On the Non-linear Relationship between Inflation and Economic Growth

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Abstract: Using a large panel data of both developed and developing economies and based on the PSTR and dynamic GMM techniques, this paper highlights two aspects of the inflation-growth relationship. First, it analyzes non-linearity and offers several thresholds for the global sample as well as for different income specific sub-samples. Second, it identifies some indirect channels effectual for inflation-growth non-linearity. Our empirical results substantiate both views and validate the fact that inflation-growth non-linearity is sensitive to financial development, investment ratio, trade openness and government expenditures. Finally, for different country groups, the indirect channels show some marked differences in this non-linear relationship.

Key Words: Inflation, Growth, PSTR, Dynamic GMM, Non-linearity.
JEL Classification*:* E31, C33, P44.

1. Introduction

The relationship between inflation and economic growth has ever remained a debatable issue among the policy makers as well as the academicians. The idea of positive long run money growth, due to nominal rigidities, has been so widely accepted that negative inflation (proposed by Friedman, 1969 and his followers) has never remained a policy agenda of any central bank across the world.[1] Nevertheless too high inflation, due to its undesirable re-distributional and welfare effects, has also been unanimously discouraged by all schools of economic thought. Yet few questions remained unanswered; first, are the detrimental effects of inflation on economic growth immune to the level of development in an economy? Second, starting from which level, inflation inhibits long run growth? And finally, which important channels determine the direction and the intensity of inflation effects on economic activity?

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[1] Recent outcome of the deflationary phase of 1990's, for the Japanese economy, shows that by adopting zero nominal interest rate, central bank loses its policy tool to respond the adverse supply shocks in the economy.

Empirical work, over the years, shows a consensus regarding the negative non-linear inflation effects on growth after some threshold level; nevertheless, alternative threshold points have been offered by different studies.[2] A possible explanation for this lack of consensus comes from the fact that inflation affects growth through different direct and indirect channels, making the overall impact ambiguous and less precise. This all implies a country specific and time specific structural break in the inflation-growth relationship (Khan and Senhadji, 2001). Moreover, these authors advance the view that since inflation could be considered as a characteristic of underdeveloped economy, this structural break is higher for the developing economies compared with the advanced countries.

Higher inflation also impacts efficient functioning of the other macroeconomic mechanisms and as a result influences growth through these channels. A well focused channel among these is the inflation effects that appear through financial deepening; for instance, high inflation disrupts the efficient functioning of financial markets and long term investment plans of the firms. Furthermore, it aggravates the price variability in the goods and the money markets which further increases the cost of hedging the financial assets among the potential trade partners.[3] Some other channels influencing this non-linearity include trade openness, public expenditures and capital accumulation etc. Higher degree of trade openness increases the cost of inflation uncertainty and thus reduces the optimal inflation. Higher level of public expenditures, in contrast, increases inflation, especially for the close economies. A relatively high public expenditure to GDP ratio generates inescapable inflation and hence reinforces the inflation-growth negativity. Finally, inflation also reduces capital accumulation in an economy through its adverse effects on real interest rate. To sum up, all these country specific characteristics are

[2] See Fischer (1993), Bruno and Easterly (1998) and Burdekin et al. (2004).
[3] Rousseau and Watchel (2002) and Rousseau and Yilmazkuday (2009) make some useful discussion on this issue.

influential in determining the inflation-growth non-linearity; nevertheless, these indirect channels have been rarely addressed in the literature.

Contemplating all these aspects, an enormous amount of research has been devoted to probe into the welfare cost of inflation at its alternative levels.[4] One of the most recent contributions came from Omay and Kan (2010) by using a Panel Smooth Threshold Regression (PSTR) for six industrialized countries. Nevertheless, their study focused only on the developed economies and also overlooked the indirect channels discussed above. Our paper fills this gap by analyzing how different degrees of trade openness, financial development, capital accumulation and government expenditures affect the relationship between inflation and growth.

Another limit of the most of the previous studies[5] consists in assuming that the inflation-growth relationship can only be affected by the cross-country variations in the level of inflation and hence neglecting the change in inflation and economic environment over time. To overcome these deficiencies, we used Panel Smooth Threshold Regression (PSTR) that authorizes a smooth transition, for a weak number of thresholds, as well as for a continuum of regimes. This approach presents two main advantages: first of all, a PSTR specification allows the inflation-growth coefficient to vary not only between countries, but also over time. This provides a simple way to appraise the heterogeneity in the inflation-growth relationship over time and across countries. Secondly, this approach allows for a smooth change in country-specific correlation depending upon the threshold variables. The last contribution of our paper is to analyze the role of income in determining the inflation-growth non-linearity by dividing the data in different sub-samples of countries depending upon the per capita GDP for each group. Our main findings support the

[4] A very brief survey of empirical work has been summarized in Section 2.
[5] Exceptions include the above mentioned studies by Omay and Kan (2010) and López-Villavicencio and Mignon, (2011), etc. for their limited data set and analysis of direct channels only.

previous literature regarding the non-linearity in the inflation-growth relationship and propose different threshold for the rich and the emerging countries. Moreover we highlight the hypothesized role of indirect channel in this nexus.

The rest of the paper is organized as follows: Section 2 summarizes some important work and possible role of indirect channels to influence inflation-growth relationship. Section 3 presents our PSTR and GMM model settings and specifications tested in the paper. Section 4 and 5 present the data and the empirical findings, respectively. Finally, Section 6 concludes.

2. Review of literature

2.1. Direct channels of inflation impact on growth

It will not be unfair to say that the empirical inflation-growth literature is inconclusive and the results are fragile with respect to specification and information set. The studies testing the robustness of this relationship i.e Levine and Renelt (1992) and Hineline (2007) conclude that the inflation-growth nexus is brittle, it changes with model specification. Notwithstanding an ambiguity in the intensity of this relationship, its nature remained same in the literature; overall negative effect of inflation on long run growth (Fischer, 1993).[6] The non-linearity tests of Fischer (1993) also suggest that adverse effect of inflation reduces at excessively high inflation. Based on these findings Sarel (1996) tried to find a specific structural break in the inflation-growth relationship and came up with the results that a structural break exists at 8% inflation; below this level inflation is innocuous and above this it is harmful for growth. Khan and Senhadji (2001) found separate thresholds for the developed and the developing countries with the findings of 1 and 11 percent threshold, for both these two categories, respectively.

[6] Bruno and Easterly (1998) revealed an important aspect of this negative relationship. Their study shows that this inverse relationship is being derived by high inflation episodes and that averaging the data for longer time period takes away this effect.

Indeed, most of the earlier literature did not properly take into account the inflation-growth non-linearity. Traditional approaches to take into account these non-linearities have either exogenously determined the threshold level or used an improper treatment of the endogenous threshold. This directed some recent authors, including Omay and Kan (2010) and López-Villavicencio and Mignon (2011), to use a new modeling technique called Panel Smooth Transition regression (PSTR) models, developed by Gonzàlez, et al. (2005) and Fok, et al. (2005). The key characteristic of this modeling technique is that the threshold level of inflation is determined endogenously. Empirical results of López-Villavicencio and Mignon (2011), for a sample of 42 economies, show that the thresholds exist at 2.7% and 17.5% for the developed and developing economies, respectively. These results are closed to those obtained by Omay and Kan (2010), which show an inflation threshold above 2.52% for six industrialized countries.

2.2. Indirect channels affecting inflation-growth non-linearity

Effectively, inflation-growth nexus can be affected by some other macroeconomic factors, as cited before. However, surprisingly, these factors have been rarely addressed in the inflation-growth discussion. Concerning the interaction of trade openness and inflation, in a monopolistically competitive closed economy environment, excess demand affects the level of inflation (Dexter et al., 2005). With greater trade openness, this excess demand gap is filled by the imported substitutes. This not only breaks the relationship between excess demand and inflation but also between inflation and capacity utilization of the firms. Hence trade openness results lower cyclical movements in both inflation and output growth.

Moreover, as explained by Romer (1993), open economies want to keep the exchange rate stable to avoid undue burden of essential imported goods.[7] Unanticipated money supply growth results a depreciation of the real exchange rate and hence an increase in the price of imported goods. Now if the imports are important determinant of inflation, higher overall prices force workers to demand higher wages which reduces the competence of the domestic firms.[8] Hence the negative effect of inflation on growth, after some level, becomes stronger in the open economies and small inflation target becomes an optimal policy choice (i.e Sachsida et al., 2003). On the other hand, closed economies usually generate unexpected inflation to get the short run incentives, which as a result increases long run inflation. However the evidence on this negative openness-growth relationship is not concrete as a parallel strand of literature gives the conditionalities for these results (see Pain et al. 2006 for more details). This justifies our attempt to study the role of trade openness in affecting the inflation-growth non-linearity.

Another indirect channel that is relatively more substantiated in the literature is the level of financial development. Since there exists a one-to-one relationship between finance and growth, higher inflation represses growth by weakening the finance-growth nexus (Rousseau and Watchel, 2001).[9] Taking into account the importance of this tripartite relationship, several attempts have been made to clear the ambiguities of this relationship and to identify the inflation threshold above which it represses the financial intermediation (Barnes and Duquette, 2006). For example, the panel data results of Rousseau and Watchel (2001) and Barnes and Duquette (2006) show the inflation threshold (for finance-growth nexus) at 13% and 14% respectively. A more

[7] Further empirical substantiation to this argument comes from Pain et al. (2006) by showing that with increasing openness in the OECD countries after 1980s, import prices became an important factor in determining domestic CPI.

[8] However these results of Romer (1993) have been countered by Terra (1998) by showing that the results are driven by 1980s' post crisis data of highly indebted developing economies.

[9] However, Andres et al. (2004) show that although the adverse effects of inflation on growth appear through financial repression, these effects are weak and do not explain the potential harms of inflation through this channel.

recent study of Rousseau and Yilmazkuday (2009) also complement these findings by using the three dimensional graphs. Their results suggest that for inflation rate from 4% to 19%, unexpected inflation reduces the beneficial effects of financial development on growth.

Inflation-growth non-linearity can also be affected by the size of public expenditures in an economy. Inflation effects on growth, appearing through public expenditure channel, are bi-directional; inflation not only enhances the public expenditures (through cost escalation) but is also being pushed up by the high government expenses.[10] Undue public expenditures aggravate the excess demand, crowd out the productive investment and hence result inflation. As shown by Bhatia (1982), based on critical limit hypothesis, when government expenditures exceed 25% of the total economic activity, high inflation is a natural outcome. Empirical results of Ezirim et al. (2008) also show that high public expenditure is followed by higher inflation in the U.S.

Some contrasting evidence to the above has been provided by Han and Mulligan (2008) for the sample of 80 countries over the period 1973-1990. The study disintegrates the changes in public expenditures into two components; permanent and transitory public expenses and finds a very weak negative relationship between permanent government expenditures and inflation whiles a slight positive relationship between inflation and transitory expenditures (i.e defense spending in war times). Hence the public finance effects on growth that appear through inflation can either be burden or impotent to price changes.

Finally, inflation effects on growth can also appear through its impediments to the long term investment plans. Although one strand of theoretical literature, starting from Tobin (1965) to the recent study of Lioui and Poncet (2008), advances the view that inflation can boost up

[10] Direct effect of public expenditures on growth has been addressed by the previous literature (i.e Barro, 1991).

investment by lowering the real interest rate, yet the empirical facts speak the reverse.[11] Theoretical justification of this controversy has been provided by Gillman and Kajal (2011) by showing that lower interest rate, due to inflation, causes a low capital-labor ratio which decreases output growth in the long run. Furthermore, Li (2006) also contemplates that inflation damages growth through its adverse effects on total factor productivity (TFP); albeit, the direct inflation effects on capital accumulation were not found significant.

To sum up the above discussion, inflation-growth relationship is not simple and inflation effects on growth can appear through various channels. This requires a broader analysis explaining the main transmission channels that are influential for the inflation-growth non-linearity. Our paper makes a first attempt to explore some of these indirect channels.[12]

3. Empirical methodology

3.1. PSTR model specification

To investigate the non-linear relationship between inflation and economic growth, we use the Panel Smooth Threshold Regression (PSTR) model proposed by Gonzàlez, et al. (2005) and Fok et al. (2005). Let us suppose a simplest case of a PSTR with two extreme regimes and a single transition function to illustrate the inflation-growth relationship;

$$y_{it} = \alpha_i + \beta_0^{'}\pi_{i,t-1} + \beta_1^{'}\pi_{i,t-1}\Gamma\left(q_{it};\gamma,c\right) + \delta_0^{'}z_{it} + \varepsilon_{it}. \qquad (1)$$

For $i = 1,...,N$ and $t = 1,...,T$, where N and T denote the cross-section and time dimensions of the panel, respectively. The dependent variable y_{it} is a scalar and denotes the growth rates of

[11] The fact that inflation decreases the real interest rate is also documented by the empirical literature as well (i.e Rapach, 2003), nevertheless, these effects are not sufficient to bring more investment (Gillman et al., 2004).
[12] Few other important channels like total factor productivity, public debt and human capital growth are left for the future work.

GDP, $\pi_{i,t-1}$ is the first lagged value of the inflation rate,[13] z_{it} is a *k*-dimensional vector of control variables usually considered in the growth literature. α_i represents the individual fix effects, and ε_{it} the error term. The transition function Γ is continuous and depends on the threshold variable q_{it}; $c=(c_1,...,\ c_m)'$ which is a vector of location parameters. Finally, parameter γ determines the slope of the transition function. Following Granger and Teräsvirta (1993), González et al. (2005) consider the following logistic transition function:

$$\Gamma(q_{it};\gamma,c)=\left[1+\exp\left(-\gamma\prod_{z=1}^{m}(q_{it}-c_z)\right)\right]^{-1},\quad \gamma>0,\quad c_1<...<c_m. \tag{2}$$

For a high value of γ, the transition becomes rougher and the transition function $\Gamma(q_{it};\gamma,c)$ tends towards the indicator function $\Gamma(q_{it};c)$. Hence, for every value of m, when γ tends towards infinite, the PSTR model reduces to Hansen's (1999) two-regime panel threshold regression (PTR) model. In the opposite case, when γ is close to 0, the transition function $\Gamma(q_{it};\gamma,c)$ is constant and the PSTR estimation becomes a panel with fixed effects. Finally, low and high values of q_{it} correspond to the two extreme regimes.

In comparison with the previous specifications (panel analysis or PTR), the use of PSTR methodology yields some theoretical advantages. The main advantage of the PSTR is that it allows the inflation-growth coefficient to vary with respect to time and country. Hence, the coefficients can take different values, depending on the value of another observable variable. The PSTR model allows individuals to move between groups and over time according to the changes in the "threshold variables". It provides a parametric approach of the cross-country heterogeneity as well as time instability of the inflation-growth coefficients, causing a smooth change in these

[13] We use the lag of the inflation rate to treat the endogeneity problem between inflation and economic growth.

variables with respect to threshold variable. For instance, if the transition variable q_{it} is different from the inflation rate $\pi_{i,t-1}$, the sensitivity of growth to inflation rate for the i^{th} country at time t is defined as follows:

$$\frac{\partial y_{it}}{\partial \pi_{i,t-1}} = \beta_0 + \beta_1 \Gamma\left(q_{it}; \gamma, c\right) \tag{3}$$

When the transition variable is the same as exogenous variable, the elasticity expression is different. For instance, if $q_{it} = \pi_{it}$, the elasticity of growth to inflation is then defined as:

$$\frac{\partial y_{it}}{\partial \pi_{i,t-1}} = \beta_0 + \beta_1 \Gamma\left(\pi_{i,t-1}; \gamma, c\right) + \beta_1 \frac{\partial \Gamma\left(\pi_{i,t-1}; \gamma, c\right)}{\partial \pi_{i,t-1}} \pi_{i,t-1}, \ \forall i, \forall t. \tag{4}$$

We notice that the elasticity of growth to inflation can be defined as a weighted average of parameters β_0 and β_1. Thus the PSTR model allows a precise assessment of the impact of inflation on economic growth.

Another advantage of the PSTR model, is that the elasticity of growth to inflation rate can be different from the estimated parameters for the extreme regimes, i.e. β_0 and $\beta_0 + \beta_1$. As illustrated by Eqs. (3-4), these parameters do not directly correspond to direct impact of inflation rate on growth. For instance, parameter β_0 corresponds to a direct effect of inflation on growth only when the transition function $\Gamma\left(q_{it}; \gamma, c\right)$ tends towards 0. In contrast, when $\Gamma\left(q_{it}; \gamma, c\right)$ tends towards 1, the elasticity of growth to inflation is equal to the sum of β_0 and β_1 parameters. Between these two extremes, there are infinite numbers of elasticity parameters of growth to inflation, which are defined as a weighted average of β_0 and β_1.

3.2. Estimation and specification tests

Gonzàlez et al. (2005) propose a testing procedure in the following order: (*i*) test the linearity

against the PSTR model, and (*ii*) determine the number r, of transition functions. The test of linearity in PSTR model (refer to Eq. 1), can be done by testing: $H_0 : \gamma = 0$ or $H_0 : \beta_1 = 0$. But under the null hypothesis, the test will be non standard in both cases, and the PSTR model contains unidentified nuisance parameters. A possible solution is to replace the transition function $\Gamma(q_{it};\gamma,c)$ by its first-order Taylor expression around $\gamma = 0$ and to test an equivalent hypothesis in an auxiliary regression. We then obtain:

$$y_{it} = \alpha_i + \theta_0^{'}\pi_{it} + \theta_1^{'}\pi_{it}q_{it} + \delta_0^{'}z_{it} + \varepsilon_{it}^{*}. \quad (5)$$

Since θ_i parameters are proportional to the slope parameter of transition function γ, testing the linearity of inflation-growth model against PSTR consists of testing $H_0 : \theta_1 = 0$ versus $H_1 : \theta_1 \neq 0$. Let us denote SSR_0, the panel sum of squared residuals under H_0, and SSR_1, the PSTR model with m regimes. The corresponding $F-$statistic is then defined by:

$$LM_F = \frac{(SSR_0 - SSR_1)/mK}{SSR_0/(TN - N - mK)} \sim F(mK, TN - N - mK), \quad (6)$$

where T, N and K stands for the number of years, number of countries and number of exogenous variables, respectively.

3.3. Robustness tests

For the robustness tests, we follow López-Villavicencio and Mignon (2011) and estimate dynamic system GMM model using both linear and non-linear specifications. Our linear specification is the following:

$$y_{it} = \alpha_i + \theta_0^{'}\pi_{it} + \delta_0^{'}z_{it} + \varepsilon_{it}^{*}. \quad (7)$$

Then the addition of interaction term of inflation and other macroeconomic variable gives the non-linear specification of dynamic system GMM as in Eq. (5). The equation (5) contains an

interaction term in order to account for non-linear growth effects of the threshold variable q_{it}. This specification allows us to appraise whether, beyond a certain level, the threshold variable q_{it} become more or less important in determining the marginal effect of inflation on economic growth. Therefore, the marginal effect of inflation on growth depends on the threshold variable:

$$\frac{\partial y_{it}}{\partial \pi_{it}} = \theta_0^{'} + \theta_1^{'} q_{it}. \qquad (8)$$

The previous equation converges to Eq. (3), when the transition function tends towards 1. The GMM specifications contain the same set of covariates as above while the interaction term will show a change in the behavior of inflation after some structural break. The system GMM models consist of the stacked regressions in levels and differences. These models are well known to deals with the endogeneity problem that appear in the panel data estimation of the growth regressions (Arellano and Bover, 1995, and Blundell and Bond, 1997). It also takes into account the biases that appear due to country specific effects or due to the presence of the initial GDP in the growth's covariates. Finally, as discussed by the above mentioned studies, GMM also allows preventing the simultaneity or the reverse causality problems. The consistency of the GMM estimator depends both on the validity of the assumption that the error term does not exhibit serial correlation (AR1) and on the validity of the instruments (AR2). All these characteristics of this modeling technique yield the results comparable with the PSTR model.

4. Data and estimation process

For the empirical analysis, we have selected the annual data of 102 countries over the period of 1960-2009.[14] Selected covariates include the initial GDP per capita to test the conditional

[14] Our data sources include World Development Indicators (2011) and International Financial Statistics (2011). The selected countries are: *High income countries* (Australia, Austria, Barbados, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Hong Kong (China), Hungary, Iceland, Ireland, Israel, Italy, Japan,

convergence in the spirit of the neoclassical growth theory (i.e Barro and Sala-i-Martin, 1995). Following the development on endogenous growth theory, we used additional control variables: (i) trade openness, measured as the ratio of imports plus exports to GDP, (ii) government expenditure to GDP as fiscal policy indicator, (iii) investment, measured as the ratio of gross fixed capital formation to GDP, (iv) the ratio of liquid liability (M3) to GDP to appease the financial depth, (v) population growth to control for population dynamics, and finally our main variable of interest, inflation rate, defined as the growth rate of consumer price index (CPI). Our endogenous variable is the growth of GDP per capita in constant 2000 USD prices. Following Beck et al. (2000) and López-Villavicencio and Mignon (2011), and in order to avoid the influence of idiosyncratic economic dynamics at business cycle frequency as well as to control for the cyclical output movements, we used five-year interval averages.

5. Results and discussion

Descriptive results (Table 1) explain the fact that deviation from mean is high for inflation rate which motivates the interest to have more homogenous sub-sample. The sub-sample results (available upon request) show an increase in openness, investment and government consumption with the income level. In contrast, output growth and investment volatility decreases with income.

Table 1: Descriptive statistics, 1960-2009; global sample

Korea. Rep, Kuwait, Luxembourg, Malta, Netherland, New Zealand, Norway, Oman, Portugal, Saudi Arabia, Singapore, Spain, Sweden, Switzerland, Trinidad and Tobago, United Kingdom, United States) - *Upper middle income countries* (Algeria, Botswana, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Fiji, Gabon, Iran, Jamaica, Libya, Malaysia, Mexico, Peru, South Africa, Turkey, Uruguay, Venezuela) – *Lower middle income countries* (Bolivia, Cameron, China, Congo, Cote d'Ivoire, Ecuador, Egypt, EI Salvador, Guatemala, Guyana, Honduras, India, Indonesia, Morocco, Nigeria, Pakistan, Papua New Guinea, Paraguay, Philippines, Senegal, Sri Lanka, Sudan, Swaziland, Syrian Arab Republic, Thailand, Tunisia) - *Low income countries* (Bangladesh, Benin, Burkina Faso, Burundi, Central African Republic, Chad, Gambia, Ghana, Haiti, Kenya, Lesotho, Madagascar, Malawi, Mali, Mauritania, Myanmar, Nepal, Niger, Rwanda, Sierra Leone, Togo, Zambia, Zimbabwe).

Variable	Mean	Std. Dev	Minimum	Maximum
GDP per capita Growth	2.040	3.260	-11.61	32.010
Initial GDP	7.512	1.6316	4.425	10.976
Pop. growth	1.970	1.2281	-6.041	10.022
Openness	66.174	45.988	2.694	409.83
Investment	20.570	6.790	3.810	59.312
Gov. expenditure	14.988	5.992	3.684	54.357
Financial depth	44.679	33.912	2.422	250.81
Inflation	12.055	20.463	-3.009	211.62

Next, we present our main findings of inflation-growth relationship, actualized by the PSTR and GMM models. As PSTR starts with defining the degree of non-linearity and the number of thresholds (no remaining heterogeneity), our preliminary findings, based on LM_F statistics, guide us to select the number of transition functions. In our case the residual sum of squares and the criteria of information[15] lead us to choose one threshold level and one transition function. This means that a weak number of transition functions are sufficient to obtain the inflation-growth non-linearity, using different threshold variables. For GMM models, serial correlation tests (AR1) and (AR2), with the null hypothesis of no first-order and second-order serial correlation for the errors in the difference equation, confirm the validity of the instruments and the consistency of the GMM models.

Table 2 presents our main findings for the global sample. Our first specification is based on the linear GMM estimation showing the overall effect of inflation on GDP. This linear model is used as benchmark for the other specifications, and allows us to show the effect of inflation, in addition to its effects that appear after thresholds; captured by the nonlinear models. Most of the control variables are significant, with their signs according to the economic theory. The negative sign of inflation shows an overall adverse effect of inflation on growth. However the initial GDP variable, which shows the conditional convergence hypothesis of neoclassical growth theory, is not significant here. Nevertheless, these overall results may be misleading; since out descriptive

[15] Details can be provided upon request.

results show a higher mean growth for rich countries than for the emerging economies. This is clear from our sub-samples results as the convergence hypothesis is strongly supported here. Negative sign of the population growth variable states the burden of overpopulation on long run growth as advocated by the Solow growth model. Same is the case with government expenditures; high level of public expenditures drains out the most efficient private investment and inhibits growth (Barro and Sala-i-Martin, 1995). Concerning the degree of financial development variable, its sign is positive, reaffirming the previous works (i.e Beck et al., 2000) that strong financial structure is essential input for capital formation and hence for growth. The next two variables, investment and trade openness also matches with the theory.

In the next step, we test non-linear PSTR and GMM for all direct and indirect channels. As shown by the results in specification (2), the value of the slope parameter is high in the transition function, showing an abrupt change of regime (as in Omay and Kan, 2010). Hence inflation rate shows two extreme regimes with rough transitions to characterize the inflation-growth relationship. The inflation threshold that appears at 12.4% is consistent with the findings of Khan and Senhadji (2001). Nevertheless, the inflation effect below this level is insignificant and above this level is it is negative and significant. Indeed, under the inflationary regime (>12.4%), other things being equal, an increase of 1% in the inflation rate reduces economic growth to 3.998%, whereas the growth effect of inflation is null for the first regime. Nevertheless, there is a continuum of points between both extreme regimes and the elasticity is defined as a weighted average of the parameters β_0 and β_1. As aforementioned, the estimated parameters β_j cannot be directly interpreted, but their signs are; for instance, the parameters β_0 and β_1 are negative. This implies that when the threshold variable (i.e. inflation rate) increases, the link between inflation and growth decreases. The coefficient of our non-linear GMM

estimates (specification 3) behaves in the same way as PSTR. A negative and significant coefficient of the interaction variable confirms the non-linear and inverse U-shaped inflation-growth relationship.

The next specifications of table 2 summarize the results of some indirect channels that amplify the inflation effects on growth. Here again, consistent with the direct channel results, the slope of the transition function is high, showing an abrupt transition. Taking the financial development channel, since inflation weakens the finance-growth nexus, the undesirable effects of inflation should be larger in more financially developed economies. Although inflation variable is insignificant, the interaction term is negative and significant. Hence, under the first regime (financial depth lower than 28%), inflation rate does not affect growth, while under the second regime; the negative impact of inflation is 5.812% (a case where financial depth is higher than 28%). As a matter of fact, the weak financial systems are often inflationary and also less sensitive to the additional variations in inflation. High inflation is also associated with low financial depth, following financial liberalization literature (i.e McKinnon, 1973). By contrast, in more financially developed systems, benefits of disinflation in terms of growth are higher (i.e Rousseau and Watchel, 2001 and Rousseau and Yilmazkuday, 2009). This hypothesis has been supported by our PSTR and GMM findings since the parameters are negative in both cases.

Regarding the second interaction variable, investment to GDP ratio, it is significant with negative sign. The negative effect of inflation on growth under high investment regime is close to 4.43%. Therefore, the countries with investment to GDP ratio higher than 19% are expected to be influenced more severely by inflation than the low investing economies.

Table 2: Inflation and output growth relationship for global sample, PSTR and GMM models

Variable		Inflation		Financial depth		Investment		Openness		Gov. expenditure	
	GMM Linear	PSTR	GMM	PSTR	GMM	PSTR	GMM	PSTR	GMM	PSTR	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Initial GDP	-1.199	-1.175	-1.487[c]	0.211	-1.376[c]	1.277	-1.183	1.211	-1.225	-1.199	-1.288
	(-0.98)	(-1.02)	(1.84)	(1.47)	(-1.84)	(1.06)	(-1.40)	(1.45)	(-1.54)	(-1.32)	(-1.62)
Pop. growth	-0.366[c]	-0.465[a]	-0.227	-0.449[a]	-0.311[c]	-0.446[a]	-0.311[c]	-0.476[a]	-0.406[b]	-0.477[a]	-0.341[c]
	(-1.94)	(-4.89)	(-0.54)	(-4.73)	(-1.75)	(-4.68)	(-1.79)	(-5.01)	(-2.05)	(-4.98)	(-1.88)
Investment	2.913[b]	3.184[a]	3.679[a]	3.414[a]	3.004[b]	3.702[a]	3.261[a]	3.334[a]	3.194[a]	3.288[a]	2.714[b]
	(2.38)	(8.95)	(3.15)	(9.65)	(2.59)	(9.62)	(3.24)	(9.45)	(3.05)	(9.29)	(2.48)
Openness	3.994[b]	0.014	2.211	-0.035	3.678[c]	-0.015	2.861[c]	0.161	2.940	-0.021	3.499[c]
	(1.99)	(0.08)	(1.50)	(-0.19)	(1.84)	(-0.08)	(1.73)	(0.82)	(1.61)	(-0.11)	(1.73)
Financial depth	0.522[c]	0.862[b]	0.822[b]	0.639[c]	0.789[b]	0.607[b]	0.715[b]	0.515[b]	0.793[c]	0.624	0.418
	(1.73)	(1.97)	(2.08)	(1.71)	(2.14)	(2.03)	(2.31)	(2.06)	(1.78)	(1.11)	(1.49)
Gov. expenditure	-2.951[a]	-1.446[a]	-3.419[b]	-1.338[a]	-2.767[b]	-1.399[a]	-2.971[b]	-1.376[a]	-2.837[a]	-1.568[a]	-2.923[a]
	(-2.61)	(-5.11)	(-2.39)	(-4.73)	(-2.81)	(4.95)	(-2.45)	(-4.86)	(-2.64)	(-5.16)	(-2.72)
Inflation	-3.611[a]	-1.611	3.653	-3.951[c]	-3.205	-0.597	-4.931	-1.659[c]	-2.390[a]	-3.781[a]	-5.997
	(-3.21)	(1.08)	(0.46)	(-1.67)	(-0.74)	(-0.46)	(-0.55)	(-1.71)	(-2.3)	(-5.06)	(-0.73)
Interaction variable		-2.387[b]		-1.861[a]	-1.256[b]	-3.838[a]	-1.047[a]	-3.315[a]	-1.238[b]	3.071	-1.782[b]
		(-2.24)		(-3.13)	(-2.08)	(-2.72)	(-3.21)	(-2.73)	(2.00)	(1.53)	(-2.45)
$Inflation^2$			-1.581[a]								
			(-2.65)								
C		12.404		27.784		18.855		30.994		21.301	
Γ		369.982		828.072		335.086		419.979		587.187	
LM_F		0.013		0.022		0.001		0.004		0.037	
AR(1)	0.000		0.000		0.000		0.000		0.000		0.000
AR(2)	0.598		0.466		0.509		0.347		0.581		0.622

Notes: t-values are presented below the corresponding coefficients. Symbols 'a', 'b' and 'c' show 1%, 5% and 10% level of significance respectively. p-values are reported for LM_F, AR(1) and AR(2) statistics.

Effectively, the countries with low level of investment are transition economies, working under a heavy influence of Balassa-Samuelson effect and as a result high optimal inflation (Brada and Kutan, 2001). Investment in these economies is normally derived through productivity growth channel, making the effect of nominal uncertainty on investment less serious compared with the developed economies.

Regarding our next indirect channel trade openness, the fact that openness aggravates the effect of inflationary shocks on growth, through export competitiveness, has also been actualized by our findings since the countries with the degree of openness (more than 31%) are expected to be influenced more intensely (5.064% under the second regime).

Finally, our government expenditure channel's investigations provide conflicting results. The PSTR approach weakly supports the fact that high level of government expenditures dampen the inflation effects on growth (supporting the balance budget multiplier) since the interaction variable is insignificant, while the GMM results strongly support the reverse; economies with a heavy role of public policy are more vigorously effected by inflation.

In the next step, we divide the sample into four groups based on the income levels of the included economies to see how income disparities among the economies alter the optimal inflation rate between them. Many other systematic differences between developed and developing economies i.e real market rigidities, government size and tax structure also plays role in this optimality difference. To illustrate, weak labor market institutions of the developing economies allow the firms to make frequent changes in the prices as wages do not respond quickly to price changes. This increases inflation tolerance of the developing countries vis-à-vis the developed economies. Moreover, seigniorage also works as tax in the emerging economies

when other distortionary taxes are hard to come by (Mankiw, 1987). All this results high optimal inflation in low income countries compared with high income countries. To take into account these differences, we intend to study the inflation dynamics between different country groups based on their income.

Table A1 in Appendix repeats the same specifications for the high income, upper middle income, lower middle income and low income countries, respectively. The most notable difference in the result is the inflation threshold which is 3.4% for the advanced economies; 10% and 12% for the upper-middle income and middle-income countries, respectively. Finally, the inflation threshold for the low income economies is around 20% showing a very strong Balassa-Samuelson effect for these countries. Lower the level of development, higher the productivity growth (due to catching up) and, as a result, optimal inflation. Consequently, an increase in inflation has more harmful impact on growth in high income countries than the emerging ones. Except the lower middle income countries, values of the slope parameter are low, showing a relatively smooth transition in this nonlinear process.

Threshold estimates for the indirect channels are also different from those of the global sample as the parameter values improves with income. To illustrate, in a rich economy, a high degree of financial development, trade openness and capital accumulation is required for the negative effects of inflation to appear through these channels. Government expenditure channel prove to be ineffective showing a lack of correlation between seigniorage and public finance for the developed economies. Thus, monetary policy in these economies is not used as a tool to finance government expenditures due to the central bank independence. Hence the systematic differences of public expenditures to GDP ratios among these economies do not bring any additional impact on the sensitivity of the relationship between inflation and growth. Our

findings also suggest that all four indirect transitional variables are not relevant for all country groups: for instance, in high income countries only financial depth is relevant, while investment ratio is significant in upper middle income countries only. In lower middle income countries the inflation-growth nonlinearity is affected by investment, trade openness and government expenditure, whereas in low income countries, investment and public expenses are significant.

6. Concluding remarks

This paper brings new evidence on the inflation-growth non-linearity by using the PSTR and GMM models for a broad data set of 102 developed and developing countries. The recent literature has persistently verified the fact that the inflation-growth relationship is non-linear and hence there exists a threshold above which inflation is harmful and below this level it is growth enhancing. However the channels through which inflation affects growth or the macroeconomic environment that influences this non-linearity is not being focused by the previous literature.

Here we mainly addressed two issues concerning this relationship; the threshold estimates, for the whole sample as well as for different sub-samples, and some indirect channels that can possibly affect the degree of sensitivity between inflation and growth. Regarding our first stage findings, the analysis complements the existing literature that inflation-growth relationship is indeed non-linear and our threshold estimates decreases with the level of income. This systematic inverse relationship illustrates the fact that inflation indexation and inflation tolerance is high in the developing economies compared with the developed countries. Our threshold estimates match with the recent work of López-Villavicencio and Mignon (2011) for a relatively small data set of 44 countries.

Now coming to the indirect channels affecting the degree of sensitivity in the inflation-growth relationship, our results validate the effectiveness of these channels and establish the point that the inflation-growth non-linearity can be affected by certain macroeconomic developments of an economy. Indeed, the degree of financial development, trade openness, capital accumulation and government size are the factors responsible for oscillating inflation-growth relationship over time and across countries. More a country is developed with respect to these indicators, severe the repercussions it will have to face for higher inflation.

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Table A1: Inflation and output growth relationship for sub-samples

Variable		Inflation		Financial depth		Investment		Openness		Gov. expenditure	
	GMM Linear	PSTR	GMM	PSTR	GMM	PSTR	GMM	PSTR	GMM	PSTR	GMM
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Panel A: Inflation and output growth relationship for high income countries, PSTR and GMM models											
Inflation	-3.218[a] (-2.66)	1.641 (1.19)	-3.489 (-1.41)	-1.518[b] (-2.132)	-2.741[b] (-2.52)	-3.675[c] (-1.92)	-1.590[b] (-2.14)	-1.271[a] (-4.27)	-0.588 (-0.13)	-2.601[a] (-4.37)	-2.501[b] (-1.99)
Interaction variable		-2.388[b] (-2.38)	-1.952[c] (-1.82)	-1.972[b] (-2.46)	-1.077[b] (-2.38)	-3.828 (-1.28)	2.402 (0.21)	-1.798[a] (-3.45)	4.804 (0.37)	1.441 (1.65)	2.635 (1.23)
C		3.408		65.767		23.261		63.885		16.574	
Γ		1.534		77.011		430.856		37.18		0.611	
Panel B: Inflation and output growth relationship for upper middle income countries, PSTR and GMM											
Inflation	-1.751[a] (-2.58)	1.023[a] (3.23)	3.442[b] (2.11)	-3.596[b] (-2.48)	-2.137[b] (-2.12)	-2.307[b] (2.36)	-1.519 (-0.73)	-3.691[b] (-2.99)	-3.278[b] (-2.21)	-2.169[a] (-2.87)	-3.342[c] (-1.79)
Interaction variable		-2.892[a] (-3.66)	-3.993[a] (-3.12)	1.914 (1.48)	3.602 (1.13)	-1.138[b] (-2.37)	-2.729[c] (-1.92)	-1.765[c] (-1.78)	1.585 (1.06)	2.521 (1.30)	2.653 (0.63)
C		10.022		45.469		17.328		81.427		10.567	
Γ		1.843		3.765		208.121		12.306		400.718	
Panel C: Inflation and output growth relationship for lower middle income countries, PSTR and GMM											
Inflation	-1.501[b] (-2.03)	-2.110[c] (1.89)	2.907[b] (2.09)	-1.472[a] (-3.01)	-1.447[b] (-2.03)	-1.968[b] (-2.41)	-1.052[b] (-2.02)	-3.488[b] (-2.28)	-2.633[b] (-2.04)	-1.728[c] (-1.94)	3.322 (1.18)
Interaction variable		-1.739[b] (-2.38)	-1.409[b] (-2.02)	-1.756 (-1.01)	-1.917 (-1.21)	-3.798[a] (-4.25)	-2.527[b] (2.04)	-3.842[a] (-4.76)	-2.862[c] (-1.85)	2.164[b] (2.19)	2.198[a] (3.76)
C		12.954		25.723		18.316		66.716		11.128	
Γ		3.019		5.418		2.174		3.045		1.285	
Panel D: Inflation and output growth relationship for lower income countries, PSTR and GMM											
Inflation	-1.044[b] (-2.05)	-2.203[a] (-3.47)	3.001[c] (1.83)	-4.329[b] (-2.11)	-1.956[c] (-1.78)	-3.258[a] (-3.83)	-2.496[b] (-2.47)	-1.908[a] (-4.48)	-2.318[c] (-1.78)	-4.707[a] (-3.93)	-4.011[c] (-1.83)
Interaction variable		1.705[a] (2.71)	-1.981[b] (-2.33)	-2.738[c] (-1.71)	-1.044 (-0.81)	-2.507[b] (-2.09)	-1.621[b] (-2.13)	3.536 (1.04)	2.481 (0.99)	2.319[b] (2.34)	3.846[a] (3.36)
C		19.586		34.801		10.487		56.365		11.126	
Γ		0.209		31.492		237.059		5.219		233.989	

Note: t-values are presented below the corresponding coefficients. Symbols 'a', 'b' and 'c' show 1%, 5% and 10% level of significance respectively. Coefficients of control variables, LM_F, AR(1) and AR(2) statistics can be provided upon request.