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Growth effects of inflation in Europe: How low is too low, how high is too high?*

Jesús Crespo Cuaresma† Maria Antoinette Silgoner‡

Abstract

This paper reassesses the impact of inflation on long-term growth for a panel of 14 EU countries. While previous research focuses on a linear nexus or allows for a piecewise linear relationship with one single threshold, we take account of a more complex relationship. We use a theoretical framework that allows for an explicit distinction between level and growth effects of inflation. The empirical estimates for the full EU sample confirm the hypothesis that the relationship between inflation and growth is positive for very low inflation rates (i.e. below an estimate of 1.6%), insignificant thereafter and negative for high, two-digit inflation levels. The estimate of the inflation level that divides the insignificant from the negative effect is found to be higher in the group of traditional cohesion countries than for the rest of the sample.

JEL classification: E31, O40, O52

Keywords: Inflation, economic growth, growth and level effect, European Union.

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1 Introduction

Today there seem to be some facts about inflation that most economists and politicians would accept without further arguing: (a) Very high inflation rates are bad for economic growth. (b) Deflation, defined as a continuous fall of the overall price level over a sustained period of time, can be harmful for the economy. (c) Between these two extreme cases there is something like an optimal level or an optimal range of inflation. With the aim of avoiding the negative effects of too high as well as too low inflation rates almost all independent central banks pursue either direct inflation targets or have an explicit definition of price stability solidly embedded into their monetary policy strategy. At the same time also other national economic policy authorities monitor inflation developments carefully and take the consequences on inflation into account when designing economic policy measures.

While the negative effects of "extreme" inflation rates seem to be common sense it is far less clear what specific levels of inflation are to be considered as too low or too high. The welfare costs of suboptimal inflation come through various channels and depending on which of these are the research focus, different implications may emerge for inflation policy.

The welfare costs of high inflation are manifold: First, both inflation and deflation can be costly because of the distortionary impact on relative prices and thus the efficiency of market allocations. Second, the interaction of nominal price and wage rigidities with both inflation or deflation may entail welfare costs. Examples are menu costs (small fixed costs for changing prices or wages) or nominal lock-in (sellers inability to modify listed prices in certain periods). Third, inflation significantly exacerbates the inefficiencies caused by the tax system. Fourth, there are direct transaction costs from inflation in the form of shoe-leather costs (losses in consumer surplus from holding real balances) or the over-development of the financial system and the corresponding withdrawal of funds from other more efficient investments. Finally, in the absence of inflation-indexed contracts, both inflation and deflation have an effect on the income distribution in the economy.[1]

The analysis of the costs of inflation in terms of welfare is usually done on a partial basis. It is therefore difficult to estimate the overall effect, not only because it proves difficult to identify and distinguish the various channels but also because of overlapping of effects. In general, the literature suggests that even moderate rates of inflation are likely to entail significant welfare losses.

[1] For an extensive overview on these channels, see e.g. Camba-Mendez et al. (2003).

The purpose of this paper is to focus on one specific welfare channel: the effect of inflation on long-term growth. There is a wealth of empirical literature on the relationship between inflation and long-term growth, and it varies considerably with respect to the theoretical foundation or the econometric specification. Starting from simple linear models, the focus shifted in recent years towards non-linear specifications in acknowledgement of the potentially more complex nature of the nexus. Section 2 provides an extensive overview of the theoretical arguments as well as the existing empirical literature.

These earlier studies provide the starting point for our assessment of the inflation-growth relationship. Focusing on the countries of the European Union as of January 2004, we aim at reassessing the impact of inflation on long-term growth, putting special emphasis on the theoretical arguments that point at the growth-harming effects of very high as well as very low (or negative) inflation rates. As compared with the previous literature, our study deviates in several substantial respects.

While in most studies on the inflation-growth nexus the estimation is based on ad hoc regressions, we explicitly make use of a fully specified theoretical framework. This approach is in response to the common criticism of a somewhat arbitrary choice of explanatory factors for growth. It is especially relevant as Levine and Renelt (1992), Levine and Zervos (1993) and Sala-i-Martin (1997), for linear models, and Crespo Cuaresma (2002), for non-linear models, found the cross-section inflation-growth relationship to be exceptionally fragile. Basing our estimation on a theoretical framework therefore reduces the risk that the results reflect data-mining.

Earlier studies usually allow for a single breakpoint in the growth-inflation nexus, which appears to us to be an oversimplification of the story. Based on the theoretical arguments summarized in Section 2, one could expect a parabolic or trapezoid shape of the curve: a positive link for very low or negative levels of inflation, an insignificant relationship thereafter, followed by a negative impact of inflation on growth for excessively high inflation. In order to test for this hypothesis we will allow for more than one breakpoint in the relationship. We will furthermore also account for the fact that the inflation-growth nexus may differ between countries in a catching-up process and countries in a more advanced stage of development.

Usually studies abstract from the question whether the impact of inflation on growth takes the form of a level or a growth effect. A negative growth effect implies that a permanently higher rate of inflation does also permanently dampen growth. A level effect, on the other hand, harms growth during a transition period while steady state growth is left unaffected. The implications in terms of interpretation are fundamentally different. Notwithstanding the difficulty of differentiating these effects empirically, we will explicitly take this issue into account and test for the existence of level and growth effects on long-term growth.

The paper is organized as follows: Section 2 provides an extensive overview of the theoretical arguments as well as the existing empirical literature on the inflation-growth relationship. Section 3 presents the theoretical framework. Section 4 reports about the empirical implementation of the model, starting with a linear framework and allowing then for non-linear effects of a different form (quadratic specification and spline model). Section 4.4 elaborates on the growth versus level effect issue in more detail. Section 5 concludes. Details on the data can be found in the Annex.

2 The theory and empirics of the inflation-growth nexus

From a theoretical point of view, one has to distinguish between the short-run and the long-run link between inflation and growth. In the short run, faster economic growth may be associated with more rapid inflation when aggregate demand exceeds aggregate supply and output cannot fully adjust. Short-term inflation dynamics are therefore mostly associated with the demand side of the economy.

In the long run, however, a significant influence of inflation on growth for high levels of inflation will most probably be related to supply side effects, more specifically to misallocation of resources that distort investment and consumption. Common arguments refer to either the average rate of inflation or to the variability and uncertainty of inflation: menu costs, search costs, transaction costs due to the declining information value of prices, the costs of economizing on holdings of non-interest-bearing money, the social costs of increased uncertainty, the vicious cycle of a wage-price spiral, etc. Very high inflation rates tend to be also more volatile, making the real returns on investments harder to forecast with subsequent consequences for savings and investment decisions. With inflation increasing even further, the widespread use of indexation systems makes it more difficult to reduce inflation in the future. At some point, finally, money may lose its role as a medium of exchange and store of value.[2]

While high inflation is obviously associated with considerable costs and risks, deflation can be at least as dangerous. The most common argument refers to inflation as the "grease of the economy." Under wage and price rigidities only a certain level of inflation guarantees a smooth adjustment of relative prices. The other risk associated

[2]For a literature survey, see e.g. Briault (1995).

with sustained periods of deflation is known as “the zero lower bound constraint”: If deflation occurs while the economy is in a recession monetary authorities may find themselves in a situation where the key interest rates are (almost) zero while real interest rates are still positive. In such a situation the most powerful monetary policy instrument has lost its power. Finding the appropriate mix of the other available monetary and economic instruments is a tricky task, as the experience of Japan over the last decade showed.

Under the assumption that a very low inflation level is associated with an increased risk of subsequent deflationary periods, one could expect a positive relationship between inflation and growth also for positive, but small increases in the price level. It is furthermore a commonly accepted fact that the measurement error in official inflation series due to the omission of quality improvements can be substantial, specifically if the measures don’t follow the hedonic pricing approach. In this case a small positive official inflation rate may in reality mask a falling price level. But there are at least two more arguments pointing to a positive growth-inflation link for relatively low inflation levels. The Mundell-Tobin effect describes a situation when increases in inflation force agents to shift their portfolio allocation away from holdings of real balances into capital investment, which results in higher levels of economic activity. Stockmann (1981), on the other hand, advances models where money and capital are considered as complements.

Summarizing these theoretical arguments, one could expect a positive impact of inflation on growth for lower levels of inflation (or deflation), followed by a “grey area” with no significant effect whatsoever. This range need not necessarily indicate the lack of any effects of inflation on growth but would rather represent an overlap of various effects in different direction. For excessive inflation finally the effect can be expected to be significantly negative. A look at the empirical literature reveals that the evidence for these hypotheses has undergone several phases with significant changes.

During the 1950s and 1960s, when periods of excessive inflation were basically unknown within the group of industrialized countries, empirical tests on the growth-hampering impact of inflation tended to fail to show any clear-cut effect. The relationship between long-term growth and inflation was found to be insignificant, in some cases even positive (see e.g. Wai, 1959, Bhatia, 1960, or Dorrance, 1966). With the two first oil price shocks and the emergence in many countries of severe periods of high and persistent inflation rates the evidence shifted. The effect was now usually found to be significantly negative, although highly dependent on the inclusion of post-1970 and therefore high inflation observations.[3]

It was only in the second half of the 1990s that the focus increasingly shifted to the issue of possible nonlinearities in the growth-inflation nexus. Acknowledging the existence of a structural break in the relationship could explain the lack of evidence for a significant negative effect in the pre-oil crisis period due to the lack of episodes with high inflation. Disregarding this break furthermore implies an underestimation of the growth-hampering effect of very high inflation levels. An estimated breakpoint in the growth-inflation nexus finally suggests a specific policy advice from a growth perspective, namely to aim at keeping inflation below the breakpoint level.

The recent literature reveals two major findings: (a) The nonlinearities in the effect of inflation on long-term growth are now widely acknowledged. (b) The estimates of the optimal level of inflation vary substantially between studies. The differences stem on the one hand from the fact that the sample of countries varies considerably, some of them covering industrialized countries only (Motley, 1998, Tsionas and Christopoulos, 2003), some including also transition or developing countries (Sarel, 1996, Gosh and Phillips, 1998, Christoffersen and Doyle, 1998, Khan and Senhadji, 2001). On the other hand, some studies – especially the earlier ones – do not explicitly estimate the breakpoint inflation level but set it exogenously. Bruno and Easterly (1998), for example, check for growth effects of inflation below and above 40%, their lower bound definition of an inflation crisis.

It was only with the development of more sophisticated econometric techniques, that the breakpoints were actually estimated. Applying the threshold panel data estimation technique (based on the methodology developed by Hansen, 1999) and using a panel of 140 countries and 39 years of data Khan and Senhadji (2001) estimate the threshold inflation level at 1-3% for industrial countries and at 11-12% for developing countries. Above these thresholds they find a negative and significant impact of inflation on growth, below the thresholds the relationship is positive and only significant for the industrial countries. The higher estimates for developing countries are partially explained by the widespread use of indexation systems that reduce the adverse effects of inflation. It can also be assumed that the inflation tolerance increases if the high inflation rates are related to the convergence process and the Balassa-Samuelson effect, which are of higher relevance for developing countries. Using a smooth transition model for a set of 15 EU countries, Tsionas and Christopoulos (2003) find a negative relation between inflation and growth throughout the sample;

[3] For a detailed study on this relationship, see e.g. Fischer (1993) or Barro (1995); for a model-based estimation, see Motley (1998); for more recent evidence on European countries, see e.g. Crespo Cuaresma et al. (2003). Temple (2000) offers an excellent critical survey on the empirical literature on the inflation-growth link.

the effect is, however, three times as large in the high inflation regime (above an estimated threshold of 4.3%) than in the range below this threshold level.

In terms of data sample and threshold estimation methodology these two pieces of research are comparable to our study. However – in contrast to their approach – our econometric specification directly relates to economic theory. We will therefore rely on a Hall and Jones (1999) type of production function in order to obtain the empirically tractable model where furthermore growth and level effects can be distinguished. An important difference concerning the estimation technique is that not only do we allow for a more complex non-linear structure but also impose continuity in the relationship between inflation and growth.

3 The theoretical framework

This section presents a human capital-augmented Solow model (Solow, 1956) where inflation is assumed to have an effect on the level of productivity of the economy. In spite of its simplicity, the power of the Solow model in explaining the post-war growth experience in both developed and developing countries is widely documented in the literature dealing with the empirics of economic growth (see e.g. Mankiw et al., 1992).

We will consider a simple human capital-augmented Solow model with a production function as in Hall and Jones (1999). The production function is given by

$$Y(t) = K(t)^{\alpha} \left[A(t)H(t)\right]^{1-\alpha},$$

where $K(t)$ is the stock of physical capital, $H(t)$ denotes the human capital-augmented labor force and $A(t)$ is a measure of labor-augmenting productivity. The measure of human capital augmented labor is given by

$$H(t) = G(E(t))L(t),$$

where $G(E(t))$ is a function mapping years of education ($E(t)$) to human capital stock per worker and $L(t)$ stands for the labor force. Following Hall and Jones (1999), let $G(E(t))$ be given by[4]

$$G(E(t)) = \exp\left[\rho E(t)\right],$$

[4]Based on empirical evidence on estimates of returns to schooling, Hall and Jones (1999) actually assume the exponent in $G(E(t))$ to be a piecewise linear function, with a kink located at $E(t) = 4$. Given that the education levels in our sample lie well above that value, we use a linear function for the exponent in $G(E(t))$.

for $\rho > 0$. Consider a specification of $A(t)$, where inflation may affect the level and the growth rate of productivity,

$$A(t, \pi(t)) = A(0) \exp \left\{ \Psi(\pi(t)) + [g + \Theta(\pi(t))]t \right\}, \tag{1}$$

where $g > 0$ is the growth of technology at zero inflation and $\Psi(\cdot)$ and $\Theta(\cdot)$ are arbitrary bounded functions. This specification nests those of Cozier and Selody (1994) (corresponding to $\Psi(\pi(t), \sigma_\pi(t)) = \mu_1 \pi(t) + \mu_2 \sigma_\pi(t)$, where $\sigma_\pi(t)$ is the volatility of inflation, and $\Theta(\pi(t)) = 0$), Motley (1998) (for $\Theta(\pi(t)) = \phi\pi(t)$ and $\Psi(\pi(t)) = 0$) and Andrés and Hernando (1997) (using both specifications above).

Assume as in the usual textbook Solow model that the dynamics of physical capital are given by

$$\dot{K}(t) = sY(t) - \delta K(t),$$

where $s \in (0, 1)$ is the (constant) fraction of output devoted to investment and δ is the depreciation rate of physical capital. The equilibrium level of physical capital per unit of effective labor $k(t) = K(t)/(A(t)H(t))$ for the model described above is given by

$$k^* = \left(\frac{s}{n + \dot{A}(t, \pi(t))/A(t, \pi(t)) + \delta} \right)^{1/(1-\alpha)},$$

n being the rate of population growth. A fixed long-run level of inflation π^* will be assumed so that the equilibrium can be written as

$$k^* = \left(\frac{s}{n + g + \Theta(\pi^*) + \delta} \right)^{1/(1-\alpha)}.$$

The adjustment to equilibrium for $y(t) = Y(t)/(A(t)H(t))$ is given by (see e.g. Mankiw, Romer and Weil, 1992)

$$d[\ln(y(t))]/dt = \lambda[\ln(y^*) - \ln(y(t))],$$

for $y^* = f(k^*) = (k^*)^\alpha$. The parameter λ captures the speed of convergence to the steady state. Consider the dynamic process for output per unit of effective labor from period t to period $t + \tau$,

$$\begin{aligned} \ln(y(t+\tau)) - \ln(y(t)) &= \left(1 - e^{-\lambda\tau}\right) \frac{\alpha}{1-\alpha} \ln(s) - \left(1 - e^{-\lambda\tau}\right) \frac{\alpha}{1-\alpha} \ln(n + g + \Theta(\pi^*) + \delta) \\ &\quad - \left(1 - e^{-\lambda\tau}\right) \ln(y(t)), \end{aligned}$$

which can be written in terms of growth of income per capita as[5]

$$\ln\left(\frac{Y(t+\tau)}{L(t+\tau)}\right) - \ln\left(\frac{Y(t)}{L(t)}\right) = \Psi(\pi(t+\tau)) - e^{-\lambda\tau}\Psi(\pi(t)) + [g+\Theta(\pi(t+\tau))](t+\tau) -$$

$$-e^{-\lambda\tau}[g+\Theta(\pi(t))]t + \rho E(t+\tau) - \rho e^{-\lambda\tau}E(t) + \left(1-e^{-\lambda\tau}\right)\frac{\alpha}{1-\alpha}\ln(s) - \quad (2)$$

$$-\left(1-e^{-\lambda\tau}\right)\frac{\alpha}{1-\alpha}\ln(n+g+\Theta(\pi^*)+\delta) - \left(1-e^{-\lambda\tau}\right)\ln\left(\frac{Y(t)}{L(t)}\right) + \left(1-e^{-\lambda\tau}\right)\ln(A(0)).$$

We will proceed by estimating (2) under the assumption of a growth effect of inflation (and no level effect, that is, $\Psi(\cdot) = 0$), a level effect (and no growth effect, that is $\Theta(\cdot) = 0$) or assuming that inflation can cause both types of effect.

4 Inflation and growth in Europe: An empirical analysis

4.1 First results: A linear growth-inflation link?

In this section we will proceed by estimating several versions of (2) under different assumptions concerning the functional form of the growth and level effect of inflation. All estimations are done for a panel comprising 14 EU countries (all member states as of January 2001 except for Luxembourg). The data sources are presented in the appendix. We use data spanning the period 1960-99, divided into subperiods of eight years. The growth variable on the left hand side of (2) is thus the growth rate of income per capita in the corresponding eight years. A relatively low variability is observed for the variable that proxies education attainment (average years of education for an adult over 25 years old) within the countries in our sample. In order to avoid multicollinearity, we assume that the changes in $E(t)$ happen in a stepwise fashion so that within a period $E(t+\tau) = E(t)$. For the empirical implementation of the model, the value will be set equal to the average educational attainment in the period.[6] The general specification which is estimated for different assumptions on the nature of $\Psi(\cdot)$ and $\Theta(\cdot)$ is

[5] Note that the existence of a constant level of inflation corresponding to the steady state in this augmented Solow model is not a necessary assumption for the stability of the solution. As long as the inflation rate is generated by an ergodic stochastic process, the growth rate of GDP per capita in the Solow steady state will remain in a bounded interval and the adjustment described above will take place towards a non-constant equilibrium that depends on the inflation rate in the period considered.

[6] This assumption does not affect the results of the paper concerning the effect of inflation on long-run growth and only has a relevant effect on the significance level of the estimate of ρ.

$$\ln\left(\frac{Y_{i,t+\tau}}{L_{i,t+\tau}}\right)-\ln\left(\frac{Y_{i,t}}{L_{i,t}}\right)=\Psi(\pi_{i,t+\tau})-e^{-\lambda\tau}\Psi(\pi_{i,t})+[g+\Theta(\pi_{i,t+\tau})](t+\tau)-$$

$$-e^{-\lambda\tau}[g+\Theta(\pi_{i,t})]t+\rho(1-e^{-\lambda\tau})\bar{E}_{i,t+\tau}+\left(1-e^{-\lambda\tau}\right)\frac{\alpha}{1-\alpha}\ln(\bar{s}_{i,t+\tau})- \quad (3)$$

$$-\left(1-e^{-\lambda\tau}\right)\frac{\alpha}{1-\alpha}\ln(\bar{n}_{i,t+\tau}+g+\Theta(\pi^*_{i,t+\tau})+\delta)-\left(1-e^{-\lambda\tau}\right)\ln\left(\frac{Y_{i,t}}{L_{i,t}}\right)+\varepsilon_{i,t},$$

where $\bar{E}_{i,t+\tau}$ refers to the average educational attainment for country i in the period ranging from t to $t+\tau$, $\bar{s}_{i,t+\tau}$ is the average investment share and $\bar{n}_{i,t+\tau}$ is the average population growth. The error term $\varepsilon_{i,t}$ is assumed to be composed of a country and a subperiod-specific error, both treated as constant, and a general i.i.d. error process, such that $\varepsilon_{i,t}=\mu_i+\kappa_t+\nu_{i,t}$ with $\nu_{i,t}\sim \text{IID}(0,\sigma^2)$. Throughout the study δ, the depreciation rate, and g, the growth of technology corresponding to zero inflation, will be set equal to 3% and 2%, respectively, in line with Mankiw et al. (1992).[7]

Equation (3) has been estimated assuming different effects of inflation on labor-augmenting productivity. The results presented in Table 1 and all later tables include a dummy for the last subperiod in the sample for Ireland. This was included because the Jarque-Bera test for all specifications strongly rejected the null hypothesis of normal distribution of the residuals. This deviation of normality turned out to be caused exclusively by the growth observation corresponding to Ireland in the period 1992-99, which the model without dummy systematically tended to underpredict. The estimated parameter for the dummy is positive and significant in all specifications.

The first column presents the results without the effect of inflation, i.e. the structural parameter estimates from (3) setting $\Theta(\cdot)=\Psi(\cdot)=0$. [8] The estimates of λ imply a convergence rate of approximately 10% per year, significantly higher than the estimates usually obtained in cross-country studies. The fixed effects panel setting allows for different steady states across economies, and the estimate of the

[7]Changing the value of these parameters inside economically sensible ranges does not qualitatively affect the results presented in the paper.

[8]Given the low within-country variability of the education measure, the size and significance of the estimate of ρ depends strongly on the inclusion of fixed subperiod effects. Results with and without time dummies are available from the authors upon request. As the exclusion of a variable with an insignificant parameter estimate may still affect the other estimates, we also reran all estimations for the model without human capital. None of the results presented in the paper were significantly affected by the omission of the education variable.

convergence rate thus refers to the convergence towards the country-specific steady state.[9] The estimate of α is in line with those reported by Mankiw et al. (1992), for example, and the estimate of ρ is positive although insignificant. This latter result is due to the low variability of education measures for the sample analyzed both across countries and through time.[10]

In a next step, we are going to let inflation affect the labor-augmenting technology. Figure 1 shows a scatter plot of average inflation versus the residuals of the estimation presented in the first column of Table 1 (that is, without modelling the effect of inflation on growth) for the 14 EU countries and all subperiods. While from a purely visual examination of the scatter plot a negative relationship between these two variables only seems to be evident for high levels of inflation, it is not possible to draw robust inference before taking into account the specification of the structural model. The second and third columns in Table 1 present the results when a linear growth and level effect of inflation, respectively, is included. The $\Theta(\pi(t))$ and $\Psi(\pi(t))$ functions used were $\Theta(\pi(t)) = \theta\pi(t), \theta \in \mathbb{R}$, and $\Psi(\pi(t)) = \psi\pi(t), \psi \in \mathbb{R}$. For the growth effect specification the estimates reported approximate the long-run inflation level for each country using the subperiod average inflation rate. Other different specifications for π^* have been tried, including the overall sample average, or exogenously set inflation rates ranging between 2% and 6%, without any qualitative change in the results. The estimates of λ, α and ρ are practically not affected by the inclusion of inflation in the specification. The results in columns 2 and 3 show that the negative effect of inflation on growth of GDP per capita appears only marginally significant in the specification which allows exclusively for a growth effect of inflation.[11]

In order to account for the potential endogeneity of inflation in (3), we also estimate the level effect specification instrumenting the inflation rate by the index of central bank independence in Hall and Franzese (1998) and money supply growth.[12] Using a

[9]The point estimate of the convergence rate using a common intercept is approximately 4%. However, the null of equality of fixed effects is strongly rejected when performing the corresponding F-test.

[10]The estimate of ρ corresponding to the model without time effects is 0.315, with a standard deviation of 0.038, and thus highly significant.

[11]The results when including both effects simultaneously are very inconclusive for all the specifications in the paper and are therefore not reported. They are available from the authors upon request. The main reason is that the identification of the structural parameters is basically done by estimating the growth effect (the part of the specification in logs), which requires non-linear estimation methods. This identification issue, together with a high degree of multicollinearity, renders most of the inflation effects insignificant when the model is too parametrized, as is the case when the level and growth effects are simultaneously assumed.

[12]The unrestricted level specification is used because it is linear in parameters and therefore

specification such as (3) without the parameter constraints implied by the structural model, the Durbin-Wu-Hausman test gives clear evidence in favor of the use of least square estimation.

4.2 Allowing for non-linear effects of inflation on growth

Assuming a linear effect of inflation on the level or growth rate of GDP per capita may, however, be a wrong modelling strategy. If the effect of inflation on growth is of the non-linear type suggested by theoretical arguments as described in Section 2, linear models would tend to underestimate its magnitude for high levels of inflation.

Table 2 presents the results based on a quadratic specification of $\Theta(\pi(t))$ and $\Psi(\pi(t))$. The models with individual growth and level effects point towards a hump-shaped relationship between inflation and economic growth. The other structural parameters remain practically unchanged by the inclusion of a quadratic specification of the growth-inflation link.

Independently of the nature of the inflation effect on growth, the estimates presented in Table 2 result in an extremely high estimate of the optimal (in the sense of growth maximizing) level of inflation. According to the results with a quadratic growth specification, the European experience would imply that increases in the inflation rate for levels below 9% (8.5% for the level specification) have been accompanied by rising long-term growth rates of GDP per capita. However, this high estimate could be due to the symmetry preimposed by the quadratic specification. If the inflation-growth link is positive for very low levels of price increase and negative for high levels but the slope associated to these links differs, the estimate of the optimal level of inflation based on a model with a symmetric relationship between inflation and growth will be distorted.

A way to overcome this limitation and allow for model asymmetry in the relationship between inflation and growth would be to let $\Theta(\pi(t))$ and $\Psi(\pi(t))$ be continuous piecewise functions (so-called *splines*), where the parameter associated with the inflation rate is allowed to change discretely depending on the level of inflation. The theoretical discussion in the introduction and in Section 2 and the evidence from the quadratic specification would call for the inclusion of a function with two differentiability breakpoints, while preserving continuity. For the growth effect, the function is defined as

the usual asymptotics for instrumental variable estimation hold. There is little guidance in the literature as to the properties of instrumental variable estimators with non-linearities such as the ones arising in the specification with a growth effect. For the linear level effect case, the Sargan test did not reject that the instruments used were valid for inflation at any sensible level of significance.

$$\Theta(\pi(t)) = \begin{cases} \theta_3\pi(t) & \text{if } \pi(t) > \mu_2 \\ \theta_2(\pi(t) - \mu_2) + \theta_3\mu_2 & \text{if } \mu_1 < \pi(t) \leq \mu_2 \\ \theta_1(\pi(t) - \mu_1) + \theta_2(\mu_1 - \mu_2) + \theta_3\mu_2 & \text{if } \pi(t) \leq \mu_1 \end{cases} \tag{4}$$

and analogously for the level effect,

$$\Psi(\pi(t)) = \begin{cases} \psi_3\pi(t) & \text{if } \pi(t) > \eta_2 \\ \psi_2(\pi(t) - \eta_2) + \psi_3\eta_2 & \text{if } \eta_1 < \pi(t) \leq \eta_2 \\ \psi_1(\pi(t) - \eta_1) + \psi_2(\eta_1 - \eta_2) + \psi_3\eta_2 & \text{if } \pi(t) \leq \eta_1 \end{cases} \tag{5}$$

The breakpoints, μ_1 and μ_2 (or, alternatively, η_1 and η_2) will be treated as unknown parameters and therefore estimated. Table 3 shows the estimates of the models where the growth and level effects of inflation are modelled by means of (4) and (5), respectively. The estimation of the breakpoints for the case of a growth effect of inflation was done by choosing the values

$$\hat{\hat{\mu}} = (\hat{\mu}_1, \hat{\mu}_2) = \text{argmin}_{\{\tilde{\mu} \in M\}} \sum_{t=0}^{T} \sum_{i=0}^{N} \left[\hat{\nu}_{i,t} \left(\hat{\lambda}(\tilde{\mu}), \hat{\alpha}(\tilde{\mu}), \hat{\rho}(\tilde{\mu}), \hat{\theta}_1(\tilde{\mu}), \hat{\theta}_2(\tilde{\mu}), \hat{\theta}_3(\tilde{\mu}) \right) \right]^2,$$

where M is the set of those inflation rates actually realized in the sample. The estimates for (5) are obtained analogously. That is, the breakpoints were estimated as the inflation values that jointly minimize the sum of squared residuals among those realized in the inflation sample (the estimation was done after trimming 5% of the extremes of the distribution of inflation rates and ensuring that at least 10% of the observations fall in the central regime). The results of the estimation for the available data are presented in Table 3.

The likelihood ratio test statistics and their associated bootstrap p-value presented in Table 3 correspond to a test for linearity computed in the spirit of Hansen (1996) and Pesaran and Weeks (2001). The null hypothesis corresponds to the restriction $\theta_1 = \theta_2 = \theta_3$ for the growth effect specification ($\psi_1 = \psi_2 = \psi_3$ for the level effect model). Under the null hypothesis of linearity the thresholds μ_1 and μ_2 (η_1 and η_2) are not identified, and standard test statistics therefore fail to converge to known asymptotic distributions. Finding optimal tests in this setting is an issue that has recently been widely studied in the econometric literature (see e.g. Andrews and Ploberger, 1994, and Hansen, 1996). In order to compute the p-values presented in Table 3, we follow a bootstrap procedure similar to that proposed by Hansen (1996). Using the actual parameter estimates of the linear model corresponding to the null hypothesis and drawing randomly from the residuals, we compute samples of growth rates. A linear and a non-linear model with a spline effect of inflation on growth are fitted to the simulated data, and the corresponding likelihood ratio test statistic is computed. Repeating this procedure a large number of times allows us to obtain an estimate of the distribution of the test statistic under the null of linearity, and therefore an estimate of the p-value corresponding to the test statistic computed with actual data. For the results presented, 500 replications of the procedure were employed. In all cases, there is evidence of a non-linear effect of inflation on GDP per capita growth of the type modelled through the continuous piecewise linear functions defined above.

The results for the individual specifications provide a very interesting insight into the relationship between inflation and growth in Europe for the period 1960-99. Both for the level and the growth effect model, the estimate of the first break is slightly higher than 1.6% (which corresponds approximately to the 10th percentile of the distribution of inflation in the pooled sample). Below this inflation level we find a significantly positive link, indicating the potential risks of very low inflation and deflation.

This area is followed by a wide range of inflation rates that do not show a significant effect on long-term growth. This does not necessarily indicate that there are no inflation effects on the economy but rather masks the overlap of negative and positive partial effects that results in an overall insignificant net impact on long-term growth. A significantly negative effect is – according to our estimation – only observable for inflation levels over 16.35%. As expected the absolute value of the parameter estimate for the negatively sloped part is much higher than the estimates implied by the linear model.

The estimated second threshold level of inflation appears surprisingly high, especially when compared to the previous literature. Several aspects have to be borne in mind when interpreting this result. Firstly, previous papers impose a non-linear structure that does not allow for more than one breakpoint, a model that proved inferior to our more complex specification.[13] If the flat middle part actually exists, such model structures will tend to underestimate the negative slope for high inflation rates and the single threshold estimate will possess limited informational value. Secondly, the estimate of the upper threshold for the full sample may be predominantly driven by only a small subsample of countries for which high inflation in earlier subperiods of our sample is related to the catching-up process and therefore presumably less harmful than for countries in a more advanced stage of economic development. This

[13] We also estimated models with a single breakpoint in the spline specification. These models pick up exclusively the negative link for high inflation rates, with an insignificant parameter attached to lower inflation levels. Bootstrapped likelihood ratio tests give clear evidence of the superiority of the specification with two breakpoints over the two-regime model.

claim will be explicitly assessed below. Thirdly and related to the latter, it should be emphasized that inflation data points above 9% are characterized by high dispersion, so that the uncertainty surrounding the upper threshold estimate is high. Actually the negatively sloped part of the relationship remains significant and higher than the linear estimate if μ_2 and η_2, respectively, are reduced to values around 10%.

The uncertainty surrounding the threshold estimates can be illustrated by computed confidence intervals for the thresholds, using a generalization of the procedure put forward in Hansen (2000). In fixing one of the two estimated thresholds, a 90% confidence interval for the remaining threshold will be defined as the (not necessarily symmetric) neighborhood around the threshold value for which the null of a two-regime model is rejected at the 10% significance level against a three-regime model. Hansen (2000) recommends to use the asymptotic critical values for the likelihood ratio test. Given that our threshold estimates tend to be close to the extremes of the empirical distribution of inflation, we will compute the confidence intervals using the bootstrap distribution of the likelihood ratio test, computed by means of 1000 replications. The alternative hypothesis in the computation of the bootstrap distribution used in each case is the one corresponding to the least square three-regime model. The resulting 90% confidence intervals for the lower threshold are [1.40%, 1.75%] for the level effect specification and [0.64%, 2.05%] for the growth effect specification. The confidence intervals for the higher threshold are much larger, spanning all values of inflation which are realized in the sample exceeding 12.85% for the level effect model, and all values higher than 13.15% for the growth effect model.

One may argue that the factors that can be made responsible for any effect of inflation on GDP per capita growth are not related to the current rate of inflation, but rather to inflation expectations. For the case of the investment-hampering effect of inflation, the link is related to expected real rates of return to capital, which may differ from those which are actually realized. It could thus be the case that the correlations obtained in our empirical analysis just reflect growth responses to unexpected inflation shocks. As a robustness check for the results presented above, we therefore reestimated the non-linear models substituting the inflation data by out-of-sample projections of ARIMA(1,1,0) models estimated on quarterly country-specific rates of inflation.[14] The estimates of the model with a non-linear growth effect of inflation do not change either qualitatively or quantitatively. For the case of the level effect model, only the second threshold value falls down to 10.27% while preserving the pattern of correlation that emerges with realized inflation rates.

[14] Augmented Dickey-Fuller tests gave evidence of unit root nonstationarity for all quarterly inflation series. Details on the estimation of the univariate time series models can be obtained from the authors upon request.

4.3 Inflation, growth and cohesion countries

One possible explanation for the surprisingly high estimate for the upper threshold is that the result is driven by a small subset of countries that show a common characteristic in the inflation-growth nexus and account for the majority of high inflation data points. A look at the underlying data for individual countries reveals that all inflation observations (8 year averages) of 13% and above in our sample relate to Italy or one of the four classical cohesion economies Greece, Ireland, Portugal and Spain, and more than half of the inflation observations of 7% and above refer to this set of countries. There are good reasons to believe that economic growth in countries in a catching-up process is less affected by high inflation rates than in countries in a more advanced stage of economic development.

A first factor is the Balassa-Samuelson effect, a common explanation for differences in service prices. The basic idea is that of an economy with an open sector producing tradable goods and a closed sector producing nontradable goods. Given that wages are assumed to be linked to labor productivity in the open sector and because wages are expected to equalize across sectors, the price level of the closed sector is determined by the productivity level prevailing in the open sector. In catching-up economies, productivity growth tends to be significantly higher in the open sector so that unit labor costs and thus also prices will consequently increase faster in the closed sector (see, for example, De Gregorio et al., 1994). This implies that inflation rates will be higher the more pronounced productivity differentials are between sectors in any country. The literature survey in Égert et al. (2004) collects estimates for that part of inflation that can directly be related to the Balassa-Samuelson with data samples covered by the different papers ranging from 1960 to 2002. For Ireland the average estimate is 2.6%, for Spain 1.9%, for Italy and Greece it is 1.9 and 1.7% respectively and for Portugal the estimate is as low as 0.8% (see also De Grauwe and Skudelny, 2002). This indicates that a fraction of inflation rates is accounted for by the Balassa-Samuelson effect and can thus be assumed to soften the growth harming effect of high inflation.

A second factor specific to countries in a catching-up process is the gradual adjustment of administrated prices – such as prices for public services, rents or utilities services – to the market level. In most cases such price adjustments remain without significant second round effects so that they may bias inflation upwards without corresponding negative consequences for growth (see e.g. MacDonald and Wójcik, 2004). A general phenomenon of catching-up economies is that inflation often reflects the pass-through of costs related to substantial modernization in the capital stock and not or to a lesser extent a pass-through of increased wage costs. As this implies that inflation goes along with an increase in the growth potential, the negative effects of inflation can be assumed to be of smaller magnitude. A further factor of relevance may be the upward bias of official inflation measures due to the omission of quality improvements, specifically if not calculated based on the hedonic pricing approach. This factor has been shown to be of higher relevance for countries in a catching-up process (see e.g. Ito et al., 1997, for Asian countries or Égert and Lommatzsch, 2003, for Central and Eastern European countries) and therefore again accounts for a part of inflation without corresponding negative effects on growth.

A final argument relates to exchange rate policies. To various degrees all of the catching-up economies in our sample used exchange rate devaluations to improve their competitiveness, as suggested by the evolution of the nominal effective exchange rate over our sample period. In this case the negative effects of the increase in imported inflation including the costs of possible second round effects will be compensated at least partially by the positive growth effects of the gain in competitiveness so that the overall effect of high inflation on growth will be weakened.

All these factors can be expected to increase the inflation tolerance in countries in a catching-up process. In this case the past high inflation experiences in those countries may bias our estimates of the upper threshold of the spline function. In order to directly assess this potential source of country heterogeneity we reestimated the models fixing the lower threshold and allowing for different high inflation thresholds for the traditional cohesion countries (Greece, Ireland, Portugal and Spain) and the rest of the countries in our sample. The results are presented in Table 4, with the parameters which are specific to the cohesion group denoted by the subindex c, and those for the rest of the sample denoted by the subindex nc. The general shape of the relationship remains robust when we allow for different upper thresholds in the two groups of countries, with an insignificant medium regime and a significant negative parameter attached to inflation in the upper inflation regime. The slopes of the regimes with a negative effect do furthermore not appear significantly different across groups of countries when tested by means of an F-test.

The estimated upper thresholds, however, confirm the hypothesis of a higher inflation tolerance in catching-up economies. For the country subsample containing Greece, Ireland, Portugal and Spain the estimate of the second kink in the spline, that is the inflation level beyond which the effect of inflation on growth is negative, is significantly higher than for the rest of the sample. It furthermore corresponds to the estimated upper threshold of the full sample estimation (16.35%), indicating the dominance of the cohesion country experience for the overall sample. For the subset of non-cohesion countries the upper threshold is now estimated at around 8% inflation rates. The rest of the parameter estimates in the model are not significantly affected by the inclusion of a group-specific upper threshold in the spline.

To sum up, estimation results for the full sample with non-linear models support our hypothesis of a more complex structure of the inflation-growth relationship. For very low or negative inflation rates there is a positive link so that further disinflation would have negative marginal growth effects. The spline model specification furthermore suggests that very high inflation rates (over an estimate of around 16%) are a major threat to growth. Between these extremes there is a range of inflation levels that show no significant effect on growth, suggesting an overlap of positive and negative partial effects. The estimate of the level of inflation that triggers the negative effect seems to be driven primarily by the subset of cohesion countries. The threshold estimate for the group of non-cohesion countries appears much lower (around 8%).

4.4 A level or a growth effect of inflation in Europe?

The results presented above give evidence that extremely low and extremely high levels of inflation are related to bad growth experiences for the analyzed sample of European countries. For the model with a spline function, the result emerges independently of whether a growth or a level effect of inflation is assumed in the underlying specification. Is there, however, evidence that one of these two specifications explains the growth experience in the EU better than the other? According to model selection criteria, and concentrating on the full sample results presented in Table 3, the model with a growth effect performs marginally better than the model with a level effect. The adjusted R^2 of the model with a growth effect is 0.803 (and thus the highest of all estimated models) against a value of 0.800 for the level effect specification. Consequently, as both models have the same number of parameters, the AIC and Schwarz criteria of the model with a growth effect are marginally smaller than those of the model with a level effect of inflation. A scientist led by model selection criteria would then be inclined to choose the model with a positive *growth* effect of inflation occurring at very low levels of inflation and a negative *growth* effect for very high levels.

Another approach to deciding upon the superiority of one of the model specifications is to perform a statistical test. We would then be interested in whether the explanation of the link between inflation and growth postulated by the model with a growth effect implies, for the data at hand, a *significant* improvement (in the classical statistic testing sense) over the level effect model. If both approaches lead to the same ranking of models, our conclusion on the nature of the link studied would be strengthened. While model selection criteria (such as AIC and Schwarz criterion) treat all competing models in a symmetric fashion, the classical statistical testing paradigm gives more weight to one of the two alternatives (the null hypothesis) and searches for significant evidence of departure from it. As opposed to model selection criteria, hypothesis testing need not lead to a definite answer concerning the preferred model for the data at hand.

The models to be compared are not nested, so the usual likelihood ratio test statistic does not have the standard χ^2 asymptotic distribution. In order to obtain the distribution of the likelihood ratio test statistic under the null hypothesis, a nonpivotal bootstrapping method similar to the one explained above for the linearity test can be used (see Pesaran and Weeks, 2001). Samples of GDP per capita growth are generated from the fitted model corresponding to the null hypothesis by using random draws from its residuals, both models corresponding to the null and the alternative hypothesis are estimated and the likelihood ratio test statistic is computed. This is repeated a large enough number of times, and by comparing the original test statistic with the empirical distribution of likelihood ratio test statistics resulting from the replications, a bootstrap estimate of the p-value can be obtained.

The model with a piecewise linear level effect of inflation can be considered more parsimonious than the model with a growth effect, and given that its explanatory power is marginally lower than that of the latter, it is the natural candidate for the null hypothesis. The likelihood ratio test statistic corresponding to the test of a level against a growth effect equals 1.09, and the estimated bootstrap p-value is 0.18, obtained with 500 replications. While the result of this test does not give significant support to the growth effect model, the test carried out with the growth effect as the null hypothesis does not significantly support the level effect model either. As opposed to the conclusion reached by using model selection criteria, nonnested model testing does not offer a definite answer about the dominance of one specification over the other, deeming both of them observationally equivalent.

5 Conclusions

The paper reassesses the impact of inflation on long-term growth for a panel of 14 EU countries. While previous research focuses on a linear nexus or allows for a piecewise linear relationship with one single threshold, we allow for a more complex relationship. Theoretical arguments point to a positive relationship between inflation and growth for very low or negative levels of inflation, followed possibly by a range of no significant effect. For very high inflation rates the impact on growth can be expected to become negative. These arguments suggest hypothesizing a trapezoid type of relationship between inflation and long-term growth.

We present a simple theoretical framework – based on the basic human capital-augmented Solow model with a production function as in Hall and Jones (1999) – that allows for an explicit empirical distinction between level and growth effects of inflation. The empirical estimates confirm the hypothesis that the relationship between inflation and growth is of a non-linear nature and that one threshold may not be enough to account for the nonlinearities. We find a significant positive slope for levels of inflation below an estimated value of around 1.6%, giving support to the "grease of the economy" and "zero lower bound constraint"-type of arguments as suggested in the literature. While these results support the growth-harming consequences of deflation we can, however, not directly conclude on the adverse growth effects of low levels of inflation without taking the potential quality improvement-related measurement errors contained in the official inflation series into account.

The positively sloped area is followed by a range of inflation rates where no significant effect on growth prevails. For the full sample estimations, this interval is surprisingly wide, with around three quarters of the observations falling within this area. The second threshold beyond which we observe the expected negative impact of inflation on growth is subject to a considerable degree of uncertainty due to the wide dispersion of high inflation observations. Our estimate of around 16% seems to be strongly affected by the convergence process of catching-up countries. Arguments for a higher inflation resistance in those countries relate to the Balassa-Samuelson effect, to the role of administrated price adjustments or measurement bias for inflation or to exchange rate policies. If we estimate different upper thresholds for traditional cohesion countries and the rest of the sample, the estimate for the sample comprising Greece, Ireland, Portugal and Spain remains around 16%, while the threshold estimate for the rest of the countries is around 8%. Compared with the models that allow for only one single threshold, our negative slope for high levels of inflation is significantly steeper. While the growth effect model explains the data marginally better than the level effect, non-nested model testing does not give evidence of the superiority of one of the models.

Our findings support the intuition of the detrimental growth effects of very low (or negative) and excessively high rates of inflation. They should, however, not be blindly interpreted as giving direct advice for current economic policy. First, the negative effects of inflation go far beyond the pure growth effects, ranging from distributional aspects to social costs and related welfare effects. Depending on the priorities of economic policy specific costs of suboptimal inflation may be in the core of interest. Second, almost all high inflation observations (of 8% and above) date 20 years back and therefore fall within a period of global shocks, lower economic integration and high catching-up related inflation components. This implies that especially the upper threshold level of inflation may be of limited relevance for current economic policy, especially taking into account that the sample of cohesion countries have caught up considerably with the rest of the European economies during the period studied.

Appendix: Data sources

- GDP per capita: Penn World Tables 6.1; Heston, Summers and Aten (2002).
- Share of investment over GDP: Penn World Tables 6.1; Heston, Summers and Aten (2002).
- Population growth: Penn World Tables 6.1; Heston, Summers and Aten (2002).
- Education: average years of education of an adult over 25 years old; corrected Barro and Lee (2001) data set by de la Fuente and Domenech (2002).
- Inflation rate: CPI inflation, averages from quarterly data, International Financial Statistics, IMF.
- Money supply growth: AMECO Database, European Commission.
- Central bank independence index: Hall and Franzese (1998).

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Table 1: Linear growth and level effect of inflation

Parameter	No inflation effect	Growth effect $\Theta(\pi(t) = \theta\pi(t)$	Level effect $\Psi(\pi(t) = \psi\pi(t)$
λ	0.100***(0.023)	0.094***(0.026)	0.094***(0.027)
α	0.403***(0.067)	0.379***(0.077)	0.379***(0.078)
ρ	0.047 (0.056)	0.035 (0.079)	0.045 (0.079)
θ	–	-0.016*(0.009)	–
ψ	–	–	-0.324 (0.211)
Obs.	68	68	68
$\bar{R}^2$	0.77	0.78	0.77
JB test	0.02	0.32	0.10

***(**)[*] stands for 1% (5%) [10%] significant. White heteroskedasticity consistent standard errors in parenthesis. Least square dummy variable estimation used in all cases, and non-linear least square dummy variable estimation used when a growth effect of inflation is parametrized. Subperiod dummies used if jointly significant. Estimates based on a panel of eight-year averages for the period 1960–99. Dummy for Ireland in the period 1992-99 included and highly significant in all cases.

Table 2: Quadratic growth and level effect of inflation

Parameter	Growth effect $\Theta(\pi(t) = \theta_1\pi(t) + \theta_2\pi(t)^2$	Level effect $\Psi(\pi(t) = \psi_1\pi(t) + \psi_2\pi(t)^2$
λ	0.088***(0.027)	0.089***(0.028)
α	0.392***(0.075)	0.383***(0.075)
ρ	0.050 (0.071)	0.042 (0.070)
θ_1	0.030*(0.017)	–
θ_2	-0.165***(0.058)	–
ψ_1	–	0.659 (0.481)
ψ_2	–	-3.505**(1.529)
Obs.	68	68
$\bar{R}^2$	0.79	0.79
JB test	1.41	1.82

$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. White heteroskedasticity consistent standard errors in parenthesis. Least square dummy variable estimation used in all cases, and non-linear least square dummy variable estimation used when a growth effect of inflation is parametrized. Subperiod dummies used if jointly significant. Estimates based on a panel of eight-year averages for the period 1960–99. Dummy for Ireland in the period 1992-99 included and highly significant in all cases.

Table 3: Growth and level effect of inflation: Spline specification

Parameter	Growth effect $\Theta(\pi(t))$ as in (4)	Level effect $\Psi(\pi(t))$ as in (5)
λ	0.092^{***}(0.027)	0.098^{***}(0.028)
α	0.366^{***}(0.071)	0.359^{***}(0.071)
ρ	0.055 (0.067)	0.047 (0.062)
θ_1	0.153^{***}(0.053)	–
θ_2	0.004 (0.011)	–
θ_3	-0.049^{**}(0.020)	–
ψ_1	–	4.754^{***}(2.039)
ψ_2	–	0.119 (0.287)
ψ_3	–	-1.052^{**}(0.441)
μ_1	1.64%	–
μ_2	16.35%	–
η_1	–	1.63%
η_2	–	16.35%
Obs.	68	68
$\bar{R}^2$	0.80	0.80
JB test	1.29	1.49
LR test	12.84	12.01
(p-value)	0.035	0.046

$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. White heteroskedasticity consistent standard errors in parenthesis. Least square dummy variable estimation used in all cases, and non-linear least square dummy variable estimation used when a growth effect of inflation is parametrized. Subperiod dummies used if jointly significant. Estimates based on a panel of eight-year averages for the period 1960–99. Dummy for Ireland in the period 1992-99 included and highly significant in all cases. The LR test statistic and its bootstrap p-value correspond to the linearity test proposed by Hansen (1996). The bootstrap was done using 500 replications.

Table 4: Cohesion versus non-cohesion countries

Parameter	Growth effect $\Theta(\pi(t))$ as in (4)	Level effect $\Psi(\pi(t))$ as in (5)
λ	0.080***(0.025)	0.098***(0.029)
α	0.429***(0.069)	0.374***(0.075)
ρ	0.062 (0.075)	0.045 (0.061)
θ_1	0.162***(0.056)	–
$\theta_{2,c}$	0.003 (0.008)	–
$\theta_{3,c}$	-0.037*(0.020)	–
$\theta_{2,nc}$	0.021 (0.021)	–
$\theta_{3,nc}$	-0.038**(0.013)	–
ψ_1	–	4.834**(2.161)
$\psi_{2,c}$	–	0.237 (0.265)
$\psi_{3,c}$	–	-1.053*(0.589)
$\psi_{2,nc}$	–	0.384 (0.490)
$\psi_{3,nc}$	–	-0.512**(0.248)
μ_1	1.64%	–
$\mu_{2,c}$	16.35%	–
$\mu_{2,nc}$	7.82%	–
η_1	–	1.63%
$\eta_{2,c}$	–	16.35%
$\eta_{2,nc}$	–	8.13%
Obs.	68	68
$\bar{R}^2$	0.80	0.80
JB test	0.55	0.75

$^{***(**)[*]}$ stands for 1% (5%) [10%] significant. White heteroskedasticity consistent standard errors in parenthesis. Least square dummy variable estimation used in all cases, and non-linear least square dummy variable estimation used when a growth effect of inflation is parametrized. Subperiod dummies used if jointly significant. Estimates based on a panel of eight-year averages for the period 1960–99. Dummy for Ireland in the period 1992-99 included and highly significant in all cases.

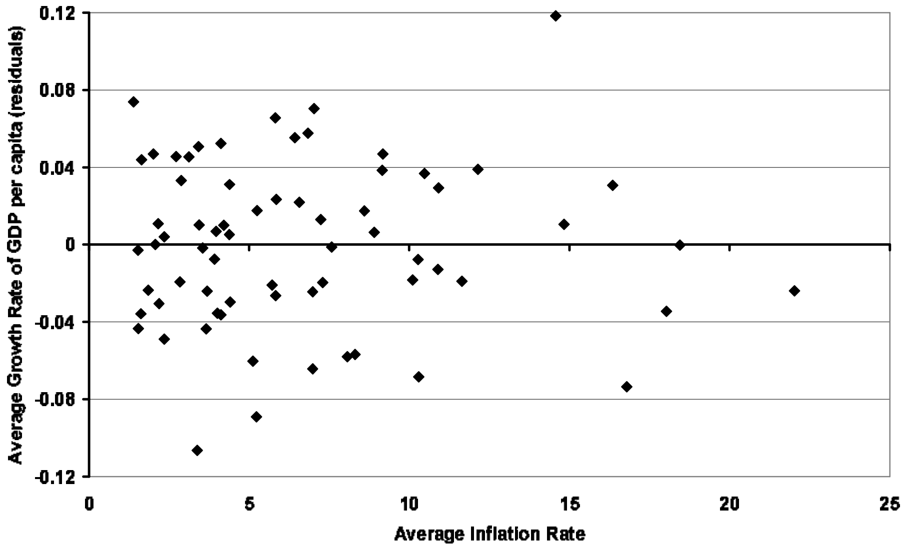

Figure 1: Subperiod-average inflation rate versus residuals for 14 EU countries (1960-99).