INFLATION AND ECONOMIC GROWTH: THE NON-LINEAR RELATIONSHIP. EVIDENCE FROM CIS COUNTRIES.

by

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Abstract

INFLATION AND ECONOMIC GROWTH: THE NON-LINEAR RELATIONSHIP. EVIDENCE FROM CIS COUNTRIES.

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In this paper we investigate the growth-inflation interaction for CIS countries for the period of 2001-2008. We found that this relation is strictly concave with some threshold level of inflation, which is in line with the previous empirical studies based on earlier sample periods. Inflation threshold level is estimated using a non-linear least squares technique, and inference is made applying a bootstrap approach. The main findings are that when inflation level is higher than 8 % economic growth is slowed down, otherwise, it is promoted. The non-linear growth-inflation interaction is quite robust to the estimation method and specification. Our findings can be used by policy makers as a guide for inflation targeting.

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GLOSSARY

IMF – International Monetary Fund.

WEO – World Economic Outlook.

The Mundell-Tobin effect – is that nominal interest rates would rise less than one-for-one with inflation because in response to inflation, the public would hold less in money balances and more in other assets, and this reaction would drive interest rates down.

Walrasian way – the total wealth in the economy equals the total value of all assets, and the total value of any individual's asset holdings must equal his or her total wealth. Thus, if the market for every asset but one clears, the market for the remaining asset must clear as well.

The "shoe leather costs" of inflation are associated with the costs of additional efforts that people make as a result of reduction in their holding of cash.

The "menu costs" of inflation are attributed to the physical costs of changing price tags during inflation/deflation.

Bootstrapping – is a random repeated resampling from an original sample using each bootstrapped sample to compute a statistic. The resulting empirical distribution of the statistic is then examined and interpreted as an approximation to the true sampling distribution.

Chapter 1

INTRODUCTION

High and stable output growth and low inflation are the two main goals of macroeconomic policy. Hence it is important to investigate the existence and nature of the link between these two variables. Numerous theoretical and empirical studies, including Christoffersen and Doyle (1998), Sarrel (1995) and Khan and Senhadji (2001), explored this issue and reached several conclusions. In particular, medium and high inflation hampers economic growth due to the adverse impact on efficient distribution of resources by changing relative prices (Fisher, 1993). However, low inflation levels promote economic growth by making prices and wages more flexible (Lucas, 1973). If high inflation is detrimental for the economy and low inflation is beneficial, then it is natural to ask what the optimal level of inflation for an economy is. This paper is devoted to the analysis of the non-linear inflation-growth relationship for several CIS countries over the period from 2001 till 2008.

Our work is motivated by several applied questions. The first one is to estimate the threshold inflation level for the set of transitional countries with comparable economic performance, namely Ukraine, Belarus, Russia, Georgia, Kazakhstan and Moldova for the selected time period. Our study is different from other studies that were conducted for transitional countries (including CIS), including Christoffersen and Doyle (1998), Ghosh (1997) and Mervar (2002), in several respects. First, we focus on a more recent time period, frequently referred to as the period of economic development, while other studies analyze the earlier period of transition (1991-1998). The issue of structural break in the data plays a very important role for the choice of our time frame. Indeed, the period of 1991-

1998 is characterized by the transition process linked to collapse of the Soviet Union, reorganization of economies from planned to market, Russian default, introduction of hryvna in Ukraine, privatization process, while the period of 2001-2008 is illustrated by active economic advancements of CIS countries. The presence of structural break is confirmed econometrically, as will be discussed in the results section. Second, we use a different set of explanatory variables in our model. The papers listed above explained the dynamics of growth employing such regressors as transition index, fiscal deficit, war dummy and structural reforms. However, this set of regressors can be used to explain economic growth only during a transition period, but not during a period of economic development.

The second and main motive for this research is directly related to the usefulness of our results for policy makers in the selected CIS countries and in particular in Ukraine. If inflation is indeed harmful for economic growth when it reaches a particular threshold level, then knowing this level as well as potential losses of output growth in the short run and in the long run is crucial for formulating macroeconomic policies.

We will analyze the non-linear interaction between inflation and growth using a non-linear least squares approach, which allows estimating the threshold level of inflation and formally testing its significance.

The rest of the study is organized as follows. Section 2 presents the literature review, briefly discussing existing theoretical and empirical evidence about the nature of association between inflation and growth. Section 3 outlines the methodology. Section 4 presents data description. Section 5 provides estimation results. Section 6 concludes.

Chapter 2

LITERATURE REVIEW

Our discussion of the existing literature starts with an overview of most relevant theoretical studies, which investigate the determinants of economic growth. Then, we will discuss related empirical studies and their findings concerning the inflation-growth relationship.

2.1. Theoretical studies

Numerous theoretical studies investigated the association between inflation and growth. They can be divided into two groups. The first one contains inflation among dependent variables. For instance, the models by Clarida, Gali and Gertler (1999) and Gali and Gertler (2007) are given by a system of three blocks of equations, describing aggregate demand, aggregate supply and monetary policy. These models are based on real business cycle theory, extended with monopolistic competition and nominal price rigidities, and its main difference from the traditional Keynesian model, according to the authors, is that "all coefficients of the dynamic system describing the equilibrium … are explicitly derived from the underlying theory". In this framework inflation influences real output through real interest rate channel (Fisher equation) in the demand block and affects growth through expectation in prices in the supply part.

A different group of growth models does not explicitly include inflation in their framework. This group contains, among other models, the endogenous growth model for a small open economy developed by Minford and Meenagh (2006) and the endogenous growth model with public goods proposed by Barro (1998). These models are derived from an intertemporal utility function and perfect competitive firm sector with some production function. These frameworks differ from each other by some minor assumptions, having at the same time the common result – they determine a steady-state growth rate endogenously.

Therefore, while the first group of models explicitly includes inflation as a factor of economic growth, the second group does not. However, the policy makers are particularly interested in first group of the models, hence we will concentrate on it.

A common problem of many theoretical models is that the resulting systems of equations, which are obtained from the underlined assumptions, are highly dimensional and non-linear, which makes it hard to solve them in closed form without additional assumptions or some transformations. For instance, the basic equations for aggregate demand, aggregate supply and policy function form the three-dimensional system, which can be solved in general form only for few non-linear specifications. One of the most popular methods is linearization which allows simplifying considerably the initial system and obtaining a solution in a feasible way. However, after this transformation all non-linear effects inside the model disappear.

At the same time several theoretical studies argued that depending on its level, inflation can either promote or harm economic growth. For instance, Lucas (1973) explained that low inflation allows overcoming rigidity of nominal prices and wages. In addition, inflation can realign relative prices in response to structural changes in production during fast modernization periods. In this case inflation is quite important for economic growth. On the other hand, high inflation creates "shoe leather costs"[1] and "menu costs"[2], discourages long-term investments and distorts a tax system (Romer, 2001).

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[1] The "shoe leather costs" of inflation are associated with additional efforts that people make to reduce their holding of cash (Romer, 2001).

[2] The "menu costs" of inflation arise from a necessity to change prices more often (Romer, 2001).

In addition, let's consider different types of channels through which inflation influences economic growth. Several recent studies discussed interesting features of non-linearity in growth-inflation association. For instance, Huybens and Smith (1998, 1999) stated that even predictable inflation may harm economic growth by impeding financial sector allocating resources effectively.

Other theoretical studies focused on the question of how expected inflation impacts the financial system. For example Choi et al. (1996) and Azariadas and Smith (1996) showed that only when inflation exceeds some critical level then it hampers economic growth, otherwise inflation has a favorable impact on growth. The authors explained this phenomenon using the so-called "adverse selection mechanism" in credit market. The brief idea is the following. There are two types of agents in the financial system: "natural borrowers" and "natural lenders". The latter have enough funds to invest but do not have access to projects, while the former have many projects but insufficient funds to undertake them. The financial system plays important role in order to ensure channel from lenders to borrowers. If inflation increases then it reduces real rate of return on assets. In such circumstance more people want to be borrowers rather than savers. At the same time new borrowers have higher default risk because they were not initially interested in getting credit, creating adverse selection problem for investors, which is called credit market rationing. However investors will not be interested in providing loans for new borrowers, causing fewer loans in the financial market. As a result, a current increase in inflation rate leads to lower economic growth in the future.

The opposite situation takes place when inflation rate is reasonable low. In this case credit market will operate in a Walrasian way[3] and "adverse selection mechanism" will be absent. Then model will generate Mundell-Tobin Tobin

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[3] The total wealth in the economy equals the total value of all assets, and the total value of any individual's asset holdings must equal his or her total wealth. Thus, if the market for every asset but one clears, the market for the remaining asset must clear as well (Romer, 2001).

effect [4] (Choi et al., 1996, Azariadas and Smith, 1996), which means that increase of inflation rate will cause substitution between resources that is agents will prefer to replace cash with human or physical capital. . Therefore, economic growth will be promoted (Choi et al., 1996). However, if inflation becomes higher than the threshold level, then credit rationing in the financial market appears harming growth.

Hence, there are theoretical arguments for a positive inflation-growth relationship for low levels of inflation and a negative one for high levels. Consequently, an inflation-growth relationship is non-linear and there exists some inflection point which changes impact from favorable to adverse. As is discussed in the next subsection, different econometric approaches can be used to estimate this relationship.

2.2. Empirical studies

Existing empirical studies, just as theoretical models, reflect different views on the relationship between inflation and output growth. Their findings differ depending on data periods and countries, suggesting that the association between inflation and growth is not stable. Still, economists now widely accept the existence of a non-linear and concave relationship between these two variables.

The traditional point of view does not consider inflation as an important factor in growth equation. This is reflected in the studies by Dorrance (1963) and Johanson (1967), who did not find any significance impact of inflation on growth in the 1960s.

Nevertheless, the traditional point of view changed when high and chronic inflation was present in many countries in the 1970s. As a result, different researchers showed that inflation has a negative impact on output growth. Fisher

[4] The Mundell-Tobin effect is that nominal interest rates would rise less than one-for-one with inflation because in response to inflation, the public would hold less in money balances and more in other assets, and would drive interest rates down (Online Economics Glossary).

(1993) and de Gregorio (1992, 1994) have investigated the link between inflation and growth in time-series, cross section and panel data sets for a large numbers of countries. The main result of these works is that there is a negative impact of inflation on growth. Fisher (1993) argued that inflation hampers the efficient allocation of resources due to harmful changes of relative prices. At the same time relative prices appear to be one of the most important channels in the process of efficient decision-making. .

Barro (1997) used a panel data for 100 countries over the period 1960-1990 and estimated growth regression using Instrumental Variables (IV) technique. He obtained clear evidence that a negative relationship exists only when high inflation data was included in the sample. But there is not enough information to argue that the same conclusion holds for lower inflation rate. Barro has estimated that 10% of inflation reduces real GDP per capita by 0.2% per year. Despite the fact that adverse impact of inflation is quite small in percentage expression, the long-term effects on standards of living in nominal values may be considerable.

Furthermore, some other studies have shown that the link between inflation and growth is significant only for certain levels of inflation. For instance, Bruno and Easterly (1995) studied inflation-growth relationship for 26 countries over the 1961- 1992 period. They found a negative relationship between inflation and growth when level of inflation exceeds some threshold. At the same time they showed that impact of low and moderate inflation on growth is quite ambiguous. They argued that in this case inflation and growth are influenced jointly by different demand and supply shocks thus no stable pattern exists.

Recently, numerous empirical studies found that inflation-growth interaction is non-linear and concave. In particular, Fischer (1993) was the first who investigated this non-linear relationship. He used cross-sectional data covering 93 countries. The author used the growth accounting framework in order to detect the channels through inflation impacts on growth. As a result, he found that inflation influences growth by decreasing productivity growth and investment. Moreover, the author showed that the effect of inflation is non-linear with breaks at 15 and 40 percent

Sarrel (1995) found the evidence of structural break in interaction between inflation and growth. He used fixed effect technique to deal with panel data sample covering 87 countries over 21 years (1970-1990). The main result is that the estimated threshold level equals to 8 percent, exceeding which leads to negative, powerful and robust impact of inflation on growth.

Khan and Senhadji (2001) investigated the inflation-growth interaction for both developing and developed countries applying the technique of conditional least squares. They used the panel data set on 140 countries (both industrial and developing) over the period 1960-1998. The authors employed the method of non-linear least squares to deal with non-linearity and non-differentiability of the inflation threshold level in growth regression. As a result, they obtained estimates of the threshold levels of 1-3% for developed and 11-12% for developing countries, which turned out to be very precise. The authors mentioned that the total negative effect of inflation may be underestimated due to the fact that they controlled investment and employment, so the main channel of impact is productivity. Nevertheless, this study asserted the idea that low inflation is a good thing for the economy because it has favorable influence on growth performance.

Christoffersen and Doyle (1998) investigated the nonlinear relationship between inflation and growth for 22 transitional countries over the time period from 1990 to 1997. They used Sarrel's (1995) approach to modeling the kinked interaction between inflation level and economic growth. As a result, the authors found that threshold level is 13%. They did not find any evidences that output will be rapidly increased by high inflation for countries that keep inflation below this threshold level. This result showed that policy makers should keep inflation at some specific threshold level where the favorable impact of inflation on growth performance is the highest.

Chapter 3

METHODOLOGY

3.1 Model

We start the quantitative analysis of inflation-growth relation using the following growth regression, which appeared as a basic step in the empirical works of Barro (1991) and Sala-i-Martin (1997):

$$d\log Y = X\beta + \varepsilon \ , \qquad (1)$$

where Y is real output, X is the matrix of explanatory variables, β is the matrix of coefficients and ε is the error term.

A common problem of numerous empirical studies based on endogenous, neoclassical and neo-Keynesian growth theories is that they do not produce an exact list of explanatory variables. For instance, all theories agree that the level of technology is an important determinant of growth, but there is no single way to measure this variable. Sala-i-Martin (1997) mentioned such potential candidates on the role of "level of technology" as market distortions, distortionary taxes, maintenance of property rights and degree of monopoly. The same is true for such growth determinants as "human capital" or "efficient government".

We choose explanatory variables using two different approaches. The first is the macroeconomic theoretical framework. In particular, neoclassical growth model developed by Cass (1965) and Koopmans (1965) insists on including such variables as investment and population growth in the growth regression. This model predicts that an increase in investment together with a decrease in population growth rate promotes economic growth. In addition, international trade theory proposes to include openness of the economy in the growth regression. For example, a model of monopolistic competition with heterogeneous firms developed by Melitz et al. (2003) predicts that greater trade openness of the economy leads to the higher economic growth. In particular, the country can stimulate exports due to higher efficiency of domestic firms-exporters, which leads to higher growth. At the same time, if the country removes trade barriers then more foreign firms will import stimulating competition on the domestic market. Hence, less productive domestic firms will have to leave the market, because only the most productive firms will be exporters. As a result growth will be promoted.

The second approach is based on the empirical growth literature, especially on works of Levine and Renelt (1992) and Sala-i-Martin (1997). These authors argued that despite the existence of a large set of explanatory regressors that can be potentially used in the growth regression only few of them may be significant. Moreover, some variables may be significant with one set of regressors, but become insignificant with others. Sala-i-Martin (1997), Levine and Renelt (1992) proposed to check robust repressors econometrically.

In particular, Levine and Renelt (1992) applied extreme bounds test to detect robust associations among growth and different regressors found in the empirical literature. However, this approach ended up with the conclusion that "nothing can be learned from this empirical growth literature because no variables are robustly correlated with growth". That is why some researchers noticed that extreme bounds test is too strong, hence very few variables can pass it (Sala-i-Martin, 1997).

Sala-i-Martin (1997) used a different methodology to choose regressors: he analyzed the entire distribution of the estimated coefficients. He assigned some confidence level to each variable first assuming that the distribution of estimates across models is normal and then relaxing this assumption. As a result, his approach allowed specifying the set of explanatory variables in the growth regression, which contains already mentioned variables: investment, population growth, inflation rate, openness of the economy and growth rate in terms of trade. Sala-i-Martin (1997) argued that inflation may be included in growth regression only in a non-linear way. Finally, we should bear in mind that not all variables that passed Sala-i-Martin's test may be applied in growth regression (1) for our data sample. In particular, such regressors as fraction of Confucius, revolutions and coups, fraction of Buddhist, fraction of catholic, absolute latitude, war dummy can not be used because of low variability (can be treated as country specific fixed effect) and lack of theoretical justification.

Therefore, in our empirical analysis we will use the following: investment, population growth, inflation rate and openness of the economy. This choice of variables is consistent with the choice made by other researchers, in particular Khan and Senhadji (2001) and Drukker et al. (2005).

Before discussing the estimation procedure of our growth regression (1), we should point out to one important issue appearing in all macroeconomics studies – the problem of endogeneity. This problem arises due to the macroeconomic nature of our independent and dependent variables, suggesting that all these variables are determined jointly by the fundamentals. Then, rather than using single regression analysis, we might apply vector autoregressive technique in order to mitigate this endogeneity problem. However, there are several arguments justifying our approach. In particular, Cukierinan et. al. (1992), found that causality is more likely to run from inflation to growth and not vice versa, using the independence of central bank as instrument for inflation rate. Moreover, Fisher (1993), Gillman and Harris (2004), Li (2006) empirically detected that causation runs only from inflation to economic growth, applying appropriate econometrics tools for testing endogeneity of regressors.

In addition, several authors (Gillman and Nakov, 2004, Mubarik, 2005) showed that these regressors are exogenous using a Granger causality test. Even though this procedure does not test for strict exogeneity and just shows whether one variable moves before another, this is a conventional exogeneity test for this type of models. As we will demonstrate in the results section, this test illustrates that growth does not Granger cause all other variables.

3.2 Estimation

The general form of our growth regression with threshold is:

$$y_{it} = \beta_0 + \mu_i + \mu_t + \beta_1' \cdot x_{i,t} I(\pi_{i,t} \le k) + \beta_2' \cdot x_{i,t} I(\pi_{i,t} > k) + \varepsilon_{it}, \tag{2}$$

where y_{it} is the dependent variable, X is matrix of explanatory variables, $\beta = \left(\beta_1', \beta_2'\right)'$ are the corresponding coefficients, I is the indicator function and $\varepsilon_{i,t}$ are the residuals. The exact specification of the model is similar to that presented by Khan and Senhadji (2001):

$$\begin{aligned} growth_{it} &= \beta_0 + \mu_i + \mu_t + \beta_1 \cdot (1 - D_{it}) \cdot (\pi_{it} - k) + \beta_2 \cdot D_{it} \cdot (\pi_{it} - k) + \\ &+ \beta_3 \cdot N_{it} + \beta_4 \cdot I_{it} + \beta_5 \cdot Open_{it} + u_{it} \end{aligned} \tag{3}$$

In this model $growth_{it}$ is an economic growth rate, π_{it} is inflation rate, k is the threshold level of inflation, N_{it} is population growth rate, I_{it} is investment as share of GDP, $Open_{it}$ is openness of the economy, *t* and *i* are time-series and cross-sectional indexes, u_{it} is error term. D_{it} is a dummy variable, which is defined in the following way:

$$D_{it} = \begin{cases} 1, if \ \pi_{it} > k \\ 0, if \ \pi_{it} \le k \end{cases}$$

Sarel (1996) suggested that it is better to use the log of inflation level rather then level of inflation due to the several reasons. Firstly, this transformation eliminates strong asymmetry in initial distribution of inflation (see *Figures 1 and 2*). Secondly, log transformation provides the best fit among non-linear models (Ghosh and Phillips, 1998).

In addition, Khan and Senhadji (2001) proposed to use the following transformation in order to deal with negative values of inflation:

$$f(\pi_{it}) = (\pi_{it}) I(\pi_{it} < 0) + \left(\log(\pi_{it}) - \log(k)\right) I(\pi_{it} \geq 0), \qquad (4)$$

where function $f(\pi_{it})$ is continuous at point k, continuously differentiable and can deal with both positive and negative values of inflation.. Hence, $f(\pi_{it})$ is a hybrid function of inflation, which consists on two parts: linear function when inflation level is less then zero and logarithmic function when inflation level is greater or equal to zero. Moreover, logarithmic transformation suggests that marginal effects of β_1 and β_2 in regression (3) will depend on initial value of inflation.

If the value of the threshold level is known, then the model (3) can be estimated by OLS or fixed effect. On the other hand, if the threshold level is unknown we should estimate it together with other parameters of the model. As Khan and Senhadji (2001) noticed, our threshold *k* enters in the growth equation in a no-differentiable and non-linear way. Therefore, conventional gradient search techniques will not work. For this reason we apply algorithm developed by Chan (1998) and Hansen (1999, 2000) – conditional least squares procedure.

The main idea of this method is to minimize the sum of squared residuals with parameter *k*. Suppose $S_1(k)$ is a residual sum of squares then:

$$k^* = \arg\min_k (S_1(k)) \qquad (5)$$

In general, the optimization search of optimal threshold should include the whole range of inflation level making computation issue very intensive. However, Hansen (1999) suggested restricting the initial search to a smaller set of values using specific quantiles, for instance integer valued. Moreover, Hansen (2000) proposed to search optimal value only in the region where we do expect the threshold should be. In other words, we will apply graphical analysis before optimizing residual sum of squares and narrow does not the range of values for inflation threshold.

3.3 Inference

In order to test the significance of the threshold, Hansen (1999) recommended computing the likelihood ratio test under the null hypothesis of no threshold:

$$F_1 = \frac{S_0 - S_1(k^*)}{\hat{\sigma}^2} \qquad , \qquad (6)$$

where S_0 and $S_1(k^*)$ are the sums of squared residuals under the null and alternative hypothesis and $\hat{\sigma}^2$ is variance of the residuals under the alternative hypothesis. We may rewrite this statistics in terms of squared sum of residuals for our growth regression (3) without and with threshold.

Hansen (1999) noted that "under null hypothesis threshold level *k* is not identified, so classical tests, such as t-test, have non-standard distribution…The asymptotic distribution of F_1 is non-standard, and strictly dominates the χ_k^2 distribution. Unfortunately, it appears to depend in general upon moments of the sample and thus critical values cannot be tabulated". In order to solve this problem Hansen (1996, 1999 and 2000) suggested to use a bootstrap technique to stimulate the likelihood ratio (F_1). This technique also allows to construct p-values which are asymptotically valid (these procedure achieves the first-order asymptotic distribution (Hansen, 1996). Hence we will use the following scheme:

1) fix regressors and threshold level
2) take the regression residuals $(\varepsilon_{11},...,\varepsilon_{nT})$ (*nT* values) and group them by country, that is the following residuals $(\varepsilon_{i1},...,\varepsilon_{iT})$ will form one particular group.
3) draw (with replacement) a sample size *n* of *T*-tuple vectors from original distribution
4) calculate dependent variable as fitted value plus residuals
5) estimate model under both null and alternative hypothesis

6) calculate the stimulated value of likelihood ratio
7) repeat given procedure a large number of times (we repeat it 1,000 times)
8) compute the percentage of draws for which stimulated likelihood ratio is greater than initial one (for whole panel sample)

This procedure allows to compute asymptotic p-value for likelihood ratio (6) under null hypothesis (threshold value is insignificant). The null hypothesis will be rejected if p-value is less than some critical value.

To construct confidence interval for the threshold level we will use the concept of "no-rejection region". As Chan (1993) and Hansen (1999) have proved, in the case of threshold effect ($\beta_1 \neq \beta_2$) our estimated threshold ($\hat{k}$) is consistent with "true value of *k*" (k_0) and its distribution is highly non-standard. Moreover, Hansen (1999) argued that the best way to construct a confidence interval for the threshold *k* is by forming the "no-rejection region" using the likelihood ration statistic. Hence, to test the hypothesis that $k = k_0$ we should calculate the likelihood ratio and compare it with the critical value:

$$LR(k) = \frac{S(k) - S_1(\hat{k})}{\hat{\sigma}^2}, \tag{7}$$

$$c(\alpha) = -2\log(1 - \sqrt{1-\alpha}), \tag{8}$$

where $LR(k)$ is a likelihood ratio function of threshold level, $S(k)$ is residual sum of squares for given threshold *k*, $S_1(\hat{k})$ is sum of residuals' squares for threshold $\hat{k}$, which can be computed in (5), $\hat{\sigma}^2$ is the variance of the residuals for threshold $\hat{k}$, $c(\alpha)$ is a critical value, and α is the significance level.

In order to construct a "no-rejection region" we will find the set of *k*, which satisfies the following inequality:

$$LR(k) \leq c(\alpha), \tag{9}$$

where *LR(k)* and $c(\alpha)$ are defined in (7) and (8) correspondingly. The most convenient way to find the "no-rejection region" is by drawing *LR(k)* function and intersect it by line $c(\alpha)$.

Chapter 4

DATA DESCRIPTION

The data come from World Economic Outlook (WEO), World Bank Quick Query selected from World Development Indicators. Our database consists of the following variables

Growth of real GDP is measured as annual percentage growth rate of GDP at market prices based on constant national currency (Aggregates are based on constant 2000 U.S. dollars);

Inflation is computed as annual percent change of average consumer price index. Data for inflation are averages for the year, not end-of-period data (The index is based on 2000=100);

Growth rate of population is measured as annual population growth rate. Population measure is based on the de facto definition of population, which counts all residents regardless of legal status or citizenship.

Investment is measured as gross capital formation (formerly gross domestic investment) and consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories.

Openness of the economy is measured as share of export plus import in GDP.

We use annual observations starting from 2001 till 2008 for each country (Belarus, Georgia, Kazakhstan, Moldova, Russia and Ukraine) to make our data set balanced. In general, panel data requires more countries and more time periods, but we have only few years of stable economic development for CIS countries. We will show in the estimation results section that additionally including five countries (Armenia , Azerbaijan, Kyrgyz Republic, Tajikistan, Uzbekistan) will change the inflation-growth association dramatically mainly due to the heterogeneity among these countries.

Table 1. Descriptive statistics

Variable	Observations	Mean	Std, Dev,	Min	Max
Growth rate of output	48	7.59	2.44	2.70	13.50
Growth rate of population	48	-0.55	0.61	-1.40	1.10
Investment as share of GDP	48	27.83	5.65	20.10	38.90
Inflation	48	12.35	9.83	0.80	61.10
Logarithm of inflation	48	2.31	0.65	-0.30	4.10
Openness of the economy	48	100.36	28.66	52	143.10

Table 1 describes our main data sample. The average value of growth rate of output is 7.6%, which is higher than in some developed countries, in particular in European Union (2.3%). Growth rate of population has the average value of -0.6%, suggesting that the population is still reducing in the CIS countries even during the period of economic development. Investment has average value 27.8%, which is slightly greater than in European Union (20.5%). Openness of the economy has average value 100.4%, which indicates that countries are very export and import oriented. Logarithm of inflation has average value 2.3%, inflation has mean 12.3%, which is higher than in European Union (2.5%). In addition, we can mention that transformation (4) made distribution of logarithm of inflation much narrow than inflation – mean (2.3% and 12.3%), minimum value (-0.3% and 0.8%) and maximum value (4.1% and 61%). Furthermore, this transformation gets rid of asymmetry in inflation distribution (see Figures 1 and 2).

Figure 1. Distribution of inflation

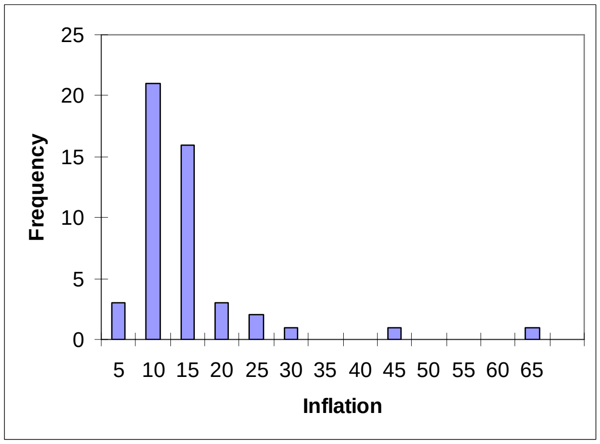
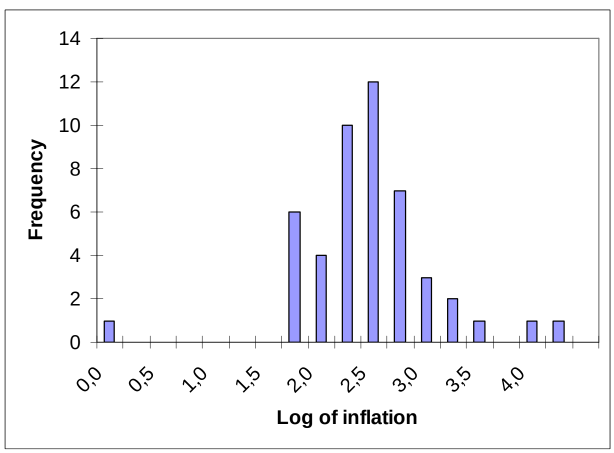
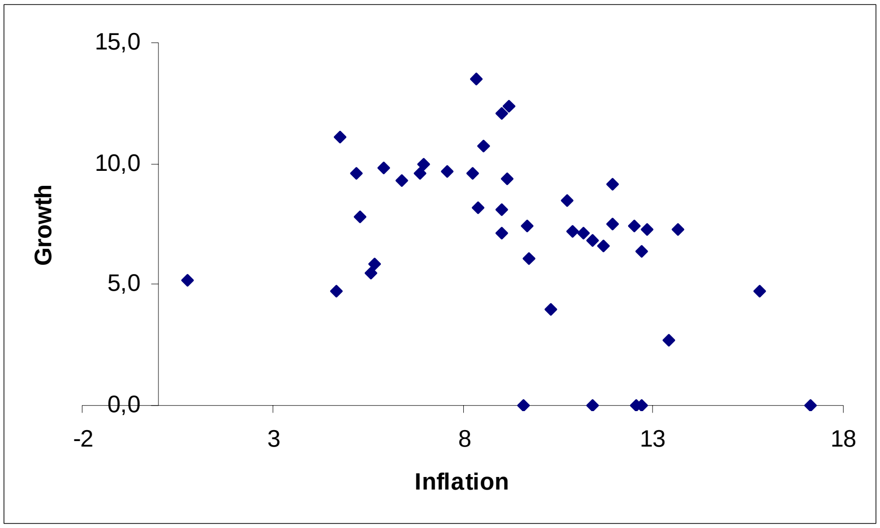


Figure 2. Distribution of logarithm of inflation



The relation between output growth and inflation levels in our sample is depicted on *Figure 3*, which suggests that this relation is indeed non-linear. Output growth seems first to increase with inflation and then decrease after inflation reaches a certain level. Visual analysis suggests that the inflection point is somewhere around 8%-10%.

Figure 3. Growth and inflation



We apply Granger test in order to test the exogeneity assumption of our regressors. *Table 2* shows that we can not reject the null hypothesis, which means that growth does not Granger cause logarithm of inflation, growth rate of population, investment and openness of the economy.

Table 2. Pairwise Granger Causality Test

Null hypothesis: variable does not Granger cause the growth	p-value
Log of inflation	0.51
Growth rate of population	0.30
Investment share of GDP	0.53
Openness of the economy	0.52

Therefore, our model, which assumes that the direction of causality from inflation and other regressors to economic growth is uni-directed, seems to be appropriate.

C h a p t e r   5

ESTIMATION RESULTS

To formally estimate the threshold level of inflation, we will employ a conditional least square technique. The idea is to minimize the sum of squared residuals in the growth regression (3) conditional on a particular threshold level, repeating the procedure for different threshold values from 3% till 15% with a step of 0.25%. *Figure 4* shows how these sums of squared residuals change as inflation threshold rate increases. The minimum is reached at the point of 7.75% when the OLS model is used, and 8.25% when the fixed-effects model is estimated (*Table 3*).

Figure 4. Sum of squared residuals

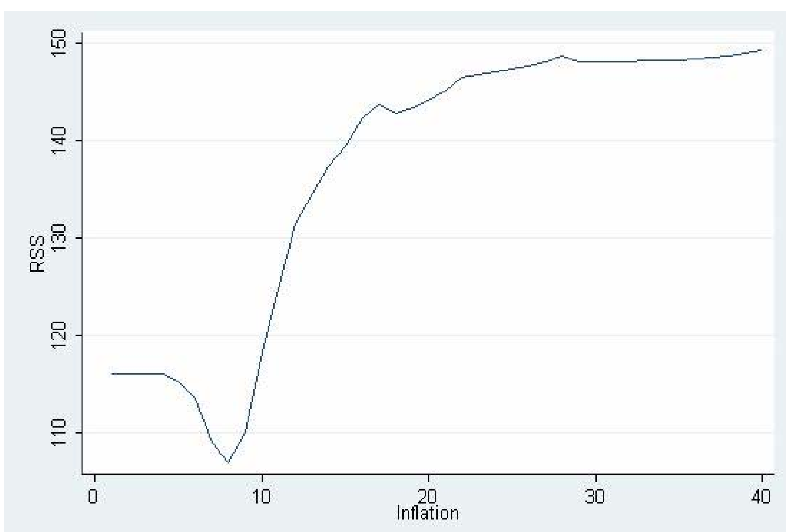


Table 3. Estimation of threshold level

Estimation method	Threshold	RSS
Fixed effect	8.25%	106.77
OLS	7.75%	192.25

Post-estimation test, namely F test, suggests that fixed effect approach is preferred than pooled OLS (see appendix). Hence, we will take it into account for calculating p-value using bootstrapping procedure and forming "no-rejection region". Therefore, the results of both approaches indicate that the inflation threshold level is around 8%.

We tested whether our threshold level significant or not using the bootstrap procedure with 1,000 replications. Computed p-value is shown in *Table 4*. We found that the test for a threshold level is highly significant with a bootstrap p-value of 0 for the chosen precision level. Therefore, there is strong evidence for existence of threshold effect in growth regression (3).

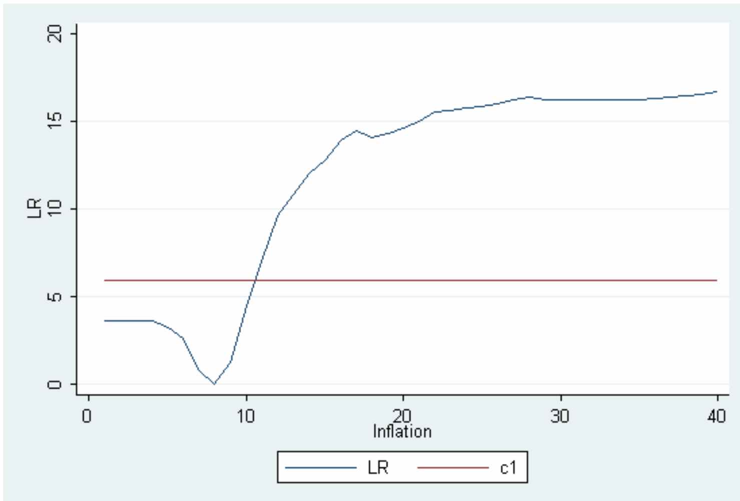
Table 4. Test for effect of threshold

F1	21.20
P-value	0.00
1% critical value	16.08
5% critical value	11.73
10% critical value	16.08

The next question is how precise our estimates are. This question is particularly important in light of the fact that previous studies ended up with a much dispersed range for threshold starting from 2.5 (Ghosh and Phillips, 1998) and finishing with 40% (Bruno and Easterly, 1995).

To answer this question, we compute critical values and plot a "no-rejection region" using relations (7) and (8). Next, we calculated 90% confidence interval (see *Figure 5*), which is [0, 10.5].

Figure 5. Confidence interval



Our computed threshold level is statistically different from previous studies (Khan and Senhadji (2001) obtained 11%; Christoffersen and Doyle (1998) came up with 13%). The asymptotic confidence interval is not so tight as in previous works, in particular Khan and Senhadji (2001) found that confidence interval for developing countries is [10.66, 11.34]. In order to make confidence interval tighter we should include more time periods, consequently we might reduce $\hat{\sigma}^2$ and increase $LR(k)$ in (7). However, this suggestion will not work in our case, due to the presence of structural break. Non linear least squared approach assumes that there is no structural break in the data, hence such stages as computing of threshold level, bootstrapping procedure and forming a confidence interval will be technically very complex if we allow non-stability. As we argued in literature review section there were transition period in 1991-1998 and period of economic development in 2001-2008. Hence we might expect that structural break happened in 1999-2000. In addition we use econometric techniques, namely Chow test to verify whether the structural break presences or not. Results of this test are presented in *Tables 5*. We concluded that structural break was present in 1999-2000 is significant with p-values equals 1%.

Table 5. Chow test

F-statistics	
F-statistics	4.52
1% Critical value	2.96
5% Critical value	2.17
10% Critical value	1.82

Also we can apply another econometric technique in order to test structural break issue, specifically Elliott-Müller test statistic for time varying coefficients. However, this approach can detect only one time period shock and can not detect gradual changes. Due to the reason that structural break in our sample is characterized by several years this approach seems to be less appropriate.

The interesting question appears here is how our results are sensitive to country sample or what will be the threshold level if we include all CIS countries. *Table 6* shows that that if we include all CIS countries that threshold level will be insignificant. This fact might be explained by heterogeneity between initial and additional samples of countries.

Table 6. Threshold level for all CIS countries

Countries in the sample	Threshold level	P-value
Belarus, Georgia, Kazakhstan, Moldova, Russia and Ukraine	8%	0.00
Belarus, Georgia, Kazakhstan, Moldova, Russia, Ukraine, Armenia, Azerbaijan, Kyrgyz Republic, Tajikistan and Uzbekistan	9%	0.16

We produced estimates for our growth regression for threshold level 8%. Estimators, robust standard errors and three level of significance (1%, 5%, 10%) are displayed in *Table 7*. [5, 6]

Table 7. Estimation results

	Fixed effect
Log of inflation below threshold	1.67**
	(0.49)
Log of inflation above threshold	-3.45***
	(0.57)
Growth rate of population	-0.79
	(1.09)
Investment as share of GDP	-0.01
	(0.07)
Openness of the economy	0.19***
	(0.04)
Constant	-10.6*
	(5.17)
R-squared	0,47
N	48

* p<0.05, ** p<0.01, *** p<0.001

We see that the logarithm of inflation rate below the threshold level is significant and has positive sign, when the logarithm of inflation rate above the threshold is significant and has a negative sign. These facts clearly indicate a non-linear relationship in growth-inflation association. Growth rate of population together with investment are insignificant hence there is no apparent relationship between these regressors and growth. Openness of the economy is significant

5 Where log of inflation below threshold, log of inflation above threshold, growth rate of population, investment as share of GDP, openness of the economy are measured in percentage.

6 We have also estimated a model, which includes growth rate in terms of trade as one of the regressors. This variable is turned out to be insignificant while other results were not affected.

and positive, which is corroborated by the theory. Each additional percentage of the openness leads to an increase of growth by 0.2%.

Next, we illustrate the application of the estimation results for Ukraine. In particular, inflation increased from 13% to 22% during two year (2007-2008). Substituting this change in our regression we can calculate that inflation reduced growth by 1.8%. The actual decrease of economic growth over this period was 1.7%, which is very close to our estimate.

The finding that an inflation level below the threshold promotes growth is also consistent with the Ukrainian data. Indeed, when inflation increased from 0.8% to 5.2% in 2002-2003, the growth increased by 4.4%., which is slightly higher than 3.1% predicted by the model.

The post-estimation tests for our growth regression (3) with (4) had the following results (see *Table 8* in appendix). The test for misspecification or joint significance showed that fixed effect estimation is better than pooled OLS. Ramsey regression specification error test (RESET) for omitted variables illustrated that model has no omitted variable. Breusch-Pagan statistic for cross-sectional independence in the residuals showed that there is no cross-sectional independence. Modified Wald statistic for groupwise heteroskedasticity in the residuals of a fixed effect regression model found that heteroskedasticity exists, hence we corrected our errors by computing a robust variance estimator. Wooldridge test for autocorrelation in panel data detected that there no autocorrelation. Tests for normality of residuals displayed that both skewness and kurtosis are not present in distribution of residuals, therefore our residuals are distributed normally.

Chapter 6

CONCLUSION

In this study we re-investigate the inflation-growth association for several CIS countries using special econometric techniques for estimation of non-linear effects and inference. We used data set, which covered six CIS countries over the period 2001- 2008 at annual frequency.

Our empirical findings convincingly support that threshold level exists in non-linear inflation-growth association. Moreover, inflation has favorable effect on growth if it is less than this threshold and impedes growth otherwise. We computed that threshold level equals 8 percent, which is significantly different from other studies dedicated to CIS countries, such as by Christoffersen and Doyle (1998). Computed threshold is strongly significant, though confidence interval is not very tight.

Analysis for robustness of our results showed that our non-linear growth-inflation interaction is robust with respect to estimation procedures (conditional least squares based upon OLS) and different specifications (including additional variable).

Regardless of the informative results several important concerns should be kept in mind. Firstly, inflation and other variables may be endogenous regressors therefore causing biases in estimators. As we discuss in methodology section in order to mitigate this problem we relied on empirical works (Fisher, 1993) and results of Granger causality test. In fact, one can alleviate the endogeneity problem using either appropriate theoretical studies or econometric framework. Hence, theoretical models, which assume that inflation can impact on growth in non-linear way, should be developed. On the other hand, one should develop extensions of non-linear least squared methodology, which can deal with endogenous regressors. Both suggestions will be useful topics for further research.

Secondly, growth regression may not take into account all channels through which inflation influence growth. In particular, Fisher (1993) argued that total factor of productivity is one of such primary channel; thereby total effect of inflation on growth will be underestimated.

To summarize, a number of central banks in the world during the last years acknowledged the importance of keeping low level of inflation because of its positive effect on economic growth. They tried to reduce inflation to one digit level and maintain it there. This study convincingly supports such initiatives and finds the level of inflation that should not be exceeded in the selected CIS countries.

BIBLIOGRAPHY

Мовшович, С. М. *Общественные потери от налогов и инфляции*, ЭММ, т.36, вып.4, 2000.

Полтерович, В.М. *Снижение инфляции не должно быть главной целью экономической политики Росси*. Экономическая наука современной России (в печати), 2006.

Alesina, A. and Lawrence H. S. *Central Bank Independence and Macroeconomic Performance: Some Comparative Evidence,* Journal of Money, Credit, and Banking, 25 (May), pp.151–162, 1993.

Azariadas, C. Smith, B. *Private Information, Money and Growth: Indeterminacies, Fluctuations, and the Mundell-Tobin effect*. Journal of Economic Growth 1, 309-322, 1996.

Barro, R. *Economic Growth in a Cross Section of Countries*, Quarterly Journal of Economics, 106, 2 (May), 407-443, 1991.

Barro, R. *Determinants of Democracy*, Mimeo Harvard, 1996.

Barro, R. *Determinants of Economic Growth, A cross Country Empirical Study*. The MIT Press. Cambridge, Mass, 1997.

Barro, R.. *Government Spending in a Simple Model of Endogenous Growth,* Journal of Political Economy, S103-S125, 1990.

Briault, C. *The Costs of Inflation*. Bank of England Quarterly Bulletin, 35,February, pp. 33-45, 1995.

Bruno, M. *Does Inflation Really Lower Growth?* Finance & Development, 1995.

Bruno, M. and Easterly W. *Inflation Crises and Long-Run Growth*, NBER Working Papers 5209, National Bureau of Economic Research, Inc. http://ideas.repec.org/p/nbr/nberwo/5209.html, 1995.

Bullard, J. and Keating, J. W. *The Long-Run Relationship between Inflation and Output in Postwar Economies*. Journal of Monetary Economies, 36, pp.477-496, 1995.

Cass, D. *Optimum growth in an aggregative model of capital accumulation*. Review of Economic Studies, 32, 233–240, 1965.

Chan, K. *Consistency and limiting distribution of the least squares estimator of a threshold autoregressive model*. The Annals of Statistics 21, 520-533, 1993.

Chan, K. and Tsay, R. *Limiting Properties of the Least Squares Estimator of a Continuous Threshold Autoregressive Model*. Biometrica, Vol. 85, No. 2, pp. 413–26, 1998.

Christoffersen, P. and Doyle, P. *From Inflation to Growth. Eight Years of Transition*, IMF Working Paper No. WP/98/100, 1998.

Choi, S., Smith, B. and Boyd, J.H. *Inflation, Financial Markets, and Capital Formation*. Federal Reserve Bank of St. Louis Review 78, 41-58, 1996.

Clarida, R., Gali, J. Gertler, M. *The Science of Monetary Policy: A New Keynesian Perspective*. Journal of Economic Literature, 37(4): pp. 1661-1707, 1999.

Cukierman, A. *Central Bank Strategy, Credibility, and Independence*. MITPress, Cambridge MA, 1992.

Cukierman, A., Kalaitzidakis P. Lawrence H. S., and Steven B. W. *Central Bank Independence, Growth, Investment, and Real Rates*. Carnegie-Rochester Conference Series on Public Policy, 39, pp. 95–140, 1993.

De Gregorio, J.*The Effect of Inflation on Economic Growth*. European Economic Review 36(2-3), pp. 417-424, 1992

De Gregorio, J. *Inflation, Growth and Central Banks: Theory and Evidence. Paper presented in Latin America seminar on Economic Growth*, June 27-28, Bogota, Colombia, 1994.

Dorrance, S. *The Effect of Inflation on Economic Development*, Staff Papers, International Monetary Fund, Vol. 10(March), pp. 1-47, 1963.

Drukker, D., Gomis-Porqueras, P. and Hernandez-Verme, P. *Threshold Effects in the Relationship Between Inflation and Growth: A New Panel-Data Approach*, Staff Papers, International Monetary Fund, 2005.

Fisher, S. *The Role of Macroeconomic Factors in Growth*. Journal of Monetary Economics 32(3), pp. 485-511, 1993.

Gali J. and Gertler M. *Macroeconomic Modeling for Monetary Policy Evaluation*. Journal of Economic Perspectives, v.21, pp. 25-45, 2007.

Gillman M. and Harris. M. *Inflation, Financial Development and Growth in Transition Countries.* Monash University, Working Paper 23/04, 2004.

Gillman M. and Nakov. A. *Granger Causality of the Inflation-Growth Mirror in Accession Countries.* Economics of Transition, Vol. 12, No. 4, pp. 653-681, 2004.

Ghosh, A. *Inflation in Transition Economies: How Much? And Why?* IMF Working Paper, 1997.

Ghosh, A. and Phillips, S. *Inflation, Disinflation and Growth*. IMF Working Paper WP/98/68 (Washington, DC: International Monetary Fund), 1998.

Hansen, B. *Inference When a Nuisance Parameter Is Not Identified Under the Null Hypothesis*, Econometrica, Vol. 64 (March), pp. 413–30, 1996.

Hansen, B. *Threshold Effects in Non-Dynamic Panels: Estimation, Testing, and Inference*, Journal of Econometrics, Vol. 93, No. 2, pp. 345–68, 1999.

Hansen, B. *Sample Splitting and Threshold Estimation*, Econometrica, Vol. 68 (May), pp. 575–603, 2000.

Huybens, E., Smith, B. *Financial Market Frictions, Monetary Policy, and Capital Accumulation in a Small Open Economy*, Journal of Economic Theory 81, 353-400, 1998.

Huybens, E. Smith, B. *Inflation, Financial Markets, and Long-run Real Activity*, Journal of Monetary Economics 43, 283-315, 1999.

Johanson, G. *Is Inflation a Retarding Factor in Economic Growth?* Fiscal and Monetary Problems in Developing States, Proceedings of the Third Rehoroth Conference, 1967.

Khan M.S., Senhadji A.S. *Inflation and Financial Depth.* IMF Working Paper No. 01/44, 2001.

Kocherlakota, N.R. *Discussion of Inflation and Growth.* In Federal Reserve Bank of St. Louis, Price Stability and Economic Growth, 1996.

Koopmans, T. *On the concept of optimal economic growth*, in (Study Week on the) Econometric Approach to Development Planning, chap. 4, pp. 225–87. North-Holland Publishing Co., Amsterdam, 1965.

Krugman, P. *It's Baaack: Japan's Slump and the Return of the Liquidity trap.* Booking papers on Economic Activity, no. 2, pp. 137-205, 1998.

Li, M. *Inflation and Economic Growth: Threshold Effects and Transmission Mechanisms.* University of Alberta, Working papers, 2006.

Levine, R. and Renelt D. *A Sensitivity Analysis of Cross-Country Growth Regressions.* American Economic Review, 82, 4 (September), 942-963, 1992.

Lucas, R. *Some International evidence on Output-Inflation Tradeoffs.* American Economic Review, v.63, pp. 326-334, 1973.

Mallik D., Chowdhury A. *The Impact of Financial Reform on Private Savings in Bangladesh.* WIDER, Discussion Paper No. 2001/78, 2001.

Mervar A.*, Economic Growth and Countries in Transition,* Economic Trends and Economic Policy), No. 92, pp. 53-87, 2002.

Melitz M. et al. *Export versus FDI*, NBER Working Papers 9439, National Bureau of Economic Research, Inc, 2003.

Minford P. and Meenagh D., *Testing a Simple Structural Model of Endogenous Growth*, Cardiff University, Working papers, 2006.

Mubarik Y. *Inflation and Growth: An Estimate of the Threshold Level of Inflation in Pakistan,* SBP-Research Bulletin Volume 1, Number 1, 2005.

Romer, D. *Advanced Macroeconomics*, second edition, Textbook, 2001.

Sala-i-Martin, X. X. *I Just Ran Two Million Regressions.* American Economic Review , May 1997, 1997.

Sarel, M. *Nonlinear Effects of Inflation on Economic Growth*. IMF Staff Papers, 43, pp.199-215, 1995.

Thirlwall A.P. Barton C.A. *Is low inflation an important condition for high growth?* Cambridge Journal of Economics, v.17 , pp.79-107, 1971.

APPENDIX

Table 8. The post-estimation tests

Test	Null hypothesis	P-value
The test for joint significance	OLS is better than fixed effect	0.00
Ramsey regression specification error test	Model has no omitted variables	0.24
Breusch-Pagan statistic for cross-sectional independence in the residuals	There is no cross-sectional independence in the residuals	0.64
Modified Wald statistic for groupwise heteroskedasticity in the residuals	There is no groupwise heteroskedasticity in the residuals	0.00
Wooldridge test for autocorrelation in panel data	There is no autocorrelation in panel data	0.09
Tests for normality of residuals	Skewness is present in distribution of residuals	0.56
	Kurtosis is present in distribution of residuals	0.74