Macroeconomic volatility and human capital formation

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Abstract

This paper discusses the effects of macroeconomic volatility on human capital formation. Simple cross-country scatterplots as well as existing empirical studies, which typically measure volatility by the standard deviation of GDP growth, show a negative relationship. Using panel data for a large group of countries in 1970-2000, we find that: (i) the negative effect of macroeconomic volatility on human capital formation in existing empirical studies is not robust; (ii) controlling for government education spending, the volatility effect on human capital can even become positive; (iii) using a time-varying volatility measure and controlling for possible endogeneity of volatility and other explanatory variables in IV-estimation, the effect we find is always positive. Theoretically, we build a simple model which can explain a positive volatility effect on human capital formation while at the same time being consistent with the basic negative cross-country correlation. A key idea is that volatility may encourage people to study for reasons of insurance. Government education expenditures may be crucial to realise this ambition

Key words : macroeconomic volatility, human capital, education.
JEL : I20, O15, H52

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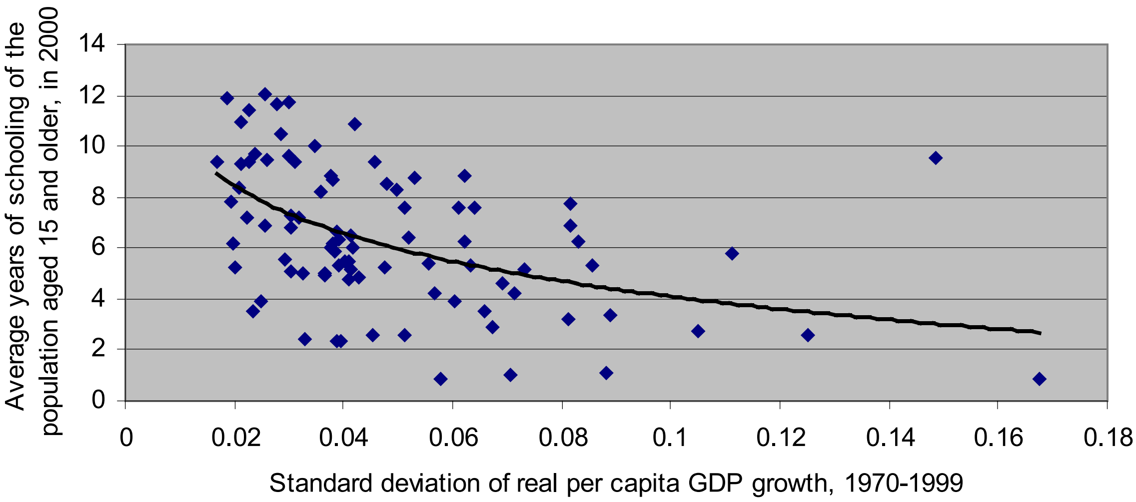
1. Introduction

Since the emergence of the real business cycle literature and the endogenous growth theory many researchers have investigated effects of cyclical fluctuations (macroeconomic volatility) on long-run growth. Theoretically, the results are ambiguous. As shown by Aghion and Saint-Paul (1998), when the activity that generates productivity growth is a substitute to production, recessions will stimulate this activity and a larger amplitude and frequency of business-cycle fluctuations may have a positive effect on long-run growth. When productivity enhancing activities are a complement to production, the opposite holds (e.g. Martin and Rogers, 1997). A negative effect of volatility on growth may also follow from higher risk and uncertainty that come with it. Empirically, Aghion and Saint-Paul (1998) find a positive relationship between volatility and growth. More studies, however, find a negative relationship (e.g. Ramey and Ramey, 1995; Martin and Rogers, 2000). More recently, Fatás (2002) and Hnatkovska and Loayza (2003) challenge the hypothesis of a simple relationship by showing that the influence of macroeconomic volatility on growth depends on structural country characteristics. In poor countries they observe a negative relationship, in richer countries with well-developed credit markets a positive one.

This paper focuses on the effects of macroeconomic volatility on human capital formation. Although the importance of human capital for growth has been widely recognized in theoretical and empirical research (e.g., Romer, 1986; Lucas, 1988; Temple, 2001; Sianesi and Van Reenen, 2003), the literature dealing with the human capital effects of macroeconomic volatility is very limited. Several potential theoretical channels have been highlighted, but the number of empirical studies is remarkably small. Existing empirical studies basically find that macroeconomic volatility, measured by the standard deviation of GDP growth, negatively affects human capital formation (Flug et al., 1998; Checchi and García-Peñalosa, 2004). A simple scatterplot for 88 countries in Figure 1, relating a measure for the human capital stock in 2000 to macroeconomic volatility in 1970-1999, is consistent with these findings. However, using alternative indicators for volatility, some studies obtain positive effects on human capital. Skidmore and Toya (2002) observe positive effects from higher frequencies of climatic disasters. Heylen, Pozzi and Vandewege (2004) find positive human capital effects from inflation crises and inflation variability.

Figure 1. Volatility and human capital, 88 countries



Data source: PWT Mark 6.1.; Barro and Lee (2000). pairwise correlation: -0,4292

This paper reconsiders and extends the analysis of the volatility – human capital relationship. Its contribution is double. First, we examine the robustness of existing empirical studies using the long-term standard deviation of GDP growth as a volatility measure. We find that robustness is very poor. Controlling for government expenditures on education we basically observe insignificant, and sometimes even positive effects of macroeconomic volatility on human capital. Moreover, when we allow our volatility measure to vary over time, the effect of volatility on the average level of schooling is always positive, also when we control for possible endogeneity of explanatory variables by means of an instrumental variables approach. Second, elaborating on Checchi and Garcia-Peñalosa (2004), we build a simple theoretical model which can explain these positive effects of volatility on human capital while at the same time being consistent with the basic negative correlation shown in Figure 1. More advanced technologies may enable skilled workers and economies with a high proportion of skilled workers to better cope with aggregate shocks (e.g. weather shocks in agriculture, energy price shocks). Labour effectiveness and the wage of skilled workers may by consequence not only be higher, but also less volatile. The economy may then move from a volatile, low human capital regime to a less volatile, high human capital regime. Government spending on education reducing the cost of studying can promote this transition. By contrast, a high relative volatility of the labour effectiveness of the skilled may discourage education, unless government spending on education is very high.

In Section 2 of the paper we briefly review the main theoretical channels and existing empirical findings with respect to the effect of macroeconomic volatility on human capital formation. Section 3 contains the results of our own empirical investigation for a large panel of developed and developing countries in 1970-2000. In Section 4 we present and discuss our theoretical model. Section 5 summarizes our main findings.

2. Macroeconomic volatility and human capital investment : existing literature

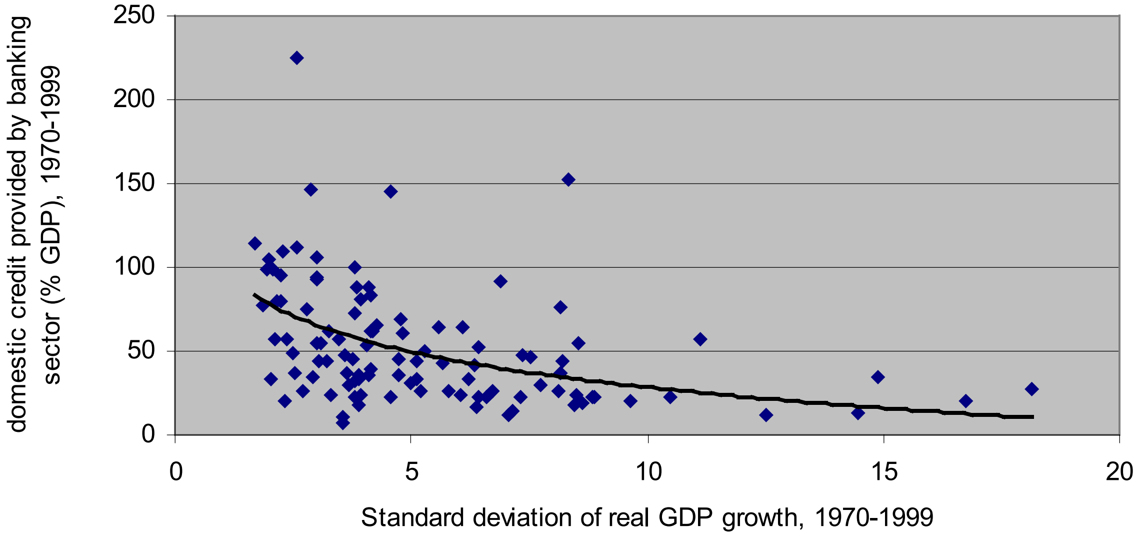
2.1. Theory

Flug et al. (1998) distinguish several potential channels along which macroeconomic volatility can affect human capital investment. Some are negative, others positive. A first hypothesis relates to the effects of risk and uncertainty that come with increasing macroeconomic volatility. In principle, the effects of risk on education are ambiguous. Levhari and Weiss (1974), however, show that there are two sufficient conditions for greater risk to undermine investment in education: the variance of income rises with the level of schooling, and agents have declining absolute risk aversion. Checchi and García-Peñalosa (2004) make both assumptions. Furthermore, Levhari and Weiss (1974) show that under these assumptions higher non-labour income (wealth) will stimulate investment in education. Wealth plays the role of insurance against the risk of studying. All other things equal, poor people will therefore study less. To the extent that government education expenditures provide agents with non-labour income, they encourage schooling.

According to the first hypothesis the negative effect of volatility on human capital formation holds whether or not credit markets exist where resources can be borrowed to finance education. This is not so for the second hypothesis. A very specific property of human capital is that investment is irreversible in the sense that human capital cannot be sold. These properties imply that investment errors are very costly. And this is where volatility comes in. In a structurally volatile environment the likelihood of making wrong decisions rises. Agents may be discouraged to invest in education. The fact that human capital cannot be sold also makes it useless as a collateral. As an immediate result, this inhibits the development of credit systems for education. Again volatility may play an adverse role. Given that volatility raises the likelihood of investment errors, one can expect the development of credit systems for education to be even more difficult in volatile environments. As with the first hypothesis, the poor are more likely to bear the negative consequence of this than the rich. Also, government support can alleviate these negative consequences. Figure 2 is consistent with the idea that volatility negatively affects the development of credit markets. This figure relates domestic credit provided by the banking sector in percent of GDP to volatility in 150 countries during the 1970s to 1990s. For each country there is one observation. Volatility is measured by the standard deviation of real per capita GDP growth. Correlation in this figure is -0,3760.

A third hypothesis predicts positive effects from volatility on human capital. A key element in the first hypothesis was that the level of risk associated with being educated is higher than with remaining unskilled. The third hypothesis basically rejects this, emphasizing that educated people face less risk and uncertainty . For example, they can apply for a broader range of (more stable) jobs. In bad times they are more likely to be hired, especially when unskilled wages are rigid downward. Also, educated people can handle more advanced technologies which may enable agents to better face aggregate risk (e.g. climate, oil shocks,...) A more volatile environment can therefore stimulate human capital investment for insurance reasons. Elaborating on this idea, one can expect the positive incentive effect of volatility to be higher when social safety nets are less developed (bad luck is more costly). Of course, to be able to study for insurance reasons initial wealth should be high enough, credit should be available, or government support provided. Again, poor people should be expected to study less, whereas government expenditures can stimulate schooling. The model we develop in section 4 puts these arguments at the centre.

Figure 2. Volatility and credit availability, 150 countries.



Data source: PWT Mark 6.1.; World Bank Development Indicators 2003

2.2. Empirical work

The available empirical evidence tends to confirm hypotheses that predict a negative effect of volatility on human capital (Flug et al., 1998; Checchi and García-Peñalosa, 2004). Flug et al. (1998) study the empirical link between volatility and the accumulation of human capital, i.e. school enrolment. Checchi and García-Peñalosa (2004) focus on the stock of human capital, i.e. average educational attainment. Both studies investigate the effects of long-term volatility. Their volatility measures are basically standard deviations of GDP growth or employment growth over long periods (respectively 1970-1992 and 1960-1990). Short-term measures would rather be a reflection of shocks. Both studies also control for income inequality, financial depth and initial GDP and/or educational attainment. The relevance of these variables follows from existing literature as well as from our brief theoretical explanation in the previous section. Income inequality is positively correlated to the incidence of poverty. Financial depth variables represent the extent of access to credit. Initial income and/or educational attainment may capture the general standard of living (and its implications for longevity), the availability of aggregate resources to develop education systems, human capital formation by the previous generation and teacher quality, etc.

Running cross-section regressions for about 60 countries in 1970-92, Flug et al. find that where employment volatility is stronger, school enrolment is lower. Using income volatility, they find only insignificant negative effects. In a fixed effects panel data set-up, however, significant negative effects show up. After splitting the cross-section into high and low-income countries, Flug et al. find that employment volatility has a significant negative effect on school enrolment in the low-income countries, while it has a positive and non-significant effect in the high-income countries. Income volatility has a non-significant effect in both low and high-income countries. Checchi and García-Peñalosa (2004) find that a greater volatility in GDP growth gives rise to a lower average educational attainment. Their largest sample covers 111 countries in 5-year intervals over 1960-95. Most of their regressions include 70 to 80 countries. Due to the absence of a temporal dimension in their volatility measure they cannot use a fixed effects estimator, but opt for a population-weighted least squares estimator and include regional dummies.

In our own empirical work in the next section we will start from – and then extend – the work by Checchi and García-Peñalosa, using a time-invariant volatility measure. One of our conclusions will be that their results are not robust. Depending on the empirical approach and regression specifications, we find both negative and positive effects from volatility on human capital. Next we consider a time-varying volatility measure and find positive effects of volatility in the vast majority of the estimations. Controlling for possible endogeneities using an instrumental variable approach does not affect the latter result. In this respect our results may sympathize with findings by Skidmore and Toya (2002) and Heylen et al. (2004) described in the introduction to this paper.

3. Macroeconomic volatility and human capital investment : empirical analysis

Equation (1) is at the basis of our empirical work. In this equation $H_{i,t}$ stands for the human capital stock in country *i* and year *t*. The human capital stock is defined as average years of total schooling for the population of age 15 and older. It is available at 5-year intervals.

$$H_{i,t}=a_0+a_1 Vol_i+a_x X_i+a_z Z_{i,t}+r_i+\lambda_t+\epsilon_{it} \quad (1)$$

Explanatory variables are a measure of macroeconomic volatility (Vol_i) as well as a number of other determinants of investment in human capital (X_i, Z_i) relating to country *i*. In our first regressions (Tables 1-3), volatility and some other explanatory variables (*X*) will have no time dimension, some other explanatory variables (*Z*) have. Furthermore, r_i is an unobserved fixed regional effect, relevant for the region to which country *i* belongs, Finally, λ_t is a time dummy common to all countries and ϵ_{it} is the error term.

Tables 1 and 2 estimate different specifications of equation (1). The dependent variable is average years of schooling. Time invariant explanatory variables *X* are :
Vol : volatility, standard deviation of real GDP growth over the whole period
Credit : credit availability
Time variant explanatory variables *Z* are :
InIneq : income inequality
EdIneq : educational inequality
Goved : real per capita government expenditures on education
Kap : physical capital/output ratio
Gdp-in : initial real per capita GDP (log)
For details about the precise definition and sources of some of these variables (e.g. *credit*) and the precise time periods considered, we refer to the notes below the tables.

Columns (1) and (2) in Table 1 have been taken directly from Checchi and García-Peñalosa (2004, their Table 2). Both show significantly negative effects of volatility on the human capital stock. Furthermore, we observe significantly positive effects from initial GDP and the physical capital / output ratio. Checchi and García-Peñalosa include the latter variable as a proxy for the demand for skilled workers. It is expected to be positively related to the returns to education. Inequality negatively affects the human capital stock. Credit availability shows up insignificant (and with an unexpected negative sign). Note that when initial GDP is not included, the credit variable obtains a significant positive coefficient. Columns (3) and (4) are a first test to the robustness of Checchi and García-Peñalosa's results. The only change we have made concerns the use of more recent real GDP data. Instead of PWT.5.6. data, regressions (3) and (4) make use of PWT.6.1. data. An important first effect of this change is a drastic reduction in data availability, mainly due the fact that for many countries[3] GDP data series have become shorter. For these countries it is no longer possible to calculate volatility over 1960-90. A second effect concerns data revisions for many countries. As can be seen, volatility is a major victim of this change in the data set. It no longer has a significant negative effect on human capital. For the other explanatory variables, changes are much smaller. Further tests make clear that the second effect (data revisions) fully explains this loss of statistical significance for volatility. For example, re-estimating regression (3) with the same 98 countries but with PWT.5.6. data yield a significant coefficient equal to –0.27 for volatility (absolute t-value 2.76).

Table 1. Determinants of average educational attainment, 1960-95

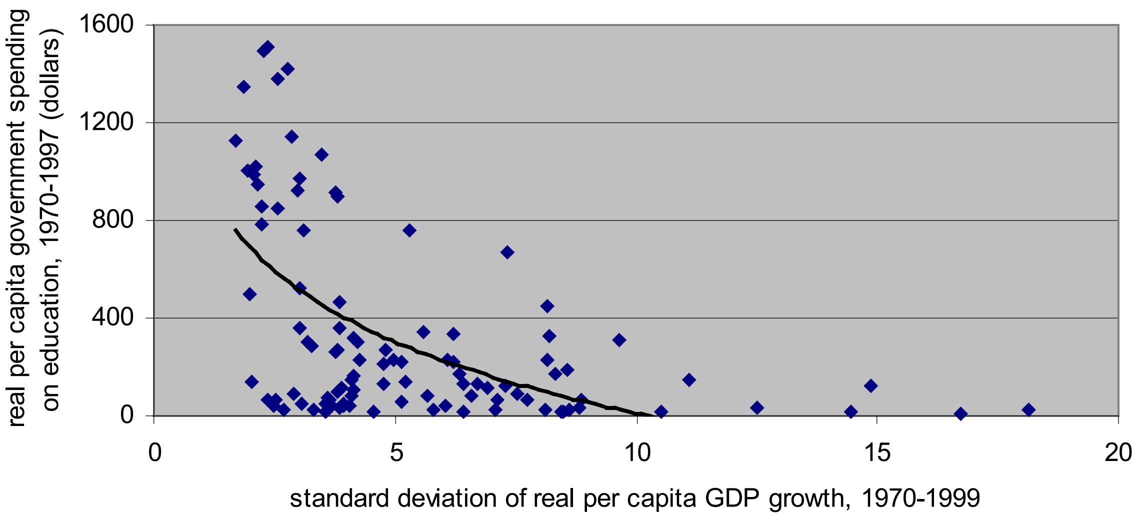
	Checchi and Garcia-P.		Checchi and Garcia-P.-PWT.6.1.	
	(1)	(2)	(3)	(4)
N.countries	111	73	98	72
N.obs.	775	547	710	542
Vol	-0.362	-0.256	-0.023	-0.180
	(2.95)	(2.74)	(0.15)	(1.40)
Inineq		-9.054		-9.596
		(3.13)		(3.16)
Credit		-1.822		-1.345
		(1.65)		(1.14)
Kap		0.458		0.422
		(2.13)		(1.98)
Gdp-in		2.595		2.477
		(5.52)		(4.78)
constant	yes	yes	yes	yes
years	yes	yes	yes	yes
regions	yes	yes	yes	yes
R^2	0.668	0.864	0.652	0.857

Notes:
Absolute t-values between brackets.
Estimation method : population-weighted least squares with robust and country-clustered standard errors.
Dependent variable : average educational attainment (years of schooling) measured at t=1965, 1970, 1975, 1980, 1985, 1990, 1995 (source : Barro and Lee, 1996)
Explanatory variables in columns (1) and (2) : *Vol* : standard deviation of real per capita GDP growth over 1960-90 (source : PWT Mark.5.6.), *Credit* : liquid liabilities in % of GDP, averaged over 1960-89 (source: King and Levine, 1993), *Inineq* : income inequality at time *t* (Gini, source: Deininger and Squire, 1996), *Kap* : physical capital/output ratio, averaged over the five years before *t* (source : Nehru and Dhareshwar, 1993), *Gdp-in* : log of real per capita GDP, averaged over the five years before *t* (source PWT Mark.5.6.).
Explanatory variables in columns (3) and (4) are the same except for volatility and initial GDP, where we now use the more recent PWT Mark.6.1.).

[3] These countries are the Bahamas, Bahrain, Bulgaria, Czech Republic, Iraq, Kuwait, Liberia, Malta, Myanmar, Oman, United Arab Emirates, Vanuatu, Yemen and the Republic of Yugoslavia.

Table 2 extends the results in Table 1 by including government education spending and alternative inequality and credit variables. In addition to income inequality, we now also consider educational inequality (see details below the table). Again we use 5-year intervals for the human capital stock. The time period studied is basically 1970-2000. GDP and volatility data have been taken from the more recent PWT.6.1. Figure 3 justifies the use of including government expenditures. As can be seen, this figure shows a strong negative correlation between volatility and real per capita government expenditures on education. Most likely, both variables are driven by common causes. Volatile countries typically share characteristics which reduce governments' ability and/or willingness to spend on education. Among these characteristics are poverty, dominance of agriculture and/or natural resource-based production, corruption, etc. (see also Gylfason, 2001). Given the potential significance of government education expenditures for human capital (Capolupo, 2000; Castelló and Doménech, 2002; Heylen et al., 2004), disregarding this variable may imply a specification error. Due to their negative correlation volatility may pick up the effect of government education spending. Its coefficient may then be biased downward.

Figure 3. Volatility and government spending on education, 103 countries



Data source: PWT Mark 6.1.; World Bank Development Indicators 2003. Pairwise correlation: -0,4473

The introduction of alternative credit and inequality variables in Table 2 has no major influence on our results. The effect of volatility is still insignificant and negative (see e.g. column 2). Including government education spending, however, does have strong influence. In line with our expectation, as soon as we control for government education spending in columns (3) and (5), the effect of volatility becomes basically zero, or even positive. An obvious explanation for this finding is the high positive correlation between per capita GDP in 1960 and education spending (+0.78). If we also include initial educational attainment (column 6), the coefficient on government education spending becomes smaller and less significant, in column (6) the volatility effect is again very close to zero.

Table 2. Determinants of average educational attainment – additional explanatory variables

	(1)	(2)	(3)	(4)	(5)	(6)
N.countries	86	86	86	90	90	90
N.obs.	265	265	265	472	472	472
Vol	-0.160	-0.200	0.185	-0.246	-0.028	0.009
	(0.70)	(0.85)	(1.63)	(1.13)	(0.33)	(0.11)
In-ineq		-7.476	-4.680			
		(2.36)	(2.23)			
Ed-ineq					-9.563	-8.904
					(5.48)	(4.83)
Credit		0.965	-0.478		-0.218	-0.004
		(1.48)	(1.73)		(0.96)	(0.01)
Goved			1.878		0.725	0.434
			(5.21)		(3.24)	(1.97)
Gdp-1960						0.730
						(1.20)
constant	yes	yes	yes	yes	yes	yes
years	yes	yes	yes	yes	yes	yes
regions	yes	yes	yes	yes	yes	yes
R^2	0.719	0.749	0.855	0.678	0.896	0.901

Notes:
Absolute t-values between brackets. Estimation method : population-weighted least squares with robust and country-clustered standard errors.
Dependent variable : average educational attainment (years of schooling) measured at t=1975, 1980, 1985, 1990, 1995, 2000 (source : Barro and Lee, 2000)
Explanatory variables: *Vol* : standard deviation of real per capita GDP growth over 1960-99 (source : PWT Mark.6.1.), *Credit* : Domestic credit provided by the banking sector, in % of GDP, averaged over the five years before *t* (source : World Bank, 2003), *Inineq* : income inequality in the period of 5 years before *t* (Gini, source: Deininger and Squire, 1996), *Edineq :* educational inequality in the period of 5 years before t (Gini, source : Castelló and Doménech, 2001), *Goved* : log of real per capita government spending on education in the period of 5 years before *t* (source: Heylen et al., 2004), *Gdp-1960* : log of real per capita GDP in 1960 (source PWT Mark.6.1.).

In Table 3 we extend the analysis in Checchi and García-Peñalosa (2004) by allowing our volatility measure to vary over time. Instead of taking simple standard deviations of real per capita GDP growth over the entire period 1960-1999, we first calculate for every year in each country the standard deviation of growth over the preceding 10 years. Next, to match with the set-up of our panel, we take the average of these gliding standard deviations over the five years before t, with t=1965, 1970,...,2000). This approach allows us to reconcile the idea of time variation in our volatility measure with the need for a structural, long-term indicator[4]. We believe this measure to be a closer approximation of macroeconomic volatility because for each *t* it truly represents the experienced volatility of the past, while standard deviations over the entire period represent mainly future volatility if *t* is small (e.g. 1965) and past volatility if *t* is large (e.g. 2000). Table 3 presents our estimation results, using this alternative volatility measure.

[4]The correlation over all countries between this new measure and the time-invariant long-term standard deviation (over 1960-1999) used in Tables 2 and 3 is 0,71.

Table 3. Determinants of average educational attainment – time-varying volatility measure

	(1)	(2)	(3)	(4)	(5)
N.countries	90	90	90	90	90
N.Obs.	472	472	472	472	472
Vol -2	0.011	0.059	0.061	0.087	0.087
	(0.16)	(1.36)	(1.37)	(1.71)	(1.86)
Ed-ineq		-12.222	-12.062	-9.453	-8.887
		(5.87)	(5.65)	(5.33)	(4.73)
Credit			0.191	-0.234	-0.009
			(0.54)	(1.04)	(0.04)
Goved				0.778	0.458
				(2.92)	(1.78)
Gdp - 1960					0.725
					(1.21)
constant	yes	yes	yes	yes	yes
years	yes	yes	yes	yes	yes
regions	yes	yes	yes	yes	yes
R-squared	0.67	0.88	0.88	0.9	0.9

Notes:
Absolute t-values between brackets. Estimation method : population-weighted least squares with robust and country-clustered standard errors.
Dependent variable : average educational attainment (years of schooling) measured at t=1975, 1980, 1985, 1990, 1995, 2000 (source : Barro and Lee, 2000).
Explanatory variables: *Vol-2*: gliding 10 year standard deviation of real per capita GDP growth (source : PWT Mark.6.1.) averaged over the 5 years before t , *Credit* : Domestic credit provided by the banking sector, in % of GDP, averaged over the five years before *t* (source : World Bank, 2003), *Edineq :* educational inequality in the period of 5 years before t (Gini, source : Castelló and Doménech, 2001), *Goved* : log of real per capita government spending on education in the period of 5 years before *t* (source: Heylen et al., 2004).

As can be seen, using the time-varying volatility measure leads to positive volatility effects. Although the estimated coefficients are not always statistically significant, they clearly show that allowing the volatility measure to vary over time has an important effect on the estimations. The results for the other variables are similar to those reported in Table 2.

The use of a time-varying volatility measure has an important advantage. It allows us to correct for potential endogeneity of all explanatory variables by using lagged values[5] as instruments[6] in a 2SLS framework. Income in 1960, which we consider to be exogenous, and once lagged values of volatility, inequality, credit and government expenditures are used as instruments.

The results of this instrumental variable estimation are reported in Table 4. Considering colums (4) and (5) , for which the Durbin-Wu-Hausman test indicates that an instrumental variable approach is required, we find significantly positive effects for the volatility measure. These results support the hypothesis that in times of higher macroeconomic volatility people choose to study more, for example for reasons of insurance (if they have the means and the opportunity to do so). The instrumental variables regression provides us with further evidence

[5] We use only the value for the previous interval as an instrument. Taking further lags does not significantly affect the results, but is rather costly in terms of the number of observations.
[6]Using only one lag implies – in this case - an exactly identified model, for which an overidentifying restrictions test cannot be calculated. However, when using two lags this test is possible , leaving us with 59 countries and 102 observations. This estimation (not reported) leads to Sargan test statistics for columns (4) and (5) of (p-value) 0,9389 and 0,9433.

that governments can stimulate the average level of schooling in an economy through expenditures on education. The effects of credit, educational inequality and initial income are similar to the ones found in Tables 2 and 3.

Following Fatás (2002) and Hnatkovska and Loayza (2003), column (6) allows for different volatility effects in richer versus poorer countries. Three groups of countries are distinguished. Empirically, we estimate these potentially different effects by specifying three dummy variables. Rich is a dummy variable equal to 1 for "rich" countries, i.e. countries with real GDP per capita in dollars (PPP) and 1996 prices in 1960 above 7047 (the 66 pct.). Middle is a dummy variable equal to 1 when real GDP in 1960 is between 3027 (the 33 pct.) and 7047, while low is a dummy for real GDP in 1960 below 3027. As can be seen, the effect of volatility on human capital in column (6) is significantly positive only for the group of "rich" countries. Also, the coefficient is larger in magnitude for this group.

Table 4. Determinants of average educational attainment – IV estimation

	(1)	(2)	(3)	(4)	(5)	(6)
N.Countries	82	82	82	82	82	82
N.Obs	229	229	229	229	229	229
Vol-2	0.459	0.258	0.26	0.496	0.5	
	(2.03)	(1.78)	(1.7)	(2.79)	(2.75)	
Vol-2 * dpoor						0.483
						(1.71)
Vol-2 * dmid						0.598
						(1.61)
Vol-2 * drich						0.637
						(2.09)
Ed-ineq		-11.979	-11.963	-6.907	-6.909	-6.480
		(14.75)	(13.87)	(4.94)	(4.90)	(2.36)
Credit			0.022	-0.875	-0.948	-1.023
			(0.06)	(2.16)	(1.89)	(1.42)
Goved				1.44	1.528	1.638
				(4.90)	(3.28)	(2.82)
Gdp 1960					-0.117	-2.645
					(0.30)	(0.42)
constant	yes	yes	yes	yes	yes	yes
years	yes	yes	yes	yes	yes	yes
regions	yes	yes	yes	yes	yes	yes
R-squared	0.68	0.87	0.87	0.87	0.92	0.86
Durbin-Wu-Hausman test (p-value)	0.0746	0.0715	0.0007	0.0009	0.0166	0.0054

Notes:

Absolute t-values between brackets. Estimation method : population-weighted 2SLS. Instruments used for Vol-2, Ed-ineq, Credit, Goved are the lagged value (value of previous interval) of each variable respectively.

Dependent variable : average educational attainment (years of schooling) measured at t=1975, 1980, 1985, 1990, 1995, 2000 (source : Barro and Lee, 2000).

Explanatory variables: *Vol-2*: gliding 10 year standard deviation of real per capita GDP growth (source : PWT Mark.6.1.) averaged over the 5 years before t , *Credit* : Domestic credit provided by the banking sector, in % of GDP, averaged over the five years before *t* (source : World Bank, 2003), *Edineq :* educational inequality in the period of 5 years before t (Gini, source : Castelló and Doménech, 2001), *Goved* : log of real per capita government spending on education in the period of 5 years before *t* (source: Heylen et al., 2004). For the specification of three dummies (rich, midd, poor) see main text.

4. Theoretical extension

In this section we show that a simple extension of the model presented by Checchi and García-Peñalosa (2004) can explain our empirical findings. Like these authors we assume an open economy with perfect physical capital mobility and immobile labour. The world interest rate is constant. However, instead of assuming two types of labour (skilled and unskilled) who work with the same technology, we allow for differences in technology. These differences imply a different level and a different volatility of labour effectiveness for each type.

4.1. Firms

Firms have the following production function:

$$Y_t = K^{\beta}[A_t L_{A,t} + h B_t L_{B,t}]^{1-\beta}, \quad 0<\beta<1 \tag{2}$$

Aggregate output is produced by physical capital K and two types of labour according to a constant returns to scale production technology. L_A workers are unskilled, L_B are skilled. Both types are perfect substitutes in production. Population is normalized to one, implying that $L_A + L_B = 1$. A key element in the production function is that workers with different skills work with different kinds of technology. Unskilled workers employ basic technologies. Each worker provides *A* units of effective labour. Skilled workers have not only acquired more human capital (*h*), they can also handle more advanced technologies. Each skilled worker provides *Bh* units of effective labour. The focus of our paper being on macroeconomic volatility, we take *h* to be non-stochastic. A and B however are vulnerable to productivity shocks. More precisely, they can take values $\overline{A}, \underline{A}$ and $\overline{B}, \underline{B}$ respectively, both with probability one half, where $\overline{A} > \underline{A}$ and $\overline{B} > \underline{B}$. They have mean $\mu_A = (\overline{A} + \underline{A})/2$, $\mu_B = (\overline{B} + \underline{B})/2$ and variance $\sigma_A^2 = \mu_A^2 - \overline{A}\,\underline{A}$, $\sigma_B^2 = \mu_B^2 - \overline{B}\,\underline{B}$. Our expectation is that since educated workers are able to handle more advanced technologies, which often allow people to better face shocks, their labour effectiveness will be less volatile $(\sigma_B \leq \sigma_A)$.

Clearly we could put more structure in the above specification. An obvious case would be that $B = \theta A$, which would imply that shocks to both productivity levels are related. In our analysis below we develop the more general case. The restriction $B = \theta A$ can however easily be imposed.

We assume that firms decide on their stock of capital after the productivity shocks are is realised and pay wages after production. They equate the (given) world interest rate *r* to the marginal product of capital[7]. This implies a constant capital labour ratio, and wages in period t of $\omega_{A,t} = A_t w$, $\omega_{B,t} = B_t h w$, where w is the constant wage per unit of effective labour[8].

[7] This leads to $\dfrac{K_t}{AL_A + BhL_B} = (\dfrac{\beta}{r})^{\frac{1}{(1-\beta)}}$. We assume that physical capital does not depreciate over time.

[8] $w = (1-\beta)(\dfrac{\beta}{r})^{\frac{\beta}{(1-\beta)}}$

4.2.Workers

Each worker lives for two periods. In the first period he decides whether or not to study. In the second period, he works either as an educated worker or as an unskilled worker. Entire consumption *c* takes place in the second period. In the second period workers also leave a bequest *b* to their children. Lifetime utility of agent *i* is $U_{it}=(1-\alpha)\ln c_{it}+\alpha\ln b_{it}$.
Note that utility is realised during the second period. Income from work during that period depends on the level of human capital of the worker and on the (good or bad) state of the economy.
The worker maximizes expected utility

$$max\, EU_{it}=\frac{1}{2}[(1-\alpha)\ln\overline{c_{it}}+\alpha\ln\overline{b_{it}}]+\frac{1}{2}[(1-\alpha)\ln\underline{c_{it}}+\alpha\ln\underline{b_{it}}]$$

subject to $\overline{Y_{it}}=\overline{c_{it}}+\overline{b_{it}}, \underline{Y_{it}}=\underline{c_{it}}+\underline{b_{it}}$, where a bar above (below) a variable indicates its value in the good (bad) state of the world.
The solution to this problem implies that, at any time, a fraction of income α is bequeathed and a fraction (1-α) is consumed, which leads to the following equation for expected utility in the optimum (see also Checchi and García-Peñalosa, 2004):

$$EU_{it}=\ln[(1-\alpha)^{(1-\alpha)}\alpha^{\alpha}]+\frac{1}{2}[\ln\overline{Y_{it}}+\ln\underline{Y_{it}}] \tag{5}$$

4.3. Education

An agent who decides to study in the first period of his life pays a fixed education cost *f*. He can pay for this cost either by using the inheritance x_{it} received from his parent $(x_{it}=b_{it-1})$ or by borrowing on the capital market at interest rate *r*. Paying this cost the agent acquires education which allows him to work as a skilled worker in the second period. Alternatively, he can choose not to pay the education cost, but to invest the received inheritance. He will then work as an unskilled worker. The expected utilities of being unskilled or skilled are, respectively,

$$EU_{it}^{u}=\ln[(1-\alpha)^{(1-\alpha)}\alpha^{\alpha}]+\frac{1}{2}\ln[\overline{A}\,w+R\,x_{it}]+\frac{1}{2}\ln[\underline{A}\,w+R\,x_{it}] \tag{6}$$

$$EU_{it}^{s}=\ln[(1-\alpha)^{(1-\alpha)}\alpha^{\alpha}]+\frac{1}{2}\ln[\overline{B}\,hw+R(x_{it}-f)]+\frac{1}{2}\ln[\underline{B}\,hw+R(x_{it}-f)] \tag{7}$$

where R=1+r. An agent chooses to study if the expected utility of doing so exceeds that of remaining unskilled. That is, if his inheritance is greater than ***x****, where

$$x^{*}=\frac{1}{2R}\frac{Rf(2\mu_{B}wh-Rf)+(\mu_{A}^{2}-\sigma_{A}^{2})w^{2}-(\mu_{B}^{2}-\sigma_{B}^{2})w^{2}h^{2}}{w(h\mu_{B}-\mu_{A})-Rf} \tag{8}$$

Differentiating expression (8) with respect to σ_A and σ_B respectively gives

$$\frac{\partial x^*}{\partial \sigma_A} = -\frac{1}{R}\frac{w^2}{w(h\mu_B - \mu_A) - Rf} < 0 \tag{9}$$

$$\frac{\partial x^*}{\partial \sigma_B} = \frac{1}{R}\frac{h^2 w^2}{w(h\mu_B - \mu_A) - Rf} > 0 \tag{10}$$

Under the assumption that the expected gain from studying is positive, i.e. $w(h\mu_B - \mu_A) - Rf > 0$, these partial derivatives imply that

- if the labour effectiveness and the wage of the unskilled become more volatile, the threshold value of inheritance needed to study ***x**** decreases. Given the initial distribution of wealth, the long-run number of educated workers will rise.
- If the labour effectiveness and the wage of the skilled become more volatile, the threshold value of inheritance needed to study ***x**** increases. Given the initial distribution of wealth, the long-run number of educated workers decreases.

Furthermore, it can easily be observed that $\partial x^*/\partial f > 0$ [9]. An increase in the cost of schooling raises the threshold value of inheritance. Given the initial distribution of wealth, the fraction of educated workers will then fall. The effects of changes in the other determinants of x^* cannot be determined analytically in general. We have therefore simulated the model. Table 6 presents starting values for the parameters. These starting values have been chosen under the restriction of obtaining realistic relative wages of skilled versus unskilled workers, a positive expected gain from studying and non-negative values for x^*. We present two sets of starting values (S1 and S2), the first of which imposes $\sigma_A > \sigma_B$, the second one where $\sigma_A = \sigma_B$.

Table 6. Simulation: starting values

Basic parameters	S1	S2	Implied values	I1	I2
β	0.34	0.34	μ_A	0.875	0.875
R	2.09	2.09	σ_A	**0.275**	**0.275**
h	2	2	Expected wage unskilled $(\mu_A w)$	0.317	0.317
$\underline{A}$	0.60	0.60			
$\overline{A}$	1.15	1.15	μ_B	1.445	1.445
$\underline{B}$	1.25	1.17	σ_B	**0.195**	**0.275**
$\overline{B}$	1.64	1.72	Expected wage skilled $(\mu_B w h)$	1.047	1.047
f	0.345	0.345	Expected relative wage $(\mu_A/\mu_B h)$	0.303	0.303

Note : The value for R follows from assuming an annual real rate of interest of 3% and periods of 25 years.

[9] An increase in f reduces the denominator in (8) , while the effect on the numerator is $2R(wh\mu_B - Rf)$, which is > 0 under our assumption that $w(h\mu_B - \mu_A) - Rf > 0$.

In addition to the above mentioned results for the effects of changes in σ_A, σ_B and *f*, the simulations reveal that a rise in *h* lower the threshold value of inheritance $\boldsymbol{x^*}$.

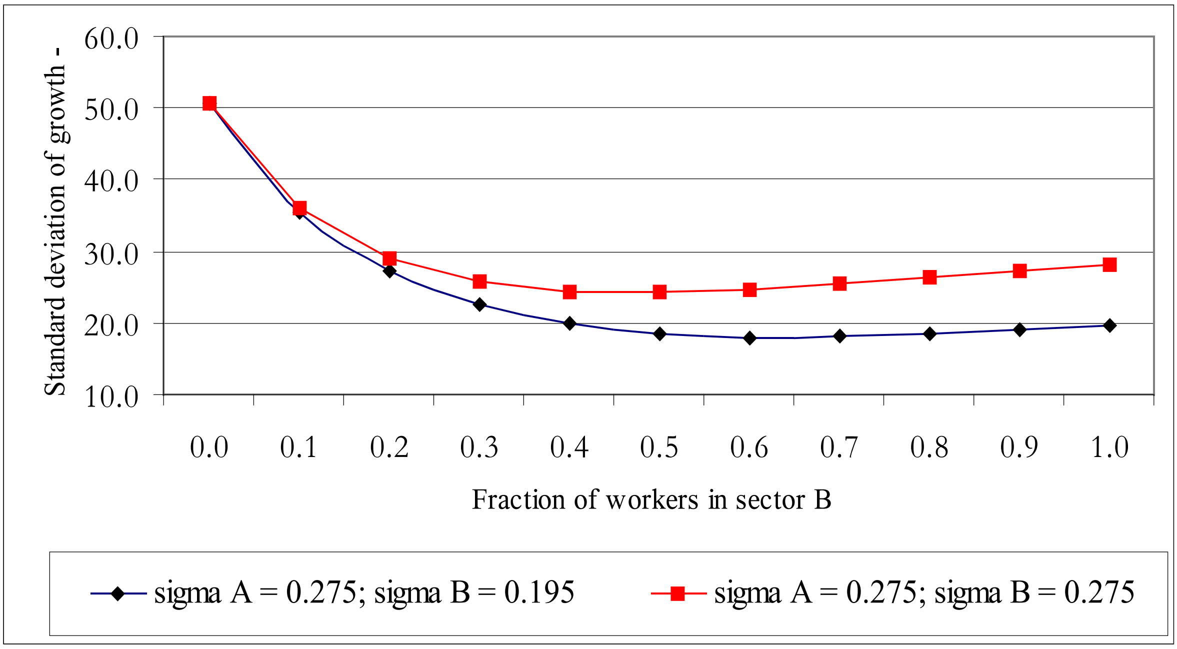
4.4.Interpretation

The data and our empirical analysis in the previous sections reveal several interesting facts. First, we have found that rising macroeconomic volatility, higher government expenditures on education and lower inequality may stimulate human capital (see Tables 3 and 4). Second, as is clear from Figure 1, more volatile economies tend to have lower human capital, and vice versa. In this section we show that our model can rationalize these facts.

The positive causal effect of macroeconomic volatility on human capital formation is not a straightforward result from our model. As the partial derivatives in (9) and (10) and additional simulations show, this positive causal effect requires macroeconomic volatility to be driven by volatility in the labour effectiveness of the unskilled. To explain the significantly positive empirical effects of government expenditures on human capital, our model can provide only indirect justification. Government behaviour has not been modelled explicitly, but one can obviously think of higher government education spending reducing the cost of schooling *f* or increasing the productivity of schooling *h*. Both effects bring down x^* and reduce the threshold level of inheritance needed for agents to decide to invest in an education.

Finally, although our model can explain a positive causal effect of macroeconomic volatility (if it is driven by volatility in the labour effectiveness of the unskilled) on human capital , it can also rationalize the simple negative correlation in Figure 1. For illustrative purposes, Figure 4 depicts the relationship between the standard deviation of the growth rate of macroeconomic output Y and the fraction of skilled workers, L_B , building on the parameter values in Table 6. The underlying growth rates have been calculated as follows. Since both *A* and *B* can be low or high, we can distinguish 4 different macroeconomic output levels for a given set of parameter values and given L_A and L_B. In two consecutive periods output can either stay at the same level, or switch to another one (because of shocks in the labour effectiveness of the skilled/unskilled). This means that for given parameter values there are 16 possible new 'states' for the economy, each implying a possible growth rate. Calculating the standard deviation over these 16 possible growth rates, we obtain a measure of the (possible) macroeconomic volatility for a given set of parameter values. By recalculating this measure for different values of L_B (and L_A) Figure 4 is obtained. As can be seen, in Figure 4 higher levels of macroeconomic volatility are associated with lower fractions of skilled workers.

Figure 4. Volatility and the fraction of skilled workers



Underlying parameter values are reported in Table 6.

5. Conclusions

Our findings in this paper can be summarized as follows.

1. Existing empirical results that macroeconomic volatility undermines human capital are not robust. Even updating to the Penn World Tables Mark 6.1. database seems to make an important difference for the results.
2. An important channel along which volatility affects human capital is its (negative) relation to government education spending. Controlling for education spending in our regressions (using a time-invariant volatility measure) turns the volatility effect from negative into non-negative.
3. We confirm standard results from the literature that government spending on education stimulates human capital (Flug et al., 1998; Christou, 2001; Checchi and García-Peñalosa, 2004). Our results for the influence of financial depth are less robust.
4. Using a time-varying measure of macroeconomic volatility we find a positive effect of volatility on human capital. The effects of macroeconomic volatility on human capital depend on countries' structural characteristics. We find that this positive effect is stronger (and significant) in rich countries, with income levels being measured in 1960. These results provide one way to explain the findings by Fatás (2002) and Hnatkovska and Loayza (2003) with respect to the effects of volatility on growth. The volatility effect remains positive when we control for possible endogeneities using 2SLS.
5. An extension of the theoretical model developed by Checchi and García-Peñalosa (2004) rationalizes our findings that the effect of macroeconomic volatility on human capital formation is not as robustly negative as stated in existing literature.

Our results are consistent with the hypothesis that volatility may make people want to study more for reasons of insurance. (Educated people may face less risk and uncertainty). Government education expenditures reducing the cost of studying may be crucial to realise this ambition. Having well-developed credit markets seems to make less of a difference.

(Human capital being poor collateral, it is generally hard to borrow for reasons of human capital investment).

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