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WORKING PAPER

Inflation, human capital and long-run growth

- an empirical analysis - *

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October 2001

2001/116

* Paper presented at the *V.V.E.-Dag voor het Wetenschappelijk Economisch Onderzoek in Vlaanderen* (LUC, Diepenbeek, 10 October 2001). An earlier version of this paper was presented at the *Money, Macro and Finance Research Group 2001 Conference* (Queen's University, Belfast, 5-7 September 2001).
** We are grateful to Dirk Van de gaer, Gerdie Everaert, Gert Peersman and Glenn Rayp for most helpful comments and to Ferre De Graeve for excellent research assistance. Any remaining errors are ours.
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D/2001/7012/17

Abstract

This paper investigates the effects of inflation on human capital formation in 89 countries in 1970-2000. Considering that human capital is often observed to be important for long-run economic growth, we highlight in this way an inflation effect on growth that has hardly received attention in the literature. Most of our empirical results point to the existence of a hump shaped relationship, with rising inflation stimulating human capital as long as inflation remains limited to rates below about 90 or 100%. Beyond this high threshold, we generally find that increasing inflation undermines human capital. These findings survive several robustness tests, although in some regressions the positive effect of inflation is insignificant for inflation rates below 20 or 25%. The second part of the paper explains our results. A basic idea is that inflation stimulates skill acquisition because it makes alternative activities like working and investing in physical capital less attractive. As to other determinants of investment in human capital, our results point to the crucial role of government spending on education. Further, we find evidence in favour of the popular hypothesis that inequality undermines human capital formation and growth.

JEL Classification: E31, J24, O40

Keywords: Human capital, inflation, uncertainty, economic growth

1. Introduction

Since the early 1980s achieving very low and stable inflation has become the primary goal of monetary policy makers in OECD economies, especially in Europe. To some extent this is surprising. First of all, there is no unambiguous theoretical justification for this policy (Orphanides and Solow, 1990; Temple, 2000). Second, among the many empirical studies that have recently tried to assess the effects of inflation on economic growth, a general agreement has only emerged that high inflation is bad for growth. For low inflation rates, say inflation rates below 10 or 15%, there is no such consensus, on the contrary. In most studies low inflation exerts no robust negative effect on growth (see e.g. Sarel, 1996; Barro, 1997; Clark, 1997; Bruno and Easterly, 1998; Gosh and Phillips, 1998; Judson and Orphanides, 1999)[1] After an extensive survey of the literature, Temple (2000, p. 420) concludes that "any case for price stability which relies on a positive growth effect should continue to be regarded with considerable scepticism". Among recent studies, only Andrés and Hernando (1999) and - arguably - Bassanini et al. (2001) suggest otherwise.

This paper is motivated by a double observation. The first relates to the importance of investment in human capital for growth. Although there are dissonant voices (e.g. Islam, 1995; Caselli et al., 1996; Klenow and Rodríguez-Clare, 1997; Kalaitzidakis et al., 2001), most authors seem convinced that having or accumulating more human capital, especially at the secondary and tertiary level, contributes positively towards raising per capita income growth (e.g. Mankiw et al., 1992; Levine and Renelt, 1992; Benhabib and Spiegel, 1994; Engelbrecht, 1997; Barro, 1999; de la Fuente and Doménech, 2000; Bassanini and Scarpetta, 2001; Castelló and Doménech, 2001). The second observation is that existing work on the effects of inflation on capital formation almost exclusively concerns physical capital. Theoretically, it seems to be taken for granted that these effects also apply to investment in education and training. Remarkably, Temple's (2000) survey contains only 11 lines relating to human capital. Empirically, we know of no study trying to estimate the long-run effects of inflation on human capital. Our main goal is to fill (part of) this gap.

The remainder of the paper proceeds as follows. In section 2 we analyse the empirical relationship between inflation and human capital. Our results point to the existence of a hump shaped relationship with rising inflation stimulating human capital as long as inflation remains below 90 or 100%. Beyond this high threshold most of our regressions reveal a negative effect from increasing inflation. Further, we find that for inflation below 20 or 25%, positive effects on human capital may be insignificant. Section 3 offers an intuitive theoretical explanation for these findings, building on the Lucas (1988) model of human capital and growth. Section 4 concludes and discusses the implications of our results.

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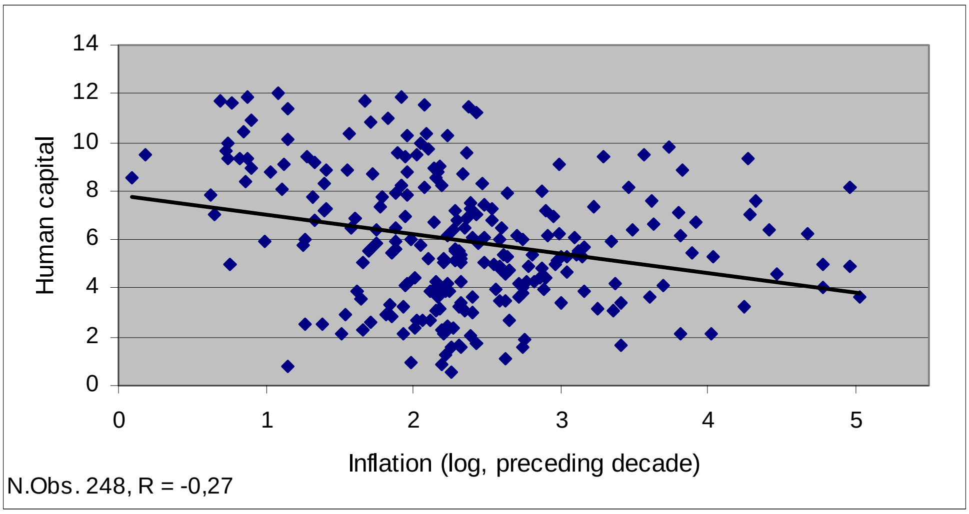
[1] For correctness, it should be mentioned that most of these studies investigate the effect of inflation in growth regressions controlling for physical capital accumulation. Sarel (1996) is an exception. Consequently, the estimated coefficient for inflation in these studies only captures effects on productivity and not on physical capital formation. Does this lead to an underestimation? Not necessarily. Considering Barro's (1997) result that the effect of moderate inflation on fixed investment is also insignificant, there is no need to change conclusions.

2. Inflation and human capital formation : the empirical relationship

Existing work on the effects of inflation on capital formation hardly considers investment in human capital. Everyone seems to assume that the expected (and often observed) negative effects of inflation on physical capital also apply to human capital. To be honest, figure 1 tends to justify this approach. This figure relates 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. The human capital stock is measured as Barro and Lee's (2000) average years of total schooling in the population of 15 and older. As can be seen, a negative relationship shows up. Correlation is –0,27. Limiting the sample to observations with an inflation rate below 20% generates a correlation of even –0,40.

Figure 1. Inflation and human capital in 89 countries in 1980, 1990 and 2000



Data sources : Human capital: Barro and Lee (2000); inflation: World Bank (2001). For further details, see appendix 1.

Figure 1 notwithstanding, this section will challenge the view that physical and human capital are equal with respect to inflation. More precisely, we present econometric results indicating that - except for low and for extreme inflation - rising inflation stimulates human capital. Underlying our empirical work is the simple idea that a person's human capital rises to the extent that time is invested in studying. If we proxy human capital by total years of schooling, it follows that $H_{t+1} - H_t = e_t$, with e_t the fraction of the year t invested in education and H_t the human capital stock at the beginning of the year. In what follows we hypothesize that average per capita investment of time in education (e_t) is mainly influenced by three variables: per capita government spending on education during t, inequality in human capital at the beginning of t and inflation during t. Higher government spending on education, i.e. more and better teachers, better books, etc., should raise the productivity of schooling and make investment in education more attractive. For human capital inequality, we expect a negative effect. A standard argument is that inequality in human capital implies inequality in income and wealth. Assuming credit market imperfections, many talented but poor individuals may then be unable to invest in human capital, implying a lower future average human capital stock in the country (Galor and Zeira, 1993; Castelló and Doménech, 2001). Another explanation may be that (high) inequality in human capital raises people's assessment of the risks involved in schooling. Not only are many successful, many also seem to drop out and fail. This risk may make schooling less attractive. Finally, investment in education is affected by inflation. As we shall see in the next section, theoretically there are reasons to expect a 'hump shaped' pattern. In this section we concentrate on the empirical relationship.

Equation (1) puts our hypotheses into a workable econometric framework. In this equation $H_{i,t} - H_{i,t-10}$ stands for the change in the human capital stock in country i between years t and t-10. The human capital stock is - like in figure 1 - defined as the average number of years of total schooling for the population of 15 and older. The years t that we consider are 1980, 1990 and 2000, the maximum number of countries is 89[2].

$$H_{i,t} - H_{i,t-10} = a_0 + a_1 H_{i,t-10} + a_2 \pi_{i,dect} + a_3 \pi^2{}_{i,dect} + a_4\, ln(GE)_{i,dect} + a_5\, ln(HINEQ)_{i,dect} \\ + time \cdot dummies + regional \cdot dummies + country \cdot dummies + \varepsilon_{it} \quad (1)$$

Explanatory variables are average annual consumer price inflation in the decade from t-10 to t-1 ($\pi_{i,dect}$), the square of average annual inflation, the log of average annual real per capita government spending on education in that same decade ($lnGE_{i,dect}$) and the log of human capital inequality in that decade ($lnHINEQ_{i,dect}$)[3]. For $HINEQ$ we use Castelló and Doménech's (2001) human capital Gini coefficient for the population of 15 and older. In line with our hypotheses it is expected that a_2 and a_4 are positive and a_3 and a_5 negative. Further, time dummies are included to capture time specific effects for the 1970s and the 1980s, common to all countries. Regional and country dummies pick up the fixed effects from all other regional and country specific determinants of human capital. Regional dummies are considered for Latin America, Sub-Saharan Africa, South Asia, East Asia and the Pacific, North America (i.e. the US and Canada), Scandinavia, OECD Europe and the European economies currently in transition. Finally, we also include $H_{i,t-10}$ at the RHS of equation (1). We expect a_1 to have a negative sign, mainly reflecting the idea that adding new years of schooling becomes more difficult the higher the number of years one already has accumulated. The simple fact that the supply of formal education is limited in practice, explains this. Further, one would expect a_1 to be negative if there were diminishing returns to investment in education. Skill acquisition would then gradually become less interesting.

Table 1, part (a), summarises our main empirical results. For data sources and methods we refer to the notes below this table and to appendix 1. We have estimated equation (1) for total population of 15 and older, as well as for females and males separately. The results support our hypotheses. First, we find in each regression that a sustained increase in per capita government spending on education (GE) has a very significant and positive effect on the average years of schooling of the population. Second, the results for human capital inequality

[2] The numbers of countries i and years t are limited by data availability for inflation and government spending on education (see appendix 1 for details).

[3] The logarithmic specification for GE reflects the idea of decreasing returns. Estimating equation (1) with $HINEQ$ instead of $lnHINEQ$ has only minor effects on our main results. With the logarithmic specification, the results are slightly better.

support the hypothesis that inequality undermines schooling. *HINEQ* obtains a significant negative coefficient in each regression, confirming the result of Castelló and Doménech (2001). Third, we observe the expected negative coefficient on H_{t-10}. Fourth, and most important, rising inflation tends to stimulate human capital formation as long as inflation is not very high. The expected hump shaped relationship clearly shows up in our regressions, especially those for total population and for females. In these regressions the estimated coefficient for π is positive, the estimated coefficient for π^2 negative. Both are highly significant. As indicated at the bottom of table 1, the top of the hump shape is situated at inflation rates of about 90%. Further, going from zero to this "top" inflation rate raises the human capital stock by 0,53 years of schooling for total population and 0,75 years for females (all other things equal). We discuss the implications of these results in section 4.

Our results for males are somewhat less clear-cut. Estimation of our basic equation (1) yields coefficients for π and π^2 with the expected signs, but highly insignificant (see regression 3). Regressions (4) and (5) generate more precise estimates. Both allow for interaction between inflation and initial (male) human capital. Regression (5) also includes a dummy to "explain" the male human capital stock in Brazil in t=2000. Dealing with this outlying observation strongly reduces estimated standard errors for some of the coefficients related to inflation. The additional regressions confirm the hump shaped relationship, but suggest that this may be stronger in countries with lower initial male human capital. Both the positive effect of inflation below the top of the hump shape and the negative effect over the top seem to be stronger in the poorest countries, i.e. countries with the lowest initial human capital[4]. As shown at the bottom of the table, the top itself is (again) situated at inflation rates between about 80% and 100%. Note that going from zero to "top" inflation has a much stronger effect on male human capital in the countries with the worst initial position. Superscript (d) is relevant for these countries. Superscript (c) concerns the median country.

Table 1(b), tables 2-4 and appendix 2 investigate the robustness of our results. Basically, we perform five tests. These concern another methodology, another dependent variable, two alternative approaches to capture the effects of inflation (and the hump shaped relationship) and changes in the dataset. Appendix 2 deals with a methodological problem. The fact that we include country dummies in equation (1) makes our pooled OLS estimator equivalent to the fixed effects estimator for panel data. As is well known, this estimator is biased and inconsistent when a lagged dependent variable is included among the explanatory variables (see e.g. Verbeek, 2000). To solve this problem an instrumental variables approach is required. However, often this solution implies a loss of efficiency in estimation because information is lost when additional lags in the dependent variable are used as instruments. In appendix 2 we show that the inconsistency problem of the OLS estimator in our sample is small. A Hausman test reveals no significant difference between the OLS and IV estimators. Moreover, and more specifically, using the IV estimator does not affect the relationship between inflation and human capital. A very significant hump shape remains. Relying on the result that there is no significant difference between both estimators and for efficiency reasons,

[4] Further regressions reveal that this interaction effect also exists for total and for female population. However, taking it into account is not crucial here. It does not affect the hump shaped relationship between π and *H*.

Table 1.

Dependent variable: (a) Change in average years of schooling

(b) Change in % of the population with secondary or higher education.

	(a)					(b)
	Total population (1)	Female population (2)	Male population (3)	(4)	(5)	Total population (6)
Constant	0,245 (1,20)	-0,326 (1,46)	2,184*** (5,73)	1,390*** (3,89)	1,321*** (3,69)	-0,430 (0,18)
H_{t-10}	-0,726*** (6,95)	-0,680*** (5,81)	-0,782*** (7,90)	-0,741*** (7,52)	-0,729*** (7,39)	-0,610*** (6,10)
π_{dect}	0,0121*** (2,81)	0,0170*** (3,59)	0,0040 (0,88)	0,0206* (1,91)	0,0251** (2,46)	0,1119*** (2,67)
π^2_{dect} (divided by 10^5)	-6,81** (2,24)	-9,67*** (3,08)	-1,69 (0,50)	-11,20 (1,22)	-15,80** (2,05)	-77,0** (2,35)
$\pi_{dect} .H_{t-10}$	-	-	-	-0,0029 (1,55)	-0,0035* (1,92)	-
$\pi^2_{dect} .H_{t-10}$ (divided by 10^5)	-	-	-	1,620 (1,01)	2,140 (1,46)	-
$ln(GE)_{dect}$	0,598*** (8,21)	0,536*** (7,23)	0,404*** (6,11)	0,469*** (6,84)	0,471*** (6,86)	4,338*** (5,13)
$ln(HINEQ)_{dect}$	-0,890*** (3,24)	-0,915*** (2,76)	-0,946*** (3,27)	-0,733** (2,56)	-0,697** (2,43)	-8,023*** (4,47)
Time dummy 1970s	-0,593*** (4,15)	-0,612*** (3,73)	-0,652*** (4,89)	-0,635*** (4,69)	-0,616*** (4,54)	-3,248** (2,06)
Time dummy 1980s	-0,336*** (3,71)	-0,344*** (3,56)	-0,351*** (4,14)	-0,347*** (4,00)	-0,325*** (3,71)	-2,088** (2,19)
Regional dummies						
North America	2,52***	2,93***	2,54***	2,95***	2,95***	10,4**
Scandinavia	1,73***	1,82 ***	1,74***	1,73***	1,72**	11,7***
OECD Europe	-	0,48**	-	0,43**	0,43**	-6,60***
Eur. Ec. in Trans.	1,51***	1,63***	1,47***	2,17***	2,20***	-
East Asia	0,50***	0,75***	-	0,65***	0,65***	-3,65**
South Asia	-	-	-0,96***	-0,46**	-0,46**	-
Latin America	0,42***	0,99***	-	0,52**	0,53**	-5,94***
Subsahara	-	-	-0,48***	-	-	-6,24***
Country dummies	yes	yes	yes	yes	yes	yes
Dummy Brazil 2000	-	-	-	-	1,07***	-
Adjusted R^2	0,457	0,476	0,493	0,490	0,494	0,480
S.E. of regression	0,479	0,475	0,502	0,503	0,501	5,139
N.obs	246	246	246	246	246	247
Inflation at hump shape top	89%	88%	118%	102%[(c)] 92%[(d)]	77%[(c)] 80%[(d)]	73%
Maximum effect of inflation on H	+0,53	+0,75	+0,24	+0,29[(c)] +0,90[(d)]	+0,27[(c)] +0,95[(d)]	+4,1

Notes: The estimation method is pooled OLS. Absolute t-values based on White heteroscedasticity-consistent standard errors in parentheses. *** (**) (*) indicates statistical significance at the 1% (5%) (10%) level. Regional dummies are included in an equation if they are significant at 10% or better. To save space, we do not report estimated t-values for these dummies. Country dummies are included if they are significant at the 5% level or better. Note that we have applied these rules to each equation separately. [(c)] computed at median $H_{t-10} = 5{,}22$; [(d)] computed at minimum $H_{t-10} = 0{,}35$. Data sources: see appendix 1.

e.g. the fact we can continue to use information related to the (for inflation) interesting 1970s, we will further stick to pooled OLS.

A second robustness test involves a change in the dependent variable. In table 1(b) this is defined as the change over a decade in the percentage of the population of 15 and older that attained secondary or higher education. Education at these levels need not have been 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 shows up significant. To successfully absorb and develop new technologies, which are important for growth, education of at least the secondary level seems to be necessary. Mankiw (1997) makes the same argument. As can be seen, the results with this alternative dependent variable fully confirm those in part (a). The top of the hump shaped relationship in this regression is situated at a somewhat lower inflation rate of 73%.

Underlying the estimated equations in table 2 is a first alternative approach to capture the hump shape. We have specified several dummies (D) which are expected to mirror the effects of inflation in seven ranges: inflation rates between 5% and 10% (86 observations), between 10% and 20% (72 observations), between 10% and 25% (82 observations), between 20% and 50% (31 observations), between 25% and 50% (21 observations), between 50% and 100% (9 observations) and between 100% and 175% (6 observations). The benchmark, for which no dummy is included, are inflation rates below 5% (42 observations)[5]. Considering the results, it is clear that the hump shaped relationship between inflation and human capital survives. Moving from the lowest to the highest inflation ranges, the estimated coefficients for the dummies in table 2 rise as long as inflation remains below 100%. Beyond 100% estimated coefficients return to much lower levels. Moreover, in each regression the estimated dummy for inflation between 50% and 100% is highly significant. In the better regressions for total population we also observe highly significant dummies for inflation between 25% and 50% (regression 3) and between 20% and 50% (regression 5). Another striking result in table 2 is the insignificance in every regression of the effect of inflation below 20%. For males we are even unable to find significant effects below 50%. Additional, unreported regressions reveal a threshold for males at about 35% to 40%. Concluding from tables 1 and 2, rising inflation seems to stimulate human capital, except when inflation is extreme (negative effects) and when it is below 20 or 25% (insignificant positive effects). For males it seems that somewhat higher inflation rates are required for significant positive effects to show up.

The fact that relatively little observations are available in the very high inflation ranges, may make our results vulnerable to the influence of outliers. Two further robustness tests, implying changes in the dataset, try to deal with this problem. First, table 3 presents the estimated coefficients for the inflation variables when we re-estimate the first regression in table 1, but gradually drop the observations with the highest inflation rates. In each of these additional regressions, a_2 and a_3 keep their expected sign. Moreover, with one exception they are statistically significant at 10% or better. The exception occurs for a_3 when the observation with the highest inflation rate is dropped (t-value 1,59). Unsurprisingly, as soon as all observa-

[5] Ideally, these ranges are defined to obtain an even distribution of observations. However, given the relatively small number of observations above 50%,the higher inflation ranges would then have to be too wide to be useful.

Table 2.

Dependent variable: (a) Change in average years of schooling
(b) Change in % of the population with secondary or higher education.

	(a)				(b)
	Total population			Males	Total population
	(1)	(2)	(3)	(4)	(5)
Constant	0,387* (1,67)	0,399* (1,86)	0,355* (1,71)	2,183*** (5,79)	1,246 (0,47)
H_{t-10}	-0,717*** (6,89)	-0,714*** (6,78)	-0,724*** (6,79)	-0,776*** (7,87)	-0,620*** (6,14)
$D(0{,}05<\pi<0{,}1)$	0,001 (0,01)	-	-	-	0,921 (0,89)
$D(0{,}1\leq\pi<0{,}20)$	0,096 (0,85)	0,095 (1,18)	-	0,053 (0,56)	1,396 (1,21)
$D(0{,}1\leq\pi<0{,}25)$	-	-	0,073 (0,95)	-	-
$D(0{,}20\leq\pi<0{,}5)$	0,137 (1,05)	0,144 (1,30)	-	0,002 (0,02)	3,912*** (2,91)
$D(0{,}25\leq\pi<0{,}5)$	-	-	0,341*** (2,58)	-	-
$D(0{,}5\leq\pi<1)$	0,509*** (3,02)	0,514*** (3,47)	0,542*** (3,83)	0,376** (2,14)	6,562*** (3,79)
$D(1\leq\pi<1{,}75)$	0,161 (0,78)	0,165 (0,83)	0,224 (1,05)	0,060 (0,25)	1,355 (0,58)
$ln(GE)_{dect}$	0,575*** (7,88)	0,566*** (7,78)	0,579*** (7,97)	0,411*** (6,23)	3,960*** (5,07)
$ln(HINEQ)_{dect}$	-0,860*** (3,08)	-0,857*** (3,04)	-0,886*** (3,15)	-0,901*** (3,07)	-6,715*** (4,49)
Time dummy 1970s	yes	yes	yes	yes	yes
Time dummy 1980s	yes	yes	yes	yes	yes
Regional dummies	yes	yes	yes	yes	yes
Country dummies	yes	yes	yes	yes	yes
Adjusted R²	0,452	0,452	0,459	0,493	0,472
S.E. of regression	0,481	0,482	0,479	0,502	5,179
N.obs	246	246	246	246	247

Notes: see table 1. The estimation results for the time, regional and country dummies are highly similar to the ones presented in table 1. Details are available from the authors upon request.

Table 3.

Estimated coefficients for the inflation variables
Dependent variable: Change in average years of schooling, total population

	π<150%	π<145%	π<140%	π<120%	π<110%		π<100%
π_{dect}	0,0108** (2,45)	0,0124** (2,54)	0,0142*** (2,72)	0,0151*** (2,78)	0,0198*** (3,02)		0,0093*** (3,83)
π^2_{dect} *(divided by 10^5)*	-5,090 (1,59)	-7,130* (1,80)	-9,450** (2,12)	-10,80** (2,16)	-17,40** (2,43)		-
N. obs.	245	244	243	242	241		240

Notes: see table 1.

vations with an inflation rate above 100% are excluded, squared inflation becomes totally insignificant. We have therefore dropped this variable in the last regression. Note that the coefficient on inflation remains positive and very significant.

Although the results in table 3 confirm the hump shaped relationship, the limited number of observations in the highest inflation ranges leaves us in an uncomfortable position. This brings us to table 4. Underlying the regression in the upper part of this table are data with a shorter time interval. The dependent variable is the change in human capital measured over five years, with t=1975, 1980, 1985, 1990 and 1995 respectively. Lagged human capital now refers to t-5. In line with this, the explanatory variables *GE* and π are averages over the preceding period of five years. The main advantage of this change is that more data points are available. To be exact, there are 423 observations spread over 95 countries. Among these observations, inflation exceeds 20% in 81 cases, 50% in 27 cases and 100% in 11 cases. The cost of turning to 5-year intervals may also be significant, however. Using averages over only five years, e.g. for inflation, our data will be much more vulnerable to business cycle effects or other temporary disturbances. As a consequence, and because shorter periods are considered, it may become harder for the estimated coefficients to pick up the long-term effects that we are interested in. The main victim of this seems to be human capital inequality. The estimated absolute t-values for *lnHINEQ* never exceed 1. This variable has therefore been dropped from the regression. For most of the other variables, our earlier results tend to be confirmed again. For inflation, a significant positive effect on human capital remains. Note, however, that the negative coefficient on squared inflation is no longer significant[6].

Table 4.

Dependent variable: Change in average years of schooling

Total population, data at 5-year intervals	*R²(adj)*	*N.obs*
$H_{i,t} - H_{i,t-5} = 0,09 - 0,141\, H_{i,t-5} + 0,0041\, \pi_{i,5yt} - 0,887\, \pi^2_{i,5yt}/10^5 + 0,223\, \ln(GE)_{i,5yt}$ (0,82) (6,39) (2,35) (1,26) (6,12) $- 0,143\, TimeD_{70-I} - 0,186\, TimeD_{80-I}$ + regional dumm. + country dumm. (2,67) (4,08)	0,205	423
Total population, data at 10-year intervals	*R²(adj)*	*N.obs*
$H_{i,t} - H_{i,t-10} = 0,93 - 0,784\, H_{i,t-10} + 0,0113\, st\pi_{i,dect} - 5,360\, (st\pi)^2_{i,dect}/10^5 + 0,520\, \ln(GE)_{i,dect}$ (3,01) (6,60) (1,70) (1,15) (7,19) $- 0,797\, \ln(HINEQ)_{i,dect} - 0,714\, TimeD_{70} - 0,380\, TimeD_{80}$ + regional dumm. (2,31) (4,35) (3,94) + country dumm.	0,473	246

<u>Notes</u> : see table 1. $TimeD_{70-I}$ and $TimeD_{80-I}$ are time dummies equal to 1 in the periods 1970-74 and 1980-84 respectively. Time dummies for the second part of both decades have been tested also, but showed up highly insignificant. We have therefore dropped them from the final (reported) regression.

[6] The insignificance of π^2 is not a robust result however. Allowing country dummies in the regression that are significant at 6,5% or better (rather than 5% or better) changes the coefficient on π to 0,005 (t-value 3,11) and the coefficient on $\pi^2/10^5$ to –1,38 (t-value -1,91).

As a final robustness check in the lower part of table 4, we have re-estimated the first regression in table 1(a) with the standard deviation of inflation over the preceding decade ($st\pi_{dect}$) as explanatory variable, rather than average inflation (π_{dect}). When it comes to the effects of inflation that are related to uncertainty (see section 3.2.), the variability of inflation may be a better variable to include in the regression. Like in the upper part of the table, we again observe a positive and significant effect from (the variability of) inflation, and a negative but insignificant effect from its square. Although this result is no hard evidence in favour of a hump shaped relationship, it neither rejects it[7].

3. Inflation and human capital formation : a theoretical explanation

The previous section has delivered the clear result that the effects of inflation on human capital differ from those on physical capital. Our results show that rising inflation stimulates human capital as long as inflation remains below 90 or 100%. This positive effect is generally very significant, except for inflation rates below 20 or 25%. For inflation rates higher than 100% most of our regressions reveal a negative effect from increasing inflation. Our aim in this section is to offer an intuitive theoretical explanation for these findings[8]. Our main source of inspiration is the Lucas (1988) model of human capital and growth. Imagine an extension of this model with uncertainty and a role for inflation.

Consider an economy populated by individual household producers. At any time *t* these producers have to decide how to allocate their output (income) between consumption and new physical capital and their time between producing (working) and studying. If a producer decides to study, he will build more human capital which will raise his future output and income. If he goes to work, he will immediately earn income which enables him to consume and to build new physical capital, generating even more income. What are the determinants of the producer's time allocation? And what role is there for inflation?

First of all, it becomes obviously more interesting to study – all other things equal – the higher the expected productivity of schooling and the lower the variance surrounding this productivity. If studying results in a stronger or a less uncertain increase in human capital, education becomes a better investment. This is a well-known result from the literature (see Becker, 1964; Levhari and Weiss, 1974; Williams, 1979; Lucas; 1988; Becker at al., 1990). Second, investment in education may be encouraged if expected total factor productivity in production falls and if the risk and uncertainty surrounding total factor productivity rise. A fall in expected total factor productivity undermines the immediate income from working as well as the productivity of physical capital. As a consequence, it makes two alternative

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[7] Dropping the insignificant $(st\pi)^2$ from the regression implies a coefficient 0,0042 for π (t-value equal to 2,29). 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 0,85.

[8] An intuitive approach is clearly not uncommon in the literature on inflation and growth. Temple (2000) speaks of a literature full of "stories short and tall". In the end, the effect of inflation is mainly an empirical matter. For a more formal approach, see Heylen et al. (2001).

activities to studying less attractive. The opportunity cost of studying will fall[9]. These alternative activities may also become less attractive if the variance of total factor productivity in production rises, making the income from working and the productivity of physical capital subject to more uncertainty. Final determinants of the producer's time allocation are the respective depreciation rates of human and physical capital. The higher the real depreciation rate, the sooner capital wears out and the less attractive it will be to form new capital. Forming new capital will also be discouraged if the uncertainty and risk surrounding depreciation rises.

Note that within this simple framework the positive effect of government education spending on investment in education and the negative effect of human capital inequality, which we have observed in section 2, can easily be rationalised. Government spending on education may be a crucial determinant of the productivity of schooling, whereas (huge) inequality in human capital may raise individuals' assessment of the risks involved in schooling. Further, building on this basic analysis of investment decisions, we can also easily explain why inflation may stimulate investment in human capital. All we need are standard arguments from the literature (see Temple, 2000, for a survey). Basically, the reason is that inflation reduces the opportunity cost of studying. For at least three reasons, inflation makes working and investing in physical capital less attractive. First, there is the general notion that inflation may undermine the efficient allocation of factors of production. Expected total factor productivity in production may fall. Second, inflation is often blamed for creating uncertainty about future real costs and revenues in production. A third argument relies on Feldstein (1983). The idea is that inflation de facto raises the real depreciation rate of physical capital. Due to shortcomings in the tax system – mainly the fact that only the historical cost of an asset can be written off – inflation implies that real depreciation allowances fall. As a consequence, producers will in the end not be able to buy the same asset. Either their real physical capital stock will fall, or their real consumption.

Within this framework the empirical insignificance of inflation for human capital in the lower inflation ranges comes as no surprise. This result simply suggests that the effects of inflation on efficiency and uncertainty in production are weak at low rates. Considering the great number of studies that find no significant negative effect of inflation on economic growth when inflation is below 15% (see section 1), this is exactly what one should expect. What about the negative slope of the hump shaped relationship at the highest inflation rates? The literature provides one clear explanation. As suggested by De Gregorio (1992), Heymann and Leijonhufvud (1995) and Temple (2000), inflation may affect the distribution of human capital across tasks. For instance, at times of (very) high inflation talented individuals may be diverted to activities in the financial sector and away from teaching[10]. This may undermine

[9] The idea that people allocate more time to education when the opportunity cost of studying falls, is empirically supported by Kodde (1986) and Fan (1993). Kodde shows for the Netherlands that there is a negative relationship between the demand for further education and expected income if one looked for a job. Fan mentions several examples that if external prospects are not very convincing, agents may choose to build more human capital. To mention one, enrollment in graduate programs in the US typically rises in recessions.

[10] 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.

the productivity of schooling for youngsters and – as a consequence – the time they allocate to building human capital. Quite likely, rather than study, to cope with high inflation these youngsters may go into financially motivated activities themselves. If these effects are strong, any positive effect of inflation on human capital will disappear at very high inflation rates.

4. Conclusions and discussion

This paper analyses the effects of inflation on human capital formation. In the literature, these effects have hardly received attention. Everyone seems to assume that the often observed negative effects of inflation on physical capital also apply to human capital. We have shown that that may be a mistake. Our results reveal that increasing inflation basically stimulates human capital. A negative effect can be observed only at very high inflation rates, say rates higher than 100%. Further, for inflation rates below 20 or 25%, the positive effect of rising inflation on human capital seems to be insignificant. With respect to other determinants of investment in human capital, our empirical results point at the crucial role of government spending on education. Further, we find evidence in favour of the popular hypothesis that inequality undermines human capital formation and growth.

The second part of this paper explains our results theoretically. The principal idea is that inflation makes alternative activities to skill acquisition (i.e. working and investing in physical capital) less attractive. Interestingly, the arguments that advocates of price stability generally raise against inflation are now arguments in favour of inflation. It is exactly because inflation (i) may undermine the efficient allocation of factors in production, (ii) may raise the real cost of physical capital because of shortcomings in the tax system, (iii) may cause uncertainty about future real costs and revenues in production, that it may stimulate people to study more. The reason why inflation seems to become detrimental to human capital at very high rates, may be that its positive effects coming from higher risk and lower efficiency in production are dominated by its negative effects on the allocation of existing human capital. Boldly, when inflation is extreme, teachers and students may shift their time and attention to other activities than education.

What are the implications of our results? Do they provide an argument for high inflation? Clearly not. Our results do not overthrow the conclusion in most studies that the (net) effects of inflation on growth are negative once inflation rises above 10 to 15%. In our view, they do however justify a more balanced view on the effects of inflation. Our results suggest that inflation may raise average school attainment among the population of 15 and older by up to 0,5 years per decade. For males, we have found an effect up to about 0,3 years in countries with median human capital and up to 0,95 years in the countries with the lowest human capital stocks[11]. Given Barro's (1999, p. 257-258) estimation 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 can be called important. For countries with median human

[11] See the results presented at the bottom of table 1. Note that the estimated coefficients in table 2 for the dummies capturing the effect of inflation in the range of 50% to 100%, are fully in line with these numbers.

capital our results suggest a positive annual growth effect of 0,21 percentage points (all other things equal). For the poorest countries, that would be 0,67. As is well known, the long-run effects on income levels of such changes in annual growth rates are sizable[12]. Limiting the discussion about inflation to consequences for physical capital, one clearly misses an important part of reality.

Appendix 1. Data sources and calculations

Data underlying the regressions in tables 1-3 and table 4, lower part.

H_t: average years of total schooling for the population of 15 and older (tables 1+2, part a) and percentage of the population of 15 and older that attained secondary or higher education (tables 1+2, part b). These data have been taken or calculated from Barro and Lee (2000). The years *t* concern 1980, 1990 and 2000.

π_{dect}: average annual consumer price inflation in the decade before *t*. Annual inflation has been calculated as the change in the natural logarithm of the consumer price index, taken from World Bank (2001). For very few countries inflation data have been derived from the GDP deflator, also available from World Bank (2001). In three cases average inflation is based on nine, instead of ten annual data. Details are available from the authors.

$st\pi_{dect}$: standard deviation of annual inflation in the decade before *t*.

GE_{dect}: average annual real per capita government spending on education in the decade before *t*. Data for total government spending on education in percent of GNP have been taken from the online UNESCO database (http://unescostat.unesco.org/statsen/statistics/indicators/indic0.htm, indicators on resources, June 2001). The earliest available UNESCO-data concern 1970. Average percentages over a decade have been calculated on the basis of all available annual data for that decade. Data for real GDP per capita (in constant dollars, 1985 international prices) have been taken from the Penn World Table (PWT 5.6, RGDPCH). For most countries these data are available until 1992. Again, the average for a decade has been calculated on the basis of all available annual data. The data for *GE* have resulted from multiplying the average for real GDP per capita and the average percentage of GNP going to government spending on education.

$HINEQ_{dect}$: human capital Gini coefficient for the population of 15 and older, taken from Castelló and Doménech (2001). For most countries, these data are available at 5-year intervals since 1960. To explain $H_t - H_{t-10}$ we use the average of the human capital Gini coefficient in *t-5* and *t-10*.

Data underlying the regressions in table 4, upper part.

The data for π and *GE* are now based on averages for the 5-year period before *t*, with *t* = 1975, 1980, 1985, 1990 and 1995. To explain $H_t - H_{t-5}$ we have used the human capital Gini coefficient in *t-5*. However, as mentioned in the main text, this variable was totally insignificant.

[12] There are two reasons to be cautious about these calculations. First, Barro's results rely on secondary and higher years of schooling only. Ours also include primary schooling. 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 male years of schooling on annual growth falls to 0,35 percentage points. It remains significant though. On the other hand, it should also be noted that in an earlier study, Barro (1997, p. 19) estimated the impact effect of male schooling on annual growth to be 1,2 percentage points.

Appendix 2. OLS versus IV estimation

We have argued in section 2 that the bias and inconsistency problem implied by the pooled OLS estimator that we use in this paper, is fairly small. Three regressions in table A1 and a Hausman test computed on the basis of regressions (2) and (3) support this argument. The first regression is the same as regression (1) in table 1. We include it here for the purpose of comparison. The second regression is an OLS re-estimation of the first, but for a shorter period. It explains human capital in t = 1990 and 2000 only. Obviously, in this regression the time dummy for the 1970s is no longer included. The third regression re-estimates the second, but uses the (consistent) 2SLS estimator. Lagged human capital ($H_{i,t-10}$) is instrumented by

Table A1

Dependent variable: Change in average years of schooling, total population

	(1) OLS t = 1980, 1990, 2000	(2) OLS t = 1990, 2000	(3) IV t = 1990, 2000
Constant	0,245 (1,20)	0,170 (0,72)	0,192 (0,71)
H_{t-10}	-0,726*** (6,95)	-0,781*** (8,61)	-0,573*** (3,37)
π_{dect}	0,0121*** (2,81)	0,0152*** (2,82)	0,0146*** (2,98)
π^2_{dect} *(divided by* 10^5*)*	-6,81** (2,24)	-8,83** (2,20)	-8,90*** (2,91)
$ln(GE)_{dect}$	0,598*** (8,21)	0,608*** (8,37)	0,500*** (4,24)
$ln(HINEQ)_{dect}$	-0,890*** (3,24)	-1,185*** (4,10)	-0,677 ° (1,45)
Time dummy 1970s	-0,593*** (4,15)	-	-
Time dummy 1980s	-0,336*** (3,71)	-0,346*** (3,80)	-0,229** (2,26)
Regional dummies			
North America	2,52***	2,22***	1,69***
Scandinavia	1,73 ***	1,94 ***	1,60 ***
Eur. Ec. in Trans.	1,51***	1,21***	0,91***
East Asia	0,50***	0,50***	0,43***
Latin America	0,42***	0,36**	0,26 °
Country dummies	yes	yes	yes
Adjusted R^2	0,457	0,398	0,370
SER	0,479	0,450	0,460
N.obs	246	163	163

Notes: Absolute t-values based on White heteroscedasticity-consistent standard errors in parentheses.
*** (**) (*) (°) indicates statistical significance at the 1% (5%) (10%) (15%) level.
The estimation method in equation (3) is Two-Stage Least Squares. H_{t-10} is instrumented by H_{t-20} and H_{t-30}. Further, all other explanatory variables as well as the time dummy for the 1980s and the regional and country dummies are included as instruments.

$H_{i,t-20}$ and $H_{i,t-30}$. These are uncorrelated with the error terms $\varepsilon_{i,t}$ and $\varepsilon_{i,t-10}$, and are therefore valid instruments[13].

A simple comparison of the results of (2) and (3) immediately reveals that differences are limited. Note especially that both regressions offer strong support to the hump shape hypothesis about inflation and human capital. The Hausman test confirms our presumption. Under the null hypothesis that both estimators are equal, the test statistic has an asymptotic Chi-squared distribution with K degrees of freedom, where K is the number of estimated coefficients involved. In our case that is 12[14]. The value for the test statistic equals 2,29 which is far below the critical value (p-value equal to 0,99), implying that the null hypothesis cannot be rejected.

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[13] Note that due to data limitations we cannot re-estimate regression (1) by using 2SLS. To avoid correlation with the (within transformed) residuals in that equation, only H_{t-30}, H_{t-40} etc. would be valid instruments. However, human capital being available only since 1960, a 2SLS estimation cannot include data for t =1980. An alternative, often recommended approach could be to first-difference our basic equation (1) and to use H_{t-20} as an instrument for $H_{t-10} - H_{t-20}$. This approach would not solve our problem though. Since no data are available for government spending on education before 1970 (see appendix 1), only two first-differenced observations for this variable are available. 2SLS-estimation unavoidably implies that one sample period is "lost".

[14] This number includes all estimated coefficients except the country dummies. Also including these dummies, we ran into the practical problem that the test statistic could not be computed (Verbeek, 2000, p. 319)

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