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8 Does Inflation Harm Economic Growth? Evidence from the OECD

Javier Andrés and Ignacio Hernando

8.1 Introduction

From 1973 until 1984 OECD economies underwent a period of macroeconomic distress in which inflation escalated to reach an average rate of 13 percent, three times as high as in the previous decade. Since then, achieving low and stable inflation has become the main goal of monetary policy in western economies. This move in monetary policy making rests on the belief, firmly rooted in many economists' and politicians' minds, that the costs of inflation are nonnegligible, so that keeping inflation under control pays off in terms of faster sustainable growth in the future.

The shortage of theoretical models explicitly addressing the issue of the long-run effects of inflation has not prevented many researchers from trying to estimate the costs of inflation. A series of recent papers have tried to assess the long-run impact of current inflation within the framework of *convergence equations.* These equations can be derived from a theoretical model of economic growth, and although the precise channels through which inflation affects growth are not always made explicit, they have several advantages for the purposes at hand. First and foremost, an explicit model reduces the risk of omitting relevant variables. Second, convergence equations allow for a variety of effects of inflation, including those that reduce accumulation rates and those that undermine the efficiency with which productive factors operate. Finally, in this framework a clear distinction can be made between *level* and *rate-of-*

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growth effects of inflation; this difference matters as regards the size and the timing of the costs of inflation. We stick to this methodology, whose main shortcoming is that it focuses on long-run issues, disregarding the short-run costs associated with disinflation, the *sacrifice ratio.* Our purpose is to study the correlation between growth and inflation at the OECD level and to discuss whether this correlation withstands a number of improvements in the empirical models, which try to address the most common criticisms of this evidence. In particular, we aim to answer the following questions: Is this correlation explained by the experience of high-inflation economies? Are the estimated costs of inflation still significant once country-specific effects are allowed for in the empirical model? Can the observed negative correlation be dismissed on the grounds of reverse causation (from GDP to inflation)?

The rest of the paper is organized as follows. Section 8.2 briefly summarizes the literature dealing with the costs of inflation, the empirical model, and the data used. In section 8.3 we present the estimated convergence equations augmented with the rate of inflation, and in section 8.4 the empirical model is further augmented to allow for cross-country heterogeneity. In these two sections, we test the sensitivity of the results to the exclusion of high-inflation countries. In section 8.4 we also estimate the long-run benefits of a permanent disinflation and address the issue of whether the cost of inflation varies with the level of inflation or not. In section 8.5 standard causality tests are applied to the inflation-growth relationship. Section 8.6 concludes with some additional remarks. The main results of the paper can be summarized as follows. Even low or moderate inflation rates (such as the ones we have witnessed within the OECD) have a negative temporary impact on long-term growth rates; this effect is significant and generates a permanent reduction in the level of per capita income. Inflation not only reduces the level of investment but also the efficiency with which productive factors are used. The estimated benefit of a permanent reduction in the inflation rate by a percentage point is an increase in the steady state level of per capita income that ranges from 0.5 to 2 percent. Although the size varies somewhat across specifications (as well as across different levels of inflation), the correlation between inflation and future income is never found to be positive. This result holds across different subsamples (even excluding high-inflation countries) and is also robust to alternative econometric specifications. In particular, inflation Granger-causes income and the current and lagged correlation between these two variables remains significant when we control for country-specific variables (such as accumulation rates) and time-invariant effects.

8.2 Theoretical Framework

8.2.1 International Evidence

The negative effects of inflation have been studied in the context of models of economic growth in which the continuous increase of per capita income is the outcome of capital accumulation along with technological progress.[1] The uncertainty associated with high and volatile unanticipated inflation has been found to be one of the main determinants of the rate of return on capital and investment (Bruno 1993; Pindyck and Solimano 1993). But even fully anticipated inflation may reduce the rate of return of capital given the nonneutralities built into most industrialized countries' tax systems (Jones and Manuelli 1995; Feldstein 1997). Besides, inflation undermines the confidence of domestic and foreign investors about the future course of monetary policy. Inflation also affects the accumulation of other determinants of growth such as human capital or investment in R&D; this channel of influence is known as the *accumulation* or *investment effect* of inflation on growth.

But over and above these effects, inflation also worsens the long-run macroeconomic performance of market economies by reducing total factor productivity. This channel, also known as the *efficiency channel,* is harder to formalize in a theoretical model;[2] nonetheless, its importance in the transmission mechanism from inflation to lower growth cannot be denied. A high level of inflation induces frequent changes in prices that may be costly for firms (*menu costs*) and reduces the optimal level of cash holdings by consumers (*shoe leather costs*). It also generates larger forecasting errors by distorting the information content of prices, encouraging economic agents to spend more time and resources in gathering information and protecting themselves against the damage caused by price instability, hence endangering the efficient allocation of resources. Although some theoretical models analyze the components of the efficiency channel in more detail, it is difficult to discriminate among them in aggregate empirical growth equations. Thus we shall not pursue this issue further here. We shall turn our attention to the empirical evidence.

Several authors have found a negative correlation between growth and inflation. Kormendi and Meguire (1985) estimate a growth equation with cross-sectional data and find that the effect of inflation on the growth rate is negative, although it loses explanatory power when the rate of investment is also included in the regression. This would indicate that the effect of inflation mainly manifests itself in a reduction in investment but not in the productivity of capital. Grier and Tullock (1989) estimate a model that excludes the rate of investment and includes several measures of nominal instability (such as the inflation

1. See Orphanides and Solow (1990), De Gregorio (1993), and Roubini and Sala-i-Martin (1995) among others.
2. Briault (1995) surveys the literature on these effects.

rate, the acceleration of prices, and the standard deviation of inflation). The results differ according to the group of countries considered, but for the OECD only the variability of inflation seems to have a significant and negative effect on growth.

More recently, the study of the long-run influence of inflation has progressed within the framework of convergence equations developed by Barro and Sala-i-Martin (1991).[3] Fischer (1991, 1993) reports a significant influence of several short-term macroeconomic indicators, in particular inflation, on the growth rate. Cozier and Selody (1992) estimate cross-sectional convergence equations for different samples and find a fairly large negative effect of inflation on income at the OECD level. These authors conclude that inflation affects the level rather than the growth rate of productivity and that the impact of inflation variability is weak.[4] This finding coincides with the result obtained more recently for a sample of 120 countries by Barro (1995, 1996), who reports a negative long-run effect of inflation using alternative instruments to correct for the endogeneity of inflation. The general conclusion of these and other studies (De Gregorio 1992a, 1992b, 1996; Motley 1994) is consistent with the negative correlation between inflation and income in the long run suggested in the theoretical literature. However, the consensus in this respect is far from absolute, and several authors have criticized these findings, arguing that the lack of a fully developed theoretical framework makes it difficult to interpret the empirical correlations and that even these are not robust to changes in the econometric specification. The latter argument is developed by Levine and Renelt (1992), Levine and Zervos (1993), and Clark (1997). Levine and Renelt carry out an exhaustive sensitivity analysis among a broad set of regressors in growth equations and conclude that the statistical significance (and even the sign) of most of these variables (inflation among them) is not invariant under changes in the information set.[5] Nor do these results, in turn, escape criticism. Sala-i-Martin (1994) argues that the problem of finding a macroeconomic variable whose effect is invariant under alternative specifications of the convergence equation should not be taken to mean that this influence is absent, but should instead be viewed as a sign of the difficulty of finding indicators that can adequately capture this effect for any period and group of countries. Gylfason and Herbertsson (1996) find that the inflation rate is robust to changes in the

3. Several exceptions, however, are worth noting: the studies of Grimes (1991) for the OECD, Smyth (1994) for the United States, Cardoso and Fishlow (1989), who use a panel of five-year averages for 18 Latin American countries, Burdekin et al. (1994), and Bruno (1993). In all these studies, a significant negative effect of inflation on growth is reported. On the other hand, Bullard and Keating (1995) find that the long-run output response to permanent inflation shocks in a structural vector autoregressive model is zero for most advanced economies.

4. Judson and Orphanides (1996) measure the variability of inflation as the variance of the quarterly rate for each country and find that it is negatively correlated with growth. These authors also find a significant negative effect of the level of inflation.

5. McCandless and Weber (1995) conclude also that the cross-country correlation between inflation and growth is zero.

conditioning set, whereas Andrés, Doménech, and Molinas (1996) show that for the OECD as a whole, short-run macroeconomic variables are at least as robust as rates of accumulation in explaining economic growth and that this holds for alternative conditioning sets as well as across different time periods.

8.2.2 Effect of Inflation in Convergence Equations

There are a number of advantages in approaching the correlation between inflation and growth within the framework of convergence equations as proposed by Barro and Sala-i-Martin (1991), which represent the main empirical proposition of growth models with constant returns.[6] In this paper we do not intend to test any particular model of economic growth, nor does the use of convergence equations mean that the exogenous growth model is the only possible representation of the evolution of OECD economies in the long run. As Gylfason and Herbertsson (1996) have pointed out, these equations might encompass the empirical implications of many endogenous growth models. The main advantage of this specification is that it systematically captures most of the factors that have usually been considered determinants of growth, reducing the risk of omitting relevant regressors entailed in ad hoc specifications.[7] The technology is represented by the following production function of constant returns (Mankiw, Romer, and Weil 1992):

$$Y_t = (A_t L_t)^{\beta} K_t^{\alpha} H_t^{\gamma}. \tag{1}$$

Total factor productivity (A_t) grows at the constant exogenous rate ϕ, whereas fixed capital (K) and human capital (H) grow in proportion to the output assigned for their accumulation.[8] Assuming that the depreciation rates of both factors are the same, it is possible to derive the following equation of growth between two moments in time:

$$y_{T+\tau} - y_T = \phi\tau + (1 - e^{-\lambda\tau})(\Omega^c + y_T^* - y_T), \tag{2}$$

where y represents the logarithm of per capita income in the period indicated by the subscript and y^* represents its steady state value. Expression (2) indicates that the growth rate of an economy will have a component determined by the growth in factor productivity, ϕ, and another resulting from the economy's propensity to move to its steady state level if, for some reason (shocks, initial conditions, etc.), it lies outside. The parameter λ is the rate at which the econ-

6. De Gregorio (1993) and Roubini and Sala-i-Martin (1995) provide more elaborate models of the interaction between inflation and growth.

7. In particular, unlike those equations that do not include the catching-up component, convergence equations provide a way of controlling the level of per capita income when analyzing the determinants of its growth rate. This turns out to be of crucial importance in obtaining a significant correlation between growth and inflation.

8. In the original formulation of Solow (1956), the rate of technological progress is exogenous, although in more recent models it can be explained by the set of resources assigned to research, market size, learning-by-doing, etc.

omy closes the gap between its current income and its potential or steady state level.[9] This level is, in turn, determined by the parameters of the production function and by the rates of accumulation of the productive factors:

$$(3) \quad y_T^* = \Omega^s + \phi T + \beta^{-1}[\alpha s_{T\mathrm{k}}^* + \gamma s_{T\mathrm{h}}^* - (\alpha + \gamma)\log(n_T^* + \phi + \delta)],$$

where s_{k}^* is the logarithm of the rate of investment, s_{h}^* represents the logarithm of the rate of accumulation of human capital, and n^* is the growth rate of the population, all evaluated at their steady state levels; δ is the depreciation rate of capital, which will be assumed equal to 3 percent, while the two constants combine different parameters of the model and the starting level of technology (A_T).

This structure allows us to test the different hypotheses considered in this paper. First, the presence of the rates of factor accumulation in equation (3) is useful to discriminate between the two channels through which macroeconomic imbalances can affect the growth rate. Thus, if inflation reduces total factor productivity, we could expect a significant coefficient of the rate of inflation in equation (5), below. In this case, the productivity index (A_t) might be assumed to evolve as in equation (4) (Cozier and Selody 1992), which reflects the influence of the inflation rate (π) and its variability (σ):

$$(4) \qquad A_t = A_0 \exp(\phi t)\exp(\mu_1 \pi_t)\exp(\mu_2 \sigma_t).$$

The empirical specification is then given by

$$(5) \qquad \begin{aligned} y_{T+\tau} - y_T = {} & \phi\tau + (1 - e^{-\lambda\tau})[\Omega - y_T + \phi T + \mu_1 \pi_T \\ & + \mu_2 \sigma_T + \beta^{-1}(\alpha s_{T\mathrm{k}}^* + \gamma s_{T\mathrm{h}}^* - (\alpha + \gamma)\log(n_T^* + \phi + \delta))]. \end{aligned}$$

However, if inflation influenced growth solely through its impact on investment (s_{k}), its coefficient in equation (5) would not be significant.[10] Unless it is necessary we shall not impose the parametric restrictions in the previous equations; we shall focus on the linear version (5′) instead:

$$(5') \qquad \begin{aligned} y_{T+\tau} - y_T = {} & \psi_0 + \psi_1 T + \psi_2 y_T + \psi_3 s_{T\mathrm{k}}^* + \psi_4 s_{T\mathrm{h}}^* \\ & + \psi_5 \log(n_T^* + \phi + \delta) + \psi_6 \pi_T + \psi_7 \sigma_T. \end{aligned}$$

Second, the exogenous growth model specifies the determinants of both the long-run level of per capita income and the sustained growth rate. Inflation can affect one or the other, although the implications in terms of welfare are different.[11] According to the specification of equation (4), the impact of inflation basically impinges on the potential level of income but not on sustained

9. This rate can be written as $\lambda = (1 - \alpha - \gamma)(n^* + \phi + \delta)$.

10. In this case, the impact of inflation on growth in the long run should be evaluated by estimating investment equations.

11. See Thornton (1996) for a discussion of this issue.

growth (represented by ϕ). To examine the latter possibility, we shall also consider an alternative specification, (4′), which allows for the influence of inflation on the long-run growth rate:[12]

$$A_t = A_0 \exp[(\phi + \phi'\pi)t]\exp(\mu_1\pi) \tag{4′}$$

such that the equation to be estimated would be represented by

$$\begin{aligned} y_{T+\tau} - y_T = {} & (\phi + \phi'\pi)\tau + (1 - e^{-\lambda\tau})[\Omega - y_T + (\phi + \phi'\pi)T \\ & + \mu_1\pi_1 + \beta^{-1}(\alpha s^*_{Tk} + \gamma s^*_{Th} - (\alpha + \gamma)\log(n^*_T + \phi + \delta))]. \end{aligned} \tag{6}$$

In section 8.3 we estimate the elasticity of growth with respect to inflation in models (5), (5′), and (6).

Our observations are four-year averages of OECD annual variables. Our data set is described at length by Dabán, Doménech, and Molinas (1997), who use OECD 1990 purchasing power parities to homogenize OECD national accounts from 1960 to 1992. When making real income comparisons among a set of countries, we must be aware of the properties of the data elaborated for that purpose. In particular, the more transitive we want our comparisons to be, the more the reference basket of goods has to depart from the most representative sample of items for each country. Since we restrict the analysis to the OECD, we avoid the use of data sets designed to homogenize information from a much larger set of countries (such as the one in the Penn World Tables, Mark 5, PWT 5; Summers and Heston 1991).

8.3 Estimation of the Effect of Inflation

Tables 8.1 and 8.2 show the instrumental variables estimates of the steady state and convergence equations, using one- and two-period-lagged regressors as instruments. The results are quite robust, both in the linear and in the nonlinear specifications, as regards the effect of inflation. Linear models (eq. [5′]) are shown in table 8.1. The models in columns (1) and (2) of table 8.1 correspond to different versions of the convergence equation. As predicted by the neoclassical model, the parameter of initial per capita income is negative and highly significant, both when steady state variables are included (conditional convergence) and when they are not (unconditional convergence). In column (2), the coefficients of the input accumulation rates have the expected sign, although the one for human capital is nonsignificant. The estimated parameter of the trend, which according to the theoretical model is approximating the rate of technological progress, has an unexpected negative sign.[13] On the other

12. This is the specification proposed by Motley (1994). The variability of inflation is excluded in order to simplify the expression.

13. A possible interpretation for this result is that the trend may be capturing the process of sustained reduction in the rate of growth of per capita income suffered by OECD countries during part of the sample period. We have tried alternative characterizations of technological progress:

Table 8.1 **Linear Models: Equation (5′)**

	Dependent Variable			
	Δy (1)	Δy (2)	y^* (3)	y^* (4)
ψ_0	0.348	−0.241	2.314	−1.044
	(8.68)	(1.08)	(25.49)	(0.96)
ψ_1	−0.010	−0.010	0.076	0.050
	(3.35)	(3.08)	(5.22)	(3.41)
ψ_2	−0.073	−0.089		
	(4.40)	(5.08)		
ψ_3		0.045		0.161
		(1.97)		(1.44)
ψ_4		0.030		0.630
		(1.02)		(4.78)
ψ_5		−0.123		−0.052
		(1.66)		(0.14)
ψ_6	−0.002	−0.001	−0.024	−0.014
	(2.94)	(1.73)	(8.50)	(4.34)
R^2	0.30	0.36	0.37	0.52
σ	0.055	0.053	0.299	0.259

Note: Estimation method is instrumental variables. Instruments are constant, trend and first- and second-order lags of the regressors, and second lag of the dependent variable. Numbers in parentheses are absolute t-ratios.

hand, the trend coefficient has the expected positive sign in the steady state equation (cols. [3] and [4]), but the values of the coefficients of the accumulation rates suggest a far too large share of human capital in the production function.

When the inflation rate and its variability (proxied by the coefficient of variation) are included, the rest of the parameters do not change significantly. The coefficient of the inflation rate is negative and significant, both in the convergence and in the steady state equation, whereas no significant effect is found from the variability of inflation. Thus the equations presented hereafter exclude this variable. When the factor accumulation rates are included (cols. [2] and [4]) the size of the inflation effect is smaller than when they are omitted (cols. [1] and [3]), but it is still significant. These results suggest that there are two channels by which inflation influences growth: first, through a reduction in the propensity to invest and, second, through a reduction in the efficiency in use of inputs.

Nonlinear models (eq. [5]) are shown in table 8.2. The estimated parameters

first, including time dummies instead of the linear trend and, second, imposing a rate of technological progress of 2 percent. The estimated coefficients, including that of inflation, do not change significantly. These results are omitted to save space.

Table 8.2 **Nonlinear Models: Equation (5)**

	Dependent Variable			
	y^* (1)	Δy (2)	Δy (3)	Δy (4)
Ω^s	−2.22			
	(2.46)			
Ω^c		−4.09	−1.97	−0.19
		(2.84)	(1.61)	(0.13)
α	0.09	0.27	0.23	0.35
	(1.31)	(2.87)	(2.56)	(3.45)
γ	0.31	0.27	0.21	0.11
	(6.30)	(3.18)	(2.54)	(1.13)
ϕ_{ss}	0.051			
	(3.35)			
ϕ_c		−0.09	−0.05	−0.05
		(2.57)	(1.79)	(1.91)
ϕ'				0.005
				(2.10)
μ_1	−0.013	−0.011	−0.025	−0.22
	(4.00)	(2.03)	(3.95)	(2.38)
λ		0.027	0.032	0.031
R^2_{ss}	0.50			
R^2_c		0.37	0.39	0.27
σ_{ss}	0.266			
σ_c		0.053	0.050	0.057

Note: Estimation method: see note to table 8.1. Numbers in parentheses are absolute t-ratios.

of the accumulation rates in the steady state equation (col. [1]) are quite far from those usually obtained in the empirical literature, the low value of α being particularly remarkable. The effect of inflation is negative and significant. The estimated coefficients in the convergence equation (col. [2]) look more reasonable, pointing toward a technology of similar factor shares ({1/3, 1/3, 1/3}), with an implicit rate of convergence around 2.7 percent. Again, the effect of inflation is negative and significant.

Additionally, some tests of the sensitivity of the inflation coefficient to the sample definition have been performed in order to ascertain whether the negative correlation between inflation and income is driven by the presence of some high-inflation countries. The most noticeable change in the estimated coefficient takes place when Iceland is excluded from the sample. In this case (col. [3] of table 8.2) the correlation between inflation and growth is almost twice as high as when it is included. This is not surprising because Iceland, the country with the second highest average inflation within the OECD, is also a high-income fast-growth economy, which may be generating a downward bias in the absolute value of the growth-inflation correlation. We have proceeded to estimate the model for different subsamples according to their average infla-

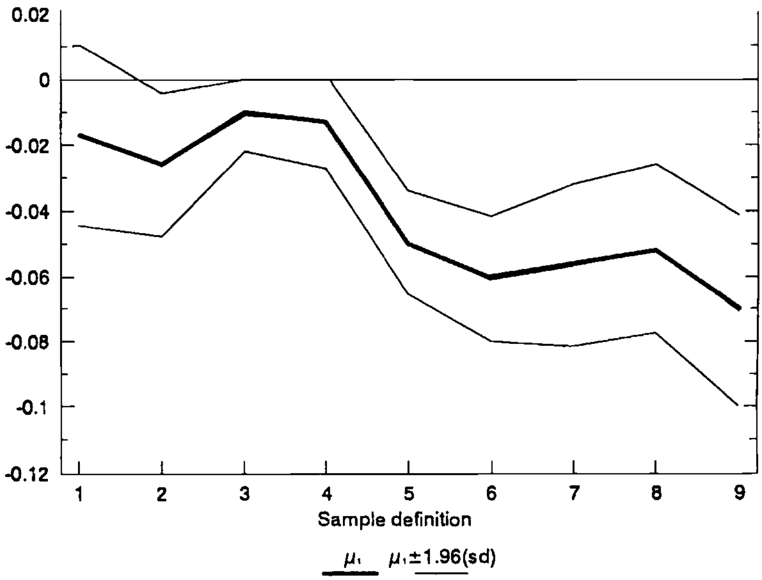

Fig. 8.1 Sensitivity of inflation coefficient to sample definition: basic model
Note: The figure depicts the estimated coefficient (μ_1) for inflation in model (5) as well as the 95 percent confidence intervals (±1.96 standard deviation band) for different sample definitions.
Sample Definition: 1—High-inflation countries (above OECD average). 2—High-inflation countries (excluding Iceland). 3—OECD. 4—OECD excluding Turkey. 5—OECD excluding Turkey and Iceland. 6—OECD excluding Turkey, Iceland, and Portugal. 7—OECD excluding Turkey, Iceland, Portugal, and Greece. 8—OECD excluding Turkey, Iceland, Portugal, Greece, and Spain. 9—Low-inflation countries (below OECD average).

tion. The results, depicted in figure 8.1, indicate that if anything, the coefficient of inflation in the convergence equation is higher (in absolute value) and more significant for low-inflation countries.

The negative effect of inflation on per capita income seems to be robust both in the steady state and in the convergence equation. Although the negative influence of inflation on per capita income is well established, its effect on the sustainable growth rate is less clear. If the inflation rate is a determinant of steady state per capita income (y^*) it should also appear in the convergence equation. But it is not clear whether the negative coefficient in this equation points to an effect on the level or on the growth rate of output. To discriminate between these effects we have estimated equation (6), allowing for an effect of inflation both on the steady state level of income (μ) and on the permanent component of the growth rate (ϕ'). Both these coefficients are negative and significant when they are introduced individually, but when they are jointly included in the model (col. [4] of table 8.2) the effect on the trend component takes an unexpected positive sign. This would indicate that the negative effect of inflation impinges on the level of per capita income but not on the sustainable rate of growth of the economy. Thus the impact on the growth rate is transitory (in the medium run) as long as convergence is under way.

Summing up, the analysis in this section, in accordance with other studies, provides evidence of an adverse influence of inflation on growth. As regards the size of this effect, if we take the coefficient in column (3) of table 8.2 as a reliable estimate of the long-run effect of inflation on growth, an increase in average inflation by 1 percentage point reduces per capita growth by 0.08 points per year. This fall in the growth rate is not permanent, but it lasts for a long period, leading to a permanent reduction in steady state per capita income of 2.5 percent.[14] However, before drawing any policy implications from these numbers it is convenient to take a closer look at the relationship between inflation and growth, trying to correct for some biases that might arise in specifications like the ones studied so far.

8.4 Country-Specific Effects and the Cost of Inflation

There are several reasons to include individual effects in convergence equations estimated with multicountry data sets. Most empirical analyses of economic growth have relied on the use of information for wide groups of countries. This makes it possible to focus on low-frequency properties of the data, taking time-series averages and still avoiding a severe shortage of degrees of freedom. However, this approach imposes a very strong restriction, namely, that the data for all the economies of the sample stem from the same theoretical distribution (i.e., the technological parameters are homogeneous across countries). This assumption is seldom explicitly tested, although its empirical implications may be very important (see Pesaran and Smith 1995). The existence of technological differences in the rates of technical progress or, as is more likely, in the initial conditions of each country would lead to the presence of idiosyncratic effects in growth equations. If these and other country time-invariant characteristics affect the growth-inflation relationship, the lagged regressors would be rendered inappropriate as instruments in growth equations (Barro 1996). The consideration of individual effects in the constant term (Knight, Loayza, and Villanueva 1993; Islam 1995) or in a more general way (Andrés, Boscá, and Doménech 1996) might then alter significantly some of the main results of the empirical growth literature.

In this section, we test whether the estimated negative effect of inflation on growth is biased by the omission of these country-specific (time-invariant) effects. The main results are summarized in table 8.3. In column (1), the linear model (eq. [5′]) has been estimated under the assumption that the omitted individual effects are not correlated with the regressors. The random effects estimates, and in particular the coefficient of the inflation rate, resemble very much those of the basic model depicted in column (2) of table 8.1. Nevertheless,

14. When Iceland is included in the sample, these figures are 0.03 and 1.1 percent, respectively.

Table 8.3 **Convergence Equation with Individual Effects: Equation (5′)**

	Dependent Variable: Δy				
	(1)	(2)	(3)	(4)	(5)
ψ_0	−0.26	1.54	1.18	1.24	1.07
	(1.22)	(2.03)	(6.44)	(2.95)	(3.22)
ψ_1	−0.01	0.04	0.03	0.02	0.02
	(2.96)	(3.16)	(3.26)	(3.04)	(3.26)
ψ_2	−0.08	−0.65	−0.48	−0.43	−0.40
	(5.15)	(4.70)	(5.44)	(5.45)	(6.99)
ψ_3	0.05	−0.16		−0.03	−0.04
	(2.34)	(1.54)		(0.84)	(1.24)
ψ_4		−0.019		−0.010	−0.02
		(0.28)		(0.25)	(0.70)
ψ_5	−0.16	−0.21		−0.007	−0.007
	(2.34)	(0.98)		(0.07)	(0.11)
ψ_6	−0.001	−0.001	−0.002	−0.002	−0.003
	(1.90)	(1.16)	(2.29)	(2.47)	(3.99)
R^2	0.36	0.35	0.50	0.48	0.48
σ	0.053	0.054	0.047	0.048	0.048
ψ_6 (LI)[a]		−0.008		−0.011	
		(2.01)		(5.18)	
ψ_6 (HI)[a]		−0.001		−0.001	
		(0.84)		(0.87)	
ψ_6 (HI-ICL)[a]		−0.002		−0.002	
		(1.83)		(1.88)	

Note: Estimation method in col. (1) is random effects (instrumental variables); instruments are first and second lags of the regressors. Estimation method in cols. (2)–(5) is country-dummies instrumental variables; instruments are as in table 8.1 plus country dummies and inflation variability. Dummy variables included: Cols. (2) and (3), one for each country except Australia. Col. 4, one for each of the following countries: Canada, Switzerland, Germany, Spain, the United Kingdom, Finland, Greece, Ireland, Iceland, Luxembourg, New Zealand, Portugal, Turkey, and the United States. Col. (5), one for each of the following countries: Iceland, Spain, Greece, and Turkey; and one for each of the following country groups: Ireland and Portugal; Canada and Germany; Switzerland, Luxembourg, and the United States; and Finland, New Zealand, and the United Kingdom. Numbers in parentheses are absolute t-ratios.

[a]HI—sample of six countries with inflation rates above the OECD average; LI—OECD excluding HI countries; HI-ICL—HI countries excluding Iceland.

the reasons to include country-specific effects in the model suggest that the assumption of noncorrelation among these and the regressors might not be appropriate in this setting. Thus, in what follows, we focus on the fixed effects estimates, which we compute including dummies in the linear convergence equation. All the models have been estimated by instrumental variables. When we add a dummy variable for each country (col. [2]) the explanatory power of most regressors changes, as compared with the models in the previous section. In particular, while inflation still has a negative effect on income, its t-statistic is now lower (-1.16).[15] The changes in the rest of the model are far more radical, though. First, whereas the negative trend coefficient was an unappealing feature of the models in section 8.3, this coefficient now becomes positive and significant, with a reasonable point estimate of 0.04. Second, the point estimates of the technological coefficients are now either nonsignificant or wrongly signed. In fact, excluding the accumulation rates from the equations, the negative correlation between growth and inflation becomes highly significant with a t-statistic of -2.29 (col. [3]). Finally, several country dummies are not different from zero, which means that the model might be overparametrized.

The search for a more parsimonious specification proceeds along the following steps. Starting from the model with a dummy variable for each country, the nonsignificant dummy variables are removed, setting aside the one with the lowest t-statistic each time. As a second step, these excluded variables are added again, one at a time, retaining those with t-ratios greater than 1.5.[16] Every time a dummy variable is added back into the model, the process is reinitiated. This procedure does not involve the analysis of every single possible specification according to all the combinations of country-specific constants. However, it provides a model selection procedure that allows us to test, at least twice, the marginal significance of each dummy variable: first against a more general model (with all the country-specific dummies) and next against a more restricted one. The model in column (4) summarizes the final outcome of this specification process. The results do not change very much from those in column (1), except in that now the coefficient of the inflation rate is negative and significant and its size is similar to that obtained for the model without individual effects. Furthermore, this result is quite robust to the set of country-specific dummies included in the regression. The same search process has also been carried out for different subsamples with different average inflation rates. The point estimates of the inflation coefficient, along with its confidence interval, are depicted in figure 8.2. The coefficient of inflation turns out to be larger and more significant whenever high-inflation countries are not considered. Hence, as was the case in models without country dummies, the estimated correlation between inflation and growth (or income) does not depend on the presence of a group of high-inflation countries in the sample.

Taking column (4) of table 8.3 as a starting point, in the model in column (5) individual dummies are clustered into country-group dummy variables. The

15. It must be noted that the fixed effect estimate of the coefficient of inflation is still significant at the 5 percent level if we focus on the low-inflation countries (LI). This coefficient is lower and weakly significant for the subsample of all countries but Iceland (HI-ICL) with inflation above the OECD average.

16. If the threshold level of the t-ratio is 2.0, the final specification is more parsimonious. Nevertheless, the estimated long-run coefficient of inflation does not depart very much from that in col. (4).

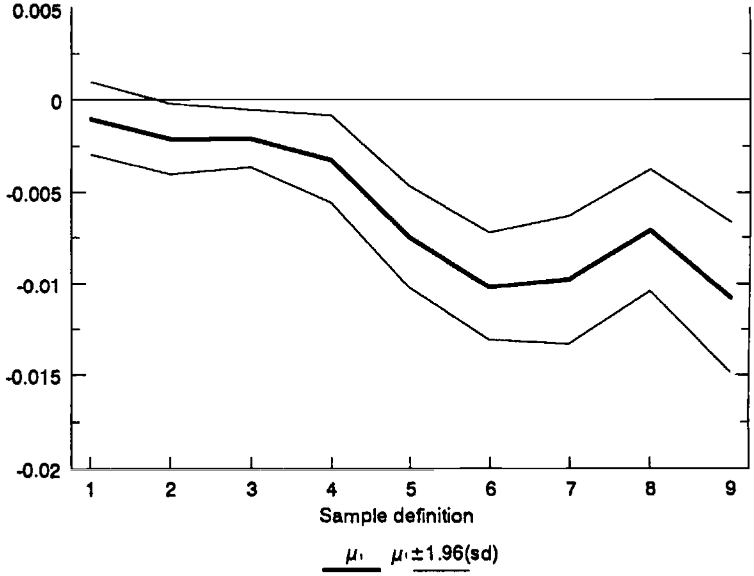

Fig. 8.2 Sensitivity of inflation coefficient to sample definition: country dummies (restricted model)

Note: The figure depicts the estimated coefficient (μ_1) for inflation in model (5) as well as the 95 percent confidence intervals (± 1.96 standard deviation band) for different sample definitions.

Sample Definition: 1—High-inflation countries (above OECD average). 2—High-inflation countries (excluding Iceland). 3—OECD. 4—OECD excluding Turkey. 5—OECD excluding Turkey and Iceland. 6—OECD excluding Turkey, Iceland, and Portugal. 7—OECD excluding Turkey, Iceland, Portugal, and Greece. 8—OECD excluding Turkey, Iceland, Portugal, Greece, and Spain. 9—Low-inflation countries (below OECD average).

t-statistic of the inflation rate increases again (up to -3.99).[17] It is quite remarkable that the negative and highly significant influence of inflation on growth during rather long periods survives all these changes in the specification. In fact, it turns out to be, along with initial per capita GDP, the most robust variable of the model. The country groups in column (5) have been defined according to the size of the individual effect. Greece shows an individual effect that is clearly negative (-0.31) as compared with the excluded countries,[18] followed by Turkey (-0.29), Ireland and Portugal (-0.22), Spain (-0.15), and Finland, New Zealand, and the United Kingdom (-0.05). On the other hand, Canada and Germany (0.04), Iceland (0.08), and Switzerland, Luxembourg, and the United States (0.1) display positive individual effects on the growth

17. As in col. (2), the coefficients for the input accumulation rates are not significant. The exclusion of these variables does not worsen substantially the fit of the equation and further increases the significance level of the inflation rate.

18. Australia, Austria, Belgium, Denmark, France, Netherlands, Italy, Japan, Norway, and Sweden.

rate. The estimated individual effects reveal a systematic pattern that, if ignored, could have led to a bias in the estimated effect of inflation. The individual effect is strongly correlated with the level of per capita income achieved at the end of the sample period. Thus, omitting the individual effect, the model would underestimate the growth of the richest countries and overestimate that of the poorest countries. Since there is a negative correlation at the OECD level between per capita income in 1993 and the average inflation rate, excluding the individual effects is a source of potential upward bias in the estimation of the effect of inflation. Indeed, although the estimated coefficient of inflation remains largely unchanged, compared with that in table 8.1, there is nevertheless a significant change in the point estimate of the long-run effect of inflation once country-specific dummies are included in the model. The coefficient of initial GDP is now almost five times as large as the one in tables 8.1 and 8.2, thus the estimated long-run cost of inflation is now lower. A permanent increase of 1 percentage point leads to a 0.75 percent permanent fall in output. This time, though, the transition period is much shorter because a higher coefficient of initial GDP means that convergence to the steady state is much faster too.

Although OECD economies have certain common institutional features, their inflation performances are rather different. Once we have a more accurate estimate of the long-run cost of inflation we can address the issue of whether this cost varies according to the level of inflation or not. The different perspectives adopted to analyze the linearity of the inflation effect have led to contradictory results. For instance, Barro (1995), estimating different coefficients for different levels of inflation, finds a greater effect of inflation on growth the greater the inflation level.[19] Motley (1994), estimating the growth model for different subsamples, concludes the opposite. We have tried these two approaches in equation (5′) and found that they also yield somewhat different results for the OECD, although the coefficients of inflation in different subsamples were not very precisely estimated. In general, though, the coefficient corresponding to lower inflation rates tends to be higher, although with a lower *t*-ratio. This would indicate that the benefits of lower inflation are indeed higher at low rates, although the functional form might be inappropriate to capture this result. As an alternative, we have estimated the basic model allowing for a nonlinear effect of inflation on growth. When π and π^2 are included, both coefficients are significant while the positive coefficient on π^2 indicates that the marginal cost of inflation is positive but decreasing with its level. Two alternative specifications that allow for a falling marginal cost of inflation have also been tried. In these, inflation is represented by log π and the ratio $\pi/(1 + \pi)$,[20] respectively. In all the specifications tried (with country dummies, excluding Iceland, and so on) these equations perform better than the ones with the level of inflation.

19. Although the null of linearity cannot be rejected (see also Barro 1996).
20. Gylfason and Herbertsson (1996) propose this nonlinear transformation.

Table 8.4 **Linearity of the Inflation Effect**

Inflation Level	Elasticity of Income with Respect to Inflation in Estimates of Linear Version of Convergence Equation
A. Whole Sample Estimates with Specific Inflation Coefficients[a]	
Low inflation	−0.091
	(2.33)
Medium inflation	−0.061
	(2.58)
High inflation	−0.066
	(4.23)
B. Subsample Estimates[b]	
Low inflation	−0.052
	(2.59)
High inflation	−0.034
	(2.15)
Very low inflation	−0.036
	(1.82)
Very high inflation	−0.046
	(1.61)

Note: Estimation method: see note to table 8.1. Numbers in parentheses are absolute t-ratios.

[a]Low inflation—observations with inflation lower than 6 percent; medium inflation—observations with inflation between 6 percent and 12 percent; high inflation—observations with inflation greater than 12 percent.

[b]Low inflation—countries with average inflation lower than the median; high inflation—countries with average inflation greater than the median; very low inflation—eight countries with the lowest inflation; very high inflation—eight countries with the highest inflation.

A further test for linearity has been carried out in the model in log π. In panel A of table 8.4, a different coefficient is allowed for log π depending on its level. These elasticities are always negative and significant but not statistically different. As an alternative approach, the homogeneity assumption may be relaxed by estimating the convergence equation for different subsamples. This approach allows all the parameters, and not only the coefficient of inflation, to vary across subsamples. The results are summarized in panel B of table 8.4. The effect of inflation is negative and significant both for low (and very low) as well as for high (and very high) inflation countries, and the coefficient of log π is similar across different subsample specifications.[21] The results of these two approaches lead us to conclude that the elasticity of income with respect to inflation does not change significantly with the level of inflation. If anything, this tells us that it pays more in a low-inflation country than in a high-inflation one to reduce the inflation rate by a given amount. By the same

21. The coefficient of initial GDP is also similar across the specifications in table 8.4, panel B. Thus the hypothesis of homogeneity in the long-run elasticity cannot be rejected either.

Table 8.5 **Long-Run Effect of Inflation on Per Capita Income (percent)**

	OECD		OECD Excluding Iceland	
Model[a]	Low π	High π	Low π	High π
π, π^2	0.80	0.40	1.10	0.60
$\pi/(1+\pi)$	0.45	0.30	0.70	0.50
$\log \pi$	2.00	0.30	2.20	0.40
π	0.75	0.75	0.75	0.75

Note: The long-run effect is calculated as the coefficient of inflation divided by the coefficient on initial income in the convergence equation augmented with country dummies. Low π—reducing inflation from 4 to 3 percent. High π—reducing inflation from 20 to 19 percent. Initial GDP is noninstrumented.

[a]The variables in the first column indicate the way in which inflation enters in each model.

token, it is more costly for a low-inflation country to concede an additional (and permanent) point of inflation than it is for a country with a higher starting rate.[22]

Table 8.5 shows the long-run impact on income of a 1 percentage point permanent reduction of inflation for a variety of specifications of the effect of inflation. All models include country-specific constants, and we report results for the OECD as a whole and also excluding Iceland. The estimated long-run benefit of a reduction of inflation from 20 to 19 percent varies between 0.30 and 0.75 percent, with an average value of 0.5 percent. At lower inflation levels (a reduction from 4 to 3 percent), the benefit is higher, with an average 1 percent increase in steady state income. These estimated values are all rather similar except for the specification in logs, which overrates the benefits of disinflation at low inflation levels.

These benefits seem lower than others reported in the literature, but it must be noted that they are obtained in equations displaying a higher than usual 2 to 3 percent convergence rate. This is most important because it means that the transition period until the increase in GDP actually takes place is shorter; thus it would not take the representative economy much time to reap the full benefits of a sustained disinflation. In table 8.6 we compare the cost of inflation

22. The exercises in table 8.4 have been carried out for different inflation regimes and also for different specifications of the equation and the inflation term. The overall picture that emerges from these exercises is the same. The coefficient of the inflation term is negative in most cases, and it tends to be bigger (in absolute value) at low inflation rates, although with lower t-statistics as well. In a few specifications the coefficient for very low inflation rates (below 3 to 4 percent) is positive, although never significant. This issue deserves more careful scrutiny because it might well be that inflation ceases to be costly at all at very low levels. Since we have very few data points with inflation under 3 percent in our sample, we have not been able to pursue this further. Sarel (1996) concludes that the cutoff point might be at an 8 percent rate of inflation. However, both the model and the data used differ from ours in several respects.

Table 8.6 Per Capita Income Gain from Reducing Inflation: Steady State and Present Value (percent)

	Basic Model	Country Effects
Steady state per capita income gain	2.5	0.75
λ	2.5	13
Half-life per capita income gain	1.25[a]	0.375[b]
Present value:[c] discount rate 4%	0.32	0.29
Present value:[c] discount rate 5%	0.23	0.27

[a]Half-life is 30 years.

[b]Half-life is 7 years.

[c]Discounted present value of half-life gain (expressed in percentage points of steady state per capita income).

estimated in the basic model (col. [3], table 8.2) with that obtained in the model with country-specific effects (col. [4], table 8.3). The estimated benefit from a permanent reduction in the inflation rate by 1 percentage point is higher in the former (2.5 vs. 0.75 percent). Nevertheless, since this is a steady state effect and the convergence rates also differ across models (2.5 vs. 13 percent), the relevant comparison should be made in present value terms, which makes the outcome depend on the discount rate. According to the figures in this example, for discount rates slightly above 4 percent the benefit of disinflation is larger in models with faster dynamics, despite the lower coefficient of the inflation rate in the convergence equation. Hence, the present value of the per capita income gain might well be within the range of those found in other studies.

8.5 Analysis of Causality

The models studied in previous sections can generate a nonnegligible bias in the estimation of the influence of inflation on growth by focusing on the contemporaneous correlation between these two variables. Inflation and growth are the joint outcome of the way an economy responds to different shocks. If demand shocks predominate, a positive association between GDP growth and inflation can be expected, whereas the association will be negative in response to supply shocks. Also, even if we consider the possibility of a true influence of one variable over the other, the theoretical literature presents arguments in favor of causality in both directions. For this reason, the contemporaneous correlation between growth and inflation may not be very informative as to the existence and magnitude of a real cost associated with inflation.

In fact, it might be the case that the estimated negative correlation between inflation and growth is driven by the predominance of negative supply shocks during the sample period. To test this possibility we have estimated the linear version of the convergence equation for two periods: 1961–72 and 1989–92, during which demand shocks predominated, and 1973–88, during which

Table 8.7 Inflation Effect for Different Periods

Estimation	Coefficient of Inflation in Linear Version of Convergence Equation[a]
A. Demand Shocks Predominance Period: 1961–72 and 1989–92	
Ordinary least squares	−0.002
	(2.33)
Instrumental variables[b]	−0.003
	(2.52)
B. Supply Shock Predominance Period: 1973–88	
Ordinary least squares	−0.004
	(3.85)
Instrumental variables[b]	−0.003
	(2.14)

Note: Numbers in parentheses are absolute *t*-ratios.

[a]Eq. (5′) excluding the trend.

[b]Instruments are constant, first- and second-order lags of the regressors, and second lag of the dependent variable.

supply shocks were probably more significant.[23] The results of this split are shown in table 8.7, where we present only the coefficient on inflation for both the ordinary least squares (OLS) and the instrumental variables (IV) estimations. As expected, the IV coefficient is higher (lower), in absolute value, than the OLS coefficient for the first (second) period given the nature of the expected bias in each case. But in all cases, the coefficients are negative and significant, meaning that the negative supply shocks that hit the OECD economies during most of the second half of the sample period are not primarily responsible for the estimated negative correlation between inflation and growth. If this had been the case, we ought to find a positive coefficient for the first period, at least in the OLS estimation. The finding of negative coefficients for both periods strengthens the view that there is indeed a genuine negative effect of inflation on growth that does not rely on the existence of supply shocks determining simultaneously inflation and growth.

In order to pursue this issue more thoroughly, this section analyzes the statistical causality, as formulated by Granger, of inflation to growth and vice versa. This perspective is broader than that of convergence equations in several ways. First, the analysis of causality focuses on the study of noncontemporaneous effects of one variable on the other. This is precisely the influence of inflation on growth predicted by the theoretical models: an influence that does not operate in the short run but that takes time to show instead. Second, in using a more flexible specification, we avoid the imposition of the parametric restrictions of the neoclassical growth model, which might make the correlation that concerns

23. Similar results were obtained when we split the period up in other two parts: 1961–76, for demand shock predominance, and 1977–92, for supply shock predominance.

us here less clear. The analysis of causality carried out in this section does not put theoretical growth models aside. Economic theory suggests a series of growth determinants that can be incorporated into the information set in the tests of causality.

To analyze the causality from the rate of inflation to the level of per capita income,[24] a test is run on the joint significance of $\{d_1, \ldots, d_p\}$ in the model:

$$(7) \qquad y_t = A + C(L)y_t + D(L)\pi_t + G(L)X_t + u_t,$$

where y_t and π_t are (24×1) vectors of current observations of the logarithm of per capita GDP and of the rate of inflation, respectively, for the 24 member countries of the OECD; X_t is a vector of additional regressors, suggested by growth theory; and A is a (24×1) vector of constants. $C(L)$, $D(L)$, and $G(L)$ are (24×24) matrices in which elements off the main diagonal are zero and elements on the main diagonal are lagged polynomials of order p such as (for $C(L)$, e.g.)

$$c_1L + c_2L^2 + c_3L^3 + \cdots + c_pL^p.$$

The rejection of the null hypothesis that the d_j are zero indicates that current inflation helps to reduce the mean-squared error in the prediction of per capita income and, therefore, that π causes y in the Granger sense. Likewise, the causality from the growth rate to inflation is tested through the joint significance of $\{e_1, \ldots, e_p\}$ in

$$(8) \qquad \pi_t = B + E(L)\Delta y_t + F(L)\pi_t + H(L)X_t + \varepsilon_t,$$

where $E(L)$, $F(L)$, and $H(L)$ are matrices of a structure similar to $C(L)$ and B is a (24×1) vector of constants. The rejection of the null hypothesis that the coefficients e_j are zero indicates that Δy causes π.

The elements of the matrices A and B, as well as the coefficients of the lagged polynomials (in $C(L)$, $D(L)$, $E(L)$, $F(L)$, $G(L)$, and $H(L)$), will be assumed to be homogeneous among countries unless expressly stated otherwise. The estimation of equations (7) and (8) raises several methodological issues,[25] the most important being the possibility that some variables are nonstationary, in which case exclusion tests do not have a standard distribution. In the case at

24. Testing the causality from the rate of inflation to the growth rate only entails adding a linear restriction on the coefficients in $C(L)$ and writing per capita income in first differences. The results of the causality tests to the growth rate are quite similar to those of the causality tests to the level of per capita income and will be omitted here to save space.

25. Since this section applies annual data relating to the variables of interest for the 24 OECD countries, it departs from the traditional approach in the empirical literature on growth, which avoids using annual information. Nevertheless, an increasing number of studies tend to use raw annual data. Moreover, in the dynamic analysis of causality, models based on time averages can be considered as restricted versions of models that use annual data. As regards the role of individual effects in multicountry regressions, we shall take them into account in this section by considering several specifications in which vectors A and B include a different constant for each country (a_i, b_i).

Table 8.8 **Causality from Inflation to Per Capita Income**

	Negative[a]			
	Significant at 5% Level	Significant at Level between 5% and 10%	Nonsignificant	Positive[a]
Causality[b]	15 (6)	10 (2)	22 (2)	0
Noncausality[b]	0	0	3 (0)	0

Note: Each cell reports the number of specifications in that case. In parentheses is the number of specifications corresponding to the model with individual effects, lagged accumulation rates, and lagged macroeconomic indicators.

[a]Sign of the t-statistic for the sum of the coefficients of the inflation lags.

[b]Causality (noncausality): The null hypothesis that the inflation coefficients are jointly nonsignificant is (is not) rejected at the 5 percent level.

hand, both per capita income and the rate of inflation are, for most countries in the sample, nonstationary. There are several ways in which the hypothesis of causality between integrated variables can be tested making use of statistics with asymptotic standard distribution. These procedures basically consist of a reparametrization of the model in order to obtain stationary regressors (see Sims, Stock, and Watson 1990). The method proposed by Dolado and Lütkepohl (1996) does not require a search for possible cointegration vectors, which is quite often a hazardous task in panel data models. These authors propose the estimation of a vector autoregression (VAR) in levels of order $p + 1$. The exclusion test performed on the p first lags is thus distributed asymptotically as an F, whereby the loss of efficiency by the overparametrization of the model is compensated by the test's consistency and simplicity.[26] The application of this method requires knowing the true order, p, of the VAR. In this paper, rather than discussing the structure of the lags in detail, we present results for a range of lags broad enough to ensure the stationarity of the residuals.

The exclusion test in equation (7) has been performed for 10 different structures of lags (p going from 3 to 12) and for five sets of additional regressors (X_t).[27] Thus the causality from the rate of inflation to the level of per capita income has been tested in 50 specifications. Table 8.8 summarizes the results of these tests, which can be read as follows. In 47 cases, the null hypothesis that the inflation coefficients are jointly nonsignificant, and hence that inflation does not cause income, can be rejected at the 5 percent level. Furthermore, the

26. For an application of this method, see Andrés, Boscá, and Doménech (1996).

27. These five sets are the following: (1) includes neither additional regressors ($g_j = 0$) nor constant individual effects; (2) includes individual constant effects so that A is a vector of different constants, one for each country; (3) incorporates, in addition to individual effects, several other regressors such as a linear trend, the saving ratio, the rate of schooling, and the growth rate of the population, all of them contemporaneous; (4) as the previous set, but with the first lag of (instead of the current) accumulation rates; and (5) as the previous set plus current export growth and the first lag of money growth, export growth, public consumption, and public deficit as a percentage of GDP.

sum of the lagged coefficients of inflation is negative in all 50 cases. This would imply that higher inflation today anticipates lower income in the future. However, the evidence of a long-run effect of inflation on income is not unequivocal because the sum of the coefficients of the inflation lags is significantly different from zero (at the 10 percent level) in just half of the cases. This is worrisome because a nonsignificant long-run coefficient can be interpreted as if the effect of inflation on growth is not permanent, casting some doubts on the validity of the correlation found in previous sections.

Table 8.8 indicates in parentheses the number of specifications corresponding to the model with the largest set of additional regressors: individual effects, lagged accumulation rates, and several macroeconomic variables. Many authors have studied the relationship between long-term growth and the short-term performance of economies.[28] The main argument on which this relationship rests is that the shocks hitting an economy or the way economic policy is conducted influences agents' accumulation decisions and the way markets operate. Thus a succession of negative shocks or an inadequately designed fiscal or monetary policy may have effects that go beyond the short term, affecting potential output and sustained growth. If this argument is correct, the causal interpretation of the estimated correlation between inflation and growth could be called into question. The estimated correlation between growth and inflation could be due simply to the fact that inflation approximates the impact of other macroeconomic variables with which it is strongly correlated. Those specifications that include other macroeconomic indicators allow for an analysis of the influence of inflation on growth while isolating it from the effect of other shocks. The numbers in parentheses indicate that after taking into account the effect of fiscal and monetary policy and export performance, the existence of causality of a negative sign from inflation to economic growth becomes more apparent. The null hypothesis that inflation does not help to improve the prediction of the future growth rate is clearly rejected in all cases. The statistic associated with the sum of the coefficients of the inflation lags is negative in all cases and statistically significant in most of them.[29]

Although the results of these causality tests are not fully conclusive, their importance is enhanced if we compare them with similar tests relating growth to other variables, such as investment in physical and human capital or public spending. Several recent attempts to corroborate the statistical causality from investment in physical capital to growth and income[30] have concluded that even though it cannot be rejected that a high rate of current investment could be explained by rapid growth in the past, the existence of causality in the opposite direction is far less conclusive. Blömstrom, Lipsey, and Zejan (1996) show that

28. See Levine and Renelt (1992), Fischer (1993), and Andrés, Doménech, and Molinas (1996), among others, for alternative views of the influence of macroeconomic shocks on growth.

29. In eight out of ten cases at a 10 percent significance level, and in six of them at the 5 percent level.

30. Correlations that are among the main findings of the empirics of convergence.

Table 8.9 Causality from Growth to Inflation

		Positive		
	Negative	Nonsignificant	Significant at Level between 5% and 10%	Significant at 5% Level
Causality	0	3 (0)	2 (0)	45 (10)
Noncausality	0	0	0	0

Note: See notes to table 8.8.

growth always precedes investment, rather than the other way round. A similar result is obtained by Carrol and Weil (1993) for the OECD sample. Andrés, Boscá, and Doménech (1996) also find that investment does not help to improve the prediction of income or of its growth rate in practically any of the specifications studied. Moreover, when investment appears to cause income, the negative sign makes this result hard to interpret. A similar effect is obtained in relation to other determinants of growth—the rate of schooling, among others. What these authors find is that most of the observed positive correlation between investment and growth (or income) can be attributed to reverse causation. Reasoning on similar grounds, many authors suspect that something of this kind might be behind the correlation between inflation and growth (Kocherlakota 1996).

Interestingly enough, unlike what happens with investment and schooling, in this case the causality running from income growth to inflation is indeed significant but with a sign that weakens, rather than strengthens, the case for reverse causality. As can be seen in table 8.9, causality from growth to inflation is not rejected in any of the 50 specifications analyzed; thus we may conclude that current growth rates help to explain the future course of the inflation rate. The t-statistic of the long-run coefficient is always positive, and significantly so (at the 5 percent significance level) in 90 percent of the cases.[31] Economic theory proposes several reasons why rapid growth is associated with higher inflation in the more or less immediate future. On the one hand, it could be a movement along a negatively sloped Phillips curve, as prices respond after a period of rapid expansion in demand. Another interpretation is derived from the so-called Balassa-Samuelson effect (Balassa 1964; Samuelson 1964). According to these authors, rapid economic growth is associated with rapid expansion in the productivity of a country's tradable goods sector, in turn leading to an appreciation of its currency. Insofar as the nominal exchange rate is not adjusted to produce this appreciation, domestic prices will grow faster. This leading correlation of a positive sign indicates that the risk of a simultaneity

31. Again, the results are even more clear-cut if we focus on the specifications with the largest set of additional regressors. In all 10 of those cases, the null hypothesis of noncausality is rejected and the sum of the inflation lags is positive and significant.

downward bias in the estimation of inflation costs is considerable.[32] As a result, the contemporaneous correlation in the convergence equations could be regarded as a lower bound of the costs of inflation, which would have to be adjusted upward in absolute value.

In the light of this evidence, the results presented in this section have an unequivocal interpretation. The current rate of inflation provides relevant information on income prospects in OECD countries. In particular, ceteris paribus, higher inflation never anticipates a higher level of income in the medium and long run. This effect is robust to alternative specifications and, most notably, survives even when accumulation rates and individual effects are included among the set of regressors. Moreover, it can be rejected that this leading correlation between inflation and income is spurious and produced by the coincidence of inflationary tendencies and slow growth in some economies. Therefore, even though the magnitude of the negative effect of inflation might be questioned, the results of this section tell us that inflation does not appear to be neutral in the long run and that in no case does the persistence of inflationary tensions favor rapid economic growth in the future.

8.6 Concluding Remarks

In this paper we have tried to assess the long-run costs of inflation, within an explicit theoretical framework stemming from the growth literature: the convergence equation. Despite its shortcomings, this approach is well suited to test the robustness of the correlation between growth and inflation in low-inflation economies with reasonably well working markets, such as the OECD countries during the 1960–92 period. The specific results are described at length in each section and will not be repeated here. The main finding is that current inflation has never been found to be positively correlated with income per capita over the long run.

In fact, in most, though admittedly not all, specifications tried we obtained a significant negative correlation between inflation and income growth during rather long periods. This negative correlation survives the presence of additional regressors, such as the investment rate, population growth, and schooling rates, and the imposition of the theoretical restrictions implied by the technology of constant returns. What is most remarkable is that the negative coefficient of inflation in growth equations remains significant even after allowing for country-specific time-invariant effects in the equations. This is striking because, as is well known in the empirical growth literature, few regressors in convergence equations withstand the explanatory power of country dummies.

32. Andrés, Hernando, and Krüger (1996) show that when observations under fixed exchange rates are excluded from the sample, the size and the significance level of the coefficient of inflation in OECD convergence equations increase substantially.

The analysis of causality gives less clear-cut results, but it is also noteworthy that causality from inflation to growth is always significant and never positive. Again, this result shows up more clearly whenever the influence of country dummies, accumulation rates, and the effect of other macroeconomic variables is controlled for.

Inflation not only reduces the level of investment but also the efficiency with which productive factors are used. It has a negative temporary impact on long-term growth rates, which, in turn, generates a permanent fall in income per capita. Our results suggest that the marginal cost of inflation diminishes with the inflation rate. The estimated benefit of a permanent reduction of inflation by 1 percentage point depends on the starting level of inflation. Thus reducing the inflation rate from , say, 20 to 19 percent may increase output by 0.5 percent in the long run. This benefit increases with further reductions in inflation and might be twice as large when inflation reaches a low 5 percent. These benefits seem to be lower than others reported in the literature, but some evidence suggests that they might be underestimated since there is a positive causation running from growth to inflation, in particular for economies with fixed exchange rates. It must also be noted that these estimates are obtained in models displaying a fast convergence rate, so that the present value of the benefits of disinflation might be quite sizable. Overall, these results indicate that the long-run costs of inflation are nonnegligible and that efforts to keep inflation under control will sooner or later pay off in terms of better long-run performance and higher per capita income.

References

Andrés, J., E. Boscá, and R. Doménech. 1996. Testing the neoclassical growth model: A causality approach. Mimeograph.

Andrés, J., R. Doménech, and C. Molinas. 1996. Macroeconomic performance and convergence in OECD countries. *European Economic Review* 40:1683–1704.

Andrés, J., I. Hernando, and M. Krüger. 1996. Growth, inflation and the exchange rate regime. *Economics Letters* 53:61–65.

Balassa, B. 1964. The purchasing power parity doctrine: A reappraisal. *Journal of Political Economy* 72:584–96.

Barro, R. 1995. Inflation and economic growth. *Bank of England Economic Bulletin* 35 (May): 1–11.

———. 1996. Determinants of economic growth: A cross-country empirical study. NBER Working Paper no. 5698. Cambridge, Mass.: National Bureau of Economic Research.

Barro, R., and X. Sala-i-Martin. 1991. Convergence across states and regions. *Brookings Papers on Economic Activity,* no. 1: 107–82.

Blömstrom, M., R. Lipsey, and M. Zejan. 1996. Is fixed investment the key to economic growth? *Quarterly Journal of Economics* 111:269–76.

Briault, C. 1995. The costs of inflation. *Bank of England Economic Bulletin* 35 (February): 33–45.
Bruno, M. 1993. Inflation and growth in an integrated approach. NBER Working Paper no. 4422. Cambridge, Mass.: National Bureau of Economic Research.
Bullard, J., and J. Keating. 1995. The long-run relationship between inflation and output in postwar economies. *Journal of Monetary Economics* 36:477–96.
Burdekin, R., T. Goodwin, S. Salamun, and T. Willett. 1994. The effects of inflation on economic growth in industrial and developing countries: Is there a difference? *Applied Economic Letters* 1:175–77.
Cardoso, E., and A. Fishlow. 1989. Latin American economic development: 1950–1980. NBER Working Paper no. 3161. Cambridge, Mass.: National Bureau of Economic Research.
Carrol, C., and D. Weil. 1993. Saving and growth: A reinterpretation. NBER Working Paper no. 4470. Cambridge, Mass.: National Bureau of Economic Research.
Clark, T. E. 1997. Cross-country evidence on long run growth and inflation. *Economic Inquiry* 35:70–81.
Cozier, B., and J. Selody. 1992. Inflation and macroeconomic performance: Some cross-country evidence. Working Paper no. 92-06. Ottawa: Bank of Canada, Department of Monetary and Financial Analysis.
Dabán, T., R. Doménech, and C. Molinas. 1997. International and intertemporal comparisons in OECD countries: A growth sensitivity analysis. *Review of Income and Wealth* 43:33–48.
De Gregorio, J. 1992a. Economic growth in Latin America. *Journal of Development Economics* 39:59–84.
———. 1992b. The effects of inflation on economic growth: Lessons from Latin America. *European Economic Review* 36:417–25.
———. 1993. Inflation, taxation, and long-run growth. *Journal of Monetary Economics* 31:271–98.
———. 1996. Inflation, growth and central banks: Theory and evidence. Policy Research Working Paper no. 1575. Washington, D.C.: World Bank.
Dolado, J., and H. Lütkepohl. 1996. Making the Wald test work for cointegrated VAR systems. *Econometric Review* 15:369–86.
Feldstein, M. 1997. The costs and benefits of going from low inflation to price stability. In *Reducing inflation: Motivation and strategy*, ed. C. Romer and D. Romer, 123–56. Chicago: University of Chicago Press.
Fischer, S. 1991. Growth, macroeconomics, and development. In *NBER macroeconomics annual*, 329–64. Cambridge, Mass.: MIT Press.
———. 1993. The role of macroeconomic factors in growth. *Journal of Monetary Economics* 32:485–512.
Grier, K., and G. Tullock. 1989. An empirical analysis of cross-national economic growth, 1951–80. *Journal of Monetary Economics* 24 (2): 259–76.
Grimes, A. 1991. The effects of inflation on growth: some international evidence. *Weltwirtschaftliches Archiv* 127 (4): 631–44.
Gylfason, T., and T. Herbertsson. 1996. Does inflation matter for growth? CEPR Discussion Paper no. 1503. London: Centre for Economic Policy Research.
Islam, N. 1995. Growth empirics: A panel data approach. *Quarterly Journal of Economics* 110:1127–70.
Jones, L., and R. Manuelli. 1995. Growth and the effects of inflation. *Journal of Economic Dynamics and Control* 19:1405–28.
Judson, R., and A. Orphanides. 1996. Inflation, volatility and growth. Finance and Economics Discussion Series, no. 96-19. Washington, D.C.: Board of Governors of the Federal Reserve System.

Knight, M., N. Loayza, and D. Villanueva. 1993. Testing the neoclassical theory of economic growth: A panel data approach. *IMF Staff Papers* 40:512–41.

Kocherlakota, N. 1996. Commentary. *Federal Reserve Bank of St. Louis Review* 78 (May/June): 170–72.

Kormendi, R., and P. Meguire. 1985. Macroeconomic determinants of growth: Cross-country evidence. *Journal of Monetary Economics* 16 (2): 141–63.

Levine, R., and D. Renelt. 1992. A sensitivity analysis of cross-country growth regressions. *American Economic Review* 82:942–63.

Levine, R., and S. Zervos. 1993. What have we learned about policy and growth from cross-country regressions? *American Economic Review* 83:426–30.

Mankiw, N., D. Romer, and D. Weil. 1992. A contribution to the empirics of economic growth. *Quarterly Journal of Economics* 107 (May): 407–38.

McCandless, G., and W. Weber. 1995. Some monetary facts. *Federal Reserve Bank of Minneapolis Quarterly Review* 19 (summer): 2–11.

Motley, B. 1994. Growth and inflation: A cross-country study. Working Paper no. 94-08. San Francisco: Federal Reserve Bank of San Francisco.

Orphanides, A., and R. Solow. 1990. Money, inflation and growth. In *Handbook of monetary economics*, vol. 1, ed. B. M. Friedman and F. Hahn. Amsterdam: North Holland.

Pesaran, M. H., and R. Smith. 1995. Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics* 68:79–113.

Pindyck, R., and A. Solimano. 1993. Economic instability and aggregate investment. NBER Working Paper no. 4380. Cambridge, Mass.: National Bureau of Economic Research.

Roubini, N., and X. Sala-i-Martin. 1995. A growth model of inflation, tax evasion and financial repression. *Journal of Monetary Economics* 35:275–301.

Sala-i-Martin, X. 1994. Cross-sectional regressions and the empirics of economic growth. *European Economic Review* 38:739–47.

Samuelson, P. 1964. Theoretical notes on trade problems. *Review of Economics and Statistics* 46:145–54.

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

Sims, C., J. Stock, and M. Watson. 1990. Inference in linear time series models with some unit roots. *Econometrica* 58:113–44.

Smyth, D. 1994. Inflation and growth. *Journal of Macroeconomics* 16 (spring): 261–70.

Solow, R. 1956. A contribution to the theory of economic growth. *Quarterly Journal of Economics* 70:65–94.

Summers, R., and A. Heston. 1991. The Penn World Table (Mark 5): An expanded set of international comparisons, 1950–1988. *Quarterly Journal of Economics* 106 (2): 327–68.

Thornton, D. 1996. The costs and benefits of price stability: An assessment of Howitt's rule. *Federal Reserve Bank of St. Louis Review* 78 (March/April): 23–38.

Comment Frederic S. Mishkin

The paper by Andrés and Hernando is excellent and significantly advances the literature on the relationship between inflation and growth. There are several reasons why I take this view.

Strengths of the Paper

The core analysis in the paper makes use of a standard convergence equation framework, which I find attractive for two reasons. First, it enables the econometric analysis to distinguish between two important alternatives: (1) the effect of inflation on growth is temporary, yet there is a permanent effect on the level of output, and (2) the effect of inflation on growth is permanent. Second, the standard convergence equation framework is a sensible theoretical construct that allows straightforward interpretation of the results.

Another important strength of the paper is that the econometric analysis is very careful. The authors pay serious attention to potential biases of coefficients by allowing for individual country effects and using instrumental variables estimation techniques. Furthermore, the authors expend substantial effort checking the robustness of their results, an extremely important attribute of good empirical research. They do this by exploring different specifications and different subsamples as well as by allowing for country dummies in their regressions.

The most important strength of the paper and what sets it apart from the earlier literature on inflation is the choice of the data set. The data set restricts itself to OECD countries, rather than including a wider range of countries as in earlier studies. This choice of data is desirable for two reasons. First, there has always been a question whether earlier results with the sample dominated by developing countries is meaningful for industrialized countries like the United States. Andrés and Hernando deal with this problem because their OECD data set makes the results particularly relevant for policymakers in industrialized countries. Since I am currently in this position, I find the results in this paper particularly valuable. Second, the choice of data set also has the advantage of having mostly low-inflation countries in the sample, which makes the results directly applicable to low-inflation countries. This is important because earlier results with samples that include high-inflation countries may not provide as clear a picture of the inflation-growth relationship when inflation is low.

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Any views expressed in this comment are those of the author only and not those of the National Bureau of Economic Research, Columbia University, the Federal Reserve Bank of New York, or the Federal Reserve System.

Results

The paper has several important findings. The primary result, which is very robust, is that there is a negative relationship between inflation and growth and this is true even in the industrialized countries that make up the OECD. A secondary finding, which is quite surprising, is that the inflation effect is larger when inflation is low; that is, the positive effect on growth is larger when inflation declines from 5 to 4 percent than when it declines from 20 to 19 percent. This result contrasts with other papers in the literature. For example, Bruno and Easterly (1995) find that the negative relationship between inflation and growth is no longer significant when inflation rates are below 40 percent, while Sarel (1996) finds that the inflation effect on growth disappears when inflation is below 8 percent. In contrast, the results in this paper suggest that the negative effect of inflation on growth is especially strong for low-inflation countries. These results are extremely important for people like me who are policymakers at central banks in countries with low inflation because the results justify our focus on price stability as the primary long-run goal of monetary policy.

As I mentioned earlier, because the empirical analysis is based on a standard convergence equation framework, it is able to determine whether the inflation effect is temporary rather than permanent. The analysis produces what I consider to be an eminently sensible finding: in the OECD countries, the inflation effect is temporary, with a 1 percent decline in inflation leading to a rise in the *level* of per capita income by 0.5 to 2 percent. The fact that the impact of inflation in the long run is on the level of output rather than the growth rate is entirely consistent with the analysis in other papers in this volume that focus on the costs of inflation.

Another interesting finding in the paper is that higher inflation reduces growth by its negative effects not only on the accumulation of capital but also on total factor productivity. Results like these may help us sort out which theoretical models better describe the relationship between inflation and growth.

The bottom line is that the paper has produced an important set of results that are highly relevant to important policy issues. Clearly, the results in this paper cannot settle the issue of whether the pursuit of low inflation enhances economic growth. Particularly important in this regard are the always present questions about causality: whether it runs from inflation to growth or the other way around, or whether a third driving factor is generating the inflation-growth correlation. Indeed, all that good empirical work can do is to move or strengthen priors and this is what the paper does. It strengthens my priors for what I like to refer to as the central bank mantra: price stability should be the primary long-run goal of monetary policy.

A Minor Quibble

No discussant worth his salt can leave a paper totally unscathed: he or she must find something to criticize. I have one minor quibble with the paper. I did not find the Granger causality results in section 8.5 very useful. My criticisms here are the standard ones about the use of Granger causality tests to make inferences about true causal relationships. Granger causality is an atheoretical technique that only tells us about predictive relationships and not about causality. Therefore, it is hard to interpret Granger causality tests unless there is a theoretical model that has implications in terms of the predictive relationships that are the focus of Granger causality tests.

It is true that the Granger causality results are consistent with the results in the paper using the standard convergence equation framework, so there really is no harm done. However, because they are hard to interpret, in contrast with the results earlier in the paper using the convergence equation setup, I do not think they add much and may even detract from the valuable results earlier in the paper.

Implications for Policy

This paper provides important ammunition in defense of the pursuit of price stability, even in low-inflation countries, and this is has important implications for the conduct of monetary policy. However, the paper does not answer a question of critical importance to central bankers in industrialized countries at the present time: how should price stability be defined? Or stated alternatively: what is the optimal level of inflation that should be the goal of monetary policy?

Answers to this question are particularly important for two reasons. First, many OECD countries are now in the enviable position of experiencing inflation below 5 percent. Yet policymakers still need to know whether inflation should be even lower. For example, in the United States the inflation rate has been running around the 3 percent level for the past five years. Should the Federal Reserve try to drive down inflation further?

Second, a new framework for the conduct of monetary policy has been gaining support in recent years: inflation targeting (see Bernanke and Mishkin 1997, and the references therein). A key element of inflation targeting is that it picks a specific numerical inflation goal for monetary policy and so necessarily requires a decision as to what the optimal inflation rate should be. Thus I would characterize the question of what the optimal inflation rate should be as a $64,000 question. It is probably the key question that faces many monetary policymakers at the present time.

My comment that the paper does not answer this question is really not a criticism because there is nothing the authors could do about it. There are several reasons why this paper is unable to address the $64,000 question. First, as is mentioned in footnote 22 of the paper, very few data points in the sample have inflation rates below 3 percent. Yet almost all the economists and monetary policymakers whom I know take the view that the optimal inflation rate is likely to be below 3 percent. The problem is, then, that any information about the question of the optimal inflation rate that comes from this paper must be obtained by extrapolating the results outside of the sample range. As is well known in the econometrics fraternity, this is a dangerous exercise. Extrapolation outside of sample ranges can produce misleading and at best highly uncertain results. Therefore, because so little of the sample in this paper includes data with inflation rates below 3 percent, the paper can tell us little on how much below 3 percent inflation should go.

There is a further reason why the paper cannot tell us what the optimal inflation rate is. There are good theoretical reasons for believing that the relationship between inflation and growth is highly nonlinear as inflation declines. Indeed, I think it is unlikely that the inflation effect on growth remains favorable as inflation drops to zero. This view relates to recent literature on why the optimal inflation rate is above zero.

In a much-discussed recent article, Akerlof, Dickens, and Perry (1996) point out that if nominal wages are rigid downward, a possibility they argue is consistent with the evidence, then reductions in real wages can occur only through inflation in the general price level. Very low inflation, therefore, effectively reduces real wage flexibility and hence may worsen the allocative efficiency of the labor market; indeed, the authors perform simulations suggesting that inflation rates near zero would permanently increase the natural rate of unemployment. Groshen and Schweitzer (chap. 7 in this volume) provide some support for the Akerlof-Dickens-Perry view that higher inflation provides "grease" for the labor market that increases its efficiency. However, Groshen and Schweitzer also argue that higher inflation puts "sand" in the labor market and so the Akerlof-Dickens-Perry results are overstated. Groshen and Schweitzer argue that low inflation has benefits in the labor market because lower levels of inflation are associated with less uncertainty and hence better allocations of labor. Although their work indicates that the benefits of inflation estimated by Akerlof, Dickens, and Perry (1996) are overstated, this line of research suggests that pursuing the goal of zero inflation may be undesirable.

A second reason why the optimal rate of inflation might be above zero is that with a goal of zero, shocks to the economy are more likely to produce deflation in which the price level is actually falling. As pointed out in the literature on financial crises, deflation—particularly if unanticipated—can create serious problems for the financial system, interfering with its normal functioning and precipitating a severe economic contraction (Bernanke and James 1991; Mishkin 1991). Deflation can be particularly dangerous if the financial system is already in a weakened state. Thus avoiding deflation may be so important that shooting for a zero inflation rate may not be desirable.

A key point is that both of these reasons for having an inflation target above zero are based on strong nonlinearities in the inflation-growth relationship. The Akerlof-Dickens-Perry view suggests that the costs of low inflation only become significant at inflation rates below 3 percent; while the view stemming from the dangers of deflation suggests that high costs only occur when inflation is so low that it is highly likely the economy will at times be tipped into deflation.

As a practical matter, countries that have adopted inflation targets have all chosen targets that are above zero, even with the inflation rate corrected for possible measurement bias. This suggests that practicing policymakers also have some concern about nonlinearities of the type described here.

Conclusion

The paper by Andrés and Hernando is very valuable because it tells us that low inflation is important to healthy growth in industrialized countries and so provides support for a position close to any central banker's heart, that price stability should be the primary long-run goal of monetary policy. The paper also provides ammunition for the view that the optimal inflation rate is below 3 percent. However, through no fault of its own, the paper is unable to tell us whether the optimal inflation rate is zero or some number slightly higher than this. Clearly, we need more research to tell us specifically what inflation rate policymakers should shoot for; this is exactly what this conference is all about.

References

Akerlof, George, William Dickens, and George Perry. 1996. The macroeconomics of low inflation. *Brookings Papers on Economic Activity,* no. 1: 1–59.

Bernanke, Ben, and Harold James. 1991. The gold standard, deflation, and financial crisis in the Great Depression: An international comparison. In *Financial markets and financial crises,* ed. R. G. Hubbard. Chicago: University of Chicago Press.

Bernanke, Ben, and Frederic S. Mishkin. 1997. Inflation targeting: A new framework for monetary policy? *Journal of Economic Perspectives* 11, no. 2 (spring): 97–116.

Bruno, Michael, and William Easterly. 1995. Inflation crises and long-run growth. NBER Working Paper no. 5209. Cambridge, Mass.: National Bureau of Economic Research, August.

Mishkin, Frederic S. 1991. Asymmetric information and financial crises: A historical perspective. In *Financial markets and financial crises,* ed. R. Glenn Hubbard, 69–108. Chicago: University of Chicago Press.

Sarel, Michael. 1996. Nonlinear effects of inflation on economic growth. *IMF Staff Papers* 43 (March): 199–215.

Discussion Summary

In response to the discussant's remarks about Granger causality, the authors noted that while the Granger causality tests do not prove causality, they protect the findings against the possible criticism that they are a result of reverse causation. The authors stated that their approach is intermediate between time-series and cross-sectional analysis.

Laurence Meyer noted that in the time-series charts shown by the authors, there is a clear negative correlation between inflation and growth because of the 1973 productivity slowdown. Is it possible that all the results are driven by the 1973 experience? The authors responded that the Granger causality tests are meant to deal with this possibility. Meyer suggested that one can test whether the 1973 experience drives the results by testing whether the results are robust to removing the years around 1973. The authors noted that this was done in a paper by Stanley Fischer and that his results were robust to removing the episode around 1973. *Martin Feldstein* noted that Stanley Fischer used a sample with many more countries, so that the robustness of his findings is not conclusive for the robustness of the current findings. *Frederic Mishkin* remarked that the identification also comes from the cross-sectional variation but acknowledged that there is a slight risk that the 1973 experience pollutes the results. Another participant suggested that the inclusion of country fixed effects that vary over time may alleviate some of the concerns.

Edmund Phelps noted that there are many other taxes besides the inflation tax and found it surprising that the authors find such a clear relation between inflation and growth while the literature has found no relation between growth and other taxes. He suggested that the authors may wish to include other taxes as controls in the growth equations. Phelps also asked what the relation between inflation and growth is in a pure cross section. The authors replied that this relation is strongly negative and emphasized that it is important to find the right balance between cross-sectional and time-series identification.

A participant inquired to what extent the productivity slowdown is taken into account in the analysis. The authors replied that both the size and significance of coefficients decrease if they add time dummies to the model. However, these dummies may capture many other things, and it is therefore hard to find the right mix of controls.

Laurence Ball expressed the opinion that Frederic Mishkin was too "soft" on the causality issue in his discussant's remarks. According to Ball the model in the paper is simply not identified, and therefore, the final results are not convincing. There are numerous factors that may lead to a negative correlation between inflation and growth. Though it is a boring remark to make, it is important to realize that Granger causality is not equivalent to true causality. Splitting the sample would be good but does not solve the fundamental identification issue. Ball apologized for the nihilism of this remark but warned that these data simply cannot conclusively identify the effect of inflation on growth.

Benjamin Friedman noted that it is striking that the present value calculations in the paper are so small compared to Martin Feldstein's results. *Martin Feldstein* replied that the annual GDP level effects of inflation are actually larger in the current paper than in his own analysis but warned that the calculations are not comparable because the calculations in the current paper are in terms of GDP whereas his calculations are in terms of welfare. *Friedman* stated that it would be helpful if the two measures somehow could be made comparable, or at least reconciled explicitly.

Anna Schwartz, referring to the discussant's remarks, noted that financial stability is indeed very important but disagreed that deflation causes financial instability. Instead, financial instability is caused by financial agents taking large bets on inflation expectations. *Mishkin* responded that deflation causes transfers from borrowers to creditors leading to information problems in financial markets. Although the deflationary harm also depends on the state of financial institutions, deflation can nevertheless be dangerous to financial stability.

Stephen Cecchetti emphasized the importance of the identification issue. According to Cecchetti, one needs a model that makes the source of the shocks explicit. It is well known that supply shocks cause a negative correlation between growth and inflation whereas demand shocks cause a positive correlation. Perhaps supply shocks were simply more prevalent in the sample period, which would explain the authors' findings of a negative effect of inflation on growth. *Matthew Shapiro* suggested that it may be valuable to use a longer time series, for example, the Maddison data. With respect to the discussion on financial instability, he noted that is it is unexpected disinflation that causes problems, not deflation as such. *Mishkin* said that this point is well taken but also expressed his amazement at how slowly some financial institutions adapt to new inflation regimes. *Martin Feldstein* disagreed with the suggestion to use long time series on the grounds that the economy has changed and that, therefore, very old data is not informative for the current economy.

Karl-Heinz Tödter said that the sample is homogenous in one respect but heterogeneous in another respect, namely, the size of countries. He wondered whether a weighted regression reflecting the countries' sizes would be more appropriate. The authors stated that they could do this, but Xavier Sala-i-Martin found in related work that weighting did not matter. *James Hines* explained that results may be stronger if the weights are GNP based rather than GDP based because the GNP weights also capture investment inflows.