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Investigating non-linearities in the inflation-growth trade-off in transition countries

Abstract

This paper investigates the inflation-growth relationship in transition countries via dynamic panel analyses. Following recent theoretical arguments, we assess the existence of non-linearities in this relationship. It has been suggested that the positive effects of low inflation on growth differ between developing and developed countries, i.e. that the optimal inflation rate might be higher for developing countries. Consequently, this paper investigates whether a similar conclusion holds for transition countries. In doing so we raise the question as to whether inflation targets have been too low in these countries.

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1.1. Introduction

The main aim of this paper is to investigate the inflation-growth relationship in transition countries in early/mid transition. Although there is a generally accepted consensus that price stability is the ultimate objective of monetary policy and, moreover, the convergence criteria for European Union (EU) member states require inflation to be at a low level, we want to raise the issue whether the emphasis on economic stability (low inflation) has been to the detriment of economic growth in transition economies in the period of early and middle transition.

Central banks in the last few years have often opted either for a quantitative target or for qualitative definition of price stability. Inflation targets are often specified as ranges rather than levels, and are usually set at 4 percent or less per year. However, recently, theoretical arguments that imply that the long-run Phillips curve may not be vertical at low inflation rates have been put forward. This could also imply that the inflation-growth relationship may be positive at low inflation rates. As Akerlof et al. (2000) note, a little inflation, when accompanied with nominal rigidities, can lower the minimum sustainable rate of unemployment. This, in turn, results in increased productivity and more employment than would exist in a non-inflationary environment, leading to increased incentives to enhance capacity through more investment, and finally resulting in higher output growth. In view of the fact that high inflation, on the other hand, leads to misallocation of resources, which, in turn, is likely to reduce the rate of growth of an economy, this paper considers this relationship in transition countries. In particular, we will present some studies that investigate the non-linearities in the inflation-growth relationship. They find that this trade-off is different for developing and developed countries. We will next analyse the inflation-growth relationship in a set of transition countries empirically. Finding a kink in the relationship, i.e. a level of inflation when its effect on growth turns from positive to negative is of special interest for transition countries, as inflation rates in these countries fall to low levels. Our empirical research differs from other analyses on the topic in that, first, we analyse transition economies, secondly, we use a theoretically guided specification as a platform for investigating the effects of inflation on growth and, finally, we, unlike other papers, specify a dynamic panel model.

The paper is organised as follows. Section 1.2 overviews the non-linearities in the inflation-growth relationship in theory, section 1.3 is a literature overview of the papers that empirically analyse this trade-off in developed and developing countries, while section 1.4 contains our empirical analysis of the non-linearities in a set of transition countries via dynamic panel analysis. Finally, section 1.5 concludes.

1.2. Non-linearities in the inflation-growth relationship in theory

Akerlof et al. (2000) develop a model that allows a trade-off between inflation and unemployment, but only at low rates of inflation. The most important implication of their work is that a low, but not zero, inflation rate generates the lowest sustainable rate of unemployment. The main assumption behind their model is that the lay public do not use the same model of the economy as do economists; i.e. the lay public are not fully but rather near rational. Akerlof et al. list three reasons why individuals do not treat inflation and its costs in the way assumed in orthodox economic models. Firstly, when inflation is low, people may ignore inflation when setting wages and prices. More precisely, they tend to edit decision problems, discarding less important factors in order to be able to concentrate on more important ones. Secondly, even if individuals do take inflation into account, they might not account for it completely, i.e. an increase in inflation would lead to an increase in wages or prices but not on a one to one basis. Finally, workers misperceive nominal changes as real changes. An increase in nominal wage, even if it does not fully reflect inflation, may increase their job satisfaction. This decline in real wages leads to less unemployment. Therefore, a positive rate of inflation cools down real wage growth and "greases" the wheels of the economy. The misperception caused by nominal wage increase may, in turn, lead to less shirking and higher productivity than in the case of no inflation. As a result, a higher level of employment and output would be sustained. When inflation increases above a certain rate, people stop being near-rational and take full account of inflation, as it is now too costly to ignore it. Hence, the unemployment rate corresponding to a low, positive inflation rate is lower than the one related to both zero and high inflation. A low, positive inflation rate, thus, minimises the sustainable rate of unemployment. The results from estimating their model for the US indicate that this low, positive inflation rate is in the range 1.5 to 4 percent. At higher rates of inflation the trade-off is reduced, disappearing completely at a certain rate.

Palley (2003) criticises Akerlof et al.'s (2000) assumptions for two reasons. First, it is unclear why workers would systematically underestimate inflation at low rates and then suddenly take full account of it after the inflation rate reaches a threshold. Secondly, some workers will tend to ignore predicable inflation even at fairly high levels. Palley explains the downward rigidity of nominal wages by moral hazard. Namely, when firms want to lower wages workers do not know whether this is the result of market conditions or opportunistic behaviour by employers. Workers will more readily accept real wage reductions resulting from increased inflation because the general price level is beyond the control of individual firms, so firms cannot opportunistically exploit workers through this means. However, workers are not willing to accept a too rapid real wage adjustment. Once the inflation rate reaches the threshold, they demand matching nominal wage increases, and this cancels out the "greasing" effects of inflation. A further reason for downward wage rigidity is that workers are usually indebted in nominal terms. In the case of nominal wage reduction their debt burden, measured by the debt-to-income ratio, would increase. Therefore, they oppose nominal wage cuts. Workers are able to prevent employers from cutting wages since employing new workers would be costly in terms of training. In Palley's paper, workers are always aware of inflation, but they only refuse to accept a reduction in real wages when inflation is high. Because of the downwardly rigid nominal wages, the resulting long-run Phillips curve is backward bending. This Phillips curve implies that there is a Minimum Unemployment Rate of Inflation (MURI), corresponding to that unemployment rate at which the Phillips curve bends backwards. The MURI provides a rationale for low inflation targeting.

Next we look at the relevance of the inflation-unemployment trade-off for the inflation-growth relationship. Irrespective of the reason why wages are downwardly rigid, the bottom line of Akerlof et al.'s and Palley's paper is that a little inflation 'helps' to achieve less unemployment than implied by the natural rate of unemployment, or less unemployment than would exist had there been no inflation at all. In addition to concluding that the workers do not fully differentiate between nominal and real changes and are hence willing to accept real wage reductions, Akerlof et al. also argue that workers' satisfaction and, consequently, productivity, might increase with a small increase in a low inflation rate. This means that a little more inflation enables firms to achieve more (higher productivity) at the same cost (wage). Therefore, in the presence of low inflation both employment and productivity will be higher. Given that the changes in output can result from changes in overall productivity and/or quantity of labour, low, positive inflation facilitates higher capacity utilisation, and results in a narrowing of the output gap. Thus, a little inflation by 'greasing the wheels of labour market adjustment' helps reduce the output gap. This, furthermore, enhances incentives to increase capacity through more investment, which results in higher output growth.

1.3. Overview of the inflation-growth relationship in empirical research

Many empirical studies find that there are non-linearities in the inflation-growth relationship. Firstly, it is found that this relationship is kinked: positive below a certain threshold and negative above it. Secondly, as emphasised by Ghosh and Phillips (1998), this trade-off is convex, which means that an increase in the annual inflation of 10-20 percent is associated with a much larger decline in growth, than an increase of 40-50 percent. The issue of the kink becomes increasingly important in transition context as inflation rates in these countries fall to low levels. The issue of kink was not central for countries in transition in the period of hyperinflation. After stabilisation programmes were implemented and inflation decreased to lower levels (below 20 percent), however, the issue of the relationship between inflation and growth became more significant.

Sarel (1996) finds that a negative effect of inflation on growth starts at inflation rates above 8 percent. Bruno and Easterly (1998) take 40 percent as a breakpoint between low and high inflation since, when testing inflation stability across ranges of inflation, they notice that above 40 percent the risk of even higher inflation rises sharply, although they admit some arbitrariness in their choice of the threshold. Their results suggest that there is a strong and robust relationship between this high inflation and growth. Ghosh and Phillips (1998) employ panel regression on a large data set covering IMF member countries for the period 1960-1996. In order to capture the 'kink' in the inflation-growth relationship they follow Sarel (1996) and use a spline technique, with turning point at an inflation rate of 2.5 percent. The placement of the kink in their study is based on visual inspection of the inflation-growth relationship, but that also happens to be the placement of the kink that yields the best fit in the multivariate growth regression. At very low inflation rates, 2-3 percent, the authors find this relationship to be positive, otherwise, it is negative. Christoffersen and Doyle (1998) estimate the threshold level for transition economies to be at 13 percent inflation. Khan and Senhadji (2000) use a dataset of 140 countries comprising of both industrial and developing countries and covering the period 1960-1998. The authors find that the threshold above which inflation significantly slows growth differs between developed and developing countries. Namely, this threshold is estimated to be at 1-3 percent for industrial countries and 7-11 percent for developing countries. The optimal threshold level is estimated as the one that minimises the sequence of the residual sum of squares in two sub-samples: industrial and developing countries. Below this inflexion point there is a positive and statistically significant relationship between inflation and growth in both groups of countries. The negative and significant relationship between inflation and growth was found for high inflation rates (above the threshold). Burdekin et al. (2004) also test for the non-linearities in industrial and developing economies separately. Within the group of developing countries they find three thresholds: at 3, 50, 102 percent, whereas in the group of industrial countries two thresholds are 8 and 21 percent. The thresholds are identified by combining different inflation rates and selecting the one that yields the highest R^2. The results for industrial countries show that there is no significant impact of inflation on growth for rates less than 8 percent, whereas the relationship is significantly negative for higher inflation rates. For developing countries it is estimated that below the 3 percent inflation threshold, the coefficient is positive and highly significant, while for the higher inflation rates it is significantly negative. The results of Burdekin et al. (2004) are in contrast with the results of Khan and Senhadji (2000), since the growth costs of inflation are found to be much higher for industrial than for developing countries. However, when Burdekin et al. use the log rather than the level of inflation, their results change and indicate that the threshold for developing countries is 10 percent (and not 3 percent anymore). They explain this by the fact that using logs disables one from taking negative inflation rates into account, since we cannot take logs of negative numbers. Usually this problem is approached in the way Sarel (1996) did, i.e. by replacing negative inflation rates with very small positive number. Burdekin et al. (2004) argue that when the negative inflation rate observations are deleted, the estimate of their threshold drops substantially, pointing to the importance of taking negative rates into account. However, countries in transition (developing countries) rarely had negative inflation rates, so these conclusions do not hold in that case. Furthermore, as noted by Sarel (1996), inflation in levels has very asymmetric distribution (the lowest tenth of its range contains 88 percent of the observations in his sample), which would put an enormous weight on the very few observations with the highest inflation rate. Therefore, it seems more logical to use the log of inflation as an independent variable.

The above literature overview indicated that the threshold above which inflation negatively influences growth is lower for developed than for developing countries. The issue of the kink becomes increasingly important in transition context as inflation rates in these countries fall to low levels. Therefore we next empirically investigate inflation-growth relationship in transition countries in the period 1990-2003.

1.4. An empirical analysis of inflation-growth relationship in transition countries

The main aim of this section is to discover whether there exists a statistically significant threshold level of inflation in a set of transition economies, below which inflation influences growth differently from that at higher rates of inflation. Empirical studies on the non-linear relationship between inflation and growth usually include only developed countries or make distinction between developed and developing countries. Transition economies are rarely analysed.

The theory is not straightforward regarding the variables that should be included in growth regressions i.e. what belong to the 'true' regression. Sala-i-Martin (1997), for example, finds a total of 62 variables used in the literature. This lack of a clear theoretical background "has led empirical economists to follow theory loosely and simply "try" various variables relating the various potentially important determinants of growth" (Sala-i-Martin, 1997a: 2).

Levine and Renelt (1991) and Sala-i-Martin (1997) are the two most cited papers that check the robustness of a variety of variables used in empirical growth literature. Levine and Renelt use a variant of Leamer's (1983) extreme bounds analysis, whereby they firstly include a vector of fixed variables that always appear in growth regressions (the initial level of income per capita, the investment rate, the secondary school enrolment rate and the rate of population growth), a vector of up to three variables taken from the pool of the remaining variables usually used in the literature and the variable of interest (that is tested for robustness). Their conclusion is that very few variables are robust, i.e. systematically correlated with growth. One problem is that there is a lot of multicollinearity among the variables included as they reflect similar economic phenomena. The only variables that do robustly affect growth rate in this setting are the average share of investment in GDP and the level of initial income per capita.

Sala-i-Martin (1997) approach differs from the one of Levine and Renelt in that instead of labelling variables just as either robust or non-robust, he assigns some level of confidence to each of the variables. The fixed variables he includes (that appear in all regressions) are the initial level of income, life expectancy and the primary school enrolment rate. Besides these three variables, he finds 22 significant variables. Interestingly, inflation is not among them. However, as noted by the author, this is possibly due to the linear instead of the non-linear treatment of this variable.

Table 1 gives an overview of some of the papers that use growth regressions and lists the variables used. Of these papers two were chosen because they give an extensive overview of the variables commonly used in growth regressions and test their robustness (Sala-i-Martin, 1997 and Levine and Renelt, 1991), while the rest of the papers analyse growth determinants either in developing countries (Khan and Senhadji, 2000 and Burdekin et al., 2004) or in transition economies (Christoffersen and Doyle, 1998), which is of interest for our research. Finally, the paper by Ghosh and Phillips (1998) was chosen because it is a commonly cited empirical analysis of the non-linear effects of inflation on growth.

Table 1

Variables	**Levine and Renelt (1991)**	**Sala-i-Martin (1997)**	**Christoffersen and Doyle (1998)**	**Ghosh and Phillips (1998)**	**Khan and Senhadji (2000)**	**Burdekin et al. (2004)**
Data set	*Cross-section*	*Cross-section*	*Panel*	*Panel*	*Panel*	*Panel*
Time span	*1960-1989*	*1960-1992*	*1990-1997*	*1960-1996*	*1960-1998*	*1965-1992*
Dependent variable / **Independent variables**	*Average annual growth rate in GDP per capita*	*Average growth rate of per capita GDP between 1960 and 1992*	*Percentage growth rate of GDP per capita*	*Real per capita GDP growth*	*Growth rate of real GDP*	*Real GDP per capita growth*
Initial GDP pc	✓	✓			✓	
Life expectancy		✓		✓		
Primary (Secondary) School Enrolment	✓	✓		✓		
Equipment investment		✓				
Number of years open economy		✓				
Rule of law		✓				
Political rights		✓				
Civil liberties		✓				
Revolutions and coups		✓				
Fraction of GDP in mining		✓				
Black market premium		✓		✓		✓
Primary exports in 1970		✓				
Degree of capitalism		✓				
War dummy		✓	✓	✓		
Non-equipment investment		✓				
Exchange rate distortions		✓				
Transition index			✓			
Change in transition index			✓			
Share of exports in GDP			✓			
Inflation			✓	✓	✓	✓
First difference of inflation rate						✓
Threshold inflation			✓	✓	✓	✓
Investment as a share of GDP	✓			✓	✓	
Population growth	✓			✓	✓	✓
Change of terms of trade				✓	✓	✓
SD of terms of trade					✓	
Ratio of real govt. expenditure to real GDP						✓
Ratio of revenues to GDP				✓		
Ratio of public consumption to GDP				✓		
Fiscal balance				✓		
Ratio of US per capita income to country *j*'s per capita income				✓		
Ratio of exports plus imports to GDP				✓		

1.4.1. Data and variables overview

There are no clear theoretical guidelines as to which variables to include in growth regression. Mankiw et al. (1992), Arnold (1994), Mankiw (1995) and Keller and Poutvaara (2005) conclude that the neoclassical model should be augmented by human capital, but that the basic structure need not change. Therefore, our approach is to firstly include variables such as initial income, investment and population growth in the spirit of neoclassical theory. We additionally include measures of human capital, such as primary and/or secondary school enrolment rates and life expectancy, and a measure of openness to trade (as suggested by some endogenous theories). A measure of fiscal policy is also included. Both neoclassical and new growth theories suggest that the effect of fiscal policy on growth exists, but differ in their expected overall impact. There are different endogenous growth models, and not all of them agree upon the appropriate model specification, i.e. theory offers no unique approach to modelling growth. Therefore, following previous empirical work, we additionally include certain variables that reflect the specific characteristics of countries in transition, such as a war dummy, and the transition index.

We proceed as follows. We firstly include those variables that Sala-i-Martin (1997) and Levine and Renelt (1991) include as fixed variables when testing robustness. These variables include the level of income per capita at the beginning of the period under investigation, life expectancy and the primary (and/or secondary) school enrolment rate, the investment rate, and the rate of population growth.

In the empirical growth literature the initial level of income is used to take account of the conditional convergence. Conditional convergence holds if the coefficient on this variable is negative. In a practical sense, this means including the level of GDP per capita in the initial year under investigation in the regression. However, given that we will use panel data approach, using the level of GDP only in, say, 1990 as an explanatory variable, would give us the same value of that variable for each year, i.e. no variability. In the fixed effects (FE) model all time invariant characteristics of a country (or any other cross-section unit) are by definition included in the FE. Therefore, initial GDP (or any unique institutional feature of a country) would, in this case, act as a country specific constant. Hence, there is no point in including this variable in the (FE) model. This issue has not, to our knowledge, been addressed anywhere in the literature. In order to still examine the possible existence of the catch-up process we use the ratio of USA's GDP per capita to country *j*'s GDP per capita for each year in the sample (in constant 2000 $)[1]. In this way we create a variable that measures the gap between the two countries and whether it has narrowed. We tested the same hypothesis using Germany's GDP per capita and the results do not differ significantly.

Life expectancy is usually used as a measure of non-educational human capital, while the primary and/or secondary school enrolment rate serves as a measure of educational human capital. An increase in human capital per worker leads to increased output per worker. Workers who are better educated and trained are better able to perform their tasks, learn new tasks and adopt new production techniques. Although some papers include primary school enrolment rates in the regression, this, in our view, does not seem to be the best option. Namely, there is too little variability in this variable, given that elementary schooling is compulsory in all transition countries. Hence, we use secondary school enrolment rates as a measure of educational human capital. In addition, some authors (Heckman and Klenow, 1997) argue that schooling and life expectancy are highly correlated (0.8 in their sample), and suggest excluding the life expectancy variable. In our sample, however, the coefficient of correlation between these variables is 0.49; hence we keep both variables in our regression. Sala-i-Martin includes only the secondary enrolment rates in the initial year under investigation (presumably because the effects of this variable on growth are not felt in the same year, but maybe 10 years later). However, including the secondary enrolment rates only in the initial year under investigation is not feasible in our model for the same reasons the initial GDP could not be used in panel data analysis. Another option is to include (enough) lags of this variable so that the effects of human capital on growth could be felt. However, another problem arises at this point (besides the lack of data for majority of previous years and majority of countries). Namely, as noted by Berryman (2000), the previous education system was poorly matched to the needs of the new market economy. There is, thus, no point in including the lags of this variable in our regression. At the same time the flow from current post-compulsory secondary enrolments has little impact on the quality of the stock of the current workforce. However, given that we have no alternative we do use

[1] We follow Ghosh and Phillips (1998) and Harris, Gillman and Matyas (2001) in this.

the current enrolment rates as they may serve as a proxy for the willingness of the population to respond to the skill requirements of the new labour market.

Investment is one of the most widely used variables in growth literature. If investment is not included in the regression, then it is unclear whether the other explanatory variables affect growth directly or through the incentives to save and invest. When, on the other hand, investment is included in the growth regression, the other channels through which other explanatory variables can affect growth is through the efficiency of resource allocation, quality of human capital or technological progress.

The rate of population growth affects GDP growth in the spirit of neoclassical theory. Namely, high population growth lowers income per capita because the amounts of human and physical capital have to be divided over the, now larger, population (Mankiw et al., 1992).

Many papers also include the black market premium and the terms of trade variable. The black market premium, as noted by Ghosh and Phillips (1998), is a measure of the overvaluation of the real exchange rate and, in some instances, of economic mismanagement more generally. This variable could also be interpreted as a sign of economic uncertainty which should tend to discourage investment (Sala-i-Martin, 1997a). It is reasonable to suppose that the existence of a sizable black market premium over long periods of time reflects a wide range of policy failures. It is also reasonable to think that these failures will be responsible for low growth. As for the terms of trade, this variable should account for the impact of external shocks. It should be noted, however, that worsening of the terms of trade can seriously disrupt growth only in countries with fixed exchange rate regimes. Countries with flexible exchange rate regimes will experience a lot milder contraction in output. It should be stressed, furthermore, that terms-of-trade shifts in developing countries are largely exogenous (Broda and Tille, 2003). This variable could reflect a possible channel through which natural resources may affect growth. However, the two variables, black market premium and terms of trade, are not obtainable for the whole period and for all countries under investigation. Given that these are not our core variables (they are neither our main variable of interest nor fixed variables that always appear in growth regressions) and that the missing data would deprive the possibility of analysis of certain years, we shall not include these variables in our model.

The endogenous growth literature suggests that countries that are open to trade seem to grow faster that those that do not have liberal trade policies (Arnold, 1994). The most basic measure of trade intensity is the so-called ''trade openness'' i.e. the ratio of exports plus imports to GDP. We use this variable to take account of the arguments put forward by the new growth theory. We also include general government expenditure (percent of GDP) as an additional explanatory variable.

In addition to commonly used variables in growth regressions, we want to address particular problems of transition. We use the EBRD transition index as a proxy for economic progress towards a fully-fledged market economy. This composite index is created as the un-weighted average of the following indices: Price Liberalisation; Foreign Exchange and Trade Liberalisation; Small-Scale Privatization; Large-Scale Privatization; Enterprise Reform; Competition Policy; Banking Sector Reform; Reform of Non-Banking Financial Institutions[2].

Additionally, our model contains a war dummy, also regularly included in growth regressions, and especially important for the period of early transition in Croatia (1991-1995), and to a lesser extent Slovenia (1991). The war dummy is included as a supply shock that distorts growth. It might also stand for the direct destruction of capital stock.

Finally, our main variable of interest is the inflation rate and its effect on growth. This variable was found to be insignificant in Levine and Renelt (1991) and Sala-i-Martin (1997). However, it was included in a linear manner, whereas the theory reviewed above suggests that it should be included non-linearly. Therefore, we include inflation in the growth regression in a non-linear fashion. The precise description of this non-linearity is explained below.

It is common practice in empirical studies on growth that use panel data analysis to use four or five year averages rather than annual data in order to smooth out the business cycle fluctuations. We have at maximum 14 years at hand. It would, thus, be possible to create three 5-year averages in our sample (with the last one containing only 4 years). However, there are certain problems with applying this method when analysing different countries. Namely, this method assumes that all countries in the sample are at the same stage of the business cycle, which need not be the case. In addition, the evaluation of business cycles for countries in transition is

[2] We follow Zeitler (2005) in this.

extremely complicated until the second half of the 1990s (Tamla, 2003). Furthermore, it might be the case that, for example, it makes more sense to join/average the first three years (in the case of Croatia this belongs to the pre-Stabilisation period) and then another, say, seven years. Therefore, we do not use averaged, but rather annual data in our analysis. Temple (2000) notes that using annual observations, or even four or five year averages may in effect be picking up government policy responses, aggregate supply shocks or some other short-lived effect, and not the long-run impact of inflation on growth. Hence he suggests it would be more sensible to use ten-year averages. This is, however, not feasible in our sample given the short time span. In support of using annual data, Alexander (1997) notes that this (higher) frequency is preferable in order not to obscure useful information in the data. Namely, the average inflation rate may be unduly influenced by a few extreme observations. Of considerable importance, in cross-sectional work and panel examination is the point that countries with vastly differing experiences of inflation may turn out to have a similar average rate over a lengthy period. Averaging simply results in the loss of too much information. In addition, Khan and Senhadji (2000) find that, although the confidence region is narrower for the averaged sample, the two methods yield similar results. The description and the definition of the variables we use are given in Appendix I.

1.4.2. The econometric model

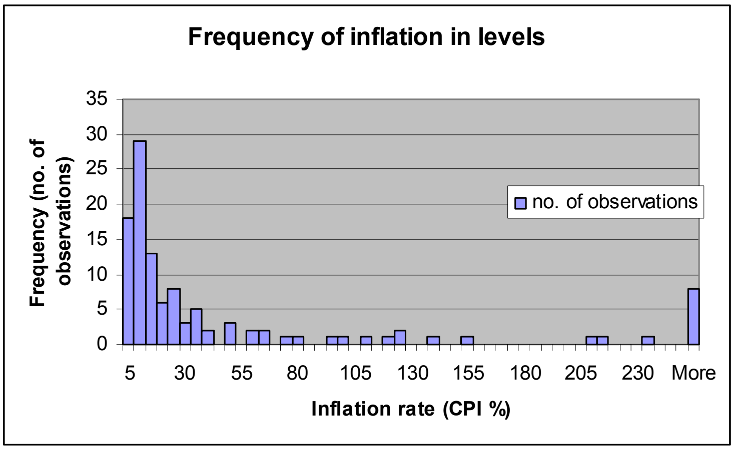
We start by analysing our main variable of interest, inflation, in more detail. Figure 1 shows the distribution of inflation across the full sample of countries (Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia) and time periods (1990-2003). The *y*-axis presents the number of observations that correspond to each inflation range (on the *x*-axis)[3]. It can be observed that the distribution is extremely skewed, with the vast majority of observations pertaining to inflation rates below 40 percent (not surprisingly). Using levels of inflation in our regression would, therefore, give much weight to the extreme inflation observations. Sarel (1996) suggests using the logarithm of inflation rates

[3] Ranges are arbitrary; the first range is from 0 to 5 percent inflation and each next range increases by 5 percentage points, up to inflation rate of 250. All inflation observations higher than 250 are placed into the category "More", as not many observations are in this range.

instead, as this would, at least to a certain degree; eliminate the observed asymmetry in the inflation distribution. The distribution of the natural logarithm of inflation is presented in Figure 2[4]. This transformation seems to have eliminated the pronounced skewness observed before. If we take a look at the descriptive statistics (to the right of Figures 1 and 2), it is evident that the coefficient of variation (obtained as standard deviation/mean) significantly decreases when the variable is logged (from 2.629 to 0.574). The median is also much closer to the mean than in the case with levels of inflation. Skewness also decreases in the logged model from 4.9 to 0.181. All in all, given the discussion above, we decide to proceed using the logarithm of the inflation rate as the independent variable (although we will also test the non-linearities using the level plus the squared term).

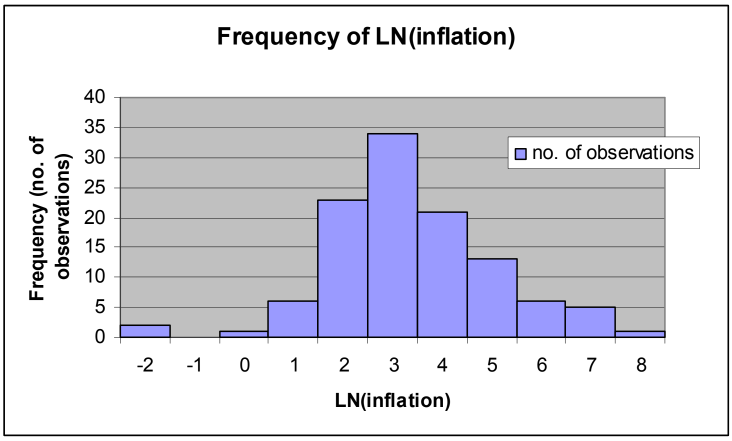
[4] We were able to use the log transformation of the inflation variable without dropping any observations as there were no negative inflation rates in the sample.

Figure 1



Variable: inflation (CPI %)	
Mean	*76.243*
Median	*11.880*
Standard Deviation	*200.420*
Kurtosis	*28.001*
Skewness	*4.900*
Range	*1499.898*
Minimum	*0.102*
Maximum	*1500.000*
Count	*112*

Figure 2



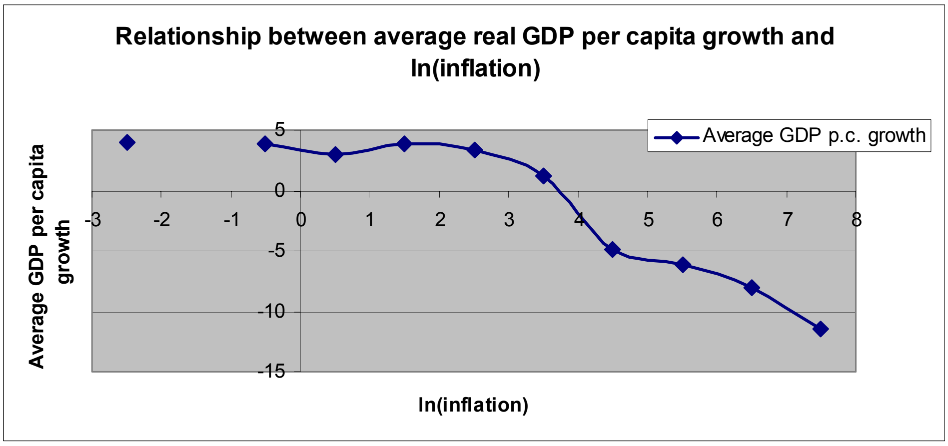
Variable: ln(inflation)	
Mean	*2.862*
Median	*2.475*
Standard Deviation	*1.643*
Kurtosis	*1.140*
Skewness	*0.181*
Range	*9.601*
Minimum	*-2.288*
Maximum	*7.313*
Count	*112*

Next, in order to investigate the possible non-linearity in the inflation-GDP growth relationship we start by plotting the two variables. We smooth the data by converting the sample to 11 categories[5]. The *y*-axis presents the average real GDP per capita growth rate that corresponds to each inflation range (on the *x*-axis). We can see from Figure 3 that the relationship between real GDP per capita growth and the log of inflation is slightly positive (or at least non-negative) for low inflation rates, and then becomes negative[6]. This negative relationship persists for all higher inflation rates. The inflexion point on the graph seems to be where the natural logarithm of inflation is between 2 and 3. This includes inflation rates in the range from 7.5 percent to 19.8 percent. Overall, inflation rates up to approximately 20 percent seem to have a non-

[5] The first category includes those observations where ln(inflation) is from -3 to -2, the second is from -2 (included) to -1, third -1-0, etc, while the last category includes all those observations where ln(inflation) is greater than 7 (and less than 8).
[6] We do not have any observations for ln(inflation) between –2 and –1 hence the break in the graph.

negative impact on growth. It should be noted again, that we do not have the same number of observations for each range of inflation, as shown in Figure 2.

Figure 3



Next we turn to empirical estimation of the kink in the relationship between inflation and growth. Most papers that investigate non-linearities in this relationship use the following model (see for example Ghosh and Phillips, 1998; Khan and Senhadji, 2000; Sepehri and Moshiri, 2004; Mubarik, 2005):

Equation 1

$$d\log(Y_{it}) = \alpha + \beta_1 \log(\pi_{it}) + \beta_2 D[\log(\pi_{it}) - \log(\pi^*)] + \gamma X_{it} + \varepsilon_{it}$$

$$D = \begin{cases} 1 \; if \;\; \pi_{it} > \pi^* \\ 0 \; if \;\; \pi_{it} \leq \pi^* \end{cases} \quad i = 1,\ldots N; \quad t = 1,\ldots T$$

where $dlog(Y_{it})$ is the growth rate of real GDP per capita, π_{it} is the inflation rate, π^* is the threshold level of inflation, D is a dummy that takes the value of 1 for inflation levels greater than the threshold inflation and zero otherwise, X_{it} is a vector of control variables. The index "*i*" is the cross-sectional index and "*t*" is the time-series index. For inflation rates higher than the threshold level[7] the impact of inflation on growth is given by $\beta_1+\beta_2$, and for those less or equal to the threshold level by β_1. The threshold level of inflation, π^*, is usually estimated as that value that minimises the sum-of-squared residuals from the regression, i.e. that maximises the R^2 (as noted above this approach is used in Sarel, 1996; Ghosh and Phillips, 1998; Khan and Senhadji, 2000 and Burdekin et al., 2004).

[7] An assumption is that the threshold is the same in each country and year in the sample.

We test for the presence of non-linearities and the placement of the kink through several models given below:

Equation

$$gY_{it} = Intercept + X_{it}\beta + \gamma_1 \pi_{it} + \gamma_2 \pi_{it}^2 + Z_{it}\lambda + \varepsilon_{it} \quad \textbf{(2)}$$

$$gY_{it} = Intercept + X_{it}\beta + \gamma \ln(\pi_{it}) + Z_{it}\lambda + \varepsilon_{it} \quad \textbf{(3)}$$

$$gY_{it} = Intercept + X_{it}\beta + \gamma_1 \ln(\pi_{it}) + \gamma_2 D_{threshold} + Z_{it}\lambda + \varepsilon_{it} \quad \textbf{(4)}$$

$$gY_{it} = Intercept + X_{it}\beta + \gamma_1 \ln(\pi_{it}) + \gamma_2 D_{threshold}\left[(\ln \pi_{it}) - \ln(\pi^*)\right] + Z_{it}\lambda + \varepsilon_{it} \quad \textbf{(5)}$$

$$D_{threshold} = \begin{cases} 1\ if\ \pi_{it} > \pi^* \\ 0\ if\ \pi_{it} \le \pi^* \end{cases} \quad i = 1,...N; \quad t = 1,...T$$

where gY_{it} stands for the per capita growth rate of GDP in country i in time t, X_{it} represents a set of variables always included in growth regressions (GDP gap, secondary school enrolment rate, population growth, investment as a share of GDP and life expectancy in country i in time t) , π_{it} stands for the inflation rate, π^* represents a threshold level of inflation, and Z_{it} includes a set of additional variables in country i and time t, either identified by past studies (share of government expenditures in GDP, openness measured as share of exports + imports in GDP) or used to account for specificities of transition (war dummy and transition index), that are potentially important determinants of growth. The random error term is represented by ε_{it}.

The core specification of Equations 2-5 can be derived from the Solow growth model augmented to include the accumulation of human capital, as shown by Mankiw, Romer and Weil (1992) and many others (see for example Knight, Loayza and Villanueva, 1993; Arnold, 1994; Mankiw, 1995; Clark, 1997 and Keller and Poutvaara, 2005). Therefore, the underlying theory is Solow's augmented production function with physical capital (proxied by investment as a share of GDP), human capital (proxied by secondary school enrolment rates and life expectancy) and labour (proxied by the rate of population growth) as the factors of production. The share of government expenditures in GDP and openness measured as the share of exports + imports in GDP serve as indicators of fiscal and trade policy, respectively. These two variables are assumed to affect growth through uncertainty. Inflation, as our main variable of interest should indicate how much monetary policy matters for long-run growth.

We expect positive signs on the physical and human capital variables, as they are assumed to increase growth. The GDP gap is also expected to exert a positive impact. Namely, were we to use initial income we would expect a negative sign (because the lower the initial GDP the higher the expected growth according to convergence theory). GDP gap represents the ratio of the USA's and country *j*'s GDP per capita in each year, hence the higher the GDP gap (the lower the initial GDP) the higher the expected growth. Population growth is expected to affect growth adversely. As for the other variables, we expect openness ((exports + imports)/GDP)) to have positive impact on growth. We do not have prior expectations with respect to sign regarding the variable representing fiscal policy. We anticipate a positive sign on the transition index, as it serves as a proxy for economic progress towards a market economy, and the better progress the countries make, the higher their growth. The war dummy should have an adverse effect on growth. Finally, we anticipate a negative sign on the squared inflation term (in Equation 2), indicating an inverted U-shape relationship between inflation and growth.

We use panel data analysis to take advantage of greater variation in the data since variables now vary in two dimensions. This also enables a more efficient estimation. Our sample consists of 8 transition countries (Bulgaria, Croatia, Czech Republic, Hungary, Poland, Romania, Slovakia and Slovenia) and 13 years (1991-2003[8]), i.e. 104 observations per each variable. The static panel analysis is commonly used in empirical analyses of inflation and growth. However, Bond (2002: 1) observes that "even when coefficients on lagged dependent variables are not of direct interest, allowing for dynamics in the underlying process may be crucial for recovering consistent estimates of other parameters". In other words, if the dynamic relationships are present in the model, estimating a static model leads to severe misspecification. Therefore, below we present only the dynamic panel results. However, we carried out also static panel analysis mainly for comparison purposes with dynamic panel, but also in order to be able to used the spline technique i.e. to test Equation 5. The results from static panel analysis are given in Appendix II. As a whole, they indicate that the inflation rates above 18-20 percent significantly and negatively affect growth. The results are non-significant for inflation rates between 8 and 18 percent. It is, however,

[8] We had to exclude 1990 from our sample as too many variables were missing for this year. Namely, GDP per capita growth for Croatia, Czech Republic, Poland and Slovenia; Government expenditure for Croatia; (exports + imports)/GDP for Croatia and Secondary school enrolment rates for Croatia and Slovenia.

suggested that those rates below 8 percent might have a beneficial effect on growth. A non-linear effect of inflation on growth is also evident from the data.

1.4.3. The results from dynamic panel analysis

The simplest linear dynamic panel model is given as (random effects):

Equation 6

$$y_{it} = \beta y_{i,t-1} + (\alpha_i + \varepsilon_{it}).$$

Because the composed error term $(\alpha_i + \varepsilon_{it})$ has a time invariant component (α_i), it influences the dependent variable in each period *(t)*. This error term, therefore, must be correlated with lagged values of the dependent variable[9], which biases estimates of β away from its true value. This group-specific effect (α_i) is, hence, removed through the differencing of Equation 6.

Equation 7

$$y_{i,t-1} = \beta y_{i,t-2} + (\alpha_i + \varepsilon_{i,t-1})$$

Namely, if we subtract Equation 7 from Equation 6, we obtain Equation 8.

Equation 8

$$y_{it} - y_{i,t-1} = \beta(y_{i,t-1} - y_{i,t-2}) + (\varepsilon_{it} + \varepsilon_{i,t-1})$$

Next, in order to overcome the problem of the correlation between the lagged dependent variable and the error term, one or more instruments are used to substitute for $(y_{i,t-1} - y_{i,t-2})$. Arellano and Bond (1991) use lagged levels to instrument the predetermined and endogenous variables in first differences. It should be noted at this point that the Arellano and Bover (1995) estimator generates more efficient estimates than Arellano and Bond. Namely, their approach uses more moment conditions, as not only are predetermined and endogenous variables in first differences instrumented with suitable lags of their own levels (Arellano and Bond, 1991), but also predetermined and endogenous variables in levels are instrumented with suitable lags of their own first differences. This approach is more useful in datasets with very short time-series, as low as three. However, we believe that Arellano and Bond is a more adequate approach for our analysis, as we have a long(er) time series (13), but

[9] Namely, for y_{i1} the composed error term contains α_i, for y_{i2} the composed error term also contains α_i etc.

relatively small cross-section (8), i.e. 104 observations, and the Arellano and Bover approach, using a lot of instruments would significantly reduce our number of observations.

In addition to including the variables discussed in section 1.4.1 and described in Appendix I, we also include the year dummies, and use robust standard errors. The first decision we have to make is whether to treat some variables as endogenous. If endogeneity exists and is not accounted for, it causes biased and inconsistent estimates, thus invalidating the results of the analysis. As noted by Temple (2000), a reoccurring topic in the literature is that inflation and growth may be two endogenous variables. He, furthermore, notes, that insufficient effort has been directed at identifying the pattern of causation. Slow growth might spur inflation in various ways. Temple lists several reasons following the literature on the topic. Namely, if growth slows and government tries to maintain seigniorage revenue as a constant proportion of GDP, inflation rises; slow growth and inflation may be the joint outcome of adverse supply shocks; governments may respond to slow growth with expansionary policies, thus fuelling inflation. Andres and Hernando (1997), furthermore, find that there is a positive causation running from growth to inflation. We, therefore, treat inflation as an endogenous variable. In addition, investment could also be treated as endogenous. Namely, Levine and Renelt (1991) note in their extensive analysis, that the causal relationship between growth and investment is ambiguous. Blomström et al. (1996) observe that simultaneity bias will inevitably be a problem in growth-investment regressions. They even find more evidence that growth precedes investment than that investment precedes growth. Podrecca and Carmeci (2001) find that the causality between investment and growth runs in both directions.

Another question is how many lags of the dependent variable to use. In order to resolve this, we must test the validity of the instruments, which includes testing for autocorrelated error terms. Namely, the Generalised Method of Moments (GMM) used for estimation of dynamic panels, does not require distributional assumptions, like normality (Verbeek, 2000; Greene, 2002), but it does require that the error terms are not autocorrelated (Arellano and Bond, 1991).

There are two ways of testing for instrument validity: testing for first-order (m_1 statistic) and second-order (m_2 statistic) serial correlation among the residuals; and the Sargan test of over-identifying restrictions. The m_1 statistic plays an auxiliary role by providing information on the robustness of the m_2 statistic. The null hypothesis states that there is no autocorrelation, so that a low *p*-value for the test on first-order serial correlation (*m1*) and a high *p*-value for the test on second-order serial correlation (*m2*) suggests that the disturbances are not serially correlated in such a way as to invalidate the specified instruments. The serial correlation tests (*m1* and *m2*) refer to the one-step robust GMM estimates. Sargan test, on the other hand, is conventionally based on two-step estimates, because its asymptotic distribution is unknown under the assumptions of the robust model (Arellano and Bond, 1991). We will use the one-step estimator for interpreting the coefficients and significance levels. Namely, as noted by Arellano and Bond (1991) and Bond (2002), empirical investigation has shown that the two-step procedure, while yielding coefficient estimates of a similar size to the one-step procedure, biases the standard errors downward, i.e. inflates *t*-ratios.

In order to determine the number of lags of the dependent variable, we adopt a testing-down procedure, starting with six lags. Mangan et al. (2005) note that it is a commonly used procedure in the applied literature to select the largest possible number of lags of the dependent variable that can be used as instruments and that are valid according to the diagnostic tests. However, given that we have a relatively small sample this procedure would leave us with too small a number of observations. Therefore, we proceed using two lags of the dependent variable when $ln(\pi)$ is included and three lags when $(\pi+\pi^2)$ is included, since in these cases the diagnostics indicate that the instruments are valid, and we loose the least observations. The diagnostics are presented in Appendix III. Equations 2-4 represent the underlying models for static panel analysis. Their dynamic version (for two lags) is given below[10]:

Equation

$$gY_{it} = Intercept + \alpha_1 gY_{it-1} + \alpha_2 gY_{it-2} + X_{it}\beta_1 + Z_{it}\beta_2 + \gamma_1 \pi_{it} + \gamma_2 \pi_{it}^2 + u_{it} \qquad \textbf{(9)}$$

$$gY_{it} = Intercept + \alpha_1 gY_{it-1} + \alpha_2 gY_{it-2} + X_{it}\beta_1 + Z_{it}\beta_2 + \gamma_1 \ln(\pi_{it}) + u_{it} \qquad \textbf{(10)}$$

$$gY_{it} = Intercept + \alpha_1 gY_{it-1} + \alpha_2 gY_{it-2} + X_{it}\beta_1 + Z_{it}\beta_2 + \gamma_1 \ln(\pi_{it}) + \gamma_2 D_{threshold} + u_{it} \qquad \textbf{(11)}$$

$$u_{it} = v_i + e_{it}$$

[10] Note that we cannot use dynamic version of Equation 5 since in the dynamic model R^2 is not reported.

$$D_{threshold} = \begin{cases} 1 \; if \;\; \pi_{it} > \pi^* \\ 0 \; if \;\; \pi_{it} \leq \pi^* \end{cases} \quad i = 1,...N; \quad t = 1,...T$$

where gY_{it} stands for the per capita growth rate of GDP in country i in time t, gY_{it-1} and gY_{it-2} are the first and second lag of GDP growth, respectively. X_{it} is a vector of strictly exogenous variables[11], and includes GDP gap, secondary school enrolment rate, population growth, life expectancy, share of government expenditures in GDP, share of exports + imports in GDP, a war dummy and transition index, in country i at time t). π_{it} again stands for our variable of interest, the inflation rate, and π^* for the threshold level of inflation. Z_{it} is a vector of endogenous covariates, and includes only inflation and investment in our final model. u_{it} is a composed error term, made up of two components: v_i - the group-level effects, which control for all unobserved influences on GDP growth that can be assumed constant over the sample period; and e_{it} - the observation-specific error term. The results are presented in Table 2.

[11] Some of these variables might be potentially endogenous but they are not our main variables of interest.

Table 2 Dynamic panel results

Dependent variable: GDP per capita growth / Independent variables	Endogenous	Equation 9	Equation 10	Equation 9 (reduced)	Equation 10 (reduced)
GDP growth (lag 1)	✓	-0.052 (0.354)	0.126 (0.230)	-0.067 (0.235)	0.186** (0.035)
GDP growth (lag 2)	✓	-0.242* (0.000)	-0.281* (0.000)	-0.195* (0.000)	-0.243* (0.000)
GDP growth (lag 3)	✓	-0.130* (0.000)		-0.099** (0.063)	
GDP gap (USA)		-0.814* (0.009)	-0.486 (0.209)		
Investment/GDP	✓	0.317* (0.000)	0.373* (0.000)	0.437* (0.000)	0.390* (0.000)
Govt. expenditure/GDP		-0.036 (0.677)	-0.034 (0.765)		
Population growth		-1.225* (0.000)	-1.819* (0.000)	-1.388* (0.000)	-1.864* (0.000)
Life expectancy		-0.624 (0.268)	-1.101* (0.003)		
Secondary school enrolment		0.070 (0.115)	0.0298 (0.528)		
(Exports + imports)/GDP		0.054** (0.031)	0.029*** (0.109)	0.086* (0.000)	0.0359* (0.001)
Transition index		3.064* (0.005)	3.703** (0.059)		4.365* (0.001)
War dummy		0.314 (0.748)	0.126 (0.839)		
Inflation	✓	-0.065* (0.000)		-0.066* (0.000)	
Ln (inflation)	✓		-0.836* (0.000)		-0.657* (0.002)
Squared inflation	✓	0.00005* (0.000)		0.00005* (0.000)	
Wald statistic $\chi^2_{(7)}$		34.67*	192.17*	20.10*	72.54*

*, ** and *** denote 1, 5 and 10 percent level of significance, respectively. Robust standard errors were used and year dummies included.

In addition to testing the assumption that the instruments are valid (*m1* and *m2* test and Sargan test), we use the Wald statistic in order to test the null hypothesis that independent variables are jointly zero. The Wald statistic in Table 2 (last row) indicates that the null hypothesis is rejected for our model, i.e. that the independent variables are jointly non-zero.

Our main goal here is not to develop an explanatory model of GDP growth, but rather to determine whether the inflation-growth relationship is non-linear and robust for a set of transition countries. Therefore, the main discussion will be confined to the effect of inflation variables on growth, and only passing remarks will be made in relation to other explanatory variables. In Table 2 the lags on the dependent variable are significant (except in some cases the first one), which suggests that there is on average a dynamic relationship. In other words, GDP growth is significantly affected by its past values. In both reduced equations (columns 5 and 6 in Table 2) the variables have the expected signs, except for inflation in (reduced) Equation 9, where we expected a positive sign on the level and a negative one on the squared term. However, were we to include only the squared term (not reported) it would be significant and negative. Population growth, investment and the fraction of exports and imports in GDP as well as a variable(s) on inflation are significant in both Equations. In addition, in Equation 10 the transition index is also highly significant. In the full model (columns 3 and 4 in Table 2) the GDP gap and war dummy have the wrong signs, but are insignificant. Secondary school enrolment, life expectancy and government expenditure are found to be insignificant.

If we compare the results in the static (Appendix II) and dynamic models we observe that there are some differences. Both the static and dynamic model find investment and population to be significant and of the expected signs. The main difference is that life expectancy and government expenditure were found to be significant and exports and imports in GDP insignificant in the static panel, whereas the opposite is true for the dynamic panel. The coefficients on the inflation variable(s) are in both cases of the same sign and significance, but differ somewhat with respect to size. In Equation 9 both the level and the square are significant, and have negative and positive sign, respectively. In Equation 10, the *ln(inflation)* is negative and significant. It should be noted that in different specifications (not reported) some variables become significant and some not, but *ln(inflation)* is consistently significant, of consistent size and of consistent sign (negative).

Next we analyse the non-linearities in the inflation-growth relationship in the dynamic model. Since the R^2 is not reported in the dynamic model we cannot use a dynamic version of Equation 5. We do, however, use Equation 11, i.e. we augment Equation 10 with a dummy that takes the value of 1 for all inflation rates above a certain threshold. We test thresholds 1-100, but report only those 1-25. The results are presented in Tables 3 and 4 with and without year dummies, respectively.

Table 3 The coefficient (γ_2) and *p*-value on the dummy variable $D_{threshold}$[12] in Equation 11, with year dummies[13]

D1	3.276 (0.121)	***D6***	0.667 (0.374)	***D11***	1.146 (0.184)	***D16***	-0.2932 (0.741)	***D21***	-0.862 (0.340)
D2	2.639* (0.010)	***D7***	0.427 (0.407)	***D12***	1.326 (0.158)	***D17***	-0.293 (0.741)	***D22***	-0.862 (0.340)
D3	2.368** (0.018)	***D8***	0.850 (0.156)	***D13***	1.188 (0.277)	***D18***	-0.293 (0.741)	***D23***	-0.921 (0.340)
D4	1.975** (0.045)	***D9***	0.528 (0.285)	***D14***	1.028 (0.431)	***D19***	-0.891 (0.295)	***D24***	0.184 (0.851)
D5	0.291 (0.722)	***D10***	1.029*** (0.066)	***D15***	1.119 (0.413)	***D20***	-1.385** (0.041)	***D25***	0.184 (0.851)

*, ** and *** denote 1, 5 and 10 percent level of significance, respectively. Robust standard errors were used.

Table 4 The coefficient (γ_2) and *p*-value on the dummy variable $D_{threshold}$ in Equation 11, without year dummies

D1	2.647 (0.183)	***D6***	0.675 (0.219)	***D11***	1.463** (0.017)	***D16***	-0.175 (0.905)	***D21***	-1.515 (0.265)
D2	1.542* (0.000)	***D7***	1.058** (0.034)	***D12***	1.816** (0.034)	***D17***	-0.175 (0.905)	***D22***	-1.515 (0.265)
D3	2.137** (0.033)	***D8***	1.478* (0.014)	***D13***	1.803** (0.052)	***D18***	-0.175 (0.905)	***D23***	-.933 (0.450)
D4	1.669 (0.134)	***D9***	1.473* (0.008)	***D14***	0.609 (0.711)	***D19***	-1.526 (0.282)	***D24***	0.457 (0.497)
D5	0.323 (0.718)	***D10***	1.295** (0.039)	***D15***	0.769 (0.665)	***D20***	-1.879 (0.159)	***D25***	0.457 (0.497)

*, ** and *** denote 1, 5 and 10 percent level of significance, respectively. Robust standard errors were used.

When the year dummies are included (Table 3) most (threshold) dummies are insignificant. This may be due to the fact that inflation in our sample is time varying in a systematic way, i.e. it declines over time (being the highest at the beginning of transition and declining gradually as a result of stabilisation programmes). The additional variable, the threshold dummy ($D_{threshold}$), divides the sample according to the inflation level. Since inflation changes systematically over time, this dummy reflects much the same influences as the year dummies, since it divides the sample into two time periods. Therefore, we believe that when the threshold dummy is included it is justifiable to exclude the year dummies. In both cases (year dummies included and not), the signs on the threshold dummies are relatively consistent, i.e. they are positive up to the threshold of 15 percent inflation, and mostly negative, albeit insignificant, afterwards. When year dummies are excluded, dummies below

[12] *D1* takes the value of 1 for all inflation rates higher than 1%, and 0 otherwise, *D2* takes the value of 1 for all inflation rates higher than 2%, and 0 otherwise, etc.

[13] The results presented in Tables 3 and 4 are those on dummies when included in the full model (see Column 4 of Table 2). However, were we to use the reduced model (Column 6 in Table 2) the results on dummies would very similar (in terms of significances and signs).

D14 are mostly significant. It should be noted, furthermore, that the dummies *D37-D100* (not reported) are significant and negative. The coefficient on *ln(inflation)* is in both cases (with and without the year dummies) constantly negative and significant, i.e. the inclusion of the dummies did not significantly influence this.

Overall the results of dynamic panel analysis suggest that the relationship between inflation and growth is non-linear. We cannot precisely establish the placement of the kink in this relationship. However, there is evidence that inflation rates below 14 percent may positively influence growth. For the rates above 37 percent the results suggest that inflation significantly and negatively influences growth. Between these two rates, 14 and 37 percent, there is evidence that inflation negatively influences growth, although this finding is not significant.

1.5. Concluding remarks

There are several conclusions we can draw from our results. Firstly, previous models that use static panel estimators for this sort of analysis may be misspecified. Namely, though our results indicated that investment and population growth are significant and of the expected signs, in both static and dynamic panel, the results differed (i.e. were the opposite) with respect to the significance of other included variables. The diagnostic tests in static panel pointed toward a problem of autocorrelation, which did not persevere in dynamic panel. In addition, lags of the dependent variable were in different settings significant in dynamic panel analysis, thus further supporting our view that this is a better model specification. Inflation, whether included as a level plus the squared term or the logarithm of inflation, was of the same sign and significance in both static and dynamic panel, which gives support to the robustness of our findings regarding this variable.

Furthermore, we find evidence of non-linearities in the inflation-growth relationship. This is confirmed through the significance of the *ln(inflation)* term, and, the squared inflation term (when included solely[14]). When analysing the placement of the kink in this relationship we find (in both static and dynamic panel analysis) that it is in a relatively low inflation range, although not as low as usually suggested for

[14] This was not reported.

developed economies. Namely, there is evidence that this inflexion point is somewhere between 8 and 13 percent inflation for the set of transition economies during this period. Furthermore, it is suggested that inflation rates above 18 to 20 percent are harmful for GDP growth. It is not possible to draw firm conclusions for inflation rates between these two levels.

It should be noted, though, that a limitation of our work is that we have a relatively short time span at hand in order to be able to observe the long-run effects. Therefore, were we not bounded by unavailability of the data it would be better to use more years and averages instead of annual observations.

The results, overall, do not warrant drawing any strong policy conclusions. They reveal more of a qualitative truth about non-linearities and corresponding thresholds rather than precise quantitative regularities. There is, on the whole, not enough evidence to be at all precise about the levels at which these pertain. However, we believe that it is a firm finding of this analysis that, in terms of the impact on economic growth, there is no evidence suggesting that inflation rates needed to be as low as 3 to 5 percent during the period of early and mid-transition.

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Appendix I: Definitions and sources of the variables

Table 5

Variable	Source	Definition
GDP per capita growth (annual %)	World Development Indicators, World Bank (2005)[15]	*Annual percentage growth rate of GDP per capita based on constant local currency. GDP per capita is gross domestic product divided by midyear population.*
GDP gap	World Development Indicators, World Bank (2005)	*GDP gap is calculated as the ratio of USA's and country j's GDP per capita in constant US dollars in each year.*
Life expectancy at birth, total (years)	World Development Indicators, World Bank (2005)	*Life expectancy at birth indicates the number of years a newborn infant would live if prevailing patterns of mortality at the time of its birth were to stay the same throughout its life.*
Secondary school enrolment rate (%)	Unicef TransMONEE database available at: http://www.unicef-icdc.org/resources/	*Total upper secondary education enrolments (gross rates calculated as percent of population aged 15-18). Since the data on this variable is missing for years 1991 and 1992 for Slovenia, for these years we put the same value as in 1993.*
Gross capital formation (% of GDP)	World Development Indicators, World Bank (2005)	*Gross capital formation (formerly gross domestic investment) consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories.*
Population growth (annual %)	World Development Indicators, World Bank (2005)	*Annual population growth rate. Population is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship - except for refugees not permanently settled in the country of asylum, who are generally considered part of the population of the country of origin.*
Exports + imports of goods and services (% of GDP)	World Development Indicators, World Bank (2005)	*Exports of goods and services represent the value of all goods and other market services provided to the rest of the world. Imports of goods and services represent the value of all goods and other market services received from the rest of the world. Variable is obtained as a sum of exports of goods and services (% of GDP) and imports of goods and services (% of GDP).*
General government expenditure (%GDP)	Unicef TransMONEE database available at: http://www.unicef-icdc.org/resources/	*General government expenditure for some countries includes state, municipalities and extra-budgetary funds (Bulgaria, Slovakia and Slovenia), and for Croatia includes net lending and represents consolidated central government.*
Transition index	EBRD Transition Report (various issues)	*Transition index is created as the un-weighted average of the following indices: Price Liberalisation, Foreign Exchange and Trade Liberalisation, Small-Scale Privatization, Large-Scale Privatization, Enterprise Reform, Competition Policy, Banking Sector Reform, Reform of Non-Banking Financial Institutions. Since the data on this variable is missing for years prior to 1994 we use the un-weighted average in 1994 and put this value in previous years. Namely, EBRD did not publish these indices before 1994, and given that they do not change drastically (but slowly increase over time), assuming that the index did not change much in the period 1991-1994 seems reasonable.*
War dummy		*Dummy variable that takes the value of 1 if a country was in war in certain year, and 0 otherwise. In our sample this variable takes the value of 1 for Croatia in years 1991-1995 and for Slovenia in 1991.*
Inflation rate, consumer prices (annual %)	World Development Indicators, World Bank (2005)	*Inflation as measured by the consumer price index reflects the annual percentage change in the cost to the average consumer of acquiring a fixed basket of goods and services that may be fixed or changed at specified intervals, such as yearly.*

[15] Available online at http://www.esds.ac.uk/international

Appendix II: The results from static panel analysis

The results for Equations 2 and 3 are given in Table 6 below.

Table 6 Static panel results

Dependent variable: GDP per capita growth / Independent variables	Equation 2	Equation 3	Equation 2 (reduced model)	Equation 3 (reduced model)
GDP gap (USA)	0.0364 (0.939)	-0.326 (0.464)		
Investment/GDP	0.358* (0.002)	0.299* (0.011)	0.356* 0.001	0.349* (0.001)
Govt. expenditure/GDP	-0.157* (0.041)	-0.124 (0.124)	-0.151* 0.028	-0.112** (0.109)
Population growth	-0.680** (0.086)	-0.812* (0.023)		-0.828* (0.024)
Life expectancy	-1.618* (0.019)	-1.997* (0.004)	-1.606* 0.007	-1.756* (0.005)
Secondary school enrolment	0.0593 (0.374)	0.0338 (0.599)		
(Exports + imports)/GDP	-0.0167 (0.573)	-0.006 (0.832)		
Transition index	-0.0147 (0.997)	0.411 (0.920)		
War dummy	-0.206 (0.917)	-0.240 (0.916)		
Inflation	-0.015* (0.039)		-0.009* 0.000	
Ln (inflation)		-1.456* (0.000)		-1.421* (0.000)
Squared inflation	5.31e-06 (0.286)			

* 5% significance; **10% significance (p-values in parenthesis); robust standard errors. In both of the above models we include year dummies in order to account for what is special in a certain year across all countries.

Diagnostic tests indicate that the model suffers from heteroscedasticity (which is why we use robust standard errors), and serial correlation.

In order to investigate the non-linearities in more depth we augment Equation 3 with a dummy that takes the value of 1 for inflation rates greater than a certain threshold level, and zero otherwise, i.e. we test Equation 4. We test for threshold levels from 1 to 25, with 1-percentage point increases. The results are presented in Table 7.

Table 7 The coefficient (γ_2) and *p*-value on the dummy variable $D_{threshold}$[16] in Equation 4, with year dummies

D1	4.221* 0.014	***D6***	-0.0084 0.993	***D11***	1.293 0.251	***D16***	-0.415 0.737	***D21***	-0.829 0.496
D2	3.647* 0.005	***D7***	-0.0737 0.932	***D12***	0.835 0.459	***D17***	-0.415 0.737	***D22***	-0.829 0.496
D3	3.276* 0.007	***D8***	0.166 0.846	***D13***	0.636 0.594	***D18***	-0.415 0.737	***D23***	-1.006 0.372
D4	2.076** 0.057	***D9***	-0.063 0.946	***D14***	0.767 0.528	***D19***	-1.017 0.442	***D24***	-0.434 0.732
D5	-0.0947 0.931	***D10***	0.496 0.640	***D15***	0.450 0.726	***D20***	-1.329 0.303	***D25***	-0.434 0.732

*, ** and *** denote 1, 5 and 10 percent level of significance, respectively. Robust standard errors were used.

It should be noted that all the dummies *D26-D44* are insignificant and negative, while dummies *D45-D100* are significant and negative. The results give some indication that inflation rates up to 4 percent significantly and positively influence growth. The rest of the dummies, however, are insignificant. Above 16 percent they are consistently negative, whereas up to 16 they are mostly positive, though some reversals of the sign are noticeable occasionally. We next repeat the procedure, this time excluding the year dummies (the rationale for this is given in section 1.4.3). The results are presented in Table 8.

Table 8 The coefficient (γ_2) and *p*-value on the dummy variable $D_{threshold}$ in Equation 4, without year dummies

D1	8.176* (0.000)	***D6***	2.369** (0.077)	***D11***	1.938 (0.227)	***D16***	-1.500 (0.357)	***D21***	-3.672* (0.025)
D2	6.114* (0.002)	***D7***	3.047* (0.009)	***D12***	1.537 (0.346)	***D17***	-1.500 (0.357)	***D22***	-3.672* (0.025)
D3	6.464* (0.000)	***D8***	2.612* (0.003)	***D13***	0.513 (0.754)	***D18***	-1.500 (0.357)	***D23***	-3.689* (0.021)
D4	4.396* (0.013)	***D9***	1.858 (0.153)	***D14***	-.244 (0.883)	***D19***	-2.594 (0.107)	***D24***	-3.538** (0.064)
D5	3.336* (0.048)	***D10***	1.688 (0.239)	***D15***	-.706 (0.676)	***D20***	-2.920** (0.066)	***D25***	-3.538** (0.064)

*, ** and *** denote 1, 5 and 10 percent level of significance, respectively. Robust standard errors were used.

Year dummies seem to have influenced the results notably. Now the dummies up to *D13* are consistently positive, while those above *D13* consistently negative.

As can be seen from Table 8, the dummies for thresholds 1-8 and above 20 are significant, while those for thresholds between 8 and 20 are insignificant. It should be noted that all the dummies *D26-D100* are significant and negative. The coefficient on *ln(inflation)* is in both cases (with and without the year dummies) constantly negative

[16] *D1* takes the value of 1 for all inflation rates higher than 1%, and 0 otherwise, *D2* takes the value of 1 for all inflation rates higher than 2%, and 0 otherwise, etc.

and significant, i.e. the inclusion of the dummies did not significantly influence this. One firm conclusion that we can draw from these results is that the average growth is significantly lower for inflation rates above 20 percent than for those lower than 20 percent. Correspondingly, the average growth is significantly higher for inflation rates below 8 percent than for those higher than 8 percent. It should be noted, in addition, that the coefficient on $ln(\pi)$ is continuously negative and significant.

Finally, we run a regression based on Equation 5, i.e. a spline regression. Following previous empirical work on the subject we estimate the kink in the inflation-growth relationship, i.e. the turning point between positive and negative impact of inflation, as that inflation rate that maximises the R^2 of the regression. The results are given in Tables 9 and 10, which present Equation 5 with and without the year dummies, respectively.

Table 9 R^2 of the model outlined in Equation 5 for different values of threshold inflation, full model, with year dummies

π^*	R^2	π^*	R^2	π^*	R^2	π^*	R^2
1	0.8384	**6**	0.8447	**11**	0.8456	**16**	0.8481
2	0.8397	**7**	0.8446	**12**	0.8465	**17**	0.8481
3	0.8426	**8**	0.8445	**13**	0.8470	**18**	0.8481
4	0.8447	**9**	0.8445	**14**	0.8476	**19**	0.8480
5	0.8450	**10**	0.8445	**15**	0.8479	**20**	0.8478

Note: R^2 is the within R^2, as this is used for fixed effects (FE) (StataCorp, 2005); π^* are a part of the expression $D_{threshold}\left[\ln(\pi_{it}) - \ln(\pi^*)\right]$ in Equation 5.

Table 10 R^2 of the model outlined in Equation 5 for different values of threshold inflation, full model, without year dummies

π^*	R^2	π^*	R^2	π^*	R^2	π^*	R^2
1	0.5685	**6**	0.6055	**11**	0.6289	**16**	0.6405
2	0.5740	**7**	0.6113	**12**	0.6333	**17**	0.6410
3	0.5857	**8**	0.6162	**13**	0.6364	**18**	0.6413
4	0.5942	**9**	0.6206	**14**	0.6385	**19**	0.6411
5	0.6006	**10**	0.6240	**15**	0.6397	**20**	0.6404

Note: R^2 is the within R^2, as this is used for fixed effects (FE) (StataCorp, 2005); π^* are a part of the expression $D_{threshold}\left[\ln(\pi_{it}) - \ln(\pi^*)\right]$ in Equation 5.

Taking the evidence as a whole, the turning point appears to be at an inflation rate of 18 percent (once again we give priority to the results without the year dummies, for the reasons stated above). It should also be noted that in both cases (with and without the year dummies) *ln(π)* is insignificant, while the coefficient on $D_{threshold}\left[(\ln \pi_{it}) - \ln(\pi^*)\right]$ is always negative and significant. Although insignificant, the sign on the *ln(π)* is positive at first, and negative later (after threshold of 24 percent inflation is reached[17]). This is not discussed in the literature that deals with similar issues. In Khan and Senhadji (2000), for example, *ln(π)* is also insignificant for the sample of developing countries and also when all countries (developed and developing) are included. In addition, Ghosh and Phillips (1998) note that $D_{threshold}\left[(\ln \pi_{it}) - \ln(\pi^*)\right]$ captures the non-linear relationship between inflation and growth, whereas *ln(π)* serves to capture the convexity of this relationship. Since our main goal is to analyse the non-linearities, we do not give much attention to *ln(π)*. What's more, the non-significance of this term may be due to a small sample effect, whereby the time-span at hand is too small to allow for both of these variables to exert individual effect.

[17] Without the year dummies.

Appendix III: The serial correlation tests for different number of lags

The results of serial correlation tests for each lag length are given in Table 11 below.

Table 11

Number of lags	**Number of observations**	***m1*** $\pi+\pi^2$	***m2*** $\pi+\pi^2$	***m1*** $ln(\pi)$	***m2*** $ln(\pi)$
6	48	0.0644***	0.1637	0.0567**	0.1166
5	56	0.0355**	0.3330	0.0285**	0.1080
4	64	0.0330**	0.5138	0.0230**	0.5701
3	72	0.0925***	0.2656	0.0533**	0.1396
2	80	0.0342**	0.0213**	0.0141*	0.1438
1	88	0.0229**	0.0647***	0.0390**	0.0227**

*, ** and *** denote 1, 5 and 10 percent level of significance, respectively. Robust standard errors were used. $\pi+\pi^2$ and $ln(\pi)$ denote the way in which inflation was included in the regression.

In addition, the Sargan test (in each case) indicates that we should not reject the over-identifying restrictions. However, the *p*-value is 1, indicating that this test is probably weak because of the presence of a lot of instruments. As discussed in Stata discussion forum, the problem might be too large a number of degrees of freedom (http://www.stata.com/statalist/archive/2005-04/msg00436.html). This issue is, however, not discussed in the literature. Most authors just take the Sargan test (with *p*-value equal to 1) as indicating that the instruments are valid. Beugelsdijk and Eijffinger (2005), for example, note that this has no serious implications for the estimation result.