Inflation and human capital formation : theory and panel data evidence

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Abstract

Existing monetary growth theories predict either negative or neutral effects from inflation on human capital. In this paper we develop a simple alternative model, which can generate positive effects. Our empirical analysis for 93 countries in 1975-1995 tends to confirm these positive effects. Using recent GMM panel data procedures, we find that rising inflation basically stimulates human capital. A negative effect can be observed only at extremely high inflation rates. A representative threshold may be 100%. For inflation rates below 15%, the effect of rising inflation seems insignificant. The latter result can also be rationalized from our model.

JEL Classification: E31, J24, O40

Keywords: Human capital, education, inflation, monetary growth models, panel data

1. Introduction

Human capital is important for long-run growth and development. Theoretically, this has been established clearly in a wide range of recent models, beginning with Romer (1986) and Lucas (1988). Empirically, although there are dissonant voices[1], the balance of recent evidence supports the hypothesis that having or accumulating more human capital, especially at the secondary and tertiary level, stimulates per capita income growth (e.g., Mankiw et al., 1992; Benhabib and Spiegel, 1994; Engelbrecht, 1997; Barro, 1999; de la Fuente and Doménech, 2001; Bassanini and Scarpetta, 2001; Castelló and Doménech, 2001; Temple, 2001; Noorbakhsh et al., 2001; Mauro and Carmeci, 2003). Considering its importance, it is surprising that the literature on inflation and growth has paid only limited attention to human capital. In the monetary growth tradition, a number of theoretical papers do include human capital as an endogenous variable, but the effect of inflation on human capital is typically not the main issue (see e.g., Wang and Yip, 1992; Gomme, 1993; Jones and Manuelli, 1995; Pecorino, 1995; Mino, 1997; Gillman and Kejak, 2002; Chang, 2002). To the best of our knowledge, empirical work on the effects of inflation on human capital does not exist. Only physical capital is considered (e.g., Barro, 1997; Bassanini et al., 2001). Given these findings, it should come as no surprise that Temple's (2000) survey of the inflation and growth literature contains only eleven lines relating to human capital. Our main goal is to fill (part of) this gap.

The structure of this paper is as follows. In Section 2 we first briefly discuss existing monetary growth models with endogenous human capital. In general, these models predict either neutral or negative inflation effects on human capital. Then, we present a simple alternative model, which can generate positive effects of inflation. Intuitively, a crucial idea is that inflation undermines the productive capacity of the economy, which makes working less attractive. To the extent that young agents expect high inflation to be temporary, they will study now and work later, with more human capital and under better expected aggregate conditions. Section 3 goes into the empirical relationship between inflation and human capital. We estimate various equations using recent GMM panel data techniques, which pay particular attention to the issues of simultaneity and country heterogeneity. Our empirical results reveal that rising inflation basically stimulates human capital. A robust negative effect can be observed only at very high inflation rates. A representative threshold may be 100%. For inflation rates below 15%, the effect of rising inflation on human capital seems to be insignificant. These results largely confirm the predictions of our alternative theoretical model. With respect to other determinants of investment in human capital, we find a

[1] See e.g., Islam (1995), Caselli et al. (1996), Klenow and Rodríguez-Clare (1997) and Kalaitzidakis et al. (2001).

significant role for government spending on education. Section 4 concludes and discusses some policy implications of our findings.

2. Inflation and human capital formation : theory

Recent models of growth, beginning with Romer (1986) and Lucas (1988), as well as the balance of empirical work (see Section 1) emphasize that human capital investment is an important factor that contributes to long-run growth. It then comes as no surprise that models on inflation and growth have gradually taken into account human capital as an endogenous variable. In general, these monetary growth models predict either neutral or negative effects from inflation on human capital investment. We briefly discuss these models' characteristics in section 2.1. In Section 2.2. we develop an alternative model. Our aim is to demonstrate that under certain conditions inflation can generate positive effects on human capital.

2.1. Existing theoretical models

Wang and Yip (1992) and Pecorino (1995) specify two-sector models where money enters as a factor of production in the final goods sector, i.e. the sector that produces consumer and physical capital goods. Money does not enter in the "education industry", where new human capital is being produced. In both models, labor supply is exogenous. There is no labor-leisure choice. Wang and Yip (1992) obtain neutral effects from money growth and inflation. A crucial element is their Lucas (1988)-Uzawa (1965) assumption that the production of human capital does not require physical capital as an input. Pecorino (1995) follows King and Rebelo (1990) and includes physical capital in the human capital production function. Inflation now undermines output growth and human capital. The reason is that higher inflation discourages the use of money, which reduces the marginal product and the output of physical capital. A smaller physical capital stock has negative consequences for the return and output in the human capital sector. Extending Wang and Yip (1992), Chang (2002) obtains negative effects from inflation by including real money as an input into human capital production.

Several authors introduce money via a cash-in-advance constraint (e.g., Gomme, 1993; Jones and Manuelli, 1995; Mino, 1997). Neutral effects of inflation on human capital and growth can be obtained in these models if the cash-in-advance constraint only applies to consumer goods and if labor supply is exogenous. Otherwise, inflation effects are typically negative. Gomme (1993) makes the first assumption, but endogenizes labor supply, as well as the allocation of labor. Labor can be employed either in goods production in profit-maximizing firms or in new human capital production outside the market. Inflation reduces the return to working since - due to the cash-in-advance constraint - income earned in the current period cannot be spent until the next one. This makes households substitute leisure for labor. Both goods and human capital production will fall. Mino (1997) obtains negative effects from inflation with fixed labor supply, but he assumes a cash-in-advance constraint on investment spending. As in King and Rebelo (1990) and Pecorino (1995), there are two sectors, both employing physical and human capital. Under a cash-in-advance constraint applying to investment in one of these sectors, higher money growth produces a direct negative inflation tax effect on the rate of return to capital, discouraging capital formation.

Another strand of literature relevant to the inflation/human capital relationship, puts the effect of inflation on the allocation of human capital at the center. Referring to among others De Gregorio (1992), Temple (2000) notes that at times of (very) high inflation, talented individuals may be diverted to activities in the financial sector and away from teaching[2]. This may undermine the productivity of schooling for youngsters and – as a consequence – the time they allocate to building human capital. Instead of education, these youngsters might prefer financially motivated activities themselves.

2.2. An alternative theoretical approach

In this section we develop a simple alternative model. First, we give up the infinitely lived agent assumption that underlies the above-described monetary growth literature. Second, instead of directly introducing money growth and inflation into the model, we build on standard results from the literature on the real effects of inflation (see Temple, 2000, for a survey). An important result is that inflation may undermine total factor productivity in production, e.g. by forcing economic agents to economize on the use of money or by disrupting the crucial role of the price mechanism in the efficient allocation of resources.

Basic assumptions

Our analytical framework consists of a simple two-period OLG model for a small open economy. We assume perfect international mobility of physical capital, but immobile labor and human capital[3]. We consider two generations, the young and the old. In each period of life people are endowed with one unit of (non-leisure) time. Young people can choose either to work and generate labor income, or to study and build human capital (a non-market

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[2] Aiyagari et al. (1998) provide an interesting empirical illustration of this argument. Although their focus is different, these authors show for high inflation countries (Argentina, Brazil, Israel) that there is a strong positive relationship between the employment share in the banking sector and consumer price inflation. English (1999) also finds that the size of a nation's financial sector is strongly affected by its inflation rate.

[3] Seminal work in this tradition has been done by Diamond (1965), using earlier insights of Samuelson (1958). Early open economy versions of the model putting human capital formation at the center, have been developed by Buiter and Kletzer (1993, 1995) and Nielsen and Sørensen (1997).

activity). Labor income is partly allocated to consumption and partly to savings. Old people do not study anymore, they only work and consume. They leave neither bequests nor debts. Economy-wide savings in a particular period (i.e. the savings by the young) generate the stock of non-human wealth in the next period. Non-human wealth is held as physical capital employed in domestic or foreign firms. The rate of return on non-human wealth is the (exogenous) world real interest rate, which equals the net marginal product of world physical capital. Domestic firms act competitively and employ physical capital together with existing technology and the labor provided by the young and the old. A final important assumption is that, following Azariadis and Drazen (1990), education generates a positive externality in that the average level of human capital of a generation is inherited by the next generation.

In what follows, we concentrate on the core elements of the model: the time allocation decision of young people, the behavior of domestic firms and the determination of aggregate output and wages. These allow us to assess the potential influence of inflation. To present the model, we shall adopt specific functional forms for the utility function, for the return to investment in education and for the production function. Also, since population growth is irrelevant to our argument, we assume that all generations are of equal size (*N*). Population is constant. Note that our results do not depend on these specifications. For example, instead of log utility, any homothetic utility function will do the job. So will any function for the return to education provided that it is increasing and concave. Furthermore, we could have population growing at a constant rate.

Individuals

The preferences of an individual born in t are represented by a log-linear utility function of the form:

$$u^t = ln\, c_1^t + \phi\, ln\, c_2^t \tag{1}$$

where the superscript t indicates the period of birth/youth. Lifetime utility is defined over consumption when young (c_1^t) and consumption when old (c_2^t). Second period utility is discounted for the rate of time preference ρ, with $\phi = 1/(1+\rho)$. Individuals will maximize Equation (1), subject to the constraints described in (2) and (3).

$$c_1^t + s_1^t = w_t(1-e^t)h_1^t \tag{2}$$

$$c_2^t = w_{t+1}h_2^t + s_1^t(1+r_{t+1}) \tag{3}$$

$$\text{with : } h_2^t = (1+g(e^t))h_1^t$$

In these equations, w_t and w_{t+1} stand for the real wage per unit of effective labor in periods t and $t+1$, r_{t+1} is the (world) real interest rate paid on savings collected in period t and held to $t+1$. The effectiveness of a full-time young worker born in t equals his human capital h_1^t, inherited from the old generation. Since young workers allocate a fraction e^t of their time to education, they earn a real wage $w_t(1-e^t)h_1^t$. In $t+1$, when they are old, they work full-time and supply $h_2^t = (1+g(e^t))h_1^t$ units of effective labor, yielding a real wage $w_{t+1}(1+g(e^t))h_1^t$. The function $g(e^t)$ describes the return on investment in education. We assume that $g(0)=0$, $g' >0$, $\lim_{e\to 0} g'=\infty$ and $g''<0$ [4]. A function satisfying these conditions is $g(e)=\dfrac{\alpha.e^{\gamma}}{\gamma}$, with $0<\gamma<1$ and $\alpha>0$. In this function, α is the main determinant of the productivity of schooling. The education externality described above implies that the young in the next period ($t+1$) also benefit from the education investment of the young in t. Algebraically, $h_1^{t+1} = h_2^t = (1+g(e^t))h_1^t$.

Equation (2) describes the constraint that young people face while sharing their time between working (fraction $1-e^t$) and investing in human capital (fraction e^t) and their income from work $w_t(1-e^t)h_1^t$ between consumption c_1^t and savings s_1^t. If young individuals decide to study, they will earn less when young, but they will develop skills which raise their effective labor and income when old. If they choose to work, they will earn income immediately which enables them to consume and to build non-human wealth, also generating more income in the future. Note that Equation (3) incorporates the assumption that old people leave neither bequests nor debts. They consume their total labor income and accumulated non-human wealth.

Substituting Equations (2) and (3) into (1), lifetime utility of a person who is young in t can be rewritten as :

$$u^t = \ln\left(w_t(1-e^t)h_1^t - s_1^t\right) + \phi \ln\left(w_{t+1}(1+g(e^t))h_1^t + s_1^t(1+r_{t+1})\right) \tag{4}$$

Maximizing with respect to s_1^t and e^t yields the following first order conditions. For the sake of simplicity, we drop the superscript t.

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[4] $\lim_{e\to 0} g'=\infty$ implies that young individuals will allocate a positive fraction of their time to schooling. Similarly, the logarithmic utility function implies that individuals will choose positive consumption levels in each period ($c_i^t > 0$).

$$\frac{1}{c_1} = \phi \frac{1+r_{t+1}}{c_2} \tag{5}$$

$$\frac{w_t h_1}{c_1} = \phi \frac{w_{t+1} g'(e) h_1}{c_2} \tag{6}$$

Equation (5) is the familiar condition equating the marginal utility of consumption when young to the discounted marginal utility when old of the consumption allowed by savings. Equation (6) imposes that the marginal utility gain from working when young (LHS) should equal the marginal utility gain from investing in human capital (RHS). The latter reflects the discounted marginal utility from consuming the additional income due to higher labor effectiveness. Substituting (5) into (6), we obtain that the optimal fraction of time allocated to studying should satisfy

$$g'(e) = (1+r_{t+1}) \frac{w_t}{w_{t+1}} \tag{7}$$

Since $g'' < 0$, it follows that young people will study more (and work less) when the real interest rate and the ratio of current to future real wages are lower. Assuming, as mentioned above, that $g(e) = \frac{\alpha . e^{\gamma}}{\gamma}$, with $0<\gamma<1$ and $\alpha>0$, it can be derived that :

$$e = \left[\frac{\alpha}{1+r_{t+1}} \frac{w_{t+1}}{w_t} \right]^{\frac{1}{1-\gamma}} \tag{7'}$$

Next to the real interest rate and the relative real wage, this equation emphasizes the major role of α, the productivity of schooling. If studying results in a stronger increase in human capital and future labor effectiveness, young people may wish to invest more in education. This is a well-known result from the literature (e.g., Becker, 1964; Williams, 1979; Lucas, 1988). One obvious determinant of α would be government education spending. More and better teachers, better books, etc., should raise the productivity of schooling and make investment in education more attractive (e.g., Capolupo, 2000; Glomm and Ravikumar, 1992).

Domestic firms, output and factor prices

Firms act competitively on output and input markets and maximize profits. All firms are identical. Total domestic output is described by the production function (8) which exhibits constant returns to scale in aggregate physical capital (K_t) and effective labor (H_t). Equation (9) describes total effective labor supplied by young and old workers. Note our assumption that both generations have equal size (N) and that young workers inherit the human capital of the old ($h_1^t = h_2^{t-1}$). Total factor productivity (A_t) is assumed to be country-specific and given, at least for the moment[5]. Competitive behavior implies in Equation (10) that firms will carry physical capital to the point where its marginal product net of depreciation equals the world real interest rate. The depreciation rate is indicated as δ. The real interest rate being given, firms will install more capital when total factor productivity improves or when the amount of effective labor increases. Furthermore, perfect competition implies equality between the real wage and the marginal product of effective labor (Equation 11). Higher real wages follow from an increase in physical capital per unit of effective labor or an improvement of total factor productivity.

$$Y_t = A_t K_t^{\beta} H_t^{1-\beta} \qquad 0 < \beta < 1 \qquad (8)$$

$$H_t = N(1-e^t)h_1^t + Nh_1^t = N(2-e^t)h_1^t \qquad (9)$$

$$r_t = \frac{\beta A_t}{(K_t / H_t)^{1-\beta}} - \delta \qquad 0 \leq \delta \leq 1 \qquad (10)$$

$$w_t = (1-\beta)A_t\left(\frac{K_t}{H_t}\right)^{\beta} \qquad (11)$$

Rewriting (8) as $Y_t = A_t\left(\frac{K_t}{H_t}\right)^{\beta} H_t$, and substituting (9) and (10) for H_t and $\frac{K_t}{H_t}$, we obtain that

$$Y_t = A_t^{1/(1-\beta)}\left(\frac{\beta}{r_t+\delta}\right)^{\beta/(1-\beta)} N(2-e^t)h_1^t \qquad (8')$$

Assuming that in steady state r and A are constant, we obtain the long-run (per capita) growth rate of the economy as

$$ln\left(\frac{Y_t}{Y_{t-1}}\right) = ln\left(\frac{h_1^t}{h_1^{t-1}}\right) = ln\left(\frac{h_2^{t-1}}{h_1^{t-1}}\right) = ln(1+g(e)) = ln(1+\frac{\alpha.e^{\gamma}}{\gamma}) \qquad (12)$$

where it is taken into account that e will be constant over generations. In line with some earlier models (e.g., Lucas, 1988; Azariadis and Drazen, 1990; Buiter and Kletzer, 1993), the long-run (per capita) growth rate is positively related to the productivity of schooling (α) and to the fraction of time that young people allocate to education (e).

The real effects of inflation

Our aim is now to demonstrate that under certain conditions inflation can stimulate (long-run) human capital and output. Mainly, it has to be assumed that the young generation in t-1 did

[5] We give up the assumption that A_t is given on the next page, where we allow for the effect of inflation shocks.

not anticipate high inflation in t, and that the young generation in t does not expect it to persist until $t+1$. Considering that generations consist of 20 to 25 years, this assumption seems not unreasonable. All we further need is the standard argument that inflation during a period t undermines the efficient allocation of factors of production in that period (Temple, 2000; Issing, 2001). In our model this is reflected by a drop in total factor productivity A_t. Since this negatively affects the marginal products of capital and labor, inflation will also bring down the physical capital stock (K_t) and the real wage (w_t). Only investment in education (e^t) may benefit. Assuming that it is not expected to persist over generations, high inflation in t will reduce individuals' perception of the relative wage w_t / w_{t+1}. The fall in w_t for given w_{t+1} will make working less, and studying more attractive (see Equation (7)). Human capital will rise[6].

Figure 1 illustrates these effects of temporary high inflation, as well as its long-run consequences. We assume that due to high inflation in period 1 total factor productivity in that period falls by 10%. This fall was not anticipated. Neither is it expected to persist. Individuals consider high inflation to be limited to one generation. We impose the following parameter values and benchmark levels for the main variables in period zero: α=0.75, β=0.5, γ=0.25, e=25%, A=N=h_1=1, H=1.75, K=0.13, Y=0.48 and w=0.137. Underlying values for the world real interest rate (r) and the depreciation rate (δ) are 1.094 and 0.72[7]. The real interest rate is assumed constant over time. The initial values for A and w are also the expected ones for later periods. The level of e and the chosen parameter values for α, β and γ determine the benchmark evolution of h_1, H, K and Y. Both parts of Figure 1 show the deviations from this benchmark caused by high inflation (low total factor productivity) in period 1. The precise numbers in this figure are of limited importance. What matters is the direction of change of the main variables, which is robust to changes in α, β and γ. The first part shows the evolution of the time allocation of young individuals, as well as the inherited human capital stock of young generations in later periods. As can be seen, there is a temporary rise in the fraction of time allocated to schooling in period 1. Due to the intergenerational education externality, this has permanent effects on the human capital stock of later young generations. The increased schooling effort of young people in period 1 explains the fall in employed effective labor (H) in that period. In later periods employed effective labor benefits from the rise in the human capital of all young and old workers. Lower total factor productivity and lower employed effective labor in period 1 cause a drastic fall in the marginal product of physical capital in that period. Firms respond by reducing the amount of capital (K) installed. In later periods the

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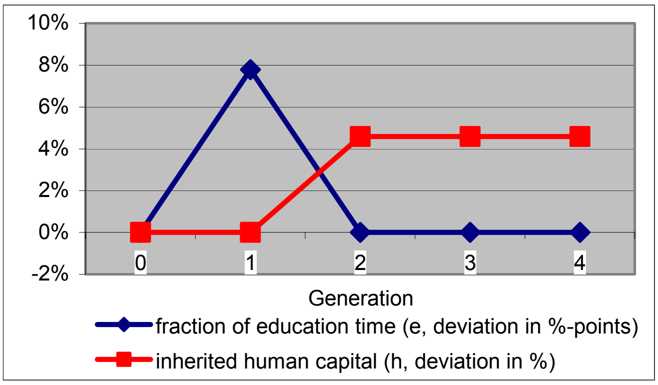
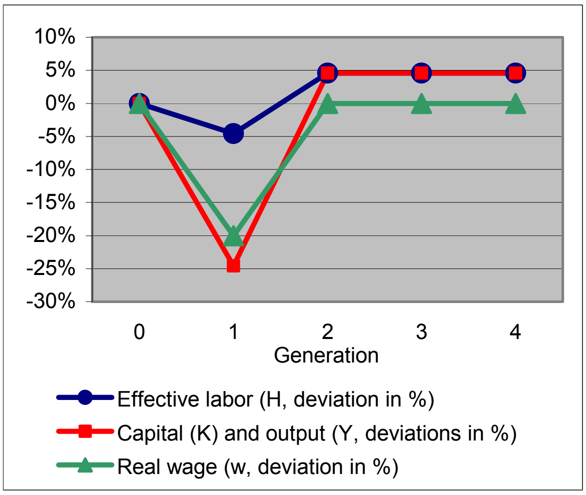
[6] Obviously, if young individuals in t expect high inflation (and low real wages) to persist, they cannot benefit from studying more. Note also the importance of our assumption that high inflation was not anticipated in $t-1$. If it were, the young generation in $t-1$ would expect a high relative real wage (w_{t-1} / w_t) and would study less. So e^{t-1} would fall, compensating the rise in e^t.

[7] Assuming that a period contains 25 years, these values correspond to annual interest and depreciation rates of 3% and 5%.

physical capital stock will be higher than ever before, due to the permanent increase in effective labor. The latter pushes the marginal product of physical capital above the world interest rate, causing an inflow of capital. The evolution of real output reflects the evolution of its underlying determinants (*A, K, H*) according to Equation (8). During high inflation, output suffers. In the long-run, however, our model predicts a positive output effect. Finally, the real wage per unit of effective labor (*w*) decreases with the fall in both total factor productivity and the ratio of physical capital to effective labor in period 1. Later, there is no influence on the real wage anymore since both *A* and *K/H* return to their initial (benchmark) levels.

Figure 1. Simulated effects of (temporary) inflation: an illustration





Note: The data show deviations from a benchmark simulation without high inflation (i.e. without a 10% fall in total factor productivity (A_t)) in period 1.

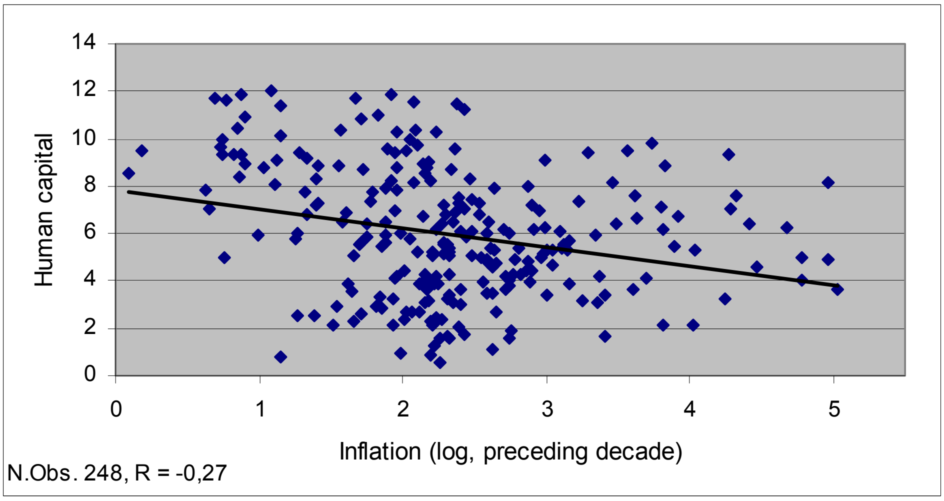
Several extensions of our model are possible. Inflation is often blamed, not only for undermining (expected) efficiency in production, but also for creating uncertainty about real costs and revenues in production. Furthermore, as emphasized by Feldstein (1983), due to shortcomings in the tax system – mainly the fact that only the historical cost of an asset can be written off – inflation de facto raises the real depreciation rate of physical capital and undermines its net return. A further reduction of the physical capital stock and the real wage in *t* are the results. These extensions provide additional arguments why inflation may make working less attractive, and studying and human capital formation more attractive.

3. Inflation and human capital formation : the empirical relationship

3.1. Some preliminary results

Despite the generally acknowledged importance of human capital for economic growth, empirical studies on the effects of inflation on growth have disregarded human capital. Everyone seems to assume that the expected (and often observed) negative effects of inflation on physical capital[8] also apply to human capital. Existing monetary growth models with endogenous human capital justify this assumption. So may Figure 2. This figure relates a proxy for the human capital stock in 89 developed and developing countries in 1980, 1990 and 2000 to average annual consumer price inflation in the preceding decade. Human capital is measured as average years of total schooling in the population of age 15 and older (Barro and Lee, 2000). As can be seen, a negative relationship becomes apparent. Correlation equals -0.27.

Figure 2. Inflation and human capital [(a)] in 89 countries in 1980, 1990 and 2000 [(b)]



[a] Human capital is measured as average years of total schooling in the population of age 15 and older. Inflation is consumer price inflation.
[b] Data sources: Human capital: Barro and Lee (2000); inflation: World Bank (2001). For further details, see Appendix 1.

Figure 2 notwithstanding, this section will challenge the view that physical and human capital are equal in their response to inflation. In line with our model, we present econometric results indicating that rising inflation stimulates human capital formation, except at extremely high and (in some regressions) very low levels. A first step is to note that the negative relationship in Figure 2 is not robust. Table 1 contains a number of illustrative regressions. The first of these describes the regression line in Figure 2. As can be seen in the second regression, as soon as one controls for lagged human capital (i.e. the human capital stock ten years earlier), the negative effect from log inflation ($\ln\pi_{i,dect}$) becomes insignificant[9]. Also including seven regional dummies in regression (3) yields an insignificant positive effect from inflation. For details about these dummies we refer to the note below the table. Regression (4) specifies

[8] See e.g. Barro (1997), Barro (1999), Bassanini et al. (2001). Recall that our model in the previous section also predicts negative effects on physical capital during periods of rising (high) inflation.
[9] Note that the estimated long-run effect of log inflation in this regression is also insignificant. The long-run coefficient equals –0.82, which is comparable to the result in Regression (1). The corresponding t-value is –1.02.

another functional form for the inflation effect. Instead of log inflation, it includes both the inflation level and its square. The former getting a positive sign and the latter a negative one, this equation shows for the first time the inverted U-shaped relationship that will become important in the remaining part of this section.

Table 1. Inflation and human capital: some simple regressions [(a)]

	$R^2(adj)$	N.obs
(1) $H_{i,t} = 7.83 - 0.795 \ln(\pi_{i,dect})$ (16.4) (4.44)	0.07	248
(2) $H_{i,t} = 1.08 + 0.96\, H_{i,t-10} - 0.033 \ln(\pi_{i,dect})$ (7.52) (54.3) (0.93)	0.94	246
(3) $H_{i,t} = 1.94 + 0.90\, H_{i,t-10} + 0.011 \ln(\pi_{i,dect})$ + regional dummies (4.57) (33.7) (0.27)	0.95	246
(4) $H_{i,t} = 1.95 + 0.90\, H_{i,t-10} + 0.0013\, \pi_{i,dect} - 0.97\, \pi^2_{i,dect}/10^5$ + regional dummies (4.71) (34.0) (0.30) (0.28)	0.95	246

[a] The estimation method is pooled OLS. Absolute t-values based on White heteroskedasticity-consistent standard errors in parentheses. The subscript *i* refers to 89 countries, the years *t* concern 1980, 1990 and 2000. $H_{i,t}$ stands for average years of total schooling in the population of age 15 and older in country *i* and year *t*; $\pi_{i,dect}$ is the average consumer price inflation rate in country *i* in the decade before *t*. Regressions (3) and (4) contain regional dummies for the OECD, North Africa and the Middle East, Sub-Saharan Africa, South Asia, East Asia and the Pacific, Latin America and the European economies currently in transition.

3.2. Basic econometric framework and considerations

This Section and the next contain more rigorous empirical work. In line with the above, we choose average years of schooling as our proxy for human capital. The main reason is that changes in years of schooling directly reveal the fraction of time invested in education *e*, which is central in our theory. For example, at an individual level, when years of schooling between *t* and *t-5* rise by 1, it will be clear that this individual has allocated 20% of his time to education. As a consequence, with data on years of schooling, testing hypotheses on the determinants of *e* is relatively easy. On the other hand, this proxy also introduces a complication. If knowledge can be maintained over generations, even without investment in education by the young, human capital will show a unit root. This is the intergenerational externality assumption from Section 2.2. With average years of schooling as a proxy, however, there can be no unit root. If the young do not study, average years of schooling will gradually fall since every period educated older people will die. Empirically, this idea of depreciation of (our proxy for) human capital will have to be taken into account.

Equation (13) puts our hypotheses into a workable econometric framework. In this equation, $H_{i,t} - H_{i,t-5}$ stands for the change in the human capital stock in country *i* between years t and t-5. The human capital stock is - as in Figure 2 and Table 1 - defined as average years of total schooling for the population of age 15 and older. The years t that we consider are 1975, 1980, 1985, 1990 and 1995, the maximum number of countries is 93[10]. Our choice for data at 5-year intervals is partly inspired by data availability, especially in the high inflation ranges. Constructing data at 5-year intervals yields 414 observations. Inflation exceeds 20% in 80 cases, 30% in 55 cases, 50% in 27 cases and 100% in 11 cases. By comparison, at 10-year intervals there are only 15 observations with an inflation rate higher than 50% and 6 observations with inflation higher than 100%.

$$H_{i,t} - H_{i,t-5} = a_0 + a_1 H_{i,t-5} + a_2 \pi_{i,5yt} + a_3 \pi^2{}_{i,5yt} + a_4\, ln(GE)_{i,5yt} + \alpha_i + \lambda_t + \varepsilon_{it} \qquad (13)$$

with α_i an unobserved country-specific fixed effect, λ_t a time dummy common to all countries and ε_{it} the error term.

Building on the theory described in the previous sections, it will be our hypothesis that average per capita investment of time in education - and therefore the change in average years of schooling - is mainly influenced by two variables: per capita government spending on education and inflation. Higher government spending on education may raise the productivity of schooling and make investment in education more attractive. Inflation is included as a determinant of the efficiency with which labor and capital can be employed in production. This directly affects the real return to working. The influence of the world real interest rate, which is obvious in our model in Section 2.2., is captured by the time dummy (λ_t).

Included explanatory variables are average annual consumer price inflation in the period of five years from t-5 to t-1 ($\pi_{i,5yt}$), the square of average annual inflation and the log of average annual real per capita government spending on education in US dollar (PPP) during that same period of five years ($lnGE_{i,5yt}$). As to inflation, Section 2 has shown that both positive and negative signs can be justified. Including inflation and its square allows for a broad range of empirical possibilities. From our model in section 2.2. we would expect a_2 to be positive. Existing monetary growth models, however, suggest a_2 to be zero or negative. The idea mentioned above of an inverted U-shape between inflation and human capital would require a_2 to be positive and a_3 to be negative. The logarithmic specification for *GE* reflects the idea of decreasing returns. Our expectation is that a_4 is positive. Finally, we also include $H_{i,t-5}$ at the RHS of Equation (13). We expect a_1 to have a negative sign, mainly capturing the idea of depreciation when educated old people leave the population. Furthermore, one would expect a_1 to be negative if investment in education gradually becomes less attractive or more

[10] The numbers of countries i and years t are limited by data availability for inflation and especially government spending on education (see Appendix 1 for details). For human capital five yearly data since 1960 are available for most countries.

difficult at high levels of schooling. A justification for the former would be diminishing returns to education, a justification for the latter the simple fact that the supply of formal education is limited in practice. Rewriting Equation (13), generates a standard dynamic panel data specification.

$$H_{i,t} = a_0 + a_{11} H_{i,t-5} + a_2 \pi_{i,5yt} + a_3 \pi^2{}_{i,5yt} + a_4\, ln(GE)_{i,5yt} + \alpha_i + \lambda_t + \varepsilon_{it} \qquad (14)$$

with: $a_{11}=1+a_1$.

The following econometric issues have to be dealt with (see also Verbeek, 2000; Loayza et al., 2000; Bond, 2002). First, given the dynamic specification of Equation (14) with a lagged dependent variable at the RHS, the standard fixed effects estimator for panel data will be biased and inconsistent in realistic samples where the number of time periods is limited. An appropriate way to deal with this problem is the use of GMM after first-differencing Equation (14). Assuming absence of autocorrelation in the error term ε_{it}, twice and three times lagged observations for H_{it} (i.e. H_{it-10} and H_{it-15}) would be reliable instruments. As to the other explanatory variables, we assume that they are strictly exogenous. Their current levels can then be used as instruments in the regression[11]. Obviously, we can statistically examine the validity of this assumption through appropriate specification tests.

The first-difference GMM estimator also has its shortcomings, however. First, taking first-differences eliminates the cross-country variation between human capital and its determinants. Only the effect of changes over time within countries can be studied. Second, as shown by Bond (2002), when the explanatory variables are persistent over time, lagged levels of these variables are weak instruments for the regression equation in differences. As to our model, (lagged) human capital and government education spending may be such persistent explanatory variables. An alternative GMM system estimator may then be more appropriate. This alternative estimator combines in a system the regression in first-differences with the regression in levels. The instruments for the regression in first-differences are the same as mentioned above, i.e. twice and three times lagged levels of human capital and current levels of the other explanatory variables. For the second part of the system, the regression in levels, once-lagged differences of the explanatory variables would be appropriate instruments[12].

[11] These assumptions imply the following moment conditions: $E\left[(\varepsilon_{it} - \varepsilon_{i,t-5})H_{i,t-10}\right] = 0, E\left[(\varepsilon_{it} - \varepsilon_{i,t-5})H_{i,t-15}\right] = 0, E\left[(\varepsilon_{it} - \varepsilon_{i,t-5})X_{it}\right] = 0$ for $X = \pi$, π^2 and $ln(GE)$. Given that data availability for X_t is limited in most countries to t being 1975, 1980, 1985, 1990 and 1995, we can estimate equation (14) in first-differenced form beginning with t=1980. The number of moment conditions will be 19.

[12] In practice this implies four additional moment conditions $E\left[(\varepsilon_{it} + a_i)(H_{i,t-5} - H_{i,t-10})\right] = 0,$ with t=1980, 1985, 1990, 1995. Only the most recent difference is used as an instrument. Using more lags, or first-differences of the exogenous explanatory variables would result in redundant moment conditions (see Loayza et al., 2000, for further references).

3.3. Empirical results

Table 2 presents our main results. The results in the first and the second column have been obtained using the first-difference GMM method. The results in the third and the fourth column follow from using the alternative GMM system estimator. The larger number of observations in the system estimations is due to the fact that the levels regression can also be run for t=1975. The first difference regressions can be run only from t=1980 onwards. Although theory suggests a role for time dummies, note that we have also estimated the model without them in the first and the third column.

As shown by Hansen (1982), the optimal GMM estimator is obtained in two steps. In our discussion, we focus on the second-step results[13]. On the whole, the specification tests in Table 2 (Sargan test for overidentifying restrictions and tests for first order and second order serial correlation) do not show evidence against our estimates. The absence of significant second order serial correlation justifies our use of twice lagged 'internal' instruments. The Sargan test does not reject their joint validity. Observing the specific results of the specification tests in the four models, one may conclude that the models with time dummies and those with the GMM system estimator perform better.

The results are supportive to our hypotheses. First, lagged human capital (H_{t-5}) has the expected positive coefficient below one. Its magnitude reveals a large degree of persistence, which may justify the use of the GMM system estimator. Second, except when we employ the first-difference GMM method and include no time dummies in the regression, we find that a sustained increase in per capita government spending on education (*GE*) has a significant and positive effect on the average years of schooling of the population. Third, and most important, rising inflation tends to stimulate human capital formation as long as inflation is not very high. Concentrating on the two models with time dummies, the estimated coefficient for π is always positive and statistically significant at 2%, the estimated coefficient for π^2 is negative and statistically significant at 5%. An inverted U-shape emerges. The results for inflation are somewhat weaker when no time dummies are included. There is no change of signs, but statistical significance is lower, especially for the first-difference GMM method. As indicated at the bottom of Table 2, the top of the inverted U-shape is situated at very high inflation rates of about 160%. In the third regression that is even more than 240%. Clearly, given the very small number of observations for inflation above 100%, these numbers have limited

[13] Bond (2002) argues that the asymptotic standard errors of the two-step GMM estimates may be a poor guide for hypothesis testing in some cases. As noted by Bond and Windmeijer (2002) this problem is especially relevant when the number of instruments grows rapidly with the time dimension, which is not the case here since we choose a fixed number of instruments per time period. We nevertheless report both the first and second step results.

significance. What is important, is the observation of a significant positive effect from inflation below 100%. This clearly supports our theoretical model in Section 2.2. If the monetary growth models are relevant, they only seem to be when inflation is extreme. A final result at the bottom of Table 2 concerns the hypothetical effect over a period of 5 years on the human capital stock when inflation were to rise from 0 to 100%. Concentrating on the better models, this effect is estimated between about 0.4 and 0.6 years of schooling (all other things equal). We discuss the implications of these results in Section 4.

Table 2. Estimation results for Equation (14), alternative estimators [a, d]

	One-step estimates with heteroskedasticity consistent standard errors			
Variable	(GMM-diff)	(GMM-diff)	(GMM-system)	(GMM-system)
H_{t-5}	0.945 (20.2)	0.665 (3.45)	0.829 (24.5)	0.776 (10.9)
π_{5yt}	0.0052 (1.52)	0.0077 (2.05)	0.0062 (1.77)	0.0050 (1.20)
π^2_{5yt}	-0.000015 (1.33)	-0.000023 (1.64)	-0.000014 (1.10)	-0.000014 (1.08)
$ln(GE)_{5yt}$	-0.0146 (0.12)	0.311 (1.49)	0.262 (5.76)	0.244 (1.18)
time dummies	no	yes	no	yes
	Two-step GMM estimates			
Variable	(GMM-diff)	(GMM-diff)	(GMM-system)	(GMM-system)
H_{t-5}	0.956 (28.0)	0.630 (4.33)	0.881 (37.4)	0.760 (15.6)
π_{5yt}	0.0039 (1.46)	0.0090 (2.68)	0.0054 (1.78)	0.0069 (2.49)
π^2_{5yt}	-0.000012 (1.34)	-0.000027 (2.20)	-0.000011 (1.07)	-0.000021 (2.07)
$ln(GE)_{5yt}$	-0.033 (0.41)	0.326 (1.94)	0.190 (6.59)	0.256 (2.02)
time dummies	no	yes	no	yes
N. Obs. (countries)	321 (93)	321 (93)	414 (93)	414 (93)
Sargan (p-value) [(b)] (df)	0.174 15	0.353 15	0.217 19	0.605 19
Test for first order serial correlation (p-value) [(c)]	0.000	0.001	0.000	0.000
Test second order serial correlation (p-value) [(c)]	0.553	0.823	0.619	0.969
Inflation at top of inverted U-shape	162%	167%	245%	164%
Effect on *H* when inflation goes from 0 to 100%	+0.27	+0.63	+0.43	+0.48

Notes: [a] Absolute t-statistics in parentheses; [b] Sargan is Sargan test of overidentifying restrictions. The null hypothesis is that the overidentifying restrictions are correct; [c] The null hypothesis is that there is no first (second) order serial correlation in the error term; [d] Data sources: see Appendix 1.

3.4. Robustness checks

We perform four robustness tests. These concern two alternative approaches to capture the effects of inflation, another dependent variable and a change to data with a longer time interval (10 years). Tables 3, 4 and 5 show the results. Note that we only report the regressions including time dummies.

A first pair of regressions in Table 3 follow from an alternative approach to test the inverted U-shape hypothesis. More precisely, we estimate a linear spline regression. This is a piecewise linear relationship between inflation and human capital with the line segments joining one another at the specified breakpoints. We allow different slopes and intercepts for inflation below 15%, inflation between 15% and 100%, and inflation over and above 100%. The choice of 15% is inspired by the result in many empirical studies that the net effect of inflation on efficiency in production and long-run growth may be insignificant at low inflation rates[14]. Some studies suggest about 10 to 15% as a threshold. The results in Table 3 are interesting. For inflation below 15%, the effect of rising inflation on human capital is negative but highly insignificant. For inflation rates between 15 and 100% a positive and statistically significant slope shows up. Over and above 100% the effect of increasing inflation is again insignificantly negative. Considering these results, it is clear that the inverted U-shape between inflation and human capital survives. In line with some of the estimates in Table 2, going from 0 to 100% of inflation raises the human capital stock by approximately 0.40 years of schooling (all other things being equal).

The insignificant negative effect from extreme inflation can, as we have argued before, be explained from the monetary growth literature. The insignificant effect from inflation below 15%, however, is a new result. Maybe surprisingly, it is not inconsistent with our model. This empirical result simply suggests that the negative effects of inflation on efficiency in production, which are central in our model, may be inexistent at low rates. Considering that many studies find no significant negative effect of inflation on efficiency and growth when inflation is below 15% (see footnote 14), this is exactly what one should expect.

Additional linear spline regressions (not shown, but available upon request) confirm these results. For example, when we specify breakpoints at inflation rates of 5%, 10%, 15%, 50% and 100%, the GMM system estimator with time dummies reveals insignificant inflation effects on human capital as long as inflation remains below 15%. The slopes of the first two segments (0-5% and 5-10%) are positive, the slope of the third segment (10-15%) is negative. Between 15% and 50%, as well as between 50% and 100%, the effects of rising inflation are positive and significant. Over and above 100%, the effect of inflation is again totally insignificant. The net effect on human capital of going from 0 to 100% of inflation is estimated to be 0.45 years of schooling.

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[14] See e.g., Sarel (1996), Barro (1997), Clark (1997), Bruno and Easterly (1998), Ghosh and Phillips (1998), Judson and Orphanides (1999). Estimating the effect of inflation on growth, most of these studies control for physical capital investment. Some control for the initial stock of human capital.

Table 3. Inflation and human capital: alternative inflation measures [a,d]

	One-step estimates with heteroskedasticity consistent standard errors			
Variable	(GMM-diff)	(GMM-system)	(GMM-diff)	(GMM-system)
H_{t-5}	0.684 (3.32)	0.789 (10.4)	0.704 (3.60)	0.688 (6.70)
π_{5yt} (with $\pi \leq 15$)	-0.0072 (0.74)	-0.0079 (0.70)	-	-
π_{5yt} (with $15<\pi \leq 100$)	0.0059 (2.11)	0.0048 (1.49)	-	-
π_{5yt} (with $100< \pi$)	-0.0008 (0.36)	-0.0006 (0.25)	-	-
$std\pi_{5yt}$	-	-	0.0028 (2.21)	0.0045 (2.25)
$ln(GE)_{5yt}$	0.196 (0.90)	0.208 (0.88)	0.312 (1.41)	0.650 (1.91)
time dummies	yes	yes	yes	yes
	Two-step GMM estimates			
Variable	(GMM-diff)	(GMM-system)	(GMM-diff)	(GMM-system)
H_{t-5}	0.685 (4.79)	0.765 (15.0)	0.676 (4.40)	0.697 (9.48)
π_{5yt} (with $\pi \leq 15$)	-0.0065 (0.80)	-0.0026 (0.33)	-	-
π_{5yt} (with $15<\pi \leq 100$)	0.0067 (6.26)	0.0051 (7.03)	-	-
π_{5yt} (with $100< \pi$)	-0.0018 (1.03)	-0.0007 (0.49)	-	-
$std\pi_{5yt}$	-	-	0.0025 (2.19)	0.0042 (2.84)
$ln(GE)_{5yt}$	0.202 (1.23)	0.265 (2.10)	0.355 (1.95)	0.557 (2.67)
time dummies	yes	yes	yes	yes
N. Obs. (countries)	321 (93)	414 (93)	321 (93)	414 (93)
Sargan (p-value) [(b)] (df)	0.544 18	0.795 22	0.841 12	0.896 16
Test for first order serial correlation (p-value) [(c)]	0.000	0.000	0.000	0.000
Test second order serial correlation (p-value) [(c)]	0.925	0.958	0.964	0.914
Inflation at top of inverted U-shape	100%	100%	-	-
Effect on H when inflation goes from 0 to 100%	+0.48	+0.39	-	-

Notes: [a] Absolute t-statistics in parentheses; [b] Sargan is Sargan test of overidentifying restrictions. The null hypothesis is that the overidentifying restrictions are correct; [c] The null hypothesis is that there is no first (second) order serial correlation in the error term; [d] Data sources: see Appendix 1.

A second pair of regressions in Table 3 re-estimate Equation (14) with the standard deviation of inflation over the preceding period of five years ($st\pi_{5yt}$) as an explanatory variable, rather than average inflation (π_{5yt}). To the extent that the main effects of inflation are related to uncertainty, the variability of inflation may be a better variable to include in the regression. Including $st\pi_{5yt}$ as well as its square led to highly insignificant results for both. Dropping the squared standard deviation as an explanatory variable, makes $st\pi_{5yt}$ statistically significant at less than 5%. In line with the previous results, it has a positive sign. Finally, including both average inflation and its standard deviation as explanatory variables makes the latter totally insignificant. Most likely, this is due to multicollinearity. Correlation between π and $st\pi$ exceeds 0.8. We can conclude that when we assess the effects of inflation on human capital by including the standard deviation of inflation, the inverted U-shape may not survive. The positive effects from higher inflation (inflation variability) do, however. As to the estimated effect of government education spending in Table 3, we observe that this is always positive. In three regressions (two-step estimates) it is also statistically significant.

The results in Table 4 involve a change in the dependent variable. Rather than average years of schooling, H_t is now defined as the percentage of the population of age 15 and older that attained secondary or higher education. Education at these levels does not have to be completed. The data are from Barro and Lee (2000). Underlying the use of this alternative variable is Barro's (1999) result that in growth regressions only schooling at the secondary and higher level occurs to be significant. To successfully absorb and develop new technologies, which are important for growth, (at least) education at the secondary level seems necessary. As can be seen, the results with this alternative dependent variable confirm the previous ones. The estimated coefficient for π is again positive and significant (at 8% or better), the estimated coefficient for π^2 is again negative. Its statistical significance is a little weaker. The calculated top of the inverted U-shape is comparable to the results in Table 2[15].

A final robustness check is presented in Table 5. Using data at an interval of five years - as we have done until now - has the obvious advantage that more data points are available. There may also be a cost, however. When one considers shorter periods, it may become harder for the estimated coefficients to pick up the long-run effects that we are interested in. A factor reinforcing this problem is that data averages over five years only, e.g. for inflation, are more vulnerable to business cycle effects or other temporary disturbances (Temple, 2000). In Table 5 we use data with a longer time interval. The underlying specification is:

$$H_{i,t} = a_0 + a_{11} H_{i,t-10} + a_2 \pi_{i,dect} + a_3 \pi^2{}_{i,dect} + a_4 \, ln(GE)_{i,dect} + \alpha_i + \lambda_t + \varepsilon_{it} \qquad (15)$$

Lagged human capital now refers to *t-10*. In line with this, the explanatory variables GE_{dect} and π_{dect} are averages over the decade from *t-10* to *t-1* (see Appendix 1 for details). Data are available for most countries for t = 1980, 1990 and 2000. Equation (15) is estimated with the first-difference GMM method, as well as with the GMM system estimator. Note also that we include two alternative variables for the human capital stock: average years of schooling and the percentage of the population with secondary or higher education.

[15] For a proper comparison of the estimated coefficients in Table 4 with those in previous tables, note that the percentage of the population with secondary or higher education varies from about 1 to 90 (percent). This range is much wider than for average years of schooling, which varies from about 0.5 to almost 12 (years).

Table 4. Estimation results for Equation (14), alternative dependent variable [a,d]

	One-step estimates with heteroskedasticity consistent standard errors		
Variable	(GMM-diff)		(GMM-system)
H_{t-5}	0.610 (3.57)		0.771 (6.75)
π_{5yt}	0.0773 (1.78)		0.0736 (1.79)
π^2_{5yt}	-0.00025 (1.63)		-0.00022 (1.54)
$ln(GE)_{5yt}$	3.705 (1.44)		4.748 (2.11)
time dummies	yes		yes
	Two-step GMM estimates		
Variable	(GMM-diff)		(GMM-system)
H_{t-5}	0.654 (6.31)		0.762 (9.73)
π_{5yt}	0.0564 (1.73)		0.0635 (2.21)
π^2_{5yt}	-0.000164 (1.47)		-0.000182 (1.83)
$ln(GE)_{5yt}$	2.253 (1.24)		2.592 (2.12)
time dummies	yes		yes
N. Obs. (countries)	321 (93)		414 (93)
Sargan (p-value) [(b)] (df)	0.351 15		0.330 19
Test for first order serial correlation (p-value) [(c)]	0.001		0.000
Test second order serial correlation (p-value) [(c)]	0.866		0.941
Inflation at top of inverted U-shape	172%		174%
Effect on *H* when inflation goes from 0 to 100%	+4.00		+4.53

Notes: [a] Absolute t-statistics in parentheses; [b] Sargan is Sargan test of overidentifying restrictions. The null hypothesis is that the overidentifying restrictions are correct; [c] The null hypothesis is that there is no first (second) order serial correlation in the error term; [d] The dependent variable H_t in these regressions is the percentage of the population with secondary or higher education.

The new results in Table 5 broadly confirm the previous ones. Except for the fourth regression where the Sargan test statistic is problematic, the available specification tests do not show evidence against our empirical approach. Again concentrating on the two-step estimates, we still observe a significant inverted U-shaped relationship between inflation and human capital. Interestingly, the top of this inverted U-shape is now situated at about 90%. This result clearly supports the idea of being cautious about the reported extreme numbers (±165%) in Tables 2 and 4. It would rather suggest 100% to be a representative threshold level. The estimated positive and generally significant effects from government spending on education in Table 5, also confirm our previous findings. As to the estimated coefficients on lagged human capital, we again observe positive coefficients below 1. Not unexpectedly, these are lower than in the case of 5 year data intervals. The estimated coefficients on H_{t-10}

also tend to confirm the need for using the GMM system estimator when highly persistent explanatory variables are included. As shown by Bond (2002), the first-difference GMM estimator may then induce a downward bias, which clearly seems to show up in our results.

Table 5. Estimation results for Equation (15), alternative dependent variables [a, d]

	Average years of schooling		Percentage of population with secondary or higher education	
	One-step estimates with heteroskedasticity consistent standard errors			
Variable	(GMM-diff)	(GMM-system)	(GMM-diff)	(GMM-system)
H_{t-10}	0.168 (1.06)	0.598 (2.65)	0.092 (0.39)	0.608 (3.32)
π_{dect}	0.0168 (1.81)	0.0245 (1.15)	0.360 (2.18)	0.310 (1.80)
π^2_{dect}	-0.000097 (1.60)	-0.000138 (1.07)	-0.0022 (2.06)	-0.0018 (1.69)
$ln(GE)_{dect}$	0.660 (2.17)	0.863 (1.14)	12.09 (1.85)	9.041 (1.80)
time dummies	yes	yes	yes	yes
	Two-step GMM estimates			
Variable	(GMM-diff)	(GMM-system)	(GMM-diff)	(GMM-system)
H_{t-10}	0.218 (1.53)	0.403 (2.65)	0.209 (1.03)	0.660 (5.61)
π_{dect}	0.0187 (2.12)	0.0335 (2.50)	0.347 (2.16)	0.315 (2.85)
π^2_{dect}	-0.000105 (1.79)	-0.000186 (2.16)	-0.00203 (1.94)	-0.00177 (2.48)
$ln(GE)_{dect}$	0.622 (2.18)	1.235 (2.69)	10.55 (1.68)	7.700 (2.61)
time dummies	yes	yes	yes	yes
N. Obs. (countries)	155 (84)	239 (84)	155 (84)	239 (84)
Sargan (p-value) [(b)] (df)	0.253 5	0.110 7	0.372 5	0.028 7
Test for first order serial correlation (p-value) [(c)]	0.005	0.006	0.019	0.002
Inflation at top of inverted U-shape	89%	90%	85%	89%
Effect on *H* when inflation goes from 0 to 100%	+0.82	+1.49	+14.4	+13.8

Notes: [a] Absolute t-statistics in parentheses; [b] Sargan is Sargan test of overidentifying restrictions. The null hypothesis is that the overidentifying restrictions are correct; [c] The null hypothesis is that there is no first order serial correlation in the error term. Note that, in contrast to previous tables, testing for second order serial correlation is not possible here due to insufficient data along the time dimension; [d] Data sources: see Appendix 1.

4. Conclusions and implications

This paper analyses the effects of inflation on human capital formation. Our empirical results reveal that rising inflation basically stimulates human capital. A negative effect can be observed only at very high inflation rates. A representative threshold may be 100%. For inflation rates below 15%, the effect of rising inflation on human capital seems to be insignificant. With respect to other determinants of investment in human capital, our results point to a significant positive role for government spending on education.

Our results for the effects of inflation are surprising when confronted with existing theory. Monetary growth models with endogenous human capital all tend to predict either neutral or negative inflation effects on human capital. At best, therefore, these models seem to be relevant to explain the effects of very high inflation. In this paper, we develop an alternative theoretical model that can explain positive effects of inflation. Instead of explicitly including money growth and inflation, our model builds on standard results from the literature on the real effects of inflation. Well-known arguments are that inflation (i) may undermine the efficient allocation and the productivity of factors in goods production, (ii) may raise the real cost of physical capital because of shortcomings in the tax system and (iii) may cause uncertainty about future real costs and revenues in goods production. Due to these effects, inflation may stimulate human capital by making alternative activities like working and investing in physical capital less attractive. Our approach can also rationalize the observed insignificance for human capital of inflation below 15%. Many empirical studies indeed find no significant negative effect of low inflation on factor productivity in goods production.

What are the implications of our results? Do they provide an argument in favor of high inflation? Clearly not. Our results do not overthrow the conclusion in most empirical studies that the (net) effects of inflation on growth are negative once inflation rises above 10 to 15%. Moreover, as suggested by our theoretical model, the positive effects from inflation on human capital only show up when inflation is expected not to persist over generations. Our empirical results do justify, however, a more balanced view on the effects of inflation. We find that if inflation were to rise - extremely - from 0 to 100%, this might over a period of 5 years raise average school attainment among the population of 15 and older by up to approximately 0.40 years. Given Barro's (1999, p. 257-258) result that, on impact, an extra year of (male secondary and higher) schooling increases the subsequent per capita economic growth rate by 0.7 percentage points per year, the positive growth effect caused by inflation via human capital formation might well prove to be significant. Simple calculation would predict a positive annual growth effect of about 0.28 percentage points (all other things equal). As is well known, the long-run effects of such changes in annual growth rates on income levels are sizeable[16]. By limiting the discussion about inflation to consequences for physical capital, one may miss an important part of reality.

[16] Obviously, there are reasons for being cautious about these calculations. First, Barro's results rely on secondary and higher years of male schooling only. Ours also include primary schooling and females (total population). As we have briefly touched upon in Section 2, one may expect the effect of primary schooling on growth to be lower. Second, when Barro also includes data on test scores in his regressions, as a measure of education quality, the estimated effect of an extra year of male schooling on annual growth falls to 0.35 percentage points. It remains significant though.

Appendix 1. Data sources and calculations

H_t: average years of total schooling for the population of age 15 and older (Tables 1-3 and 5) or percentage of the population of age 15 and older that attained secondary or higher education (Tables 4-5). These data have been taken or calculated from Barro and Lee (2000).

π_{5yt} (π_{dect}) : average annual consumer price inflation in the period of five years (decade) before t. Annual inflation has been calculated as the change in the natural logarithm of the consumer price index, taken from the World Bank (2001). For very few countries, inflation data have been derived from the GDP deflator, also available from the World Bank (2001). Details are available from the authors.

$st\pi_{5yt}$: standard deviation of annual consumer price inflation in the period of five years before t.

GE_{5yt} (GE_{dect}) : average annual real per capita government spending on education in the period of five years (decade) before t. Government spending on education in percent of GNP has been drawn from the online UNESCO database, now available on http://www.uis.unesco.org/i_pages/IndPGNP.asp. The earliest available UNESCO data concern 1970. Average percentages over a period of five years (decade) have been calculated on the basis of all available annual data for that period. Data for real GDP per capita (in constant US dollar, 1985 international prices) have been taken from the Penn World Table (PWT 5.6, RGDPCH). For most countries, these data are available up to 1992. Again, the average for a period of five years (decade) has been calculated on the basis of all annual data available. The data for *GE* were obtained by multiplying the average for real GDP per capita in US dollar and the average percentage of GNP going into government spending on education.

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