Inflation and economic growth: some evidence for the OECD countries[1]

Javier Andrés and Ignacio Hernando

Introduction

During the last decade, inflation control has become the main goal of monetary policies in western economies. This move in monetary policy-making is firmly rooted in the belief, shared by many economists as well as politicians, that the costs of inflation are non-negligible, whereby keeping inflation under control pays off in terms of higher per capita income in the future.

The lack of theoretical models explicitly addressing the issue of the long-run effects of inflation has not prevented many researchers from trying to estimate inflation costs. The evidence so far is not conclusive. A series of recent papers have tried to assess the long-run impact of current inflation within the framework of the so called *convergence equations*. These equations can be derived from a theoretical model of economic growth, although the reasons for including the inflation rate among the determinants of growth remain somewhat unclear. This paper adheres to this approach to estimating the impact of inflation upon the long-run performance of the OECD countries. The approach has several advantages as compared with more standard ones. First, and foremost, an explicit model prevents the omission of relevant variables. Second, convergence equations allow for a variety of effects of inflation including those which reduce accumulation rates and those which undermine the efficiency with which productive factors operate. Finally, in this framework a clear distinction can be made between *level* and *rate of growth* effects of inflation; this difference matters as regards the size and the timing of the costs of inflation. The methodology also has some shortcomings. First, growth models focus on long-run issues, disregarding the short-run costs associated with disinflation (*the sacrifice ratio*). Second, the use of multi-country data sets imposes too many restrictions on the parameters to prevent a shortage of degrees of freedom. Also, the direction of causality among the variables included in convergence equations is not unambiguous. This paper tries, in several ways, to overcome these limitations to check the robustness of the inflation-growth empirical link.

The rest of the paper is organised as follows. Section 1 briefly summarises the literature dealing with the cost of inflation; the empirical model and the data used are also discussed in some detail. In Section 2 we present the convergence equations augmented with the rate of inflation. In Section 3, cross-country heterogeneity is allowed for in the convergence model, whereas in Section 4 standard causality tests are applied to the inflation-growth relationship. The final section concludes with some additional remarks. The main results of the paper can be summarised as follows. Even low or moderate inflation rates (as the ones we have witnessed within the OECD) have a negative but temporary impact upon long-term growth; 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 cost of a 1% rise in the inflation rate is a reduction, during rather long periods, of the annual growth rate of about 0.06%; in the long-run this leads to a reduction in the steady-state per capita income of about 2%. This result holds across different sub-samples (even excluding high-inflation countries) and is also robust to alternative econometric specifications. In particular, inflation Granger-causes income and the current and lagged

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correlation between these two variables remains significant when we control for country-specific variables (such as the accumulation rates) and time invariant effects.

1. The theoretical framework

1.1 International evidence

The negative effects of inflation have been studied in the context of the models of economic growth (Orphanides and Solow (1990), De Gregorio (1993) and Roubini and Sala-i-Martín (1995)). The continuous increase of per capita income is the outcome of capital accumulation and the continuous improvement in the efficiency with which productive factors are used. The uncertainty associated with a high and volatile unanticipated inflation has been found to be one of the main determinants of the rate of return of capital and investment (Bruno (1993) and Pindyck and Solimano (1993)). But even fully anticipated inflation may reduce the rate of return of capital given the non-neutralities built into most industrialised countries' tax systems (Jones and Manuelli (1993) and Feldstein (1996)). Besides, high and volatile inflation undermines the confidence of 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 constitutes what 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 the efficiency with which factors are used. This latter channel, also known as the *efficiency channel*, is harder to formalise in a theoretical model;[2] nonetheless, it is widely agreed that its importance in the transmission mechanism from inflation towards lower growth cannot be denied. A high level of inflation induces frequent changes in price lists which may be costly for firms (*menu costs*) and reduces the optimal level of cash holdings by consumers (*shoe-leather costs*). It also induces bigger forecast errors by distorting the information content of prices, encouraging economic agents to spend more time and resources on gathering information and protecting themselves against the damages caused by price instability, hence endangering the efficient allocation of resources.

Many authors have found a negative correlation between growth and inflation. The following paragraphs sum up the most significant features of several of these studies. Kormendi and Meguire (1985) estimate a growth equation with cross-section 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 (inflation rate, price acceleration and standard deviation of inflation). The results differ according to the group of countries in question, but for the OECD only the variability of inflation seems to have a significant and negative effect on growth.

Starting from these seminal works, the study of the long-run influence of inflation has primarily developed within the framework of convergence equations drawn from economic growth theory.[3] Fischer (1991, 1993) detects a significant influence of several short-term macroeconomic

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2 As Briault (1995) has rightly pointed out, it is very difficult to derive a significant effect of inflation on factor productivity in frictionless general equilibrium competitive models.

3 The next section develops these equations and discusses their properties. Several exceptions, however, are worth noting: the studies of Grimes (1991) for the OECD, Smyth (1994) for the United States, Cardoso and Fishlow (1989)

indicators on the growth rate. Inflation reduces both capital accumulation and total factor productivity. Cozier and Selody (1992) find that, for the sub-sample of OECD countries, inflation affects the level rather than the growth rate of productivity, whereas the variability of inflation does not seem to have any appreciable effect. This finding coincides with the result obtained more recently by Barro (1995) for a sample of 120 countries, who reports a negative long-run effect of inflation,[4] which is more pronounced at higher levels of the inflation rate. The general conclusion of these and other studies (De Gregorio (1992a, 1992b and 1994) and 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 criticised these findings, arguing that the lack of a fully developed theoretical framework makes it difficult to interpret the empirical correlations and that these are not robust to changes in the econometric specification. The latter argument is developed in Levine and Renelt (1992), Levine and Zervos (1993) and Clark (1993). Levine and Renelt carry out an exhaustive sensitivity analysis of the set of explanatory variables contained in the literature on economic growth, showing how the effect of most of these variables (inflation among them) is not invariant to changes in the information set on which this effect depends. Nor do these results, in turn, escape criticism. Sala-i-Martín (1994) argues that the problem of finding a macroeconomic variable, the effect of which is invariant to 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. Lastly, Andrés, Doménech and Molinas (1996b) show that, for the OECD as a whole, the variables of macroeconomic policy are even more robust than the rates of accumulation in explaining economic growth.

1.2. The effects of inflation in a neoclassical growth model

There are a number of advantages to estimating the correlation between inflation and growth within the framework of the convergence equations proposed by Barro and Sala-i-Martín (1991), as these represent the main empirical approach to growth models with constant returns.[5] Let us consider a growth model (Mankiw, Romer and Weil (1992)) in which technology is represented by the following production function with constant returns ($\alpha + \beta + \gamma = 1$),

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

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.[6] Let us also assume that the depreciation rates of both factors are the same. With these assumptions, it is possible to arrive at the following equation of growth in per capita income between two moments in time (t, $t + \tau$):

$$y_{T+\tau} - y_T = \phi\tau + \left(1 - e^{-\lambda\tau}\right)\left[\Omega^C + y_T^* - y_T\right] \tag{2}$$

who use a panel of five-year averages for 18 Latin American countries, Burdekin, Goodwin, Salamun and Willett (1994) and Bruno (1993). In all these studies, a significant negative effect of inflation on growth is reported.

4 Whereas the effect of the variability of inflation is not invariant to alternative specifications.

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

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

where y represents the logarithm of per capita income in the periods indicated by the subscripts, and y^* represents its stationary state value. According to equation (2), the growth rate of an economy will have a component determined by the growth in factor productivity at a rate ϕ and another resulting from the economy's propensity to move towards its steady-state level if, for some reason (shocks, initial conditions, etc.), it lies outside. λ is the rate at which the economy closes the gap between its current income level and its potential or steady-state level.[7] The latter is, in turn, determined by the parameters of the production function and by the rates of accumulation of the productive factors in the stationary state:

$$y_T^* = \Omega^s + \phi T + \beta^{-1}\left[\alpha s_{Tk}^* + \lambda s_{Th}^* - (\alpha + \gamma)\log\left(n_t^* + \phi + \delta\right)\right] \tag{3}$$

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 level; lastly, δ is the depreciation rate of capital (physical and human). This we will assume to be exogenous and equal to an annual 3%,[8] while Ω^c and Ω^s are two constants that combine different parameters of the model and the starting level of technology (A_T).

The use of equations (2) and (3) as the analytical framework does not presuppose the acceptance of the exogenous growth model as the only possible representation of the behaviour of OECD economies in the long run. The main advantage of this model is that it systematically captures most of the factors that the literature on economic growth has pointed to as determinants of growth; this reduces the risk of omitting relevant regressors entailed in ad hoc specifications.[9] To test the influence of inflation on income in the long run the usual procedure (Cozier and Selody (1992)) is to augment equations (2) and (3), by assuming that the productivity index (A_T) evolves in accordance with expression (4), which reflects the influence of the inflation rate (π) and its variability (σ):

$$A_t = A_0 \exp(\phi t)\exp(\mu_1 \pi)\exp(\mu_2 \sigma) \tag{4}$$

The system of equations to be estimated is thus one formed by equations (2) and (3'):

$$y_T^* = \Omega^s + \phi T + \mu_1 \pi_T + \mu_2 \sigma_T + \beta^{-1}\left[\alpha s_{Tk}^* + \gamma s_{Th}^* - \left(\alpha \overset{\circ}{+} \gamma\right)\log\left(n_T^* + \phi + \delta\right)\right] \tag{3'}$$

This simple structure allows us to test the different hypotheses considered in this paper. First, the presence of the rates of factor accumulation in (2) and (3') is useful to discriminate between the two channels through which macroeconomic distress can influence the growth rate. Thus, if inflation influenced growth solely through its direct impact on total factor productivity, we could expect the coefficient μ_1 estimated in equations (2) and (3') to be independent of the rates of accumulation. In contrast, this coefficient varies substantially, we can conclude that there is an inflation effect on agents' investment efforts.[10] Second, the exogenous growth model specifies the

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

8 To use a value that is standard in the literature.

9 Unlike growth equations that do not include the catching-up component, the convergence equation provides a way of controlling the level of per capita income when analysing the determinants of its growth rate.

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

determinants of the level of per capita income in the long run and also of the sustained growth rate. Inflation can affect the one and/or the other, although the implications in terms of welfare are different. According to equation (4), the impact of inflation basically manifests itself in the potential level of per capita income, but not in sustained growth (represented by ϕ). To examine the latter possibility, we will later consider an alternative specification, (4'), which allows inflation to influence the long-run growth rate:[11]

$$A_t = A_0 \exp[(\phi + \phi'\pi)t] \exp[\mu_1 \pi] \exp[\mu_2 \sigma] \tag{4'}$$

resulting in a new system of equations being estimated as:

$$y_{T+\tau} - y_T = (\phi + \phi'\pi)\tau + \left(1 - e^{-\lambda\tau}\right)\left[\Omega^c + y_T^* - y_T\right] \tag{5}$$

$$y_T^* = \Omega^s + (\phi + \phi'\pi)T + \mu_1 \pi + \mu_2 \sigma_T + \beta^{-1}\left[\alpha s_{Tk}^* + \gamma s_{Th}^* - \left(\alpha \overset{\circ}{+} \gamma\right)\log\left(n_T^* + \phi + \delta\right)\right] \tag{6}$$

The specification can be also used to test for possible non-linear effects of inflation on income. A linear version of the convergence equation is given by:

$$y_{T+\tau} - y_T = \psi_0 + \psi_1 T + \psi_2 y_T + \psi_3 s_{TK}^* + \psi_4 s_{TH}^* + \psi_5 \log\left(n_T^* + \phi + \delta\right) + \psi_6 \pi_T + \psi_7 \sigma_T \tag{5'}$$

This approach also has some drawbacks. Cross-country convergence regressions are often blamed for two misspecification flaws: the ambiguous pattern of causality among the variables included in the equations and the absence of a proper account of country specifics. We take account of these shortcomings in Sections 3 and 4. In Section 2 we estimate the elasticity of growth with respect to inflation in a standard convergence equation. We use four-year averages of OECD annual data; for a detailed discussion of the features of the data base, see Dabán, Doménech and Molinas (1996).

2. Estimation of the effect of inflation

Tables 1 and 2 present the results of estimating the steady-state and convergence equations derived from the exogenous growth model. In order to reduce the risk of simultaneity biases, all equations reported have been estimated by instrumental variables, using one and two-periods-lagged regressors as instruments. The results seem to be quite robust, both in the linear and in the non-linear specifications. Linear models (equation (5')) are presented in Table 1. In columns 1 and 2 we estimate different versions of the convergence equation whereas in columns 3 and 4 we present estimates of the steady-state equation. The evidence in columns 1 and 2 is consistent with the convergence property implied by the Solow growth model. The parameter for 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 estimated coefficients for the input accumulation rates have the expected sign, although the one for human capital is non-significant. The estimated parameter for the trend, which according to the theoretical model is proxying technological progress, has an unexpected negative sign.[12] On the other hand, the

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[11] This is the specification proposed by Motley (1994), from which the effect of the variability of inflation is excluded in order to simplify the expression.

[12] One reason 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. As an alternative approach, time

estimated coefficient for the trend has the expected positive sign in the steady-state equation (columns 3 and 4). However, the values of the estimated parameters for the input accumulation rates merit caution in interpreting the results.

Table 1
Linear models (equation (5'))

Dependent variable:	(1) Δy	(2) Δy	(3) y^*	(4) y^*
ψ	0.350 (8.98)	-0.275 (1.21)	2.304 (25.50)	-1.527 (1.39)
ψ_1	-0.010 (3.33)	-0.010 (3.02)	0.077 (5.27)	0.044 (2.97)
ψ_2	-0.074 (4.60)	-0.090 (5.12)	-	-
ψ_3	-	0.044 (1.95)	-	0.169 (1.54)
ψ_4	-	0.026 (0.82)	-	0.771 (5.64)
ψ_5	-	-0.143 (1.91)	-	-0.000 (0.00)
ψ_6	-0.0019 (2.98)	-0.0012 (1.71)	-0.023 (8.25)	-0.012 (3.75)
R^2	0.31	0.39	0.38	0.55
σ	0.055	0.053	0.298	0.258

Notes: Estimation method: instrumental variable. Instruments: constant, trend and first and second-order lags of the dependent variable and of the regressors.

When the inflation rate and its variability (proxied by the Pearson coefficient) are included, both individually and jointly, the rest of the parameters do not change significantly. When both variables are jointly included, the coefficient for the inflation rate is negative and significant, both in the convergence and in the steady-state equation, whereas no significant effect is found for the variability of inflation. Thus, the equations presented hereafter only include the inflation rate. When the factor accumulation rates are included (columns 2 and 4) the size of the inflation effect is smaller than when they are omitted (columns 1 and 3), but it is still significant. This suggests 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 the use of inputs.

Non-linear models are presented in Table 2 (equations (5)-(6)), with technological progress proxied by a trend.[13] The estimated parameters for the input accumulation rates in the steady-state equations (column 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 coefficients for the convergence equation, when estimated independently (column 2), are more reasonable with an implicit rate of convergence of around 2.7%. The estimated values for α and γ are slightly smaller than those found in the literature. Again, the effect of inflation is negative and

dummies have been included (instead of the trend) to proxy the deterministic component of growth. The parameters of the model do not change significantly and these results are not reported to save space.

[13] Alternative characterisations of technological progress have been tried. First, substituting time dummies for the trend and, second, imposing a value for the rate of technological progress equal to 2%. The estimated parameters for the basic variables of the growth model and for the effect of inflation do not change significantly.

significant. Both equations (steady-state and convergence) have been estimated jointly imposing the theoretical restrictions across the coefficients α, γ and μ. These restrictions are not rejected (although in some cases they are accepted only marginally). The input shares (coefficients of the production function) obtained in the joint estimation are near to 0.1, 0.6 and 0.3 for physical capital, human capital and labour, respectively, and the implicit value for the convergence rate is 3.3%.

Table 2
Non-linear models (equation (5)-(6))

	(1)	(2)	$(3)^j$	(4)	(5)
Dependent variable:	y^*	Δy	$y^*, \Delta y$	Δy	Δy
Ω^s	-3.02 (3.28)	-	-2.98 (3.97)	-	-
Ω^c	-	-3.97 (2.88)	-1.97 (2.85)	-1.7 (1.48)	-0.81 (0.60)
α	0.08 (1.38)	0.27 (2.79)	0.10 (1.92)	0.23 (2.46)	0.34 (3.46)
γ	0.35 (6.23)	0.27 (3.03)	0.33 (6.42)	0.21 (2.36)	0.12 (1.24)
ϕ_{SS}	0.045 (2.94)	-	0.048 (3.25)	-	-
ϕ_c	-	-0.090 (2.55)	-0.071 (2.85)	-0.05 (1.73)	-0.03 (1.31)
ϕ'	-	-	-	-	0.003 (1.57)
μ	-0.011 (3.29)	-0.012 (2.16)	-0.012 (4.12)	-0.02 (4.39)	-0.014 (1.89)
λ	-	0.027	0.033	0.032	0.031
R^2_{ss}	0.52	-	0.51	-	-
R^2_c	-	0.38	0.33	0.41	0.34
σ_{ss}	0.265	-	0.262	-	-
σ_c	-	0.053	0.054	0.050	0.055

Notes: Estimation method: see notes in Table 1. *j*: joint estimation with cross-equation restrictions.

$\chi^2(\alpha)$: 4.04; $\chi^2(\gamma)$: 3.80; $\chi^2(\mu)$: 2.51; $\chi^2(\alpha,\gamma,\mu)$: 5.48.

The sensitivity of the results to the exclusion of some countries has also been tested. More precisely, when high-inflation countries, such as Turkey, Greece, Portugal or Spain, are omitted from the sample the results do not change significantly. However, this is not the case with Iceland. When Iceland is excluded from the sample (column 4) the effect of inflation on growth is almost twice as high as when it is included. This is not surprising since Iceland, being the country with the second highest average inflation within the OECD, is also a high-income fast-growing economy which may be generating a downward bias in the absolute value of the growth-inflation correlation.

The negative effect of inflation on per capita income appears as a robust result both in the steady-state and in the convergence equation. Although the negative influence of inflation on per capita income is solidly established, the effect on the sustainable growth rate is less clear. If the inflation rate is a determinant of steady-state per capita income (y^*), it will also appear in the convergence equation. But it is not clear if the effect found in this equation is an effect on the level or on the growth rate. To discriminate between these effects, an alternative specification is pursued in which A_t has been defined as in (4') and the convergence equation was estimated from the system (5) and (6) (column 5). This specification distinguishes between an inflation effect on the adjustment component of the convergence equation (μ) – i.e. the effect on the steady-state per capita income level

– and an effect on the trend component of the growth rate (ϕ'). Both are negative and significant when they are introduced individually, but when they are jointly included the effect on the trend component is non-significant and, in some cases, positive. This suggests that inflation impinges on the level of per capita income but not on the long-run rate of growth of the economy. The impact on the growth rate will thus be transitory (in the medium run), as long as real convergence is under way.[14]

Finally, a relevant issue to address is the linearity of the effect of inflation, in particular whether the marginal cost of inflation is constant or varies according to the level of inflation. Unlike most of the empirical work in this field which uses the Summers-Heston data set, our sample is confined to OECD countries, which share certain institutional features but have rather different inflation performances. Thus the OECD sample may be useful in analysing the sensitivity of the relationship between inflation and growth to the level of inflation.

The different perspectives adopted to analyse 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. Motley (1994), estimating the growth model for different sub-samples, concludes the opposite. In this paper, both approaches are used to analyse the marginal impact of changes in inflation on growth. First, in line with Barro (1995), the following specification, including different coefficients for three different inflation intervals, has been estimated:

$$y_{T+\tau} - y_T = \psi_0 + \psi_1 T + \psi_2 y_T + \psi_3 S^*_{TK} + \psi_4 S^*_{TH} + \psi_5 \log\left(n^*_T + \phi + \delta\right) + \psi_a \log\pi_a + \psi_b \log\pi_b + \psi_c \log\pi_c \quad (7)$$

where π_a is the level of inflation if it is lower than 6% and 0 otherwise; π_b is the level of inflation if it belongs to the interval 6-12% and 0 otherwise; and π_c is the level of inflation if it is greater than 12% and 0 otherwise.

The inflation coefficients obtained so far can be interpreted as semi-elasticities. For the purpose of comparing the inflation costs across groups with (by construction) very different average inflation rates we focus instead on elasticities; thus the inflation rate is specified in logs.[15] The estimated values for these elasticities are reported in part A of Table 3. The elasticity of income with respect to inflation is negative but not statistically different across the different average inflation levels. As an alternative approach, the homogeneity assumption may be relaxed by estimating the convergence equation for different sub-samples. This approach allows all the parameters – and not only the coefficient of inflation – to vary across sub-samples. The results are summarised in part B of Table 3. The effect of inflation is negative and significant for both low- (and very-low-) as well as for high- (and very-high-) inflation countries.

Thus, the two alternative approaches yield very much the same result: the elasticity of income with respect to inflation is the same regardless of the level of inflation. Since we deal with elasticities, this means that OECD countries have quite similar proportional output gains for a given proportional reduction of their inflation rate. If anything, this tells us that it pays more for a low-inflation country than a high-inflation country to reduce the inflation rate by a given amount. By the same token, it is rather 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.

To sum up, the analysis performed in this section, in accordance with other empirical work, supports the existence of an adverse influence of inflation on growth. As regards the size of this effect, if we take the coefficient in column 4 as a reliable estimate of the long-run effect of inflation upon growth, an increase in average inflation of one percentage point reduces, during rather long

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[14] As suggested by the discussant, it is interesting to emphasise that although there is not a growth effect, the effect on the level occurs during a rather long period.

[15] Iceland is excluded from the sample.

Table 3

Linearity of the inflation effect

Elasticities of income with respect to inflation in estimates of the linear version of the convergence equation

A. Whole sample estimates with specific inflation coefficients	
Low inflation[1]	-0.101 (2.24)
Medium inflation[1]	-0.066 (2.44)
High inflation[1]	-0.064 (4.08)
B. Sub-sample estimates	
Low inflation[2]	-0.045 (2.51)
High inflation[2]	-0.037 (2.41)
Very low inflation[3]	-0.040 (1.93)
Very high inflation[3]	-0.052 (2.21)

Notes: Estimation method: see notes in Table 1. Absolute *t*-ratios in parentheses.

[1] Low inflation: observations with inflation lower than 6%; Medium inflation: observations with inflation between 6% and 12%; High inflation: observations with inflation greater than 12%.

[2] Low inflation: countries with average inflation lower than the median; High inflation: countries with average inflation greater than the median.

[3] Very low inflation: 8 countries with the lowest inflation. Very high inflation: 8 countries with the highest inflation.

periods, per capita growth by 0.08% per year, which leads to a reduction in steady-state per capita income of about 2 percentage points. In the next two sections we take a closer look at the relationship between inflation and growth by trying more general specifications to avoid the two main drawbacks of the methodology adopted so far: the assumption of homogeneity across countries of the technological parameters, and the direction of causality among the variables in the convergence equations.

3. Country-specific effects and the cost of inflation

There are several reasons for including individual effects in convergence equations estimated with multi-country data sets. The existence of technological differences in the rates of technical progress or, as is more likely, in the initial conditions of each country, will be reflected in the relevance of idiosyncratic effects in growth equations. Empirical analysis of the characteristics of economic growth has relied quite often on the use of information for wide groups of countries. It is extremely important to exploit the cross-section variability of multi-country data sets, given the way in which long-term growth and shorter-term fluctuations interact, and use time series averages. However, this approach imposes the very strong constraint that the data for all the economies of the sample stem from the same theoretical distribution; i.e. technological parameters are homogeneous across countries. Usually, this assumption is not explicitly tested, although its empirical implications may be very important.[16] The consideration of individual effects in the constant term (Knight et al. (1993), Islam (1995)) or, in a more general way, (Andrés, Boscá and Doménech (1996)) may alter significantly some of the main empirical results.

Table 4

Convergence equation with individual effects (equation (5'))
Dependent variable: Δy

	(1)	(2)	(3)	(4)	(5)
ψ	1.41 (2.00)	1.18 (8.18)	1.14 (2.77)	0.93 (3.07)	1.06 (10.15)
ψ_1	0.03 (3.48)	0.03 (4.28)	0.03 (3.76)	0.02 (3.63)	0.02 (4.09)
ψ_2	-0.55 (6.12)	-0.49 (7.95)	-0.46 (6.80)	-0.44 (7.38)	-0.42 (8.06)
ψ_3	-0.11 (1.32)	-	-0.02 (0.55)	-0.16 (0.67)	-
ψ_4	-0.001 (0.13)	-	-0.001 (0.03)	-0.04 (1.40)	-
ψ_5	-0.12 (0.64)	-	-0.02 (0.20)	-0.02 (0.26)	-
ψ_6	-0.001 (1.33)	-0.002 (2.32)	-0.002 (2.48)	-0.002 (2.82)	-0.003 (3.21)
R^2	0.54	0.59	0.57	0.55	0.55
σ	0.050	0.047	0.047	0.047	0.046

Notes: Estimation method: instrumental variable. Instruments: constant, trend, country dummies, initial per capita income, accumulation rate of human capital and first and second order lags of initial per capita income, inflation, inflation variability, accumulation rates of human capital, investment rate and growth rate of population.

Dummy variables included:
Columns (1) and (2): one for each country, except Australia.
Column (3): one for each of the following countries: Canada, Switzerland, Germany, Spain, Finland, the United Kingdom, Greece, Ireland, Iceland, Luxembourg, New Zealand, Portugal, Turkey and the United States.
Columns (4) and (5), one for each of the following countries: Spain, Greece, Iceland 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.

In this section, by adding individual effects to the linear version of the convergence equation in (5'), we test if the negative effect of inflation on growth is due to a misspecification caused by the omission of individual effects. The main results are summarised in Table 4. Including individual effects in the convergence equation does not involve additional problems in the estimation process, given that the availability of eight time observations allows a specific constant to be estimated for every country. All the models have been estimated by instrumental variables in order to correct the simultaneity bias caused by the endogeneity of some of the regressors (inflation in particular).[17] When we add a dummy variable for each country (column 1) 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, the t-statistic of the rate of inflation is now lower (1.33). The changes in the rest of the model are far more radical. First, whereas a negative trend

[16] See Pesaran and Smith (1995).

[17] Instruments are listed in Table 4.

coefficient was an unappealing feature of the models in Section 2, this coefficient now becomes positive and significant, with a reasonable point estimate of 0.03. Secondly, the point estimates of the technological coefficients are now either non-significant or wrongly signed. In fact, when excluding the accumulation rates from the equations, the negative correlation between growth and inflation becomes highly significant with a t-statistic of -2.32 (column 2). Finally, several country dummies are not different from zero, suggesting that estimating a more parsimonious model is advisable.

Starting from the model with a dummy variable for each country, the non-significant dummy variables have been removed, setting aside the one with the lowest t-statistic each time. As a second step, these excluded variables have been added again, one at a time, retaining those with a t-ratio greater than 1.5. 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. This procedure allows the contribution of each dummy variable to be assessed, not only in terms of fitting but also in terms of its influence on the coefficients of the rest of the variables.

The estimate in column 3 summarises the final outcome of this specification process. The results do not change very much with respect to those in column 1 and the coefficient of the inflation rate remains negative and significant, with a size 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. As in column 1, the model does not reproduce other results of the exogenous growth model: more precisely, the coefficients for the investment rate and for the accumulation rate of human capital are still non-significant.

Taking column 3 as a starting point, the model in column 4 substitutes country-group dummy variables for the individual country dummy variables. The country groups 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 New Zealand, Finland 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 rate. The estimated individual effects reveal a systematic pattern which, if ignored, could bias 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, while overestimating 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 bias in the estimation of the effect of inflation.

In column 4, the t-statistic of the inflation rate has increased again (up to -2.82); however, as in column 1, the coefficients for the input accumulation rates are not significant. In fact, the exclusion of these variables (column 5) does not worsen substantially the fit of the equation and further increases the significance level of the inflation rate. 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, together with the initial per capita income, it turns out to be the most robust variable of the model. As for the size of the effect of inflation on per capita income in the long-run, it is also similar to that obtained in the models without individual effects. Thus, according to columns 3 and 4, a reduction of one percentage points in the average inflation rate would increase real per capita income of around 0.06 percentage points per year, which leads to a permanent rise in the

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

steady-state per capita income of about 2%. The size of this effect is smaller than that obtained in the models without individual effects.[19]

4. Inflation and growth: analysis of causality

The models studied in previous sections can give rise to a notable 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 in which 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 favour of causality in either of the two 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.

This section analyses the statistical causality, as formulated by Granger, between inflation and growth. This perspective is broader than that of convergence equations in several ways. First, the analysis of causality focuses on the study of non-contemporaneous effects and the marginal explanatory power of one variable over the other. This is precisely the influence of inflation on growth assigned by the theoretical models: an influence that does not operate in the short run but instead manifests itself slowly through a reduction in factor accumulation or in the deterioration of its efficiency. Second, in using a more flexible specification, we avoid the imposition of the parametric restrictions that are often included in the neo-classical growth model and which can affect the test of the correlation that concerns us here. The analysis of causality can, however, benefit from the teachings of the theoretical framework for the convergence equations by suggesting a series of determinants of growth that can be incorporated into the information set in the causality tests.

4.1 The econometric model

The Granger test of causality is a test of exclusion in the following bivariate VAR system:

$$\begin{bmatrix} \Delta y_t \\ \pi_t \end{bmatrix} = \begin{bmatrix} A \\ B \end{bmatrix} + \begin{bmatrix} C(L) & D(L) \\ E(L) & F(L) \end{bmatrix} \begin{bmatrix} \Delta y_t \\ \pi_t \end{bmatrix} + \begin{bmatrix} u_t \\ \varepsilon_t \end{bmatrix} \tag{8}$$

where y_t and π_t are vectors (24x1) 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, and A and B are vectors (24x1) of constants. $C(L)$, $D(L)$, $E(L)$ and $F(L)$ are matrices of order (24x24) in which the elements outside the main diagonal are zero and the elements on the main diagonal form a lagged polynomial of order p such that for $C(L)$:

$$c_1 L + c_2 L^2 + c_3 L^3 + \ldots + c_p L^p$$

The elements of the matrices A and B, as well as the coefficients of the lagged polynomials (in $C(L)$, $D(L)$, $E(L)$ and $F(L)$), will be assumed to be homogeneous among countries unless expressly stated otherwise.

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[19] We also performed several tests on the linearity of inflation elasticity in models with individual country dummies. The results, not reported here to save space, display a similar pattern to those in Table 3. The coefficient of inflation remains significant in all cases, with no significant differences across inflation levels.

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 Δy as formulated by Granger. Likewise, the rejection of the null hypothesis that the coefficients e_j are zero indicates that Δy causes π. On the other hand, testing the causality between y_t and π_t only entails eliminating a linear restriction on the coefficients in $C(L)$ and $E(L)$, such that per capita income cannot be written in first differences. The estimation of equation (8) gives rise to several methodological questions concerning the information set, the presence of individual effects, the appropriateness of subjecting the tests to a broader information set, and the non-stationarity of the model's variables. Since this section applies annual data relating to the variables of interest for the 24 OECD countries, it departs somewhat from the traditional approach in the empirical literature on growth, which avoids using annual information by applying more or less refined filtering procedures.[20] As to the possibility of individual effects relating to each OECD country, we noted in the previous section that their presence may be necessary to correct the biases in the estimated correlation between π and y. We will include these effects in this section by considering several specifications in which the vectors A and B include a different constant for each country (a_i, b_i).

The most important problem posed by the exclusion test in equation (8) is the possibility that some variables are not stationary, in which case these tests do not have a standard distribution. In the case at hand, both per capita income and the rate of inflation are non-stationary.[21] In the literature, several different methods are proposed for testing the hypothesis of causality between integrated variables, making use of statistics with asymptotic distribution $\chi^2(p)$. These procedures basically consist of re-parametrising the model in order to obtain stationary regressors.[22] Of these approaches, the method proposed by Dolado and Lütkepohl (1994) does not require a search for possible cointegration vectors among the model's variables. They propose the estimation of a VAR in levels of order p+1. The exclusion test performed on the p first lags[23] is thus distributed asymptotically as an F, whereby the loss of efficiency by the over-parametrisation of the model is compensated by the test's consistency and simplicity.[24] 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 will present results for a sufficiently broad range of lags which ensure that the residuals are stationary.

4.2 Results

To analyse the causality from the rate of inflation to the growth rate of per capita income, a test is run on the joint significance of $\{d_1,...,d_p\}$ in the model:

$$\Delta y_t = A + C(L)\Delta y_t + D(L)\pi_t + G(L)X_t + u_t \tag{9}$$

where $G(L)$ is a matrix of a structure similar to $C(L)$ and X_t is a vector of additional regressors, suggested by economic growth theory and whose composition is defined for each specification. Likewise, the causality from the growth rate to inflation is tested through the joint significance of $\{e_1,...,e_p\}$ in:

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20 An increasing number of studies tend to use raw annual data. Moreover, in the dynamic analysis of causality, models based on averages (five-year averages, for example) can be considered restricted versions of models that use annual data.

21 At least for many of the countries in the sample.

22 See Sims, Stock and Watson (1990).

23 In other words, on d_1, d_2,..., d_p or on e_1, e_2,..., e_p.

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

$$\pi_t = B + E(L)\Delta y_t + F(L)\pi_t + H(L)X_t + \varepsilon_t \qquad (10)$$

Also, to analyse causality from the level of per capita income, a test is performed on the significance of the parameters $\{e_j\}$ and $\{d_j\}$ in (10'), obtained by replacing the growth rate of per capita income (Δy_t) in (10) by its level (y_t).

The first of these tests (Table 5) summarises the significance level for the null hypothesis that the inflation coefficients are jointly non-significant in diverse models. In addition, it gives the t statistic for the sum of these coefficients. All the models were estimated for a structure of lags (p+1) that goes from 4 to 13, and the related tests were run for the p first lags in each case. In the first column, the model estimated (model 1) includes no additional regressor (g_j = 0) nor constant individual effects (A is a vector of equal constants). The results of this first exercise are not very conclusive. In most of the specifications, inflation appears to cause the growth rate as formulated by Granger (the significance level of the statistic only marginally exceeds 5% for p=8 and for p=10). However, the sign of this causality is far from unequivocal, because in general the sum of the coefficients of the inflation lags is not significantly different from zero. In model 2, individual constant effects were included such that vector A is a vector of different constants by country. Although in this case causality can be rejected at 5%, for long inflation lags, the influence of inflation becomes more sharply negative. The t statistic is negative in most of the specifications and clearly significant for recent inflation (p=3).

Table 5

Causality from inflation to growth

p	**Model 1**		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	CHI	T	CHI	T	CHI	T	CHI	T	CHI	T
3	0.00	-1.57	0.00	-2.26	0.00	-2.73	0.02	-2.05	0.00	-2.97
4	0.00	-0.63	0.00	-1.25	0.00	-1.45	0.02	-0.68	0.00	-1.85
5	0.00	-0.29	0.00	-1.14	0.00	-1.71	0.01	-0.67	0.00	-1.67
6	0.02	0.52	0.02	-0.38	0.00	-0.92	0.03	-0.37	0.01	-1.26
7	0.04	0.18	0.06	-0.78	0.00	-1.58	0.05	-0.80	0.01	-1.11
8	0.06	0.59	0.10	-0.48	0.02	-1.56	0.08	-0.76	0.03	-1.45
9	0.02	-0.75	0.05	-1.51	0.00	-2.54	0.02	-1.81	0.01	-2.31
10	0.06	-1.29	0.14	0.34	0.02	-0.91	0.04	-0.45	0.02	-0.91
11	0.00	-0.64	0.05	-1.20	0.00	-2.52	0.01	-1.87	0.01	-2.06
12	0.02	0.00	0.17	-0.41	0.01	-1.87	0.13	-1.35	0.11	-1.41

Notes: Model 1: Basic model with no individual effects nor additional regressors. Model 2: Model with individual effects. Model 3: Model with individual effects and accumulation rates (investment rate, schooling, rate of growth of population and trend). Model 4: Model with individual effects and lagged (t-1) accumulation rates. Model 5: As in model 4 including some lagged (t-1) macroeconomic indicators (money growth, exports growth and public consumption as a percentage of GDP).

Models 3 and 4 incorporate, in addition to individual effects, several other regressors such as a linear trend, the savings ratio, the rate of schooling and the growth rate of the population. In model 3 these regressors are included contemporaneously, whereas their first lags are included in model 4 to avoid biases of simultaneity. The incorporation of these regressors leads to a substantial fall in the value of the F, with an increase in the absolute value of the t statistic. In model 3 the null hypothesis of non-causality is rejected for any value of p; moreover, the sign of the long-run influence of inflation on the growth rate is negative in all cases, although it is not always significant at the 5 per cent level. Model 4 displays a very similar pattern to that of model 3, although both the causality and the negative sign of the influence of inflation on growth are less clear-cut.

Model 5 incorporates, in addition to the regressors of model 4, the first lags of several other macroeconomic variables such as the growth rate of the money supply, the growth rate of exports and the growth of public spending as a percentage of GDP. Many authors have studied the relationship between long-term growth and the short-term performance of economies.[25] The main argument on which this relationship rests is that the shocks in an economy or the way economic policy is conducted influence 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 as it could be due to the fact that inflation approximates the impact of other macroeconomic variables with which it is, in turn, strongly correlated.

A specification that includes other macroeconomic indicators has the advantage that it permits an analysis of the influence of inflation on growth while isolating it from the effect of other shocks. The variables chosen have often been considered in empirical models of economic growth, albeit with different results as to their influence in the long run.[26] After taking into account the effect of fiscal and monetary policy and the performance of competitiveness, the existence of causality and a negative sign from inflation to economic growth become more apparent. Once again the null hypothesis that inflation does not help to improve the prediction of the future growth rate is clearly rejected at 5% and even at 1% (except for p=12). The statistic associated with the sum of the coefficients of the inflation lags in (8) is negative in all cases, with a value of t higher than unity (except for p=10), and significantly different from zero (at the 5% significance level) in four cases.

Table 6
Causality from inflation to per capita income

p	**Model 1**		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	CHI	T	CHI	T	CHI	T	CHI	T	CHI	T
3	0.00	-3.37	0.00	-2.85	0.00	-3.03	0.01	-2.24	0.00	-3.18
4	0.00	-1.84	0.00	-1.25	0.00	-1.52	0.04	-0.43	0.01	-1.67
5	0.00	-2.57	0.00	-1.83	0.00	-2.27	0.02	-1.12	0.00	-2.18
6	0.00	-1.73	0.00	-1.30	0.00	-1.18	0.02	-0.56	0.00	-1.57
7	0.00	-1.52	0.06	-1.10	0.01	-1.28	0.06	-0.52	0.01	-0.94
8	0.01	-1.46	0.01	-1.24	0.03	-1.55	0.09	-0.73	0.02	-1.38
9	0.01	-1.88	0.01	-1.80	0.01	-2.20	0.05	-1.39	0.02	-2.04
10	0.00	-1.07	0.01	-1.40	0.01	-1.40	0.03	-0.94	0.01	-1.36
11	0.01	-1.47	0.02	-1.65	0.01	-1.89	0.03	-1.38	0.01	-1.78
12	0.00	-1.54	0.02	-2.10	0.00	-2.25	0.01	-1.88	0.02	-2.03

Notes: see Table 5.

Table 6 shows the statistics of joint significance and of the sum of the parameters $\{d_j\}$ in specifications similar to those of Table 5, but without imposing the restriction of first differences in the dynamics of per capita income.[27] In most of these models the non-causality of inflation to per

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[25] See Fischer (1993), for example.

[26] See Levine and Renelt (1992) and Andrés, Doménech and Molinas (1996a) for alternative views of the influence of macroeconomic shocks on growth.

[27] Causality analysis cannot discriminate between the *level* and *growth rate* effects, since the model in levels is merely a less restricted version of the model specified in differences. The purpose of this exercise is simply to check whether the results given in Table 5 depend on the dynamic specification.

capita income is rejected, even at the 1% significance level. Moreover, the sign of the influence of inflation on income is always negative, with a t statistic often higher than 1.5 and significant (at 5%) in a third of the specifications applied. The inclusion of individual effects (model 2 versus model 1) marginally alters the estimated effect of inflation on per capita income. The inclusion of additional regressors has a similar effect on the statistics. Model 4 reflects an across-the-board fall in the joint significance of the inflation lags, not only due to the increase in the significance level of the F (which moves close to or higher than 5%, but in no case reaches 10%) but also due to the decline in the absolute value of the t of the sum of the coefficients of the lags. This variation (also apparent in the analysis of causality from π_t to Δy_t) could be interpreted in terms of the channel through which the influence of inflation manifests itself. In particular, the increase in the significance level at which the null of non-causality is rejected and the decrease in the size of the long-run coefficient of inflation would indicate that causality is largely explained by the investment channel. Finally, once the effect of other short-run macroeconomic indicators is taken into account, the effect of inflation on income is seen more clearly. In model 5, once again, the value of the F is high enough to reject the null hypothesis of non-causality in all cases (at the 5% level). Moreover, the sum of the inflation lags is significantly negative in four cases at the 5% level and at slightly lower significance levels in three other cases. We have finally tested the existence of reverse causality from the rate of economic growth onto the rate of inflation. As can be seen in Table 7, causality is only rejected in one out the 50 specifications presented. 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 significant in more than 90% of the cases. The size of this effect peaks at p equal to 4 falling thereafter. The inflationary effects of growth are subject to a certain delay and, as expected, they diminish over time.

Table 7

Causality from growth to inflation

p	**Model 1**		**Model 2**		**Model 3**		**Model 4**		**Model 5**	
	CHI	T	CHI	T	CHI	T	CHI	T	CHI	T
3	0.00	3.12	0.00	3.18	0.01	2.62	0.02	2.42	0.14	1.89
4	0.00	5.76	0.00	5.66	0.00	4.51	0.00	4.48	0.00	4.15
5	0.00	4.99	0.00	4.72	0.00	3.88	0.00	3.34	0.00	2.98
6	0.02	5.15	0.00	4.69	0.00	3.91	0.00	3.53	0.00	3.40
7	0.00	4.38	0.00	4.38	0.00	3.14	0.00	2.55	0.00	2.24
8	0.00	4.17	0.00	4.00	0.00	3.03	0.00	2.49	0.00	2.51
9	0.00	3.76	0.00	3.72	0.00	2.74	0.00	2.19	0.00	2.38
10	0.00	3.86	0.00	3.87	0.00	2.61	0.00	1.94	0.00	2.18
11	0.00	2.23	0.00	3.03	0.00	1.77	0.00	1.04	0.00	1.37
12	0.00	2.09	0.00	2.58	0.01	0.87	0.01	0.28	0.03	0.63

Notes: see Table 5.

Economic theory proposes several explanations why rapid growth is associated with higher near-term inflation. 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,[28] whereby 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 positive correlation indicates that the risk of a simultaneity bias in the estimation of inflation costs is considerable. However, this effect creates a downward bias in the

[28] Balassa (1964) and Samuelson (1964).

estimated impact of inflation on growth.[29] 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 upwards.

The statistics summarised in Tables 5, 6 and 7 allow us to draw a first general conclusion as regards the importance of the effects studied here. Current inflation helps forecast future income. Although the negative effect of inflation on per capita income in the long run is not always significant, the sign of the sum of the lagged inflation coefficients in models (10) and (10') is never positive or significantly higher than zero. Thus, a high level of inflation today may or may not be bad news but it can never be taken as good news, as far as the future income prospects of an economy are concerned.

The importance of these results becomes more apparent if the causality from inflation to income is compared with the influence on growth of other variables such as investment in physical or human capital or the expansion in public spending. Several recent attempts to corroborate the statistical causality from investment in physical capital to growth and income 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, for a group of 101 countries, how growth always precedes investment in simple growth equations. 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.[30] A similar effect is obtained in relation to the other fundamental variable in the determinants of growth, the rate of schooling, as a proxy for investment in human capital. The authors argue that the estimated correlation in most growth equations between income and investment can be explained by the existence of a simultaneity bias or by the exclusion of country-specific effects in these equations. The existence of a simultaneity bias cannot be rejected because, according to the above-mentioned studies, income helps to explain investment, in the sense that the higher the income, the higher the rate of saving and investment of OECD economies.

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 anticipates a lower 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. This would indicate that inflation can influence not only saving and investment in economies but also the efficient use of productive factors. 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 allow us to affirm that inflation does not appear to be neutral in the long run and that in no case does the persistence of inflationary tensions favour rapid economic growth in the future.

Concluding remarks

The purpose of this paper has been to study the correlation between growth and inflation at the OECD level, within the framework of the so called convergence equations. It further discusses

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29 In this respect, see Andrés, Hernando and Krüger (1996).

30 This is consistent with the findings by Carrol and Weil (1993).

whether this correlation withstands a number of improvements in the empirical models, which try to address the most common criticisms on this evidence. Despite its many 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 main finding is that there is a significant negative correlation between inflation and income growth during rather long periods. This negative correlation survives the presence of additional regressors, such as savings, population growth and schooling rates, and the imposition of the theoretical restrictions implied by the constant returns of technology. 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 since, as is well known in the empirical growth literature, few regressors in convergence equations withstand the explanatory power of country dummies. 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 most clearly when the influence of country dummies, accumulation rates and the effect of other macroeconomic variables is controlled for.

According to the point estimate of its coefficient, inflation has a negative but temporary impact upon long-term growth rates, which, in turn, generates a permanently lower level of per capita income than would otherwise have been achieved. The estimated cost of an additional 1% in the inflation rate is a reduction, during rather long periods, in the annual growth rate of about 0.06%, that leads to a reduction in the steady-state per capita income of about 2%. Inflation not only reduces the level of investment but also the efficiency with which productive factors are used. Our results seem to suggest that the marginal cost of inflation is independent of the inflation rate. Nonetheless, the long-run costs of inflation are non-negligible and efforts to keep inflation under control will sooner or later pay off in terms of better long-run performance and higher per capita income.

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Comments on: "Inflation and economic growth: some evidence for the OECD countries" by Javier Andrés and Ignacio Hernando

by R. Sean Craig

This paper is an interesting contribution to the cross-country growth regression literature that tests for an effect of inflation on economic growth. As is well known, this literature is plagued by two problems:

1) estimation results are not robust to changes in specification or the addition of variables;

2) Problems of interpretation arising from the fact that the direction of causality may be the reverse of that assumed in the model.

The paper attempts to address these problems using panel data to estimate the relationship between growth and inflation in OECD countries. It does this in three ways: first, rather than estimate a reduced-form regression, as is often done in the literature, it estimates a structural model based on a fairly sophisticated version of the Solow growth model to help clarify the problem of interpretation noted above. Second, the paper subjects the model to a number of robustness tests. Third, it uses Granger causality tests to test whether the causality does in fact run from inflation to growth. These latter tests generally show that the causality runs in the appropriate direction, and represent a significant contribution to the literature.

The structural model allows for a number of different variables to influence growth: inflation, physical and human capital accumulation, population, the level of income and a time trend. In the model, inflation lowers per-capita income by reducing the efficiency of investment. While the use of a theoretical model is a nice feature of this paper, its usefulness is limited by the fact that it does not allow for other channels through which inflation could reduce growth that could be important. Specifically, it does not incorporate the effect, identified by Martin Feldstein, where, through the interaction of inflation and the tax system, inflation increases the after-tax cost of capital. Nor does it allow for the possibility that inflation, or inflation variability, can lower the investment rate by distorting inter-temporal decision-making.

The paper does not find a relationship between inflation and the *growth rate* of GDP but, rather, a statistically significant negative relationship between inflation and the *level* of per-capita GDP. However, since this latter effect occurs over 30 years it is quantitatively very similar to a growth-rate effect. Moreover, in estimation it is hard to distinguish these two effects statistically. Also, the paper does not find an effect of the variability of inflation on growth or per-capita income. This may reflect the limitations of the data since the level of inflation and the variability of inflation are highly correlated so it would be difficult to identify separate effects from these two variables.

While the negative relationship between inflation and per capita income remains statistically significant for all specifications that are estimated, the magnitude of the effect is sensitive to the choice of specification. Specifically, the size of the estimated coefficient is particularly sensitive to the addition of variables representing physical and human capital accumulation. When these variables are added, the estimated coefficient falls by ½. The authors interpret this result as indicating that the negative effect of inflation on growth occurs partly through an investment channel where inflation reduces the rate of capital accumulation. However, this possibility is not tested for (by, for example, estimating the relationship between investment and inflation). Another problematic feature of the regression is that the time trend intended to capture productivity growth has the wrong sign.

The estimated relationship is also sensitive to the addition of fixed effects (country-specific constants) in the panel regression. When these are added, the time trend has the right sign, but the positive impact of physical and human capital accumulation on growth disappears. This suggests that the statistically significant effect of these latter two variables may be spurious in the sense that their significance in the original specification is due to the inappropriate restriction that the country specific constants are equal across countries. In the paper, the authors acknowledge this possibility but do not test for it. Finally, another results that suggests that the model may be subject to robustness problems is that the estimated relationship is sensitive to whether outliers such as Iceland and Turkey are included.

Finally, the results provide only weak support for the theoretical model, since a number of variables other than inflation that the model suggests should be included in the specification are not significant. This weak empirical support for the model limits the extent to which it can help address the problems of interpretation noted above.