Does inflation matter for growth?

Thorvaldur Gylfason[a,*], Tryggvi Thor Herbertsson[b]

[a]*University of Iceland, Reykjavìk, Iceland, SNS — Center for Business and Policy Studies, Stockholm, Sweden, CEPR*
[b]*Institute of Economic Studies, University of Iceland, Reykjavìk, Iceland*

Abstract

The interaction between inflation and economic growth is studied within a simple model incorporating money and finance into an optimal growth framework with constant returns to capital. The model includes the potential impact of inflation on growth, via (a) saving and real interest rates, (b) velocity and financial development, (c) the government budget deficit through the inflation tax and tax erosion, and (d) efficiency in production through the wedge between the returns to real and financial capital. The hypothesized effect of inflation on long-run growth through these channels is estimated by applying the random-effects panel model to two sets of unbalanced panel data side by side, from the Penn World Tables and from the World Bank, covering 170 countries from 1960 to 1992. The cross-country links between inflation and growth are economically and statistically significant and robust. Specifically, the results show that inflation in excess of 10–20 percent per year is generally detrimental to growth. © 2001 Elsevier Science B.V. All rights reserved.

1. Introduction

Economists have long had reason to wonder whether inflation is generally conducive or detrimental to economic growth. Various arguments have been put forward on both sides, not least in the ongoing debate among development economists on the long-term development of Latin America. In this debate, which was particularly vivid in the 1960s, monetarists generally considered price stability a prerequisite for economic growth. Structuralists, on the other hand, contended that attempts to achieve price stability through monetary or fiscal restraint would result in unemployment and slow growth.

---

* Corresponding author. Tel.: +354-525-4533; fax: +354-552-6806.
E-mail address: gylfason@hi.is (T. Gylfason).

For a long time, historical and comparative studies did not provide clear empirical conclusions about the relationship between inflation and growth in Latin America or elsewhere. The economy of the United States, for example, has grown relatively rapidly and slowly in periods of both inflation and deflation. So have most other economies. In one of the earliest cross-country studies of inflation and growth, Thirlwall and Barton (1971) report a positive relationship between low inflation (i.e. below 8 percent per year) and growth (unadjusted for population change) in a cross section of 17 industrial countries during 1958–1967, and a negative relationship between high inflation (i.e. above 10 percent per year) and growth in a cross section of seven developing countries over the same period.

Over the past 10–15 years, however, the contours of an inverse connection between inflation and growth across countries have begun to emerge from econometric studies. Heitger (1985) reports a significantly positive relationship between the rate and variability of inflation and a significantly negative relationship between inflation variability and economic growth, inferring that inflation was detrimental to growth in a large cross section of industrial and developing countries during 1950–1980. Barro (1990) reports a negative but weak relationship between inflation and the growth rate of real per capita gross domestic product (GDP) during 1970–1985 in a cross section of 117 countries. Even so, he finds a significantly negative relationship between the intensification of inflation (from 1960–1970 to 1970–1985) and growth, as do Kormendi and Meguire (1985) in a cross section of 47 countries during 1950–1977. Using time series for 21 countries over 27 years, Grimes (1991) reports that an increase in the inflation rate from 0 to about 9 percent per year reduces the annual rate of economic growth in each country by around 1 percent (i.e. 1 percentage point, to be precise) on average.

Applying nonparametric methods to small samples, Gylfason (1991) shows that economies with high inflation (i.e. 20 percent or more per year) grew significantly less rapidly on average than economies with low inflation (i.e. below 5 percent per year) during 1980–1985. Sarel (1996) suggests an even lower threshold, i.e. that inflation rates above 8 percent a year impede economic growth. Bruno and Easterly (1998) report that inflation rates above 40 percent a year for at least 2 years in a row are generally harmful to growth.

Fischer's (1991, 1993) cross-sectional regression estimates based inter alia on the Penn World data, from 1960 to 1989, indicate that an increase in inflation from, say, 5 to 50 percent a year from one country to another reduces the growth of GDP by 1.8 percent per year, other things being equal. Based on data for 100 countries from 1960 to 1990, Barro (1995, 1997) reports that an increase in average inflation of 10 percent a year reduces per capita growth by 0.2–0.3 percent a year, ceteris paribus. This means that an increase in inflation from 5 to 50 percent a year would reduce per capita growth by 1–1.5 percent per year. According to Barro, statistically significant effects of inflation on growth arise only when high-inflation experiences are included, but no threshold is presented. Even so, Barro's data do not reject the hypothesis that the relationship between inflation and growth is negative at low rates of inflation and of the same magnitude as that observed at higher inflation rates. By the same token, Gylfason's (1999) results based on cross-sectional data from the World Bank covering 105 countries during 1985–1994 indicate that an increase in inflation from 5 to 50 percent a year from one country to another reduces the growth of GDP per head by 2.3 percent per year, ceteris paribus. In this case, the threshold is quite

high: the inverse relationship between inflation and growth is driven by countries with average annual inflation in excess of 110 percent. An increase in inflation by 1 percent a year reduces productivity growth in the United States by 0.03 percent a year according to Motley (1994), and by 0.25 percent a year according to Taylor (1996). Thus, by linear extrapolation, an increase in inflation from 5 to 50 percent per year reduces growth by 1.4 and 11.2 percent, respectively, according to the two studies.

Using panel data from 12 Latin American countries from 1950 to 1985, De Gregorio (1993) finds a semi-elasticity of per capita growth with respect to average inflation equal to −0.008. This means that an increase in annual inflation from 5 to 50 percent from one country to another reduces per capita growth by 0.7 percent per year, ceteris paribus. Roubini and Sala-i-Martin (1992) use data from 98 countries from 1960 to 1985 and find that an increase in annual inflation from 5 to 50 percent from one country to another reduces per capita growth by 2.2 percent per year, ceteris paribus. Rousseau and Wachtel (2001), in their panel study of 84 countries during 1960–1995, report a smaller but still significantly negative effect of inflation on growth.

The empirical results reviewed above are summarized in Table 1.[1]

Fig. 1 shows the average rates of inflation and growth of real GDP per capita from 1960 to 1992 for all countries included in the Penn World Tables (upper panel) and all those reporting to the World Bank (lower panel). The figure illustrates the absence of a clear relationship between inflation and growth across countries. It was not until the advent of the theory of endogenous growth in the mid-1980s that economists began to specify empirical growth models in a way which made it possible to isolate the analytical and empirical links between inflation and growth. Even so, the long-run properties of some endogenous growth models can be interpreted as, and may even be empirically indistinguishable from, the medium-term properties of the neoclassical growth model.

The purpose of this paper is to present a simple model of the simultaneous determination and interaction of inflation and growth and to estimate the growth part of the model. The model is constructed by incorporating money and finance into an optimal growth framework with increasing returns to scale. Several channels through which increased inflation tends to reduce growth and declining growth tends to amplify inflation are discussed. Special attention is paid to the potential impact of inflation (a) on saving through real interest rates, (b) on the income velocity of money or, equivalently, financial depth, (c) on the government budget deficit through the inflation tax and tax erosion, and (d) on efficiency through the wedge between the returns to real and financial capital. The model indicates that, although a wide variety of outcomes is possible, inflation and growth tend to be negatively correlated for reasonable values and constellations of the structural parameters of the model. In particular, budget deficits, through their interplay with inflation, via saving behavior, portfolio choice, financial development, and taxes, tend to deter growth in the long run. This result, which appears also in Alogoskoufis and van der Ploeg (1994) in a model of endogenous growth with overlapping generations, differs from the results of earlier models of money and growth following Tobin (1965), where increased monetary expansion can raise the capital:output ratio and the level of output per head in the long run, but not its rate of growth.

---

[1] For a critical review of the emerging empirical literature on inflation and growth, see Temple (2000).

Table 1
Inflation and growth: overview of empirical studies[a]

Studies	Countries	Periods	Data	Effects of an increase in inflation from 5 to 50 percent a year on growth
Thirlwall and Barton (1971)	51	1958–1967	Cross section (UN)	Not available
Heitger (1985)	115	1950–1980	Panel data (PWT)	−0.9 to −4.5
Kormendi and Meguire (1985)	47	1950–1977	Cross section (IMF), PC	Not available
Barro (1990)	117	1960–1985	Cross section (PWT), PC	Insignificant and weak
Fischer (1991)	73	1970–1985	Cross section (PWT), PC	−2.1
Grimes (1991)	21	1960–1987	Panel data (IMF)	−5.0
Gylfason (1991)	37	1980–1985	Cross section (WB), PC	−2.0
De Gregorio (1992, 1993)	12	1950–1985	Cross section (BW, WB, PWT), PC	−0.7
Roubini and Sala-i-Martin (1992)	98	1960–1985	Cross section (BW), PC	−2.2
Fischer (1993)	80	1960–1989	Cross section (WB)	−1.8
Motley (1994)	78	1960–1990	Cross section (PWT), PW	−1.3 to −4.5
Barro (1995, 1997)	100	1960–1990	Cross section (PWT), PC	−1.0 to −1.5
Sarel (1996)	87	1970–1990	Panel data (WB, PWT), PC	−5.8
Taylor (1996)	United States	1952–1993	Time series	−11.2
Bruno and Easterly (1998)	97	1961–1992	Panel data (WB), PC	−1.2
Gylfason (1999)	105	1985–1994	Cross section (WB), PC	−2.3
Rousseau and Wachtel (2001)	84	1960–1995	Panel (WB), PC	−0.14
This study	170	1960–1992	Panel (PWT, WB), PC	−0.6 to −1.3

[a] PWT denotes Penn World Tables; WB, World Bank; IMF, International Monertary Fund; BW, the Barro–Wolf data set, and UN, United Nations. PC refers to the use of GDP per capita and PW, per worker.

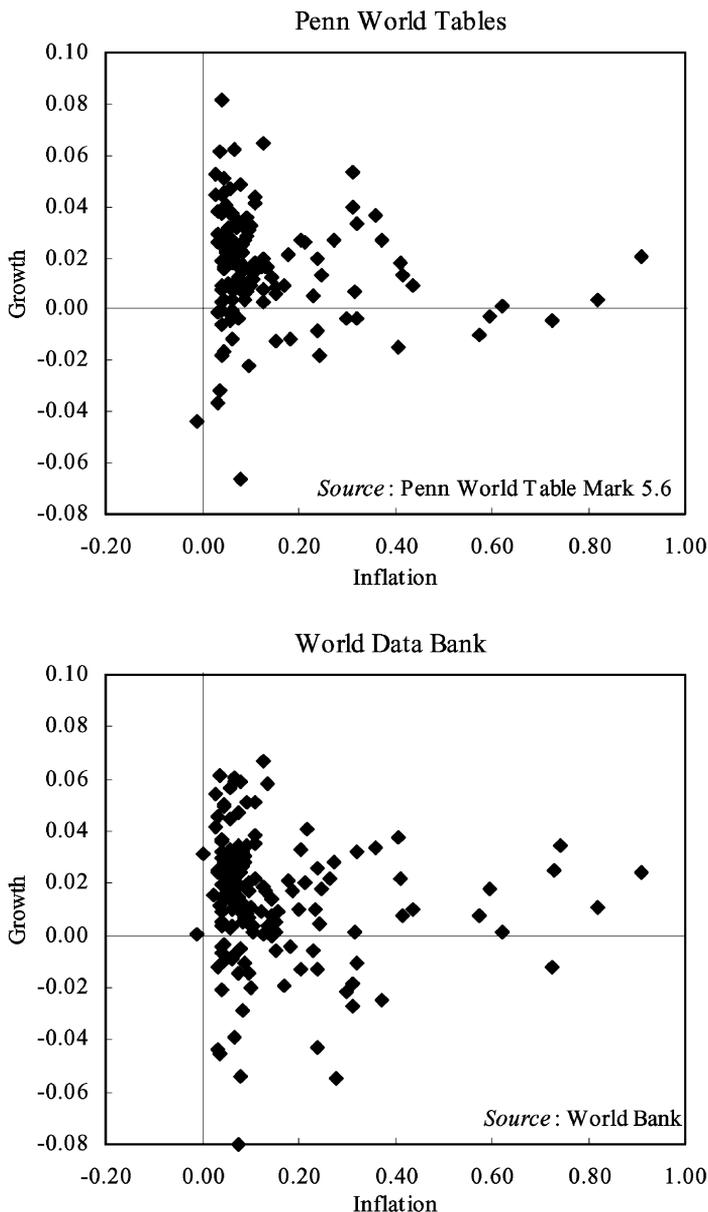## Penn World Tables

World Data Bank

Fig. 1. Average inflation and growth of GDP per capita, 1960–1992.

A growth equation derived from the model is tested by the random-effects panel model by incorporating inflation (as in Fischer, 1991, 1993) and raw-material exports (as in Sachs and Warner, 1995) into the standard Barrovian growth framework. Our specification is estimated with unbalanced panel data constructed from the Penn World Tables (where

the growth figures are derived from purchasing-power-parity-adjusted output figures) and from the World Data Bank (where the growth figures are unadjusted). This gives us the largest possible number of observations (countries) with which to test our model. Our method also enables us to exploit both the time-series and cross-sectional properties of the data. Within our theoretical framework, which we use to trace some channels through which inflation influences long-run economic growth, we find, in both of these data sets, robust and strong evidence of a negative relationship between inflation and growth. This is the main message of the paper. We also find that the threshold which inflation must pass in order to become an impediment to long-run growth is lower than that reported by Bruno and Easterly (1998).

The paper proceeds as follows. Section 2 lays out the theoretical framework. Section 3 reports the results of the regression analysis. Section 4 provides a summary and a brief discussion of the main findings.

2. Theoretical framework

2.1. Production

Aggregate output Y depends on labor N, real money balances M/P, and capital K, through an extended Cobb–Douglas production function:

$$Y = AN^\alpha \left(\frac{M}{P}\right)^\beta K^{1-\alpha-\beta}, \tag{1}$$

where M is the supply of money, P the general price level, A a technological shift parameter, and α, β, and $1 - \alpha - \beta$ are the elasticities of output with respect to labor, real balances, and capital. Money is held by firms to facilitate production by enabling them to economize on the use of other inputs and by sparing them the cost of running short of cash (Fischer, 1974; Gylfason, 1998). Alternatively, the presence of real balances in the production function can be interpreted as a proxy for the effect of financial depth on output (King and Levine, 1993; Levine, 1997; Gylfason and Zoega, 2001; Rousseau and Wachtel, 2001). Further, we assume capital-embodied technology and spillovers (externalities) across firms in the form of $A = BK^\alpha$ for the economy as a whole, so that $Y = BN^\alpha (M/P)^\beta K^{1-\beta}$. This implies increasing returns to scale and constant returns to real money balances and capital broadly defined (Romer, 1986; Rebelo, 1991). The parameter B reflects the intensity of factor use (e.g. the number of hours machines are kept running per day). The aggregate production function thus becomes:

$$Y = EK, \tag{2}$$

where

$$E = B^{1/1-\beta} N^{\alpha/1-\beta} v^{-\beta/1-\beta} \tag{3}$$

and $v = Y/(M/P)$ is the velocity of money. E represents the efficiency of real capital, and is simply the inverse of the capital:output ratio. By increasing velocity or reducing financial

depth, increased inflation reduces efficiency as long as money plays a role in the production function ($\beta > 0$), other things being equal.[2]

To maximize profits, firms equate the marginal product of capital to the real interest rate:

$$(1 - \alpha - \beta)E = r. \tag{4}$$

In their calculation, the firms thus do not take the technological spillovers into account. Similarly, profit maximization requires equality between the marginal product of money and the nominal interest rate, where π is the rate of inflation:

$$\beta v = r + \pi \tag{5}$$

(and also between the marginal product of labor and the real wage). Eqs. (3)–(5) together produce a Fisher–Mundell effect: when inflation goes up, velocity also increases by Eq. (5), so that efficiency decreases by Eq. (3) and the real interest rate goes down by Eq. (4).[3] If $\beta = 0$, however, real balances vanish from the production function (1) and the Fisher–Mundell effect also disappears. As long as N and v are constant in equilibrium, output is proportional to the capital stock. Therefore, Y and K must grow at the same endogenously determined rate, which can be positive even if the labor force is fixed by assumption.[4] With increasing returns to scale and constant returns to money and capital, the capital:output ratio does not adjust automatically to ensure equality between the rates of growth of output and the labor force in the long run (with or without labor-augmenting technological progress), as it does in the neoclassical model with constant returns to scale and decreasing returns to capital. The deactivation of this dynamic adjustment mechanism is the key to endogenous growth in this framework.

With the automatic adjustment mechanism of neoclassical growth theory out of commission, the literature on endogenous growth has been concerned in part with the determination of the (broad) capital:output ratio, i.e. efficiency, research and development, and their implications for growth. This model introduces money, finance, and inflation into the story in a way that is intended to illuminate the effects of monetary and fiscal policy, private saving, and portfolio choice on inflation and thereby also on growth in the long run. In contrast to De Gregorio (1992), where inflation affects growth through investment and its productivity, and Roubini and Sala-i-Martin (1992), where financial repression provides the link between inflation and growth, the linkage here is established by combining the quantity theory of money and portfolio choice with an optimal growth model that includes money.

2.2. Money and finance

General macroeconomic equilibrium requires equality between money supply and money demand: $M/P = Y/v$. If the optimal ratio of real money balances to real wealth,

[2] Our specification of money in the production function (1) is operationally equivalent to the shopping cost model of Dornbusch and Frenkel (1973), where $Y = AN^{\alpha}K^{1-\alpha}[1 - \phi(M/PY)]$ with, e.g. $\phi = -\ln[1 + M/PY]$, so that $\phi(0) = 0$, $\phi' < 0$, and $\phi'' > 0$. This gives $Y = EK$ as in Eq. (2) if $E = BN^{\alpha}[1 + \ln(1 + v^{-1})]$, see Eq. (3). A cash-in-advance constraint can also be used to establish a supply-side link between money and output.

[3] In the shopping cost model, the two first-order conditions are $(1 - \alpha)E = r$ and $Y_0/(1 + v^{-1}) = r + \pi$, where Y_0 is output when $M = 0$, and the Fisher–Mundell effect follows as in the text. In either case, if $v \to 0$, then $\pi = -r$ (the Friedman rule) and both E and Y, and hence also g by Eq. (9), tend to ∞.

[4] If the labor force grows at an annual rate n, the capital stock depreciates at rate δ, and technology progresses at rate γ, then $g_Y = g_K - \delta + (\alpha n + \gamma)/(1 - \beta)$, where g_Y and g_K are the growth rates of Y and K for given v.

$(M/P)/[(M/P) + K]$, is denoted by h, which varies inversely with inflation, the corresponding optimal velocity of money is $v = (1 - h)E/h$, which varies directly with inflation. By substituting this into Eq. (3), we get the following inverse relationship between inflation and efficiency through h, for given B and N: $E = BN^{\alpha}((1 - h)/h)^{-\beta}$. If h and E are both constant in equilibrium, so that v is also constant, the Fisher equation $M/P = Y/v$ can be expressed in rates of change:

$$\pi = m - g, \tag{6}$$

where π is the rate of inflation, m the rate of monetary expansion, and g is the growth of GNP (and of GNP per capita, because the labor force is fixed).

If the government finances its budget deficit by printing money, the rate of monetary expansion equals velocity times the ratio of the deficit to GNP, d:

$$m = vd. \tag{7}$$

The deficit:GNP ratio can be written as $d = c - m/v$, where c is an exogenous component (i.e. government spending less direct and indirect taxes divided by GNP) and m/v represents inflation tax revenue as a proportion of GNP. Thus, $m = vc/2$. This gives the following inverse relationship between inflation and growth:

$$\pi = \tfrac{1}{2}vc - g. \tag{8}$$

Hence, both inflation and growth are constant in equilibrium. An increase in the autonomous part of the government budget deficit relative to GNP (i.e. a rise in c) increases inflation for given growth. Likewise, an increase in velocity v or, equivalently, a reduction in financial depth, increases inflation for given growth.

2.3. Consumption and saving

Consumers choose a path of consumption C_t that maximizes their utility U_t over time. Specifically, they maximize $\int_0^{\infty} U_t(C_t) e^{-\rho t} dt$, where ρ is the discount rate, subject to the constraint that $C + \Delta K + \Delta M/P = rK + (r + \pi)M/P + wL + X$, where Δ denotes change, wL is labor income and is fixed by assumption, and X denotes the lump-sum transfer of seigniorage from the government to households. Hence, the consumption of households plus their accumulation of capital and real balances must equal their income from renting capital and real balances to firms plus their labor income and seigniorage receipts.[5] The budget constraint can be rewritten as $\Delta A = rA + wL + X - C$, where $A = K + M/P$. If the utility function is $U_t = (C_t^{1-\theta} - 1)/(1 - \theta)$, where θ is the inverse of the intertemporal elasticity of substitution, we obtain the Ramsey rule which, on substitution from Eq. (4), yields

$$g = \frac{1}{\theta}[(1 - \alpha - \beta)E - \rho], \tag{9}$$

---

[5] The nominal interest rate $r + \pi$ represents the cost to households of holding real balances, see Eq. (5).

where g is the rate of growth of consumption and, therefore, also of output and capital along the optimal consumption path.[6,7] The optimal rate of growth can also be expressed as

$$g = [s - (1 - s)\psi] E, \tag{10}$$

where $\psi = (m - \pi)/v$. Eq. (10) is derived by writing the flow of real saving $S = \Delta A$ first as the sum of ΔK and $\Delta(M/P) = (M/P)(m - \pi)$ and then as a fraction s of income including accumulated real money balances, that is, $Y + (M/P)(m - \pi)$.[8] This yields the optimal propensity to save:

$$s = \frac{S/Y}{1 + \psi} = \frac{(g/E) + \psi}{1 + \psi} = \frac{[(1 - \alpha - \beta)E - \rho](E + v)}{[(1 - \alpha - \beta)E - \rho]E + \theta v E} \tag{11}$$

by Eqs. (6) and (9). The optimal saving rate is constant for given v, E, ρ, and θ.

If increased inflation reduces money demand and thus raises v for given Y, then s must fall for given E, ρ, and θ, because $ds/dv = -g(1 - g/E)/(v + g)^2 < 0$ as long as $0 < g < E$. Quantitatively, however, this link turns out to be weak, as can be confirmed by substituting plausible values of g, E, and v into the expression for ds/dv above. A potentially more important inverse relation between inflation and saving can be derived (a) by noticing that $ds/dE = (v/E)[g(1 - g/E) + (1 + v/E)\rho(1/\theta)]/(v + g)^2$, which is positive at least as long as $0 < g < E$; (b) by remembering that $r = (1 - \alpha - \beta)E$ in Eq. (4); and (c) by exploiting the Fisher–Mundell effect, $dr/d\pi < 0$. Hence, increased inflation lowers the real interest rate, reduces efficiency, and reduces the saving rate independently of the elasticity of intertemporal substitution.

2.4. Inflation and growth

The simultaneous determination of inflation and growth is described by the following nonlinear quasi-reduced-form equations:[9]

$$\pi = \frac{vc}{2} - \frac{sE}{1 + ((1 - s)/v)E}, \tag{12}$$

$$g = \frac{sE}{1 + ((1 - s)/v)E}. \tag{13}$$

Eq. (13) follows directly from Eqs. (6), (10) and (12) is obtained by substituting Eq. (13) into Eq. (8). The qualitative comparative-statics properties of the model are shown in Table 2.

---

[6] If money affects utility, so that $U_t = \{[C_t^\lambda (M_t/P_t)^\mu]^{1-\theta} - 1\}/(1 - \theta)$, where $\lambda + \mu < 1$ as in Fischer (1979), then the optimal rate of growth of consumption, real balances, capital, and output is $g = [(1 - \alpha - \beta)E - \rho]/\theta[(\lambda + \mu)(1 - 1/\theta) + 1/\theta]$, which is larger than the growth rate shown in the text as long as $\theta > 0$ and $\lambda + \mu < 1$. Without money in the utility function (i.e. with $\lambda = 1$ and $\mu = 0$), the above expression for optimal growth simplifies to the one shown in the text.

[7] In the absence of externalities (i.e. if firms were able to take the technological spillovers behind Eq. (4) into account), then the growth formula (9) would be $g = ((1/\theta)E - \rho)$, which exceeds the externality-based competitive equilibrium growth rate shown in Eq. (9).

[8] Eq. (10) can also be derived by assuming a fixed saving rate without explicit intertemporal optimization (Tobin, 1965).

[9] A simple diagrammatic version of the model is presented in Gylfason (1999, pp. 94–98).

Table 2
Effects of exogenous increases in v, c, s, and E on inflation and growth

	v	c	s	E
π	+	+	−	−
g	+	0	+	+

An increase in the autonomous parts of s and E stimulates growth and slows inflation down, ceteris paribus,[10] whereas an increase in the autonomous part of v increases both inflation and growth; the direct link between velocity and growth stems from the Tobin effect introduced in Eq. (10).[11] The total effect of financial deepening, including the indirect effect of a decrease in v through E, on growth is ambiguous in principle, however, and likely to be positive in practice (see Section 2.5). In so far as the government budget deficit is financed through foreign borrowing, increased external indebtedness (i.e. an increase in the autonomous part of c) results in higher inflation without raising growth as long as saving behavior and portfolio choice are impervious to increased borrowing. By increasing inflation, however, an increase in the government budget deficit generally reduces the saving rate and efficiency, and thereby reduces growth. In sum, therefore, inflation and growth can be positively or negatively correlated, or uncorrelated, depending on the changes in the underlying exogenous parameters of the model. Any observed pattern of inflation and growth must be the consequence of changes in their underlying determinants. Our model is compatible with a wide variety of such patterns.

2.5. Numerical analysis

Before turning to the econometric analysis, a numerical calibration of the model may illuminate its properties further. The structural parameters of the model can all be quantified. Therefore, it is possible to test the sensitivity of the equilibrium solution for the rates of inflation and growth to realistic variations in the parameters. To conserve space, we restrict our attention to the pattern of inflation and growth resulting from exogenous, mutually independent variations in the parameters, without considering the implications of endogenous, mutually interdependent parameter variations.

We take 1994 as our benchmark. That year, the unweighted world average income velocity of money, defined as nominal GNP divided by money holdings broadly defined (M_2), was 3.6 (World Bank, 1996, Table 2). Accordingly, we set $v = 3.6$ to start with. The

[10] Because the optimal saving rate depends on both v and E, inter alia, as shown in Eq. (11), other parameters of the model are implicitly assumed to change to make it possible for s to change for given v and E, and so on.

[11] Quantitatively, the inclusion of the Tobin effect in the growth Eq. (10) does not make much difference. Without money in the model, the neoclassical growth equation is restored: $g = sE$. The corresponding solution for inflation is $\pi = vc/2 - sE$. The qualitative comparative-statics properties of the simplified model are the same as in Table 2, except the plus sign in the lower left corner of the table is replaced by 0. Therefore, not much would be lost by abstracting from the role of money and portfolio choice in the growth process described in Eq. (10) with a constant velocity of money.

Table 3
Means and standard deviations of structural parameters

	v	c	s	E
Means	3.6	0.03	0.16	0.30
S.D.	2.4	0.05	0.14	0.24

overall central government deficit amounted to 3 percent of GNP on average in all reporting countries in 1994 (World Bank, 1996, Table 2). We set $c = 0.03$ initially.[12] A broader measure of the government budget deficit would be preferable for the purpose at hand, but internationally comparable figures on consolidated public-sector deficits are not available. The gross domestic saving rate was 0.16 on average in 1994 (World Bank, 1996, Table 13). We set $s = 0.16$ initially. Lastly, the ratio of gross domestic investment to GDP was 0.21 on average in 1994 (World Bank, 1996, Table 13). The efficiency of capital in each country equals the inverted long-run equilibrium capital:output ratio, which equals the investment:GDP ratio divided by the depreciation rate. We set $E = 0.30$ initially. This number is consistent with an investment:GDP ratio of 0.21 and a depreciation rate of 0.05.[13] A broader measure of capital, including human capital, would be more appropriate here, but the requisite data are unavailable for most of the countries under review. The unweighted averages and corresponding standard deviations of the structural parameters are summarized in Table 3.

Given the mean values of the parameters listed above, the equilibrium solution to the model is 3.2 percent inflation and 4.5 percent growth per year. For comparison, the GDP deflator and real GDP for the world as a whole rose by 14.8 and 3.1 percent per year on average during 1980–1990 (World Bank, 1996, Table 11). Inflation is underestimated in the model in part because of the narrow definition of the government budget deficit; a doubling of the deficit:GNP ratio to 0.06 almost trebles the equilibrium inflation rate predicted by the model to 8.6 percent without affecting growth.

Consider now the sensitivity of the reduced-form equilibrium rates of inflation and growth to variations in the structural parameters of the model.

1. An increase in velocity by 1 S.D. from 3.6 to 6.0 increases inflation from 3.2 to 6.7 percent, ceteris paribus, but leaves growth practically unchanged: the growth rate rises only from 4.5 to 4.6 percent.
2. An increase in the deficit:GNP ratio by 1 S.D. from 0.03 to 0.08 (with $v = 3.6$ again) makes inflation jump from 3.2 to 12.2 percent without affecting growth, because s and v are independent of c by assumption.
3. A decrease in the saving rate by 1 S.D. from 0.16 to 0.02 (with $c = 0.03$ again) increases inflation from 3.2 to 5.1 percent and reduces growth from 4.5 to 0.6 percent.

---

[12] This estimate of c does not include inflation tax revenue. Because of seigniorage, increased inflation reduces the rate of monetary expansion $m = vd = vc - m = (1/2)vc$ that is needed to finance the government budget deficit for given v and c.

[13] Specifically, $E = (1/n)\sum_{i=1}^{n}[\delta/(I_i/Y_i)]$, where I_i/Y_i is the investment ratio in country i, δ is the depreciation rate, and n is the number of countries.

4. An improvement in efficiency by 1 S.D. from 0.30 to 0.54 (with $s = 0.16$ again) increases growth from 4.5 to 7.7 percent and reduces inflation from 3.2 to 1.6 percent.

These experiments show that inflation and growth move within a reasonable range in response to realistic variations in the parameters of the model. In particular, exogenous shocks to s and E produce a negative correlation between inflation and growth, whereas exogenous shocks to v and, especially, c produce no such correlation. Furthermore, the experiments can be combined in different ways. For example, based on experiments (1) and (4), our results imply that financial deepening (i.e. a decrease in v which increases E by Eq. (3)) stimulates growth for a given saving rate, but reduces inflation. To take another example, based on experiments (2) and (3), a simultaneous decrease in the saving rate s and in the government budget deficit c for given v and E can reduce both inflation and growth. Thus, in theory, inflation and growth can move all over the map.

3. Estimation

We now proceed to consider the potential effects of inflation on economic growth, via the saving rate, efficiency, and velocity, see Eq. (13). First, the saving rate varies directly with the real interest rate and inversely with inflation, because increased inflation reduces the real interest rate in our model. The optimal saving rate is positively related to efficiency by Eq. (11) and thus also to the real interest rate. Moreover, inflation may increase uncertainty about the future and thus adversely affect saving independently of interest rates. Either way, by reducing saving, increased inflation retards growth by Eq. (13), ceteris paribus. Second, inflation reduces efficiency by driving a wedge between the returns to real and financial capital (Gylfason, 1998). This link is explicit in the model through the dependence of efficiency on velocity or financial depth in Eq. (3). Third, the velocity of money varies directly with inflation (financial depth varies inversely with inflation), because inflation reduces the real value of money independently of efficiency. Through this channel per se, increased inflation can stimulate growth.[14] In sum, inflation affects s, E, and v in Eq. (13), and thereby growth. The budget deficit c affects inflation and hence also growth through s, E, and v. Accordingly, our modeling strategy is to regress growth on the main determinants of s, E, and v in Eq. (13), including especially inflation.

3.1. Data

We use two sets of unbalanced panel data side by side, based on the Penn World Tables and the World Data Bank (see Appendix). The data cover the period 1960–1992 and comprise seven units of 5-year averages for the variables in question (the last unit, however, is only 2 years). In the first regression, we use World Data Bank for 170 countries with a maximum of seven observations per country and a minimum of one (986 d.f.). As we move step by step to a more general model specification, the number of observations decreases

---

[14] Moreover, the ratio of the budget deficit to GNP varies directly with inflation through the erosion of tax revenues; see Tanzi (1978). Increased inflation can amplify itself through all the above channels: by raising the deficit and velocity and by reducing the saving rate, increased inflation feeds back on itself.

until we are left with 447 d.f. and 109 countries. When we move to the Penn World Tables, the maximum number of countries is 145 (857 d.f.), which drops in stages to 94 countries (365 d.f.) in the last regression. This approach enables us to use as much as possible of the information available for each model.[15]

3.2. Estimation methods

The industry standard of the empirical growth literature of recent years is ordinary-least-squares (OLS) estimation with dummy variables (as in Barro, 1991; Mankiw et al., 1992). Since the inclusion of dummies represents a lack of knowledge about the underlying model, it is natural to describe this lack of knowledge through the error term of the statistical model. The model-specification problem in turn suggests that the structure of the error term may be a complex one, since it is assumed to result in part from the effects of omitted variables. The difficulty arises because the error term is likely to consist of time-related errors, cross-sectional errors, and a mixture of both in a panel of countries. The random-effects panel model is a natural solution to this problem. The basic regression model for an unbalanced panel data set is:

$$y_{it} = X_{it}\beta + u_{it}, \tag{14}$$

where $i = 1, \ldots, N$, $t \in [1, T]$ and u_{it} is based on the following decomposition:

$$u_{it} = \varepsilon_i + \mu_t + \eta_{it},$$

where ε_i is the individual country effect, μ_t the time effect, and η_{it} is the purely random effect. This estimator is designed to allow the systematic tendency of u_{it} to be higher for some countries than others (individual country effect), and possibly also higher for some periods than for others (time effect). It treats the constant term in X_{it} as a random variable, so that its stochastic component, ε_i, can be included in the error term of the regression. Because the constant term is common for all the time series of a given country, the covariance matrix of the errors in (14) is no longer diagonal and the equation has to be estimated by "generalized least squares". However, because the random-effects model treats the country-specific effect as part of the error term, it suffers from possible bias due to a correlation with the regressors, see Hausman and Taylor (1981). We assume that individual error components are uncorrelated with each other, both across countries and time.

3.3. Estimation and diagnostics

We analyze the robustness of our results by applying a variation of Leamer's (1983) extreme-bounds test.[16] The robustness of the inflation parameter is examined by alterations

---

[15] See Gylfason and Herbertsson (1996), (Appendix) for a detailed description of the two data sets and for a list of the countries (and the number of observations per country) included in the estimation. This information is also available at http://www.hi.is/~gylfason/datajwe.htm.

[16] In Gylfason and Herbertsson (1996), we test for the exogeneity of our regressors. Our main conclusion is that weak exogeneity cannot be rejected. Therefore, we see no need for modeling the marginal processes or using instrumental-variables methods.

in the conditioning information set. Regressions (1) and (7) represent the standard (unconditional) convergence regression. In the second and eighth regression, we add inflation, and in regressions (3)–(6) and (9)–(12), we add further variables that are widely believed to affect the rate of growth of GDP per capita. If the parameter on inflation does not change sign or become insignificant in this exercise, it is robust according to Leamer. If, on the other hand, its sign or significance does change, the parameter is fragile, see Levine and Renelt (1992).

In Table 4, we report our findings on the partial association between growth and inflation, the standard errors of the estimates (SE), d.f., and some diagnostic tests.

To test for potential misspecification of functional forms, e.g. for omitted variables, we use the Ramsey RESET test. The functional form is tested against a more general relationship involving higher-order terms in the regression. In the first four models, the hypothesis of misspecification cannot be rejected. In Model (5), on the other hand, misspecification is strongly rejected. In Model (6), misspecification is only marginally rejected. In Models (7) to (10), misspecification cannot be rejected, but it is strongly rejected both in Models (11) and (12). First-order autocorrelation is rejected in all cases on the basis of the Durbin–Watson autocorrelation test. Lastly, we tested for heteroscedasticity using the Breusch–Pagan Lagrange–Multiplier test. The hypothesis of heteroscedasticity was rejected both in the Penn World and World Bank data.

The rest of this section describes in further detail the results obtained for the variables considered as determinants of growth.

3.3.1. Initial GDP

Model (1) represents an unconditional β-convergence regression. The GDP parameter reflects the speed at which poor countries converge towards rich ones. This parameter is insignificantly different from 0 and small, implying a speed of convergence of only 0.1 percent per year.[17] This is contrary to the conventional wisdom that has emerged from the convergence literature, where a convergence speed of approximately 2–3 percent per year is a common result. However, our findings are in line with those of Barro and Sala-i-Martin (1995, p. 445) when using World Bank figures on GDP. In the Penn World data the convergence parameter has the right sign in all the regressions but is insignificantly different from 0 in Model (8), when the inflation variable is added. With a convergence speed of 1.2 percent in Model (11), convergence is more rapid in the Penn World data than in the World Bank data. This is, however, less than the 2–3 percent usually found in the literature, see Barro and Sala-i-Martin (1995, p. 445).

3.3.2. Africa dummy

We use a dummy variable for Africa throughout, because our models are not likely to capture some special factors that may be relevant to growth in African countries. The Africa dummy is significantly different from 0 in all of our regressions.

---

[17] This is consistent with a capital share of 0.987 in the Solow model with a population growth rate of 1 percent per year, a productivity increase of 2 percent per year, and a depreciation rate of 5 percent per year.

Table 4
Partial association between growth and inflation[a]

	World Data Bank						Penn World Tables					
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Initial GDP	−0.001 (0.001)[b]	−0.002 (0.001)[b]	−0.006 (0.001)	−0.004 (0.009)	−0.004 (0.001)	−0.006 (0.002)	−0.004 (0.002)	−0.003 (0.002)[b]	−0.011 (0.002)	−0.012 (0.002)	−0.012 (0.002)	−0.012 (0.003)
Inflation	–	−0.100 (0.006)	−0.080 (0.005)	−0.032 (0.005)	−0.021 (0.005)	−0.022 (0.005)	–	−0.011 (0.005)	−0.011 (0.005)	−0.010 (0.005)	−0.045 (0.014)	−0.047 (0.005)
Investment	–	–	0.104 (0.019)	0.111 (0.016)	0.163 (0.020)	0.171 (0.021)	–	–	0.161 (0.018)	0.154 (0.018)	0.148 (0.025)	0.146 (0.028)
Openness	–	–	–	0.001 (0.003)[b]	0.006 (0.004)[b]	0.012 (0.004)	–	–	–	0.008 (0.003)	0.017 (0.004)	0.022 (0.004)
Primary exports	–	–	–	–	−0.028 (0.008)	−0.094 (0.012)	–	–	–	–	−0.055 (0.009)	−0.100 (0.012)
Primary education	–	–	–	–	–	−0.000 (0.009)[b]	–	–	–	–	–	0.017 (0.009)[b]
Secondary education	–	–	–	–	–	0.007 (0.010)[b]	–	–	–	–	–	−0.012 (0.007)[b]
Constant	0.030 (0.012)	0.052 (0.012)	0.051 (0.012)	0.030 (0.009)	0.016 (0.012)[b]	0.026 (0.014)[b]	0.060 (0.014)	0.049 (0.014)	0.079 (0.014)	0.083 (0.014)	0.078 (0.018)	0.084 (0.020)
Africa dummy	−0.012 (0.004)	−0.015 (0.004)	−0.012 (0.003)	−0.012 (0.002)	−0.011 (0.003)	−0.011 (0.003)	−0.017 (0.003)	−0.015 (0.003)	−0.010 (0.003)	−0.012 (0.003)	−0.011 (0.004)	−0.010 (0.004)
SE	0.060	0.053	0.038	0.027	0.025	0.024	0.032	0.031	0.030	0.030	0.029	0.029
R^2	0.01	0.20	0.25	0.14	0.21	0.29	0.04	0.03	0.12	0.13	0.21	0.29
d.f.	986	980	876	739	503	447	857	760	759	758	484	365
Durbin–Watson	1.83	1.80	1.94	1.83	2.01	2.11	1.87	1.85	1.90	1.91	2.09	2.02
Misspecification test	590	759	784	28	1.51	6.40	30	16	8.53	14.86	0.01	0.31

[a] Standard errors appear within parentheses after the coefficients.

[b] Not significant at the 1 percent level. The Ramsey RESET misspecification test is an F-test and the cut-off point is $F(1,\infty) = 6.63$ at the 1 percent level. Generalized-least-squares estimation with random effects.

3.3.3. Inflation

In Model (2), we add inflation to our regression. The inflation coefficient has the right sign and is strongly significant statistically in all the regressions and both data sets. The effects of an increase in inflation from 5 to 50 percent per year from one country or time to another on annual growth is −0.6 percent in the World Bank data, Model (5), and −1.3 percent in the Penn World data, Model (11). These estimates are a bit smaller than those reported in several of the studies summarized in Table 1, but they are nevertheless well within the −1.0 to −1.5 percent range reported by Barro (1995, 1997) based on the Penn World data and also the representative estimate of −1.2 percent reported by Bruno and Easterly (1998). The inflation coefficient neither changes sign nor becomes insignificant as we add regressors, and, therefore, according to Leamer's extreme-bounds test, it seems robust.

3.3.4. Investment

Model (3) includes investment as a proportion of GDP. The parameter on investment is economically and statistically significant everywhere and has the right sign. According to our Eqs. (5) and (11) in Table 4, an increase in the investment rate from 20 to 30 percent of GDP from one country or time to another increases growth by 1.5–1.6 percent a year, ceteris paribus. This result is consistent with those of Levine and Renelt (1992) and Sachs and Warner (1995). While an investment effect of this magnitude may appear plausible, a reliable assessment of the contribution of investment to growth cannot be offered without adjusting investment for quality, which is an important topic for further research.

3.3.5. Openness

In Model (4), we add the share of trade (exports plus imports) in GDP as a measure of openness. The hypothesis of a zero coefficient is not rejected in the World Bank data, except in Model (6), but this coefficient is, on the other hand, highly significant throughout in the Penn World data. The magnitude (0.017 in the Penn World data, Model (11)) is in the neighborhood of the 0.014–0.016 range reported by Dowrick (1995).

3.3.6. Primary exports

Model (5) includes the ratio of primary exports to GDP (see Sachs and Warner, 1995). Our findings support their hypothesis that abundant natural resources are a mixed blessing in terms of growth, as also found by Gylfason et al. (1999) and Gylfason (1999). Our benchmark estimates in Models (5) and (11) are a bit smaller than those of Sachs and Warner. The economic growth differential between countries where primary exports amount to 10 percent and 20 percent of GDP is approximately −0.5 to −0.8 according to Sachs and Warner and −0.3 to −0.6 according to our findings, ceteris paribus. These results are also in line with Lane and Tornell (1996). Moreover, some types of primary export production involve limited labor skills and low technology, and may thus be inversely related to human capital (Gylfason, 1999; Gylfason et al., 1999). This may to some extent explain the negative effect of primary exports on growth.

3.3.7. School enrolment

Finally, Model (6) includes proxies for human capital, primary and secondary enrolment ratios, which are normally used in this kind of work. Neither coefficient is significantly different from 0. However, measuring output (human capital) by input (number of pupils)

seems likely to be misleading (Herbertsson, 2001). Gylfason (2001) and Gylfason and Zoega (2001) report strong effects of increased secondary enrolment on economic growth across countries.

3.4. Is low inflation harmless?

Our empirical results show that inflation tends to hurt economic growth in the long run. However, in view of the number of high-inflation countries in our sample (Fig. 1), this finding does not preclude the possibility that low inflation may be harmless to growth, perhaps even beneficial, a possibility that is fully consistent with our model. For example, Akerlof et al. (1996) argue that low inflation enhances real wage flexibility, and is thus preferable to no inflation at all from a social point of view. In our model, this phenomenon may lead to increased efficiency of real capital, E, which stimulates growth by Eqs. (9), (10) and (13), other things being equal. Moreover, in recent years prominent economists, including Krugman (1998), have recommended more rapid monetary expansion and inflation in Japan in order to reduce real interest rates below 0 and thereby stimulate investment and growth. In our model, this proposal may be interpreted as a plan to stimulate long-run growth through increased velocity in Eq. (13), provided that moderate inflation does not significantly discourage saving or reduce efficiency. Therefore, we must ask: how high does inflation have to become for long-run growth to slow down?

To find out, we first ranked the countries in our sample by their average inflation rate over the sample period, in ascending order. We then estimated our benchmark Model (11) recursively, using first only the data from the seven countries with the least inflation and then adding one country at a time until the country with the highest inflation was reached and the sample was thus restored to its original size. Fig. 2 shows a scatterplot of the estimated coefficient on inflation with two standard errors and average inflation in 1960–1992. The upper panel of the figure suggests that inflation may actually be good for growth up to a long-run average inflation rate of about 20 percent per annum (corresponding to $\pi/(1 + \pi) = 0.17$), whereas inflation above 20 percent seems to hurt growth. Further, the figure shows that the inflation coefficient reported in column (11) of Table 4 remains virtually unchanged even if all countries with inflation rates above 40 percent per year on average (corresponding to $\pi/(1 + \pi) = 0.28$) are removed from the sample. In Barro (1997, p. 100), by contrast, the removal of more than a small number of episodes with inflation in excess of 40 percent per year changes the results, but how much the results change is not indicated. Unlike us, Bruno and Easterly (1998) find no evidence of a relationship between inflation and growth when countries with high-inflation crises (i.e. with inflation in excess of 40 percent per year for 2 years in a row or longer) are excluded from their sample. However, because the time unit in Bruno and Easterly's panel data is 1 year rather than 5 years like here or 10 years like in Barro (1997), their results probably reflect a mixture of short-and long-run effects of inflation on growth.

The lower panel in Fig. 2 suggests that the corresponding inflation threshold in Model (5), based on the World Bank data rather than the Penn World data, is around 10 percent per year.[18] Again, our results remain unchanged if all countries with inflation rates above 40

---

[18] The World Bank data set has more countries with high inflation than the Penn World Tables. Hence, the different scale of the horizontal axes in the two panels.

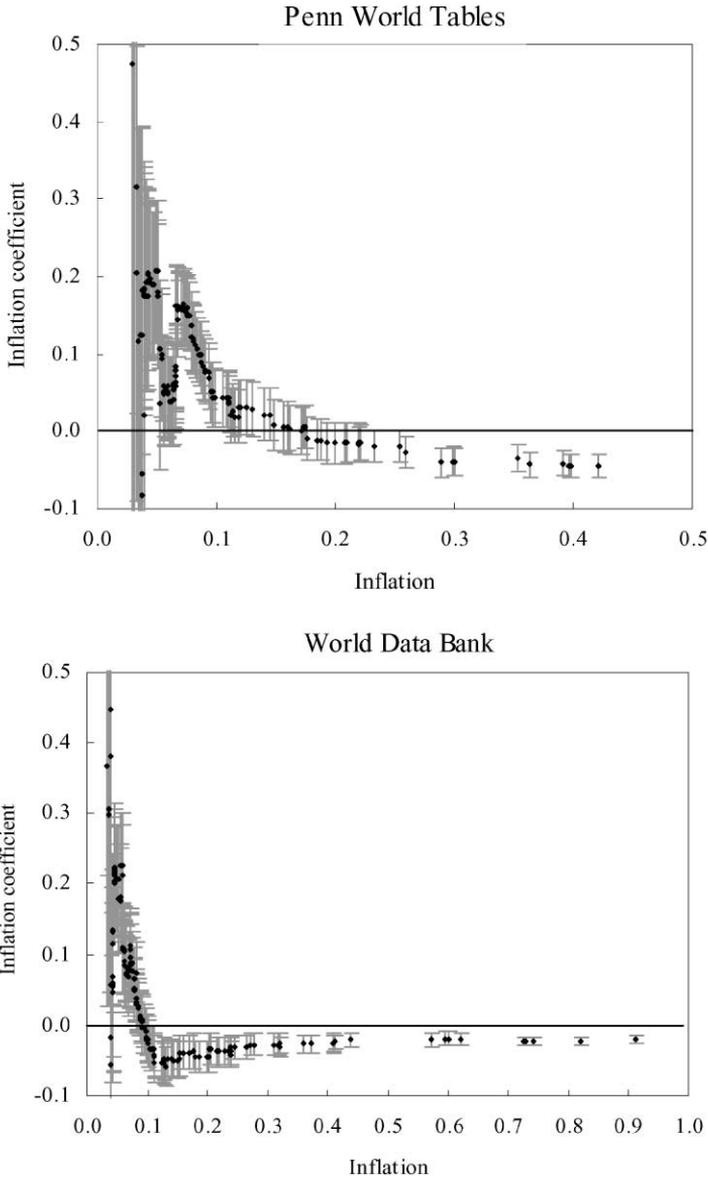## Penn World Tables

World Data Bank

Fig. 2. The inflation coefficient and average inflation, 1960–1992.

percent per year on average are removed. Further, the figure shows that the removal of all countries with inflation rates above 20 percent per year on average strengthens the effect of inflation on growth and brings it into the range between −0.04 and −0.05 as in Model (11). The inflation coefficient remains stable and statistically significant even if we remove all countries with inflation rates in excess of 14 percent per year from the World Bank sample.

We conclude from these results that long-run average inflation in excess of 10–20 percent per year tends to impede economic growth over the long haul and, moreover, that our findings are not driven by the presence of high-inflation countries (with annual average inflation in excess of 40 and 20 percent, respectively) in our two samples.

We also tried another way to locate the inflation threshold, i.e. to find the rate of inflation at which its effect on growth turns from positive or 0 to negative. We did this by adding the square of $\pi/(1 + \pi)$ to Model (11) and then re-estimating the model. To see this, consider the growth equation $g = a + bx - cx^2$, where $x = \pi/(1 + \pi)$ and all the terms in Model (11) other than inflation are subsumed in a. Then, $\partial g/\partial x = b - 2cx$ and the threshold is $x = b/2c$. Our estimate of b is 0.036 ($t = 1.05$) and that of c is 0.180 ($t = 2.56$), which gives a threshold of $x = 0.10$ and $\pi = 0.11$. These estimates show that the effect of inflation on growth in the Penn World data varies directly with inflation and, moreover, that the threshold rate is in the neighborhood of 10 percent per year, but the confidence interval is quite wide. Higher-order polynomials or nonparametric threshold methods may be required for a more precise quantification of the threshold. This is a topic for further research.

The above range of critical rates of inflation, from 10 to 20 percent per year, is far below the 40 percent threshold reported by Bruno and Easterly (1998), even if the two criteria are not directly comparable because our inflation threshold refers to average inflation over the whole sample period whereas Bruno and Easterly's threshold refers to 40 percent inflation per year 2 years in a row or longer. Therefore, we ask: when we rank our samples by inflation in ascending order, as we did above, how many high-inflation countries relative to the size of the samples as a whole have to be removed for the negative effect of inflation on economic growth to vanish? In our Penn World sample, 23 (45) countries had an average rate of inflation in excess of 20 (10) percent per year from 1960 to 1992; the remaining 147 (125) countries had less than 20 (10) percent inflation. Thus, our 10–20 percent threshold means that we have to exclude, from above, between 14 and 26 percent of the countries in our samples for long-run growth to become immune to inflation. By comparison, Bruno and Easterly (1998) needed to exclude high-inflation episodes that amounted to only 8 percent of the observations in their sample for the effect of inflation on growth to disappear.

For further comparison, Sarel (1996) reports that inflation in excess of 8 percent per year is bad for growth. Sarel comes to this conclusion by regressing growth on inflation and other relevant variables, hypothesizing that inflation above a certain critical rate has a stronger effect on growth than does inflation below this threshold. He then tries different critical rates of inflation, and finds that the R^2 of his growth regression is highest when the assumed structural break occurs at 8 percent inflation. It is not clear from his results, however, how significant the drop in R^2 is when the structural break is assumed to occur at higher rates on inflation.

4. Conclusion

Because inflation is a monetary phenomenon and economic growth is real, many economists find it unlikely that inflation can have lasting, systematic effects on growth.[19]

---

[19] For example, Barro and Sala-i-Martin (1995) do not mention inflation as a potential determinant of growth, nor do Aghion and Howitt (1998). See also Sala-i-Martin's sceptical discussion of Fischer (1991, pp. 368–378).

Others disagree, including central bankers: they argue that price stability is a prerequisite for rapid growth.

The econometric evidence reported in this paper supports the latter view. From 1960 to 1992, increased inflation tended to retard growth in a large group of countries at all income levels, both across countries and over time. The link between inflation and growth appears fairly strong, both statistically and economically: an increase in inflation from 5 to 50 percent a year from one country or time to another reduces the rate of growth of GDP per capita by 0.6–1.3 percent a year according to our benchmark regressions (see Table 4, columns 5 and 11), other things being equal. The link is nonlinear: growth is relatively more sensitive to an increase in inflation by, say, 45 percentage points a year at low than at high rates of inflation. The link also seems quite robust: it survives the inclusion and stepwise introduction of several further conditioning variables: (a) initial income (to capture the catch-up effect, or convergence), (b) investment (unadjusted for quality), (c) human capital (as measured by primary-and secondary-school enrolment), (d) primary exports (to capture the inefficiency caused by rent seeking, the Dutch disease, and perhaps also by the spillover effects of low technology and low-skilled labor in some primary-export industries, e.g. agriculture in developing countries), and (e) a dummy variable for Africa. True, the link between inflation and growth in our data can be traced to countries with moderate or high inflation, but not very high: our results indicate that inflation rates above 10–20 percent per year are generally detrimental to long-run growth. These findings are not driven by the presence of high-inflation countries (with annual average inflation of 40 and 15 percent, respectively) in our two samples.

The effect of inflation on growth is significant and sizeable both in the panel regressions based on the World Data Bank and in those based on the Penn World Tables. The inflation effect is stronger in the Penn World data, where growth drops by 1.3 percent a year ceteris paribus as inflation goes up from 5 to 50 percent a year, compared with a 0.6 percent drop in growth in the World Bank data according to our benchmark regressions (see again Table 4, columns 5 and 11). A likely explanation for the difference is that the growth figures in the Penn World Tables are adjusted for differences in purchasing power across countries, in contrast to the unadjusted growth figures from the World Bank. Inflation-prone countries, whose currencies periodically become overvalued in real terms, tend to have real exchange rates that are too high (i.e. exceed their normal equilibrium values) on average over long periods. This may harm foreign trade, economic efficiency (E in Eq. (13)), and growth. The impact of inflation on growth through this channel is generally more transparent in the purchasing-power-parity-adjusted measures of GDP than in the unadjusted figures, because the unadjusted figures tend to overstate GDP, when the currency is overvalued; indeed, the main purpose of PPP adjustment is precisely to correct output for unrealistic exchange rates. In our sample, and in the world, there are many more (small) countries with overvalued currencies than there are (large) countries with correspondingly undervalued currencies. Hence, the possible bias, which may also help explain why, thus far, relatively few empirical growth studies have been based on World Bank data (see Table 1, column 4). Even so, the critical rate at which inflation begins noticably to hurt growth is lower in the World Bank data than in the Penn World data (Fig. 2).

But the overvaluation of national currencies is not the sole possible source of the observed link between inflation and growth, far from it. Inflation may also distort

production by driving a wedge between the returns to real and financial capital, and by thus reducing liquidity and financial depth, and hence also efficiency. It may, moreover, reduce saving and the quality of investment by reducing real interest rates, often far below zero, thus accelerating the depreciation of the capital stock. At last, inflation may be a common denominator for imperfect institutions (e.g. fragile banks and financial markets), unsound policies (e.g. persistent government budget deficits), and other factors (e.g. political upheaval and ethnic strife) that together help undermine saving, efficiency, and economic growth. Inflation can be detrimental to economic growth through one or all of these channels, as shown in Eq. (13). The relative importance and interplay of these transmission mechanisms is an important topic for further econometric research.

Acknowledgements

Appendix. The data

We use data from the World Data Bank and the Penn World Tables. The data can be downloaded from http://www.hi.is/~gylfason/datajwe.htm. The variables are as follows.

- *Growth of GDP*: For the World Bank data, this is a 5-year average of the log difference of GDP per capita in 1987 US dollars, given by the formula: $(1/5)\sum_{t=1}^{5}[\log(\text{GDP}_t) - \log(\text{GDP}_{t-1})]$. The RGDPCH (real GDP per capita at 1985 international prices, chain index) is used for the Penn World GDP growth rates.
- *Initial GDP*: GDP per capita measures the total output of goods and services for final use occurring within the domestic territory of a given country, regardless of its allocation to domestic and foreign uses. GDP at purchaser values (market prices) is the sum of GDP at factor cost and indirect taxes less subsidies. GDP_0 is the first observation in the corresponding 5-year interval. For the Penn World regressions, we use RGDPCH as defined above.
- *Inflation*: This variable is defined as $\pi/(1+\pi)$, where π is the 5-year average of the log difference of the GDP deflator. This transformation reflects the magnitude of the inflation distortion in production (as in Gylfason, 1999) and, equivalently, the implicit inflation tax rate. It is intended to capture the nonlinear relationship between growth and inflation: growth is thus less sensitive to an increase in inflation from 500 to 600 percent per year than, say, an increase from 0 to 100 percent per year. The deflator is derived by dividing current-price estimates of GDP at purchaser values (market prices) by constant-price estimates. The World Bank inflation measure is used in all regressions.
- *Investment*: This is a 5-year average of the sum of gross domestic fixed investment and the change in stocks, as a percentage of GDP, for the World Bank regressions, and for

the Penn World regressions, we use gross domestic investment, private and public, as percentage of GDP.

- *Openness*: This is a 5-year average of the sum of exports and imports of goods and services divided by GDP. Exports (imports) of goods and services represent the value of merchandise exports (imports) plus amounts receivable from (payable to) nonresidents for the provision of nonfactor services to residents. Nonfactor services include transportation travel, insurance, and other nonfactor services such as government transactions and various fees. For the Penn World regressions, we use 5-year averages of the sum of exports and imports of goods and services divided by CGDP (real GDP per capita at current international prices).
- *Primary exports*: Lack of data made 5-year averages impossible. Instead, if one measurement fell into the 5-year period, it was used. Exports of primary products comprise commodities in SITC revision 1, Sections 1–4 and 68 (food and live animals, beverages and tobacco, animal and vegetable oil and fat, and crude materials). The World Bank measure of primary exports is used in all regressions.
- *Primary education*: We use 5-year averages of gross enrolment of students at the primary level as a percentage of school-age children as defined by each country and reported to UNESCO. Only four or sometimes three measurements were available in some periods, but this probably causes no harm where these series are not undergoing any dramatic changes between years. For some countries with universal primary education, the gross enrolment ratios may exceed 100 percent, because some pupils are younger or older than the local primary school age.
- *Secondary education*: Here, we use 5-year averages of gross enrolment of students at the secondary level as a percentage of school-age children as defined by each country and reported to UNESCO. As with primary education, only four or sometimes three measurements were available in some periods. Late entry of more mature students as well as repetition and ''bunching'' in the final grade can influence these ratios.

References

Aghion, P., Howitt, P., 1998. Endogenous Growth Theory. MIT Press, Cambridge, MA, London, UK.

Akerlof, G.A., Dickens, W.T., Perry, G.L., 1996. The macroeconomics of low inflation. Brookings Papers on Economic Activity 1, 1–76.

Alogoskoufis, G.S., van der Ploeg, F., 1994. Money and endogenous growth. Journal of Money, Credit, and Banking 26 (4), 771–791.

Barro, R., 1990. Comment on R. Dornbusch, F. Sturzenegger, H. Wolf, Extreme inflation: dynamics and stabilization. Brookings Papers on Economic Activity 2, 68–75.

Barro, R., 1991. Economic growth in a cross section of countries. Quarterly Journal of Economics 106, 407–443.

Barro, R., 1995. Inflation and economic growth. Bank of England Quarterly Bulletin, 166–176.

Barro, R., 1997. Determinants of Economic Growth: A Cross-Country Empirical Study. MIT Press, Cambridge, MA, London, UK.

Barro, R., Sala-i-Martin, X., 1995. Economic Growth. McGraw-Hill, New York.

Bruno, M., Easterly, W., 1998. Inflation crises and long-run growth. Journal of Monetary Economics 41, 3–26.

De Gregorio, J., 1992. The effects of inflation on economic growth: lessons from Latin America. European Economic Review 36, 417–425.

De Gregorio, J., 1993. Inflation, taxation, and long-run growth. Journal of Monetary Economics 31, 171–198.

Dornbusch, R., Frenkel, J.A., 1973. Inflation and growth: alternative approaches. Journal of Money, Credit, and Banking 5, 141–156.

Dowrick, S., 1995. Trade and Growth: A Survey and New Evidence, manuscript.

Fischer, S., 1974. Money and the production function. Economic Inquiry 12, 517–533.

Fischer, S., 1979. Capital accumulation on the transition path in a monetary optimization model. Econometrica 47, 1433–1439.

Fischer, S., 1991. Growth, macroeconomics, and development. NBER Macroeconomics Annual, 329–364.

Fischer, S., 1993. The role of macroeconomic factors in growth. Journal of Monetary Economics, 32, 485–512.

Grimes, A., 1991. The effects of inflation on growth: some international evidence. Weltwirtschaftliches Archiv 127 (4), 631–644.

Gylfason, T., 1991. Inflation, growth, and external debt: a view of the landscape. World Economy 14 (3), 279–297.

Gylfason, T., 1998. Output gains from economic stabilization. Journal of Development Economics 56, 81–96.

Gylfason, T., 1999. Exports, inflation, and growth. World Development 27, 1031–1057.

Gylfason, T., 2001. Natural resources, education, and economic development. European Economic Review 45, 847–859.

Gylfason, T., Herbertsson, T.T., 1996. Does Inflation Matter for Growth? CEPR Discussion Paper No. 1503.

Gylfason, T., Herbertsson, T.T., Zoega, G., 1999. A mixed blessing: natural resources and economic growth. Macroeconomic Dynamics 3, 204–225.

Gylfason, T., Zoega, G., 2001. Natural Resources and Economic Growth: The Role of Investment. CEPR Discussion Paper No. 2743.

Herbertsson, T.T., 2001. Accounting for human capital externalities: with an application to the nordic countries, European Economic Review (in press).

Hausman, J.A., Taylor, W.E., 1981. Panel data and unobservable individual effects. Econometrica 49, 1377–1398.

Heitger, B., 1985. Bestimmungsfaktoren internationaler wachstumsdifferenzen. Weltwirtschaft 1, 49–69.

King, R.G., Levine, R., 1993. Finance and growth: Schumpeter might be right. Quarterly Journal of Economics 108, 717–737.

Kormendi, R.C., Meguire, P.G., 1985. Macroeconomic determinants of growth: cross-country evidence. Journal of Monetary Economics 16, 141–163.

Krugman, P.R., 1998. It's baaack! Japan's slump and the return of the liquidity trap. Brookings Papers on Economic Activity 2, 137–187.

Lane, P.R., Tornell, A., 1996. Power, growth and the voracity effect. Journal of Economic Growth 1, 213–241.

Leamer, E.E., 1983. Let's take the con out of econometrics. American Economic Review 73, 31–43.

Levine, R., 1997. Financial development and economic growth: views and agenda. Journal of Economic Literature 35, 688–726.

Levine, R., Renelt, D., 1992. A sensitivity analysis of cross-country growth regressions. American Economic Review 82, 942–963.

Mankiw, N.G., Romer, D., Weil, D., 1992. A contribution to the empirics of economic growth. Quarterly Journal of Economics 107, 407–437.

Motley, B., 1994. Growth and Inflation: A Cross-Country Study, paper presented at CEPR — Federal Reserve Bank of San Francisco, Stanford, CA.

Rebelo, S., 1991. Long-run policy analysis and long-run growth. Journal of Political Economy 99, 500–521.

Romer, P.M., 1986. Increasing returns and long-run growth. Journal of Political Economy 94, 1002–1037.

Roubini, N., Sala-i-Martin, X., X., 1992. Financial repressions and economic growth. Journal of Development Economics 39, 5–30.

Rousseau, P.L., Wachtel, P., 2001. Inflation, financial development and growth. In: Negishi, T., Ramachandran, R., Mino, K. (Eds.), Economic Theory, Dynamics and Markets: Essays in Honor of Ryuzo Sato. Kluwer Academic Publishers, Amsterdam.

Sachs, J.D., Warner, A.M., 1995. (1995 revised 1997, 1999), Natural Resource Abundance and Economic Growth. NBER Working Paper 5398, Cambridge, MA.

Sarel, M., 1996. Nonlinear effects of inflation on economic growth. IMF Staff Papers 43, 199–215.

Tanzi, V., 1978. Inflation, real tax revenue, and the case for inflationary finance: theory with an application to Argentina. IMF Staff Papers 25, 417–451.

Taylor, J.B., 1996. Stabilization policy and long-term economic growth. In: Landau, R., Taylor, T., Wright, G. (Eds.), The Mosaic of Economic Growth. Stanford University Press, Stanford, CA, pp. 129–149.

Temple, J., 2000. Inflation and growth: stories short and tall. Journal of Economic Surveys 14, 395–426.

Thirlwall, A.P., Barton, C.A., 1971. Inflation and growth: the international evidence. Banca Nazionale del Lavoro Quarterly Review 98, 263–275.

Tobin, J., 1965. Money and economic growth. Econometrica 33, 671–684.

World Bank, 1996. World Development Report. Oxford University Press, Oxford, New York.