyclicality of human capital accumulation (through PSE). However, the countercyclicality is stronger in the model compared to the data. Regarding aggregate labor supply, the model can explain about 63% of the volatility empirically estimated (which is consistent with previous results in the literature). Labor supply volatility of high types, instead, is predicted quite well by the model. The empirical estimates of hours worked volatility relative to output volatility is 0.67, while the model prediction is 0.65. The prediction for low types, instead, is significantly lower than the empirical estimate. Therefore, the model can better explain the behavior of high types than that of low types. This becomes more clear by looking at Figure 5 which shows the labor supply volatility by age for the whole economy, high types and low types, respectively[8].

[8]Empirically, high and low types are consistently defined as before: low types have at most a high school diploma and high types have at least completed one year of post-secondary education.

Table 2: Real business cycle statistics

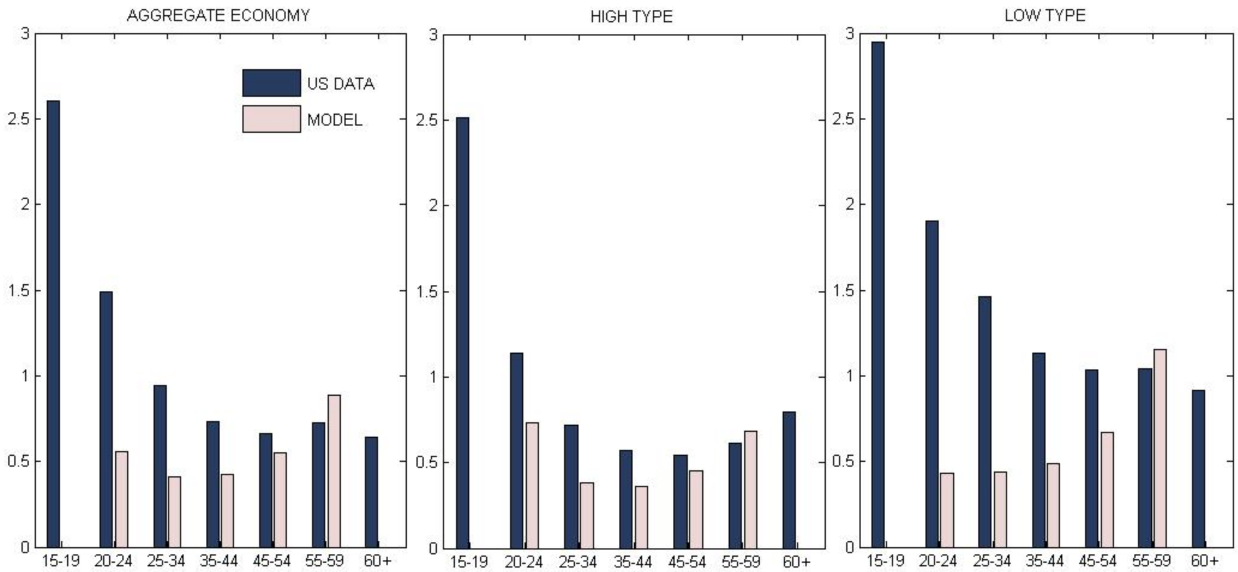
X	σ_X		$\frac{\sigma_X}{\sigma_Y}$		$corr(X,Y)$	
	Data	Model	Data	Model	Data	Model
Output	1.77	2.11	1	1	1	1
Consumption	1.77	0.43	0.99	0.20	0.95	0.94
Physical capital investment	8.63	3.90	4.86	1.85	0.89	0.99
Education	2.38	1.50	1.34	0.71	-0.44	-0.77
Labor supply	1.39	1.06	0.79	0.50	0.85	0.95
Labor supply low type	2.10	1.64	1.18	0.77	0.86	0.96
Labor supply high type	1.19	1.38	0.67	0.65	0.77	0.94
Labor supply (15-19)	4.62	-	2.6	-	0.78	-
Labor supply (20-24)	2.64	1.17	1.49	0.56	0.81	0.95
Labor supply (25-34)	1.67	0.86	0.94	0.41	0.83	0.93
Labor supply (35-44)	1.29	0.89	0.73	0.42	0.84	0.95
Labor supply (45-54)	1.17	1.16	0.66	0.55	0.86	0.95
Labor supply (55-59)	1.28	1.87	0.72	0.89	0.79	0.96
Labor supply (60+)	1.14	-	0.64	-	0.65	-

The model does not provide estimates regarding the labor supply of the first and last age group because the working period starts at age 20 and ends at age 60.

Both the model and the data show a U-shaped volatility profile: labor supply is more volatile for young and old agents compared to middle-age agents. However, the magnitude of aggregate labor supply volatility cannot be successfully predicted by the model (first graph). It is underestimated for young agents and overestimated for old agents. By looking at the distinction between high and low type, however, it is clear that this is mainly due to low types. While the high type's behavior can be tracked quite well by the model, the volatility of low types is not successfully predicted. This may depend on unemployment, which is absent from the model. Since unemployment affects especially young low-types, the predicted volatility for this group is lower than the empirical estimate. Further, the presence of mandatory education increases the volatility of agents who are closer to retirement (see Gomme *et al.*, 2004). This may explain the overestimation of labor supply fluctuations for old agents.

To conclude, the results suggest that the volatility puzzle is mainly due to differences among agents. In particular, heterogeneity by productivity type seems to be more relevant than heterogeneity by age. Obviously, differences in the productivity level may also reflect other factors including the industry in which the individual works. If high types are more concentrated in certain industries, while low types spread more across sectors, it is more difficult to predict the volatility of low-productivity agents. This suggests that more research should be done in this direction in order to identify how heterogeneity

Figure 5: Labor supply volatility for the aggregate economy



The x-axis refers to the age group. The y-axis refers to the labor supply volatility. The model does not provide estimates regarding the labor supply of the first and last age group because the working period starts at age 20 and ends at age 60.

affects the predictions of RBC models.

4 Empirical Analysis

The theoretical results have been empirically tested using American data from the Current Population Survey, March Supplement (1986-2010). Earlier data cannot be used because one of the main education variables is available starting from 1986 only. The sample includes 307,700 observations. A person is considered to be enrolled if she is attending a full-time or part-time program in a post-secondary institution.

As largely documented in the literature, enrollment rates in post-secondary education are affected by several factors: demographics, geography, family resources, parental education, tuition, university premium, real interest rate and national unemployment rate. The last variable, in particular, is a proxy for business cycle fluctuations. If there is a positive relationship between enrollment rates and unemployment, then enrollments in PSE are countercyclical. In particular, given the set of characteristics listed above, the probability of being enrolled is estimated using a probit regression:

$$Pr(enrolled_{it} = 1) = \Psi(constant + \alpha X + \beta U),$$

where $enrolled_{it}$ is a dummy variable equal one if individual i is enrolled at time t and zero otherwise, Ψ is the standard normal distribution function, X is the vector of specific characteristics and U is unemployment. Table 3 reports the marginal effects. The main variable of interest is unemployment, which has a positive marginal effect. In particular, a one-percent increase in the unemployment rate increases the probability of being enrolled in PSE by 0.69%. This implies that enrollment rates are countercyclical, which is consistent with the theoretical results. Further, the estimated marginal effect is very close to the estimates computed by Dellas and Sakellaris (2003) and Dellas and Koubi (2003): 0.67% and 0.79%, respectively.

Moreover, the impact of age on enrollment is positive but decreasing. Females have a higher probability to be enrolled than males, *ceteris paribus*. A single person is more likely to enroll in PSE compared to a non-single person. Family income and house ownership positively affect the probability of being enrolled; while family size decreases the likelihood of enrollment. If the head of the household is employed, the probability of college enrollment is higher. Also parental education affects schooling decisions. In particular, if parents did not go to college, their child is less likely to go to college. Further, schooling decisions are more affected by father's education rather than mother's education. Regarding university premium, the marginal effect is positive and significant. A one-percent increase in the university premium increases the probability of being enrolled by 4.8%. This variable is computed by taking the log difference between earnings of high-school graduates and college graduates. Finally, the nominal interest rate has the expected sign but it is not significant.

Some may be surprised by the positive effect of tuition on enrollment decisions. However, this variable has a double effect on enrollments. On one hand, higher tuition fees discourage enrollment because the cost of education is higher. On the other hand, tuition is positively related to the quality of education. Therefore, students may be willing to enroll in costly universities because they have a higher reputation. This is in accordance with the fact that over time enrollment rates in PSE have increased despite the increase in tuition.

The sample has also been divided into two groups defined by productivity type. In particular, the only proxy available in CPS for productivity in learning is parental education. Therefore, the two types are defined as follows. High types are those individuals whose parents studied at least one year at a post-secondary institution. Low types are those individuals whose parents have at most a high-school diploma. The results are presented in columns 2 and 3. In particular, a one-unit increase in unemployment increases the probability of being enrolled by 0.95% for low types. There is no significant

Table 3: Estimated probit coefficients and marginal effects

Dependent variable: college enrollment (=1 if enrolled in PSE, =0 otherwise)						
	WHOLE SAMPLE		HIGH TYPES		LOW TYPES	
Variable	dydx	Std.err.	dydx	Std.err.	dydx	Std.err.
Unemployment	.0069***	(.002)	.0017	(.003)	.0095***	(.002)
Age	2.21***	(.016)	2.13***	(.039)	1.83***	(.024)
Age^2	-.053***	(.0004)	-.051***	(.0009)	-.044***	(.0006)
Female	.098***	(.003)	.062***	(.004)	.103***	(.003)
Married	-.284***	(.016)	-.264***	(.034)	-.276***	(.019)
Separated	-.234***	(.022)	-.182***	(.041)	-.244***	(.027)
Divorced	-.187***	(.027)	-.182***	(.051)	-.175***	(.032)
Widowed	-.049	(.157)	-.316	(.288)	.004	(.146)
ln(family income)	.017***	(.001)	.021***	(.002)	.014***	(.001)
ln(family size)	-.048***	(.005)	-.027***	(.008)	-.059***	(.006)
House ownership	.095***	(.005)	.080***	(.009)	.097***	(.005)
Head of HH empstat	.025***	(.004)	.015**	(.006)	.026***	(.005)
Metropolitan area	.041***	(.004)	.019***	(.006)	.045***	(.004)
University premium	.048**	(.021)	-.015	(.029)	.087***	(.025)
Nominal interest rate	-.001	(.001)	-.002	(.002)	-.0003	(.002)
Inflation	.011***	(.002)	.004*	(.003)	.014***	(.002)
Tuition	2.1e-5***	(1e-05)	2.0e-5***	(1e-05)	2.1e-5***	(1e-05)
Mother's education:						
< high school diploma	-.166***	(.005)	-	-	-.153***	(.006)
= high school diploma	-.102***	(.004)	-	-	-.090***	(.005)
Father's education:						
< high school diploma	-.185***	(.005)	-	-	-.169***	(.005)
= high school diploma	-.121***	(.004)	-	-	-.110***	(.005)
Observations	307,700		106,090		201,592	
Pseudo R^2	.41		.45		.36	

The standard errors are reported in brackets. The stars indicate the significance level:
* indicates 10-percent significance level
** indicates 5-percent significance level
*** indicates 1-percent significance level.
The regression also includes ethnicity dummies, regional dummies and a linear time trend. The results do not change if a quadratic trend is used instead.
There are no estimates for parental education in the "high types" group because the corresponding dummy variables are equal zero for this group.

effect, instead, among high types. This is consistent with the predictions of the theoretical model: the countercyclicality is stronger for low-productivity individuals.

5 Conclusions

This paper shows that during an economic crisis the education sector helps the economy to react to the income reduction. The decrease in wages reduces the opportunity costs of education. Therefore, agents invest more in human capital because it is cheaper (therefore more efficient) to do so. This implies that enrollment in PSE is countercyclical. However, the countercyclicality is stronger for young and low-productivity agents. In fact, since both are less productive at work, they are more likely to substitute work for schooling. These results are empirically confirmed using US data. In particular, a one-percent increase in the unemployment rate increases the probability of being enrolled by 0.69%. This marginal effect increases to 0.95% for low-productivity types, while it is not statistically different from zero for high types.

Moreover, the results presented in Section 3 add new insights regarding the labor supply volatility in RBC models. The inability of these models to match the empirical evidence seems to be determined by heterogeneity among agents. In particular, differences in the productivity level are very important. However, more research should be done in this direction in order to further investigate how heterogeneity among agents affects the volatility puzzle.

Appendix

Table A1: Calibration

	parameter	calibrated value
Household maximization problem:	β	0.9434
	γ	1.9
	η	2
	δ	0.06
Production function:	α	0.36
Human capital accumulation function:	ϕ^{high}	0.16
	ϕ^{low}	0.0556
	δ_h	0.005
	$h_{1,t}^{high}$	0.5943
	$h_{1,t}^{low}$	0.5416
Technology shock:	ρ	0.814
	σ	0.0142

Table A2: Data Sources

Variable	Source
Unemployment rate:	US Bureau of Labor Statistics
Nominal interest rate:	Federal Reserve
Inflation rate:	Federal Reserve
Tuition:	US Bureau of Labor Statistics
Other controls:	Current Population Survey

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