On the impact of inflation on output growth: does the level of inflation matter?

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Abstract

This paper investigates the growth effects of inflation on a wide sample of countries, including both industrialized and emerging economies. Relying upon the estimation of smooth transition and dynamic GMM models for panel data, our findings offer strong evidence that inflation non-linearly impacts economic growth. More specifically, there exists a threshold beyond which inflation exerts a negative effect on growth, and below which it is growth enhancing for advanced countries.

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1 Introduction

The question relating to the effects of inflation on economic growth is a subject of intense interest and debate in the literature (see e.g. Gillman and Kejak (2005)). Although this debate is still open, it is generally accepted that inflation has globally a negative impact on medium and long-run growth (Kormendi and Meguire (1985); Barro (1991); Chari, Jones and Manuelli (1996); Barro (2001) and Gylfason and Herbertsson (2001) for a survey).

However, it has also been advanced that the relationship between economic growth and inflation, far from being linear, is influenced by the inflation level.

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Indeed, investigating the non-linearity of the relationship between inflation and growth, Fischer (1993) puts forward the existence of a threshold above and below which the growth effects of inflation differ. More specifically, he shows that the relationship between inflation and growth is positive for low levels of inflation, but negative or non significant for high levels. The existence of such a non-linear pattern has been confirmed by other authors, such as Sarel (1996), Ghosh and Phillips (1998), Christoffersen and Doyle (1998), Bruno and Easterly (1998), Judson and Orphanides (1999), Khan and Senhadji (2001), Burdekin, Denzau, Keil, Sitthiyot and Willett (2004) and Gillman and Kejak (2005). Additionally, in the negative case, the marginal growth costs seem not to remain constant as the inflation increases: the marginal effect of inflation on growth is stronger at lower inflation rates than at higher ones (Ghosh and Phillips (1998); Harris, Gillman and Mátyás (2001); Burdekin et al. (2004)). Although the non-linearity of the inflation-growth relationship seems to be widely accepted, there are still controversies about (i) the level of inflation that acts as the threshold, (ii) the sensitivity of this non-linear relationship to the frequency of the data, the considered framework (cross-country / time series) and the methodology used, the countries under study (developed / developing), and the existence of high-inflation observations.

From a theoretical viewpoint, the effects of inflation on economic growth are also mixed and depend on the way money is introduced in the models. Sidrauski (1967) introduced money in the utility function and puts forward a transitional effect of inflation on the output growth rate (see also Brock (1974)). The same effect is obtained by Ireland (1994) considering a cash-in-advance economy with an explicit credit sector. When money is regarded as a substitute for capital (Tobin (1965)), higher monetary growth enhances capital accumulation, causing inflation to have a positive effect on long-run growth. When money is required for purchasing capital goods (Stockman (1981)), higher anticipated inflation decreases steady-state real balances and capital stock, and hence a reversed Tobin effect emerges. If money is introduced through a pecuniary transaction cost function (Dornbusch and Frenkel (1973)), the real effect of money is ambiguous. When money serves as a transaction device through a shopping-time technology (Saving (1971); Kimbrough (1986)), the theoretical predictions become more clear-cut. In endogenous growth models, the relationship between inflation and growth is accounted for *via* the marginal product of capital, being either physical capital (AK models), or human capital (AH models), or both:

the inflation rate impacts the growth rate through its effects on the rate of return to capital.[1] Considering AK models, inflation acts as a tax on physical capital that decreases the rate of return to capital and tends to lower growth. In AH models, within a monetary exchange framework,[2] inflation acts as a tax on human capital and also impacts the output growth rate: it leads to a substitution between goods and leisure, decreasing the return to human capital, which in turn leads to lower the return on all capital and the economic growth rate.

In the general monetary endogenous growth model proposed by Gillman and Kejak (2005), including both physical and human capital, the non-linear effect of inflation on growth is explained through the money demand elasticity. In case of a growing elasticity, with inflation rising, the substitution away from inflation is easier, inducing the non-linearity property. On the contrary, when the elasticity is constant, the growth effect of inflation tends to be linear. Indeed, for low values of the inflation rate, the money demand elasticity is low since, in this case, money is mainly used and the amount of credit is weak—the substitution from goods to leisure is high. When the inflation rises, so does the elasticity, the substitution towards credit increases, leisure grows at a decreasing rate and the growth rate falls by increasingly smaller amounts. This explains why the inflation-growth relationship is expected to be lower in size at higher inflation rates.

Other explanations of the non-linearity property have been suggested, notably through models that explicitly account for unemployment. In Akerlof, Dickens and Perry (2000) and Palley (2003), an economy with a low level of inflation tends to converge towards a less level of unemployment than that implied by the natural rate of unemployment, or to a less level of unemployment than that would have been reached in case of no inflation. According to these models, low inflation favors both employment and productivity, resulting in higher capacity utilization, lower output gap and, as a consequence, higher output growth. As a result, the relationship between inflation and output growth may be positive for low levels of the inflation rate.

This paper aims at contributing to the empirical literature on the link between

[1] For a survey, see Gillman and Kejak (2005).

[2] See Lucas (1980), Lucas and Stokey (1987), McCallum and Goodfriend (1987) among others.

inflation and output growth by paying a special attention to the potential non-linearity of this relationship. First, we rely on a wide sample of countries, including both developed and emerging economies. Using a large panel of countries allows us to (i) investigate whether the impact of inflation is the same or not for industrialized and developing countries, (ii) put forward differences, if any, in the value of the threshold above and below which the impact of inflation may differ for both types of countries, (iii) obtain results that are independent on a particularly policy rule. Regarding this last point, relying upon a wide panel of countries permits to deal with various policy rules: inflation targeting, constant growth rate rule for the money supply, feedback rule for the money supply where the growth rate of money is determined by the inflation rate... Second, we investigate the non-linearity of the relationship between inflation and GDP growth by estimating panel smooth transition (PSTR) models. To our best knowledge, these models have not been applied before to our considered topic, although they seem to be highly relevant. Indeed, such models allow us to distinguish the growth effects of inflation according to its various levels. More specifically, two regimes—low and high inflation—will be endogenously determined, corresponding to two distinct growth equations; the transition from one regime to the other being smooth and governed by the inflation variable. Through the estimation of these models, we will be able to provide the "appropriate" value of inflation, i.e. the threshold value below which inflation may have growth-enhancing effects for the different considered economies. Alternatively, for robustness checks, we also rely on the dynamic generalized method of moments (GMM) that includes quadratic interaction terms in the growth equation.

The rest of the paper is organized as follows. Section 2 outlines our methodology through the presentation of the PSTR and panel dynamic GMM specifications. Data are described in Section 3. Section 4 presents the results regarding the estimation of the growth effects of inflation. Finally, Section 5 provides some concluding remarks.

2 Methodology

To investigate the potential non-linearity of the relationship between inflation and output growth, we rely, in a first moment, on the PSTR models developed by González, Teräsvirta and van Dijk (2005) and Fok, van Dijk and Franses (2005). These models have several interesting features that make them suitable for our purposes. First, growth regression coefficients can take different values, depending on the value of another observable variable. In other words, the observations in the panel are divided into a small number of homogenous groups or “regimes”, with different coefficients depending on the regimes. Second, regression coefficients are allowed to change gradually when moving from one group to another: PSTR is a regime-switching model where the transition from one regime to the other is smooth rather than discrete. Finally, individuals are allowed to change between groups over time according to changes in the “threshold variable”.

More specifically, denoting by y_{it} the dependent variable, the growth model can be expressed as follows:

$$y_{i,t} = \mu_i + \beta_0' \pi_{i,t} + \beta_1' \pi_{i,t} g\left(s_{i,t}; \gamma, c\right) + \alpha_0' z_{i,t} + v_{i,t} \tag{1}$$

for $i = 1, ..., N$ and $t = 1, ..., T$. In Equation (1), μ_i is an unobservable time invariant regressor, $\pi_{i,t}$ is the inflation rate, $s_{i,t}$ is an observable transition variable (in our case the inflation rate, $s_{i,t} = \pi_{i,t}$) which governs the regime switching, $z_{i,t}$ is a k-dimensional vector of control variables usually considered in the growth literature (see *infra*) and $v_{i,t}$ is the error term. $g\left(s_{i,t}; \gamma, c\right)$ is the transition function defined by:

$$g\left(s_{i,t}; \gamma, c\right) = \left[1 + \exp\left(-\gamma \prod_{j=1}^{m} \left(s_{i,t} - c_j\right)\right)\right]^{-1} \tag{2}$$

This function is continuous, normalized and bounded between 0 and 1, γ is the speed of transition, and c denotes the threshold parameter ($c_1 \leq c_2 \leq ... \leq c_m$). Depending on the realization of the transition variable, the link between $y_{i,t}$ and π_{it} will be specified by a continuum of parameters, namely β_0 in Regime 1 (when $g(.) = 0$), and $\beta_0 + \beta_1$ in Regime 2, when $g(.) = 1$. In other words, according to the value of the inflation rate, inflation has a different impact (elasticity) on GDP growth: this model allows us to investigate if non-linearity in the elasticity could be associated with changes in the inflation rate. Indeed, whereas the elasticity in a linear model is constant and equal to β_0' in Equation (1), in the PSTR model the elasticities vary between countries and time according to the value of the transition function. In particular, the elasticity of growth to inflation for the ith country at time t is defined as a weighted average of the parameters β_0 and β_1:

$$\frac{\partial y_{i,t}}{\partial \pi_{i,t}} = \beta_0 + \beta_1 * g(s_{it}; \gamma, c) \quad (3)$$

The two most common cases for the transition function (Equation (2)) correspond to $m = 1$ (logistic) and $m = 2$ (exponential). In the first case, the dynamics is asymmetric and the two regimes are associated with small and large values of the transition variable relative to the threshold. On the contrary, in the case of an exponential specification, the two regimes have similar structures—meaning that increases and reductions of the transition variable have similar dynamics—but the middle grounds are characterized by a different dynamic than that in the extremes.

Relying upon the methodology used in the time series context, González et al. (2005) suggest a three step strategy to implement PSTR models: (i) specification, (ii) estimation, and (iii) evaluation. The aim of the identification step is to test for homogeneity against the PSTR alternative, and to select between the logistic and the exponential specification of the transition function. In the estimation step, non-linear least squares are used to obtain the parameter estimates, once the data have been demeaned.[3] Finally, the evaluation step consists in applying misspecification tests in order to check the validity of the estimated PSTR model and determining the number of regimes.[4]

For robustness checks and comparative purposes, we also estimate a single growth equation which includes interaction terms:

$$y_{i,t} = \mu_i + \beta_0' \pi_{i,t} + \beta_1' \pi_{i,t}^2 + \alpha_0' z_{i,t} + v_{i,t} \quad (4)$$

where the variables are defined exactly as in Equation (1). Equation (4) includes a quadratic interaction term to account for non-linear growth effects of the threshold variable, namely the inflation rate. This allows us to investigate whether, beyond a certain level, the threshold variable becomes more or less important in determining the marginal effect of inflation on growth.

Therefore, the inclusion of an interaction term means that the marginal effect (either positive or negative) of inflation is larger or smaller at higher levels of

[3]It should be noted that demeaning the data is not straightforward in a panel context (see Hansen (1999), and González et al. (2005)).

[4]For further details, see Hansen (1999), González et al. (2005), and Colletaz and Hurlin (2006).

this variable. Indeed, at the margin, the total effect of increasing inflation can be calculated by examining the partial derivatives of GDP growth with respect to π_{it}:

$$\frac{\partial y_{i,t}}{\partial \pi_{i,t}} = \beta_0 + \beta_1 \pi_{i,t} \tag{5}$$

To estimate Equation (4), we use the generalized method of moments (GMM) for dynamic panels developed in Arellano and Bond (1991), Arellano and Bover (1995) and Blundell, Bond and Windmeijer (2000). This involves estimating a system comprising a first differenced equation to eliminate country-fixed effects and an additional equation in levels. One major concern has to be mentioned at this stage, namely the issue of endogeneity—which may be potentially important when dealing with growth regressions. Endogeneity may be due to the correlation of country-specific, time-invariant, factors and the right-hand side regressors. The GMM methodology allows us to address this issue of joint endogeneity of all explanatory variables in a dynamic formulation and accounts explicitly for the biases induced by the presence of the initial GDP in the growth regressors, as well as potential biases due to country-specific effects. On the whole, the GMM procedure not only eliminates any endogeneity, but also allows to prevent simultaneity or reverse causality problems.

3 Data

3.1 The sample

The dataset includes 44 countries and covers the period 1961-2007. More specifically, we consider the following countries:

- High income OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Italy, Japan, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom, United States.

- Upper middle-income countries:[5] Colombia, Costa Rica, Dominican Republic, India, Korea, Malaysia, Mexico, Singapore, Thailand, Trinidad and Tobago, Uruguay.

[5] Notice that four hyper-inflation, upper middle-income countries—Argentina, Brazil, Chile, and Israel (high income)—have been excluded to prevent for bias caused by extreme high inflation observations.

- Lower middle-income and low-income countries: Cameroon, Cote d'Ivoire, Egypt, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Morocco, Nigeria, Pakistan, the Philippines, Senegal, Sri Lanka, Togo.

- Emerging countries: this group is composed by upper-middle income, and lower-middle to low income countries.

3.2 Growth regressors

Despite the vast number of cross-country growth studies that followed the seminal papers of Barro (1991) and Mankiw, Romer and Weil (1992), there remains a broad number of possible specifications concerning the choice of the regressors. Based on previous studies,[6] we retain the following determinants:[7]

- The initial level of real GDP per capita, used to control for conditional convergence in the spirit of the neoclassical growth theory (see Barro and Sala-i Martin (1995) among others).

- Relying on some developments of the endogenous growth theory, we include determinants reflecting trade and macroeconomic stabilization policies, and institutions: (i) trade openness, measured as the sum of exports and imports, in percentage of GDP; (ii) government consumption in percentage of GDP, used as an indicator of fiscal policy (see Barro (1991); Barro and Sala-i Martin (1995)), (iii) gross domestic investment (in percentage of GDP), and (iv) population growth.

- Finally, in addition to these control variables, we include our variable of interest, namely the inflation rate $\pi_{i,t}$, defined as the growth rate of the CPI index. More specifically, we retain the following expression for inflation in the growth regressions: $log(1 + \pi_{i,t})$. This choice may be notably justified by the fact that the logarithmic transformation reduces the asymmetry of the distribution of $\pi_{i,t}$—which is known to be highly skewed.[8]

[6]See the reference papers by Barro (1991), Mankiw et al. (1992) and Sala-i Martin (1997).

[7]See Table 5 in Appendix which provides some descriptive statitics on our data.

[8]It should be noticed that inflation enters as $log(1+\pi_{i,t})$ in the estimation of the regressions, but the results displayed in the tables regarding the value of the threshold parameter have been converted to be directly interpretable: the threshold parameters $\hat{c}$ directly give the threshold values of the inflation rate $\pi_{i,t}$. For the sake of completeness and to check the robustness of our results, we have also reestimated our models using $\pi_{i,t}$ instead of $log(1 + \pi_{i,t})$ in the growth equations. The results are very similar to those reported in the paper since we obtained the following values for $\hat{c}$: 13.80 for the whole sample, 1.32 for the advanced economies and 13.05 for the emerging countries.

The dependent variable is the growth rate of GDP per capita in constant 2000 USD prices. The data are annual and come from the World Bank WDI database for all the considered series. To avoid the influence of idiosyncratic economic dynamics at business cycle frequency, we used five-year interval averages. Indeed, by controlling for cyclical output movements, the averaging procedure has the advantage to remove business cycles effects from the growth rate.

4 Results and discussion

We begin by testing the null hypothesis of linearity in Equation (1) using the González et al. (2005) test with the inflation rate as the relevant transition variable. In other words, we test if there exists a different GDP growth effect of inflation, when facing high and low levels of inflation. The results are reported in Table 1 which displays the p-values of the Lagrange multiplier and Fisher-type tests for the null hypothesis of linearity against the alternative of a logistic ($m = 1$) or exponential ($m = 2$) PSTR specification. Our findings indicate that (i) the null of linearity is rejected at the 5% significance level, and (ii) since the rejection of linearity is stronger for $m = 1$, the logistic specification is preferred to the exponential one. This result evidences that inflation impacts the GDP growth differently, depending on the level of the inflation rate. We thus carry on the estimation of our non-linear growth model using both the PSTR specification and the GMM procedures.

Table 1: **LM and F tests of linearity (p-values)**

	Whole sample		Advanced economies		Emerging economies	
	$m = 1$	$m = 2$	$m = 1$	$m = 2$	$m = 1$	$m = 2$
LM	0.002*	0.005	0.025*	0.039	0.008*	0.016
F	0.003*	0.009	0.033*	0.053	0.011*	0.023

Notes: (1) LM and F are the Lagrange multiplier and F tests for linearity; (2) H_0: linear model, H_1: PSTR model; (3) $m = 1$ and $m = 2$ are the logistic and exponential transition functions respectively; (4) * indicates the strongest rejection of linearity.

Tables 2, 3 and 4 respectively report the estimation of our growth model for the whole sample of countries and then by subgroups: advanced and emerging countries (divided by middle and lower-income countries). Let us start with a general comment relating to the control variables for the three considered samples. All the explanatory variables have the expected sign, whatever the retained specification (PSTR or GMM). Indeed, the initial GDP per capita coefficient is negative, meaning that the conditional convergence hypothesis is evidenced: holding constant other growth determinants, countries with lower GDP per capita tend to grow faster. The initial position of the economy is thus a significant determinant of growth, as preconised by the neoclassical theory. As expected, the coefficient associated with the government consumption in percentage of GDP is negative, reflecting the fact that the ratio of government consumption to GDP can be viewed as a proxy for the government burden (see Barro (1991); Barro and Sala-i Martin (1995) and Loayza, Fajnzylber and Calderón (2004) among others). The investment variable has also the right sign, as predicted by the Solow growth model: its positive sign reflects the increasing relationship between capital accumulation and growth.[9] Trade openness positively affects growth, a fact that is in line with both the neoclassical approach and the endogenous growth theory. Indeed, according to the former, the positive impact of trade on growth is explained by comparative advantages, be they in resource endowment or differences in technology. Turning to the endogenous growth literature, it asserts that trade openness positively affects growth through economies of scale and technological diffusion between countries. Finally, as predicted by the Solow growth model, the population growth coefficient is negative.

Regarding now our main variable of interest, the growth effect of inflation appears strongly non-linear. Indeed, the impact of inflation on GDP growth depends on the level of the inflation rate in the sense that negative effects only begin after some threshold has been reached. Consider first the full sample of countries (Table 2). Regarding the PSTR estimation results, the estimated threshold for the inflation rate is 15%. In the first regime, our results indicate that the growth effect of inflation is zero for inflation rates below 15%. However, results strongly differ in the second regime, corresponding to high inflation levels (i.e. inflation rates higher than 15%). Indeed, in this inflationary regime, the impact of the inflation on output growth is negative and significant: in the extreme case (when $g(s_{it}; \gamma, c) = 1$), other things being equal, an increase in the

[9] As recalled by Sala-i Martin (1997), investment is a variable that always appear in growth regressions. Indeed, this variable is considered as a Solow-type growth determinant, but is also a key fundamental in endogenous growth models. Note that in the later case and accounting for the endogeneity of the saving rate, the sign of the investment variable may be non positive (see Loayza et al. (2004) among others).

inflation rate of 1% contributes to a reduction in GDP per capita growth of 0.75 percentage points.[10] There are, however, a continuum of points between these two extreme cases. Indeed, between these two values, the elasticity is defined as a weighted average of the parameters β_0 and β_1. Consequently, it is generally difficult to directly interpret the values of these parameters that correspond to extreme situations. It is therefore preferable to interpret (i) the sign of these coefficients, which indicates an increase or a decrease of the elasticity with the value of the threshold variable, and (ii) the time varying and individual elasticity of the output with respect to the inflation rate (see Colletaz and Hurlin (2006)). The GMM estimation confirms the PSTR results since the coefficient of inflation is non significant, while the interaction term is negative and significant, putting forward the robustness of the non-linear effect of inflation on output growth.

This global result may however mask important disparities among countries. Indeed, as an illustration, Table 6 in Appendix reports the inflation-output growth elasticities obtained from the PSTR estimation for a selection of countries and sub-periods. As shown in this table, the elasticities are always negative for emerging countries, while their sign and values differ across periods for the advanced economies. In particular, for the developed countries, the elasticities are positive on the recent period, while being negative for the two other sub-periods, illustrating the fact that inflation may be growth enhancing for low inflationary levels. To account for these disparities across countries, we proceed to the estimation of our growth-inflation relationship on two sub-samples of economies. Comparing Tables 3 and 4 leads to many interesting facts. First, the estimated threshold strongly differs between the two groups of countries: only 1.2% for developed countries and 14.5% for the whole sample of emerging countries. The finding of a higher threshold for emerging countries is not surprising, given the much higher inflation rates observed in this economies. A consequence of this finding is that the inflation tolerance is higher in emerging countries than in advanced ones, generally characterized by lower inflation rates (see Table 5 in Appendix).

Second, according to the PSTR specification, while there is no growth effect of inflation in emerging countries below the estimated threshold, inflation is growth enhancing for advanced countries for low levels of the inflation rate. This result

[10]Remember that the coefficient in the second regime is equal to $\beta_0 + \beta_1$ in Equation (1); that is, -0.029-0.717=-0.746 in Table 2.

puts forward the positive effects of a monetary policy that promotes price level stability for advanced economies,[11] and that there is no growth enhancing effects of moderate inflation in developing countries.

Third, turning to the emerging countries, the same global pattern is observed whatever their classification (upper middle-income versus lower middle and low-income countries), with a negative impact of inflation on growth only beyond a certain threshold. The main difference lies in the value of the threshold, which is higher for lower middle and low-income countries (19.6%); a result that may be notably explained by the fact that this sub-sample of countries account for the majority of high inflation data points. As previously, these findings are robust to the methodology used since the GMM estimation also highlights these non-linear effects.

Table 2: **Inflation and output growth: PSTR and GMM models, whole sample**

	PSTR		GMM	
Variable	Coef.	*t*-stat	Coef.	*t*-stat
Initial level of GDP	-1.387	-4.05	-1.797	-2.65
Pop. growth	-0.702	-3.54	-0.520	-1.71
Investment	0.174	2.93	0.175	2.64
Openness	0.011	1.95	0.010	1.07
Gov. Consumption	-0.220	-7.10	-0.257	-4.07
Inflation	-0.029	-1.14	0.642	0.82
Inflation* $g(s_{it}; \gamma, c)$	-0.717	-4.37		
Inflation^2			-0.391	-2.12
Transition parameters				
$\hat{c}$	15.001			
$\hat{\gamma}$	5.000			

Notes: (1) $\hat{c}$ and $\hat{\gamma}$ respectively denote the estimated location parameters and estimated slope parameters in Equation (2); (2) Inflation corresponds to $\log(1+\pi)$; (3) The estimated location parameter can be interpreted directly as the level of inflation.

As previously mentioned, an important concern in growth regressions is the issue of endogeneity. Indeed, some of the explanatory variables, such as trade openness and investment, could potentially be explained by unobserved common factors and, therefore, engender endogeneity problems that must be taken

[11] This result is in line with those of Khan and Senhadji (2001) who find a positive growth effect of inflation above a threshold between 1-3% for advanced economies.

Table 3: **Inflation and output growth: PSTR and GMM models, advanced economies**

	PSTR		GMM	
Variable	Coef.	t-stat	Coef.	t-stat
Initial level of GDP	-2.336	-5.08	-2.409	-3.32
Pop. growth	-0.826	-3.08	-1.482	-4.23
Investment	3.367	3.98	3.506	3.78
Openness	1.456	1.56	0.034	2.83
Gov. Consumption	-0.158	-3.32	-0.289	-4.62
Inflation	1.386	2.62	0.022	0.04
Inflation* $g\left(s_{it};\gamma,c\right)$	-1.467	-2.81		
Inflation^2			-0.323	-2.27
Transition parameters				
$\hat{c}$	1.231			
$\hat{\gamma}$	1.585			

Notes: (1) $\hat{c}$ and $\hat{\gamma}$ respectively denote the estimated location parameters and estimated slope parameters in Equation (2); (2) Inflation corresponds to $\log(1+\pi)$; (3) The estimated location parameter can be interpreted directly as the level of inflation.

into account to avoid potential bias in the estimated parameters. To address this issue, we proceed to robustness checks by instrumenting the inflation rate, trade openness and investment by their own lagged values. The summarized results are reported in Table 7 in Appendix. Using one lag for each variable, our estimations show that the growth effects of inflation are globally similar to those obtained in Tables 2, 3 and 4. Indeed, while there are some differences regarding the estimated values, the global findings remain the same: there exists a threshold beyond which inflation exerts a negative effect on growth, the value of this threshold being higher for emerging countries (17.5%) than for advanced ones (2.7%). For developed countries, inflation is thus growth enhancing for levels lower than 2.7%. Once this threshold has been reached, the positive effects tend to be reduced and gradually become negative. Our conclusion that inflation non-linearly affects economic growth is thus robust to endogeneity issues. These findings can be linked to those of Aghion, Bacchetta, Rancière and Rogoff (2009). As argued by the authors, our empirical analysis has some characteristics that reduce the potential endogeneity problem. Indeed, our aim is to put forward contrasting growth effects of inflation for its different levels. We are thus in presence of interaction terms that reduce the endogeneity bias compared to the single variables case (see Aghion et al. (2009) for more details).

Table 4: **Inflation and output growth: PSTR and GMM models, emerging countries**

	PSTR		GMM	
Variable	Coef.	*t*-stat	Coef.	*t*-stat
Emerging countries				
Initial level of GDP	-1.013	-1.96	-1.619	-1.99
Pop. growth	-0.795	-2.78	-0.550	-1.45
Investment	0.170	2.36	0.169	2.14
Openness	0.006	0.850	0.009	0.85
Gov. Consumption	-0.181	-3.89	-0.197	-2.43
Inflation	-0.124	-0.45	1.886	1.62
Inflation* $g(s_{it}; \gamma, c)$	-0.612	-3.68		
Inflation^2			-0.679	-2.69
Transition parameters				
$\hat{c}$	14.549			
$\hat{\gamma}$	17.052			
Upper middle				
Initial level of GDP	-1.479	-1.97	-1.209	-1.63
Pop. growth	-1.208	-2.62	-1.486	-3.54
Investment	2.958	2.59	1.938	1.51
Openness	-0.003	-0.28	-0.004	-0.49
Gov. Consumption	-0.365	-4.05	-0.547	-5.47
Inflation	0.179	0.25	1.369	0.97
Inflation* $g(s_{it}; \gamma, c)$	-0.826	-2.04		
Inflation^2			-0.597	-2.10
Transition parameters				
$\hat{c}$	10.273			
$\hat{\gamma}$	9.655			
Lower middle and low				
Initial level of GDP	-1.310	-1.70	-2.367	-2.29
Pop. growth	-0.222	-0.55	0.095	0.20
Investment	0.117	1.52	0.112	1.38
Openness	0.024	1.68	0.047	2.71
Gov. Consumption	-0.162	-2.87	-0.134	-1.84
Inflation	-0.185	-0.51	2.110	1.58
Inflation* $g(s_{it}; \gamma, c)$	-0.909	-2.16		
Inflation^2			-0.646	-2.06
Transition parameters				
$\hat{c}$	19.640			
$\hat{\gamma}$	5.001			

Notes: (1) $\hat{c}$ and $\hat{\gamma}$ respectively denote the estimated location parameters and estimated slope parameters in Equation (2); (2) Inflation corresponds to $\log(1+\pi)$; (3) The estimated location parameter can be interpreted directly as the level of inflation.

On the whole, in addition to the fact that inflation rates are higher in developing countries than in industrialized ones, the larger values of the threshold estimates for the developing countries may also be explained by various other factors: (i) the widespread use of indexation systems, (ii) the Balassa-Samuelson effect, and (iii) exchange rate policies (see Khan and Senhadji (2001) and Crespo Guaresma and Silgoner (2004), among others). Regarding the first point, the gradual price adjustments in many emerging economies do not lead to second round effects, meaning that the pass-through of increased wage costs is highly limited. As a consequence, this may biais inflation upwards without generating important negative growth effects—because relative prices do not strongly change—for "reasonable" levels of inflation. Turning to the second point, a possible interpretation is that the inflation tolerance increases if the high inflation levels are related to the convergence and catching-up processes and the Balassa-Samuelson effect, which is known to be more relevant for less developing countries than for more advanced ones: for these countries, inflation rates are associated with the Balassa-Samuelson effect, which tends to lower the negative growth effects of high inflation rates. Considering the last point, the potential explanation lies in the fact that exchange rate policies such as devaluations—employed by many emerging countries—may be used to improve the country's competitiveness and thus promote growth, leading to weaken the negative growth effects of imported inflation. All these features, together with the fact that inflation rates are globally higher in emerging countries than in advanced ones, may explain the different values of the threshold between developed and developing countries—and among emerging countries themselves—and the higher inflation tolerance in less developed economies.

5 Conclusion

Relying upon the estimation of smooth transition models and GMM for panel data, this paper investigates the growth effects of inflation on a wide sample of countries, including both industrialized and emerging economies. Our findings offer strong evidence that inflation non-linearly impacts economic growth. More specifically, there exists a threshold beyond which inflation exerts a negative effect on growth. This threshold value of the inflation rate strongly differs among advanced and developing countries, the estimates being 2.7% for industrialized economies and 17.5% for emerging ones. Moreover, for inflation rates of around 3%, the inflation-growth link is positive in advanced economies, while it is non significant in developing countries below a 17.5% inflation level.

The difference in these threshold values among country groups obtained from the PSTR methodology illustrates a higher inflation tolerance for emerging countries, which may be explained by various factors, such as the Balassa-Samuelson effect, the use of indexation systems, the exchange rate policies and the high levels of inflation encountered by those countries. These results are robust to the retained methodology since similar findings are obtained using the GMM estimator on a growth equation including quadratic interaction terms.

Given that the inflation rate and the rate of change of money supply are highly correlated,[12] the fact that inflation non-linearly affects economic growth may have important implications in terms of monetary policy. Indeed, the growth rate of money supply being the central bank's major instrument for monetary policy, the existence of a non-linear relationship between inflation and output growth suggests that monetary policy may have different effects on GDP depending on the inflation level. As a consequence, this questions the long-run neutrality of money.

A natural extension of this paper would be to account for potential non-linearities that may be induced by other growth determinants than the inflation rate. Within this context—and following Barro (1990b), Barro and Sala-i Martin (1992) and Colletaz and Hurlin (2006) highlighting non-linear effects of government spending on the long-run growth rate—a promising extension would be to introduce non-linearities in the effect of government consumption in our growth model.

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[12] See Vogel (1974), Lucas (1980), Barro (1990a), McCandless and Weber (1995), Rolnick and Weber (1997), and Crowder (1998).

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Appendix

Table 5: **Descriptive statistics. 1961-2007, five-year interval averages**

Variable	Mean	Std Error	Minimum	Maximum
Whole sample				
GDP per capita growth	2.43	2.38	-6.56	10.65
Initial level of GDP	8.20	1.54	5.24	10.62
Pop. growth	1.55	1.02	-0.72	4.71
Investment	3.96	3.86	1.76	37.70
Openness	66.27	52.72	8.36	484.50
Gov. Consumption	14.53	5.19	3.87	30.09
Inflation	8.57	10.54	-0.44	79.02
Advanced economies				
GDP per capita growth	2.64	1.63	-1.16	10.37
Initial level of GDP	9.71	0.50	7.86	10.62
Pop. growth	0.68	0.49	-0.72	2.34
Investment	3.13	0.20	2.80	3.99
Openness	59.48	29.43	9.42	175.95
Gov. Consumption	18.11	4.60	7.56	29.11
Inflation	5.98	6.25	-0.44	49.38
Emerging economies				
GDP per capita growth	2.29	2.80	-6.56	10.65
Initial level of GDP	7.05	1.01	5.24	10.21
Pop. growth	2.25	0.77	0.24	4.71
Investment	4.65	5.07	1.76	37.70
Openness	72.59	65.11	8.36	484.50
Gov. Consumption	11.86	3.92	3.87	30.09
Inflation	9.11	9.39	0.20	75.78
A. Upper middle				
GDP per capita growth	3.47	2.72	-4.25	10.65
Inflation	13.15	16.47	0.51	79.02
B. Lower middle and low				
GDP per capita growth	1.61	2.68	-6.56	8.89
Inflation	7.33	5.56	0.20	27.28

Table 6: **Inflation and output growth: elasticities obtained from the PSTR models. Selected periods and countries**

	1961-65		1981-85		2001-2005		Average	
Country	π	Elasticity	π	Elasticity	π	Elasticity	π	Elasticity
France	3.71	-0.09	9.66	-0.75	1.92	0.63	4.71	0.05
Italy	4.91	-0.37	13.77	-0.82	2.42	0.39	6.72	-0.22
Norway	4.05	-0.18	9.07	-0.73	1.75	0.36	4.91	-0.08
Sweden	3.64	-0.07	9.00	-0.73	1.46	0.87	4.97	-0.04
Canada	1.61	0.79	7.47	-0.65	2.32	0.44	4.19	0.06
Japan	6.05	-0.53	2.77	0.24	-0.44	1.52	3.52	0.40
Spain	4.92	-0.37	13.59	-0.82	3.23	0.06	7.59	-0.42
UK	3.55	-0.04	7.22	-0.63	2.43	0.39	6.12	-0.26
USA	1.28	0.96	5.51	-0.46	2.55	0.33	4.19	-0.03
Colombia	12.80	-0.20	37.36	-0.74	6.48	-0.12	16.45	-0.48
Mexico	1.86	-0.13	62.38	-0.74	4.92	-0.12	22.33	-0.43
Egypt	3.39	-0.12	14.07	-0.73	5.13	-0.12	9.11	-0.24
India	6.22	-0.12	9.35	-0.12	3.98	-0.12	7.49	-0.13
Korea	15.76	-0.61	7.34	-0.12	3.34	-0.12	8.97	-0.28
Morocco	4.01	-0.12	9.88	-0.13	1.41	-0.12	4.84	-0.13
Haiti	4.79	-0.12	10.10	-0.12	21.37	-0.73	12.37	-0.30
Senegal	2.00	-0.12	11.94	-0.12	1.50	-0.12	5.16	-0.15
Cameroon	2.00	-0.12	12.10	-0.12	2.02	-0.12	5.84	-0.13

Notes: (1) The elasticities correspond to the estimated values in Tables 3 and 4 for advanced and developing countries, respectively; (2) π is the average inflation rate on the considered period.

Table 7: **Inflation and output growth: PSTR with lagged regressors**

	Whole sample		Advanced economies		Emerging economies	
Variable	Coef.	t-stat	Coef.	t-stat	Coef.	t-stat
Inflation	-0.148	-0.89	0.353	0.96	-0.151	-0.65
Inflation* $g\left(s_{it};\gamma,c\right)$	-0.545	-4.80	-0.858	-2.63	-0.954	-4.43
$\hat{c}$	13.59		2.74		17.54	
$\hat{\gamma}$	29.19		2.29		7.48	

Notes: (1) $\hat{c}$ and $\hat{\gamma}$ respectively denote the estimated location parameters and estimated slope parameters in Equation (2); (2) Inflation corresponds to $\log(1+\pi_{t-1})$; (3) The estimated location parameter can be interpreted directly as the level of inflation.